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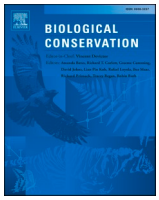

Surveying First Nations perspectives on marine genetic conservation practices

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ABSTRACT

There is an increasing need for conservation action to help degraded ecosystems recover from anthropogenic disturbances like climate change. Historically there has been a lack of recognition of First Nations peoples in marine genetic conservation, contributing to existing inequalities. To better understand First Nations' perspectives, specifically within Traditional Owner (TO) groups within Australia, a mixed-method approach (surveys and interviews) was used. Two groups along the Great Barrier Reef (GBR) were interviewed, including Lama Lama from the northern and Woppaburra from the southern GBR. Overall, perceptions varied within and between groups. There were differences in perception over equity of resource sharing in genetic conservation practices, including the sharing of coral offspring and their removal from one location to another group's Sea Country. There was, however, a strong sense of the "greater good" (benefits extending outside locations of individual groups). Their willingness to be included in most aspects of the conservation process was unanimous. These results highlight the importance of involvement of First Nations people in the decision-making process to ensure social equity in climate change conservation strategies in a way that respects local communities and cultures.

1. Introduction

Marine environments and the people depending on them are under increasing threat from climate change and other anthropogenic pressures (Good and Bahr, 2021; Hughes et al., 2017). The rapid degradation of reefs globally has spurred efforts to re-evaluate the management of marine ecosystems and increase the more active conservation of these habitats through enhanced stakeholder involvement and the incorporation of genetic techniques through active restoration strategies (Quigley et al., 2022). As part of this effort, there have seen broad, but slow, trends toward increasing engagement of Indigenous and First Nations peoples in applied ecology (Housty et al., 2014; Jessen et al., 2022).

Unfortunately, the practice of 'parachute science' often occurs regularly in applied ecology and conservation practices (labelled 'colonial science') and reflects a research activity that is undertaken without Free and Prior Informed Consent (FPIC) of First Nations people. This typically refers to researchers from developed nations undertaking field studies in other (usually developing nations) without collaborating with local people (Asase et al., 2021; Stefanoudis et al., 2021). Hence, biodiversity conservation is often linked with misrecognition of First Nations groups and misrepresentation of their cultural practices (Martin et al., 2016). This contributes to inequities and exclusions of traditions and livelihoods (Bennett et al., 2021; Murdock, 2021). Not only is this unethical and inefficient but it ignores local needs and research efforts (Sidik, 2022; Stefanoudis et al., 2021).

Increasing engagement with First Nations groups is emerging (i.e. the slow decolonization of science) in both marine and terrestrial research fields, including research on birds (Taylor, 2022) and fish (Eckert et al., 2018), and in the setting of government policy to fight the climate crisis (Deranger et al., 2022). For genetic research, in particular, there are often specific aspects of research that represent barriers to engagement with non-specialist groups, including Indigenous peoples, such as the lack of funding for expensive genetic techniques and access to scientific literature and software (Hogg, 2023). Importantly, one false, and now de-bunked belief is the assumption that genetics is incompatible with or beyond the scope of Indigenous Knowledge (Polfus et al., 2016). Indigenous communities have rich and nuanced

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understandings of marine environments, including the behaviour of marine species, seasonal changes, and the interconnectedness of marine ecosystems with human well-being. Indeed, Indigenous knowledge and collaboration with local communities are increasingly recognized as crucial components in ecological research and the success of conservation efforts marine environments (Macdonald et al., 2022, see "rule 2" in Quigley et al., 2022 and references therein including Barnes et al., 2022). However, further progress in equity is critically needed. Indeed, the incorporation of traditional knowledge should be viewed as a strategic need for maintaining ecological resilience (Molnár et al., 2023). This is especially true as more restoration practices are being considered in marine environments, including those that involve genetic techniques (Quigley et al., 2019).

Equity in conservation design, actions, and benefits must be prioritized. Here, we define equity to mean the inclusive and fair distribution of decision-making and benefit sharing (Bennett, 2022). Planning for equity ensures fairness across resource sharing, funding, and access to information (Asase et al., 2021), and can lead to better outcomes compared to the lack of inclusion, thereby decreasing negative social outcomes like conflict (Grorud-Colvert et al., 2021). As environmental stewards of their land, First Nations peoples have prioritized conservation and resource management through their cultural practices for generations (von der Porten et al., 2019). Moving forward, management strategies should involve collaboration with First Nations knowledge-holders and incorporate traditional and local ecological knowledge that obtain approval and partnerships from local communities (Ens et al., 2021). Long-term success should ensure the best outcomes for both people and nature (Bennett et al., 2021; Eckert et al., 2018). For example, on reefs in Hawai'i, stewardship and economic incentives for restoration increased with engagement and shared responsibility with the Native Hawaiian community (Kittinger et al., 2016).

Efforts to halt or mitigate the devastating impacts of climate change and stem biodiversity loss are incomplete without a focus on First Nations participation and guidance in this process, including FPIC to undertake research. There is a growing recognition of the importance in weaving Indigenous knowledge, western science, and management together in conservation (for specific examples in conservation, management, and ecology, see Hill et al., 2019; Housty et al., 2014; and Polfus et al., 2016, for further review see Jessen et al., 2022). At a minimum, this includes the development of a participatory process that includes the acknowledgment and integration of First Nations leadership and rights in conservation practices (Macdonald et al., 2022). The importance of a participatory process in conservation management is further highlighted by the fact that 85 % of biodiversity conservation areas (proposed and current) can be found within First Nations lands and seas, although this group makes up only 6 % of the global population (Garnett et al., 2018; Schmidt and Peterson, 2009). Furthermore, there is global incongruency between where restoration efforts are performed and where they are needed (Fisher et al., 2011), setting up potential mismatches between local knowledge and priority action that should be avoided. Therefore, First Nations peoples can and should play an important role in conservation as critical partners. An in-depth survey of their perceptions and opinions is one of the first steps in aligning participatory conservation practices.

A section of modern genetic conservation practices aims to harness the underlying natural adaptive capacities of organisms (Voolstra et al., 2021; Chen et al., 2021), but have only begun to weave in Indigenous knowledge. For example, terrestrial conservation research using genetic methods already has a history of implementing complementary Indigenous conservation efforts. Notable examples include breeding programs with the Australian Bilby (Paltridge and Skroblin, 2018) and Rock Wallaby (Muhic et al., 2012), and dispersal efforts with the Black Bean (Fahey et al., 2022; Rossetto et al., 2017). There are relatively few examples of this in modern marine conservation best-practice. It is especially required on coral reefs given habitat degradation has been extreme and the geographic location of most reefs. A number of genetic conservation methods are underway to accelerate adaptation of corals to survive future climate warming (Voolstra et al., 2021; Quigley et al., 2019, 2020). These include the movement of heat tolerant coral colonies and/or their selectively bred offspring to cooler reefs to introduce more stress tolerant genotypes (assisted gene flow, AGF; Quigley et al., 2019; Voolstra et al., 2021). Although many practical guides now exist for traditional coral propagation and genetic conservation (Baums et al., 2019; National Academies of Sciences and Medicine, 2019; Shaver et al., 2020, 2022; Voolstra et al., 2021), less information exists on pathways to incorporate perspectives from First Nations people into marine genetic conservation activities.

Although progress toward equity and justice are being made (Bennett, 2022), they are overdue. In Australia, there are over 500 recognized Traditional Owner (TO) groups and at least 44 along the GBR, including more than 13 % recognized by formal statutory arrangement (Dale et al., 2016). Here, equity has been progressed by significant campaigners for land rights, like Eddie Koiki Mabo, whose work led to the recognition of rights, laws and customs (Native Title Act 1993). In 2009, Australia joined other colonial territories and agreed to the UN Declaration on the Rights of Indigenous Peoples (UNDRIP), which commits to "consult and cooperate in good faith with the indigenous peoples … in order to obtain their free, prior, and informed consent before adopting and implementing legislative or administrative measures that may affect them." Processes for ensuring rights, respect, and recognition have also been further developed in research through interactions with the Australian government (Guidelines for Ethical Research in Australian Indigenous Studies 2012; AIATSIS, 2012), and outlined in the marine sciences through documents like the Reef 2050 Traditional Owner Implementation Plan (The Reef 2050 Traditional Owner Steering Group, 2022). However, full TO approval pathways and participation are still in progress, with many examples of Indigenous peoples not being consulted prior to activities on their lands and seas.

Here we define participation to mean having an active seat at the table to co-lead the decision-making process (Di Sacco et al., 2021). Traditional Owner here refers to one way that First Nations people of Australia self-identify and includes all Aboriginal and Torres Strait Islander Traditional Custodians of Country. 'Country' and 'Sea Country' are terms used to refer to environments within their traditional boundaries that are associated with the land and the sea, respectively, to which cultural, social, and economic relationships are attached (Rist et al., 2019; Smyth et al., 2016).

To better understand this urgent need for improved equity in marine genetic conservation, the social, spiritual, and cultural characteristics of reefs from First Nations' perspectives should be understood alongside more traditional environmental and economic factors needed in conservation planning (Hein et al., 2019). To help address this, we undertook a literature search to quantify the extent of this potential gap in the literature and also developed a mixed-method approach involving survey and interviews to better understand TO perceptions of genetic-based conservation strategies on coral reefs along the Great Barrier Reef World Heritage Site, Australia. The aim of this study was to understand TO perceptions of coral genetic conservation methods (specifically AGF) in their Sea Country.

2. Methods

2.1. Positionality statement

We acknowledge that our position as non-First Nations scientists has influenced this project to some extent. The study was designed, and the interviews were undertaken by the first author who self-identifies as a European, White Australian woman, the second author self-identifies as a Dravidian Indian woman, the third author self-identifies as a Japanese American woman, and the fourth as a Pakistani American woman. We acknowledge there are many possible realities and therefore present these findings as one possible interpretation of the respondents'

perceptions based on our positionality. This study does not aim to generalise or represent all Traditional Owner groups along the GBR. Instead, we hope to show the various perceptions of these two groups concerning genetic conservation actions on Sea Country in hopes of bringing awareness about First Nations perceptions in western science and serves as only the start of a conversation.

2.2. Study design and interview structure

The study was developed as a structured face-to-face interview. The underlying structure was modified from ecological questions based on Hein et al. (2019) but modified to focus on genetic conservation techniques, specifically Assisted Gene Flow. This initial pilot study was undertaken with two Traditional Owner groups along the GBR from far ends of the GBR, including Lama Lama TOs from the northern GBR and Woppaburra TOs from the southern GBR (Fig. 1). One author had a history of working with these groups already and they represented the potential extremes in benefit sharing from the specific genetic practice of AGF. To design the first draft of the survey, an initial consultation of the approach was undertaken with the social science office at the Great Barrier Reef Marine Park Authority. Multiple discussions with designated members of each group were undertaken during the planning process and Ethics application process. During these consultations with group members and the Ethics board, the study design was amended to best fit cultural practices (e.g., group interviews were preferred over individual interviews). The final drafted study design and risk assessment paperwork was then submitted to the Australian Institute of Aboriginal and Torres Strait Islander Studies (AIATSIS) Research Ethics Committee for various rounds of revision before approval was ultimately given (REC Reference Number, including COVID-19 Pandemic variation: EO173-14042020). Note that university human ethics approval is not associated with these interviews because, at the time of submission of the human ethics application and of the surveys, no universities were affiliated with this research. However, at this time, we did submit an initial ethics application to a university for their approval, but we were advised to submit it through AIATSIS instead. The Coronavirus (COVID-19) Pandemic impacted countries globally and resulted in the closure of many Traditional Owner communities across Australia given the greater risk of illness due to COVID-19. Given this, it was decided through mutual agreement that interviews would continue online once people were able to participate again. Written and/or verbal free and informed consent to participate in the study was obtained from all participants, to be lodged with AIATSIS at the project conclusion as per project planning documentation.

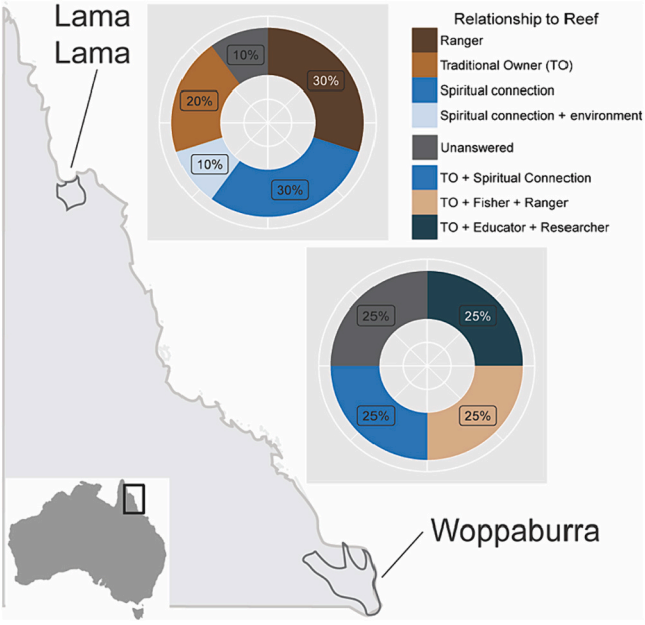

Fig. 1. The locations of the Traditional Owner communities that were surveyed during this study using a mixed-method approach. Locations were situated in the Far North (Lama Lama) and Southern Queensland (Woppaburra), Australia. Pie diagrams represent the percentage of self-identified relationships to the reef for each group. Respondents from each group self-identified their relationship to the reef as mostly spiritual, and/or as a Traditional Owner or Ranger.

The survey and interviews were initially intended as a one-on-one session with individual TOs but after consultation with the two TO groups, it was suggested to undertake these in a collaborative, group setting. These were performed over three sessions with each group due to complications with travel and risk exposure during the COVID-19 Pandemic. These included one session that included an overall orientation to the genetic practice, survey design and process (via presentation and discussion). The group survey and interviews were then completed over two sessions with Lama Lama TOs and two sessions with Woppaburra TOs. The interviewer had been working with some members from both TO groups on genetic conservation methods for about 1–3 years prior to the interviews. Nevertheless, the initial presentation was essential to provide background information for all members participating in the study and to review the genetic techniques in question before surveys and interviews. Questions were then asked one at a time, and each person responded on uniquely coloured sticky notes to query their responses. Questions ranged across topics relating to perception of reef quality (before and after genetic restoration), spiritual connection to the coral from their Sea Country, as well as preferences on engagement during the process of undertaking genetic restoration activities. Respondents were asked a series of questions, primarily Likert scale questions (rate on a scale from 1 to 10, strongly disagree to strongly agree; Likert, 1932) and dichotomous questions (yes/no), followed by open-ended questions to explain their choices. Once all the responses were analysed, the interviewer returned to each community to share a presentation of the results and hold a question-and-answer period with each community specific to those results.

To ensure anonymity of responses, participants were assigned a code based on their TO group; Lama Lama (L) and Woppaburra (W), followed by a unique number, during the survey and interviews. The answers written on sticky notes that were then entered to Microsoft Excel for data analysis. Although the number of respondents may be deemed "traditionally" low (Lama Lama: n = 10 people, Woppaburra n = 4 people), these people represent Elders and other important cultural authorities as people actively engaged in leadership within their communities and as individuals chosen by the community to represent them, from all age groups and backgrounds (Figs. S1–S4). Importantly, although we acknowledge these sample sizes would traditionally be considered low for a survey/questionnaire format alone, we should not discount their perceptions given this is the main goal of the survey. We are of the belief that each voice is important, even if from a small group, and especially those who have been elected to representative councils to act on behalf of larger bodies. This should act to discourage the practice of invisibility (*sensu* Molnár et al., 2023).

To further understand how this study could potentially fill knowledge gaps in the field of coral reef restoration and to quantitatively assess the need for this study, a literature search was conducted post-interviews. The aim of this search was to identify what research had occurred that bridges the intersection between First Nations engagement, the application of genetic conservation techniques, either on coral reefs or in other ecosystems. This was performed using Web of Science searches and was conducted between 20 January 2022 and 1 February 2022 (SI2).

2.3. Statistical analysis of qualitative and quantitative data

Various analyses were then applied to the qualitative and quantitative data from the interviews. Specifically, qualitative data included

open ended responses during the interviews in which respondents answered in a non-structured way without prompts. This data was transcribed and analysed using the social science software NVivo (v. 12.7.0). Answers were systematically coded into various emerging themes similar to those listed in the interview questionnaire, including equity, trust, risk, benefits, spirituality, acceptability, and involvement (SI).

The raw data from quantitative responses (i.e., responses in scales of 1–10, yes or no responses) were standardized. This standardization included changing missing values to NAs, filtering only those columns relevant to specific plots for figure outputs, or consolidating specific values (e.g., responses including 'Yes but' and 'Yes, depends on scale' changed to 'Yes'; 'No and Yes' changed to 'Maybe'; 'No, but always some risk' changed to 'No'). To not lose the nuance in responses, these full responses were explored in the qualitative responses as well. Analyses and plotting of quantitative data were completed in RStudio (v. 4.2.1). Bar plots were created using 'ggplot2' included within the package 'tidyverse' (Wickham et al., 2019). This produced plots to visualise the percentage of values (or responses) for each question, compared between the two TO groups. Once the final questions were selected, these were arranged in a grid using 'ggarrange' from the 'ggpubr' package (Kassambara, 2020). The final bar plots were exported using the 'ggsave' function. An alluvial plot was created to visualise the relationship between surveys and interviews responses to questions C1 and B4.a. Data for the alluvial plot was manually rearranged in Excel for further analysis in RStudio and visualized using the 'ggalluvial' package (Brunson, 2020).

A dumbbell plot was used to visualise the average response between four sets of related questions - beauty and abundance of the reef before and after AGF. Questions B1-D7c, B2a-D8a, B2b-D8b, and B2c-D8c were filtered by group, and plotted against one another using the 'ggplot' package. The percent change and standard error was then quantified between each question in each set from the average group response. Each group plot was then faceted together for easy visualisation of the average response and percent change between the groups. A radar plot was used to visualise the differences in responses between the two groups. The questions surrounding the perception of risk and benefits were filtered by group and the average response to each question per group was calculated. The radar plot was created using the 'radarchart' function in the 'fmsb' package (Nakazawa, 2019).

3. Results

3.1. Interviews

In total, 14 Indigenous Australians were interviewed from two TO communities in relation to their perceptions of using genetic methods on Sea Country, including Lama Lama (L), from Far North Queensland and Woppaburra (W), from southern Queensland. There were more than two times as many Lama Lama (n = 10) respondents compared to

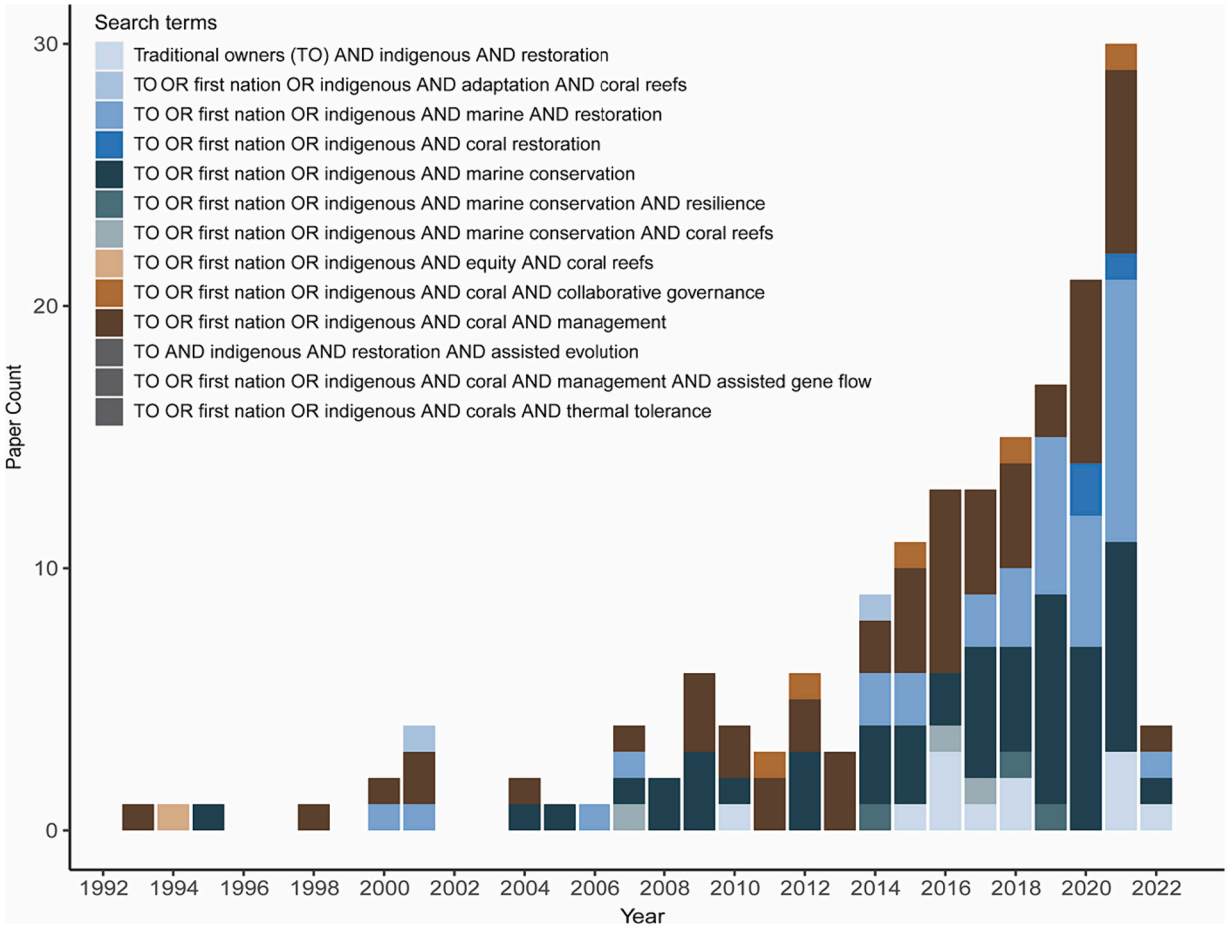

Fig. 2. Meta-analysis results using Web of Science search terms of publications retrieved between 1992 and 2022. The number of relevant publications (y-axis) per year (x-axis) which matched selected criteria (filled in colours) according to search terms related to categories like Traditional Owners, restoration, and genetic restoration methods like assisted gene flow. The number of relevant papers per search term can be found in Table S1. These results suggest that although recognition of First Nations peoples in marine management has been increasing steadily since the early 2000's (dark brown) and conservation (medium blue), there has historically been a lack of research and recognition of First Nations peoples in genetic marine conservation (grey-blue, greys), potentially contributing to existing inequalities in this space. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Woppaburra (n = 4) respondents (SI). Overall, the ages, gender, location of residence, and relationship to the reef varied between and among both groups (Fig. 1; S1–S5). Ages ranged from 20 to 64, with the majority (n = 11) of respondents over the age of 40. Of the people interviewed, gender ratios were 70:30 (women to men) for Lama Lama respondents, with an equal number of women and men respondents in Woppaburra (Fig. 2). No participant identified as other gender categories. The relationship with reef information varied greatly between respondents, with one respondent from Lama Lama and three from Woppaburra not providing a response. Most of Lama Lama reported their relationship to the reef as being a Ranger (30 %) or having a spiritual connection (30 %), with 20 % listing their TO status as the basis for their relationship to the reef (Fig. 1). However, all Woppaburra participants who gave a response self-identified as a TO connected to Sea Country as part of their response. This was reported either explicitly or through phrases such as "custodian of the reef" or "Saltwater Murrie". These responses were coded separately due to the additional answers given, including 'spiritual connection', 'fisher and ranger', and 'educator and researcher' and to provide the greatest resolution of self-identification as possible.

Overall, the literature search identified a gap in the literature around research involving TO perspectives and genetic restoration techniques, both on coral reefs as well as more broadly in the marine sciences (Fig. 2, Table S1). Publications that included "Traditional Owners", "First Nations", or "Indigenous" and "marine restoration and/or conservation" have increased by 1350 % in the last 30 years (from 2 to 29 papers per year from 1993 to 2021). During this time, the search terms that identified the most numerous and relevant results were those based on "coral AND management" (57 %), "marine conservation" (30.2 %), and "marine AND restoration" (19.6 %). However, no relevant results (0 of 151 outputs) were found that include "Traditional Owners" or "First Nations", or "Indigenous" that also included genetic techniques (terms related to "assisted evolution", "assisted gene flow", and/or "thermal tolerance"). However, increasingly more research is highlighting the importance of TOs in marine management (brown categories), conservation (teal), or restoration (blue), but not for the proposed applied genetic techniques (grey) (Fig. 2).

In the qualitative and quantitative assessment of responses, we saw distinctions in the perceptions of uncertainty, impact on culture/community and the equity around benefits sharing. For example, this was examined in responses to questions around fairness (e.g., "Do you feel it is fair to use your corals for restoration on other reefs?"). Lama Lama respondents conveyed more uncertainty compared to Woppaburra respondents (SI2, Fig. S6). This was also apparent in the qualitative results, which showed the frequency of particular words, such as "unsure" listed in their top five words used (1.75 % of total words, i.e., "unsure" occupied a large space in the word cloud; Fig. S6). Qualitative results on uncertainty in the fairness of AGF were mirrored in our quantitative analyses, and could be quantified given the responses available to respondents, including "yes", "maybe", and "no". On average, responses from Lama Lama were lower and more varied (mean = 4.1) compared to Woppaburra (mean = 5; Fig. S7). When asked to elaborate ("Who do you think it is fair to, who would this be disadvantaging?"), the majority of Lama Lama responses suggested that they would be disadvantaged (Table 1). However, when asked about the benefits of AGF ("To whom would an AGF restoration program benefit?"), most Lama Lama respondents said they, as a community, and the entire Reef as a whole would benefit from this type of genetic restoration technique (Table 1). One Woppaburra respondent answered they might benefit from AGF by receiving training or employment, however if it negatively affected the reef they would rather not be employed (Table 1).

Table 1
Survey and interview questions with exemplary quotes from Lama Lama and Woppaburra participants.

Question number	Survey/interview question	Exemplary quote
D5a	Who do you think it is fair to, who do you think AGF is not fair to?	"Not fair to Lama Lama but fair to the bottom [southern] groups" (LL03) "[Coral] not coming back and disadvantage Lama Lama" (LL08)
C6a	Do you think an AGF restoration program provides any benefits? To whom?	"Great Barrier Reef" (LL02) "Yes as Lama Lama people it would" (LL03) "Traditional Owners, Lama Lama community" (LL05) "Yes (Lama Lama people)" (LL08) "We might benefit from jobs and training, [but] if at expense of Sea Country, would rather not be employed" (W4)
D2	Is it okay to experiment on the reef?	"Yes, to protect but consequences still unsure? Where do we draw a line?" (LL04) "Unsure/maybe ask for local acknowledge" (LL05) "We (industry + society) are destroying quicker than it can regenerate!" (W04)
D1	Does this sound dangerous to you?	"Might take over the original reef" (LL02 & LL03) "We could make mistakes & alter things negatively" (LL04) "Might cause more damage?" (LL06) "No, but always some risk. Looks fine, no problem with it. Caveat: never know what will happen down the track." (W04)
D11b	When do you want to be involved?	"Start to finish on country" (LL01) "In person, trips" (LL02) "More feedback on current projects" (LL04) "Whenever TO's need to be consulted about sea country management & caring for country" (LL09) "Be involved in all aspect, and involvement after to bring back the information." (W3)
D11c	How do you want to be involved?	"Do joint projects on sea country & full training" (LL01) "Share data, share research, ongoing consulting at all levels" (LL04) "By email, newsletter, phone" (LL05) "Along with rangers" (LL06) "ASAP. Through meetings with Traditional Owners" (LL07) "Through training" (LL08) "Sitting at a table" (LL09) "[In the] field, science, before and after" (W3) "Verbal report and pictures to TUMRA, later more training, University degree, step process, grow, to full employment" (W4) "Don't know until we speak to the whole group" (LL03)

3.2. Openness to genetic conservation methods

To understand the perception of the need for genetic conservation actions on reefs ("restoration needed"), people were asked to rate their receptiveness to this (Fig. 3). This uncertainty toward "restoration needed" was also demonstrated directly. When asked "Do you think it is okay to experiment on reefs?", 20 % (n = 2) of Lama Lama participants responded "maybe", 20 % (n = 2) answered "no", and 60 % answered "yes" (n = 6, Fig. 3). In contrast, 100 % (n = 4) of Woppaburra participants answered "yes". When asked why, answers from uncertain Lama

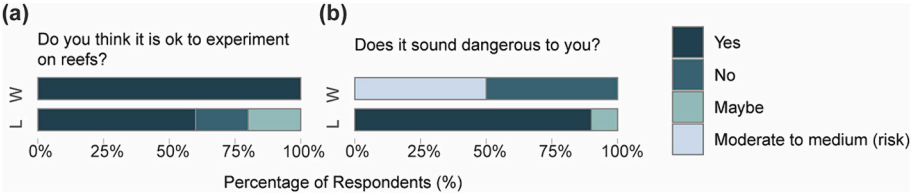

Fig. 3. Risk and science acceptability. A greater percentage of Woppaburra (W) and Lama Lama (L) respondents generally agreed that it is acceptable to experiment on coral reefs (A), but differed in their perceptions of danger associated with experiments (B), with Woppaburra respondents perceiving less danger overall.

Lama participants included concerns about where research would lead and if local knowledge had been incorporated (Table 1). Alternatively, when asked why it was okay to experiment on reefs, answers from Woppaburra respondents included the urgent need given climate change pressures. Lama Lama respondents had a greater perception of risk and feelings of danger toward AGF experiments on the reef. When asked "Does this sound dangerous to you?", 90 % (n = 9) of Lama Lama participants answered "yes" and the remaining 10 % (n = 1) answered "maybe" (Fig. 3). Woppaburra respondents who answered this either said "risk is moderate to medium" (50 %, n = 1) or "no" (50 %; n = 1, Fig. 3). When asked to elaborate about risk, answers included concerns whether the AGF corals might outcompete native corals, unintentional damage due to uncertainty over methods or if enough information was available (Table 1).

3.3. Potential risks associated with genetic conservation methods

To understand if there were differences in the level of concern between the use and/or movement of adult corals compared to their offspring, we also surveyed and interviewed participants about the concerns to either adult corals or their offspring. Overall, participants from both groups displayed more concern toward using coral offspring (larvae or juveniles) compared to using adults (Fig. 4). Respondents from Woppaburra rated their concern (on a ten-point average Likert scale, where 1 is not at all concerned and 10 is very concerned) for using adult corals as a "3.5" (50 %) or a "4" (50 %; Fig. 4.a) compared to 100 % of respondents who rated "6" toward using coral offspring (Fig. 4.b). Similarly, 70 % of Lama Lama participants rated their concerns toward using adults a "5" or higher, compared to 100 % of participants who answered "5" or higher in their concerns toward using offspring, with the majority being a "10".

Moreover, concerns for future generations of offspring were a common theme throughout the qualitative responses during this approach. In the Lama Lama group, the word "future" was tied with "coral" as the second most frequently used word during the process (Fig. 2.a). Respondents were also asked about their spiritual connection to the coral from their Sea Country (Fig. 4.c,d). Participants from both groups demonstrated approximately the same level of spirituality toward both offspring and adults. Woppaburra respondents rated both an 8 out of 10 (with 10 being extremely spiritual), whereas 50 % of Lama Lama respondents rated their spiritual connection as a "10" for both adults and offspring. The remaining 50 % of Lama Lama participants reported a range of feelings of spirituality toward both adults (20 % = 8 and 10 % = 3, 6, 9 respectively) and offspring (20 % = 3 and 10 % = 9, 7, 6 respectively).

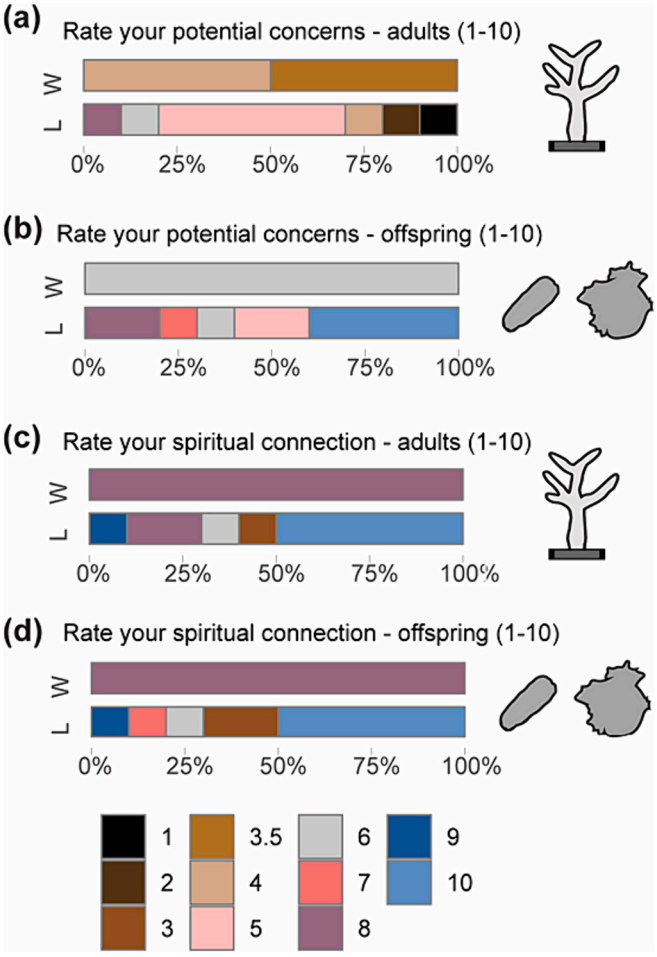

Fig. 4. Responses from Lama Lama (L) and Woppaburra (W) participants when asked questions about their concerns. Responses were recorded on a ten-point Likert-scale, where 1 is not at all concerned and 10 is very concerned. Questions include their concerns for the use of their (a) adult coral, (b) coral offspring (larvae or juveniles), as well as their spiritual connection (rated 1 - not at all spiritual to 10 - extremely spiritual) to their (c) adult corals, and (d) coral offspring. Overall, participants from both groups displayed more concern toward using coral offspring (larvae or juveniles) compared to using adults for genetic conservation methods on coral reefs. Both groups reported approximately the same level of spirituality toward both offspring and adults.

3.4. Acceptability of genetic conservation methods

We also wanted to understand the balance between the perception of benefit and risk of genetic restoration between both groups that were surveyed (Fig. 5). Overall, between the two groups, the perception of risk was similar (as shown in the high overlap), with the exception of questions relating to concerns in the use of coral offspring and changes in spiritual connections if mixing coral genetics (D3.b and D4.c). The perceptions of potential benefits were more divergent between TO groups, specifically regarding overlap on the perception of whether or not their specific corals would have any benefit for the Reef generally (C5.a). Interestingly, Lama Lama perceived a great benefit to the Reef as a whole given the use of their corals compared to Woppaburra (C5.a: W = 6.5, L = 9.8). Additionally, Lama Lama demonstrated slightly greater pride knowing their corals could help the Reef (C5.d) with the average answer being 10 out of 10 (extremely proud), while the average answer for Woppaburra was only slightly lower (9.5). We also explored other relationships that we expected to be related, including the perceived

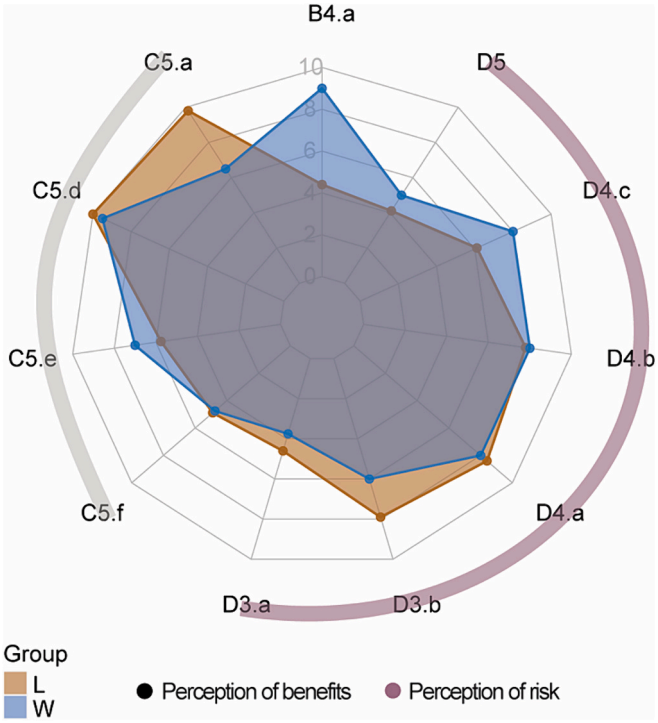

Fig. 5. Perception of risk and benefits. Radar plot outlining the differences and similarities of the perception of risk (e.g., D3.a, D3.b, D4.a, D4.b, D4.c, and D5 highlighted in purple) and the perception of benefits (e.g., C5.a, C5.d, C5.e, and C5.f, highlighted in grey) between Woppaburra (W, shaded in blue) and Lama Lama participants (L, shaded in brown). For the list of questions, see the survey and interview questionnaire in the Supporting Information (SI). Overall, between the two groups, the perception of risks was similar, but the perceptions of potential benefits were different. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

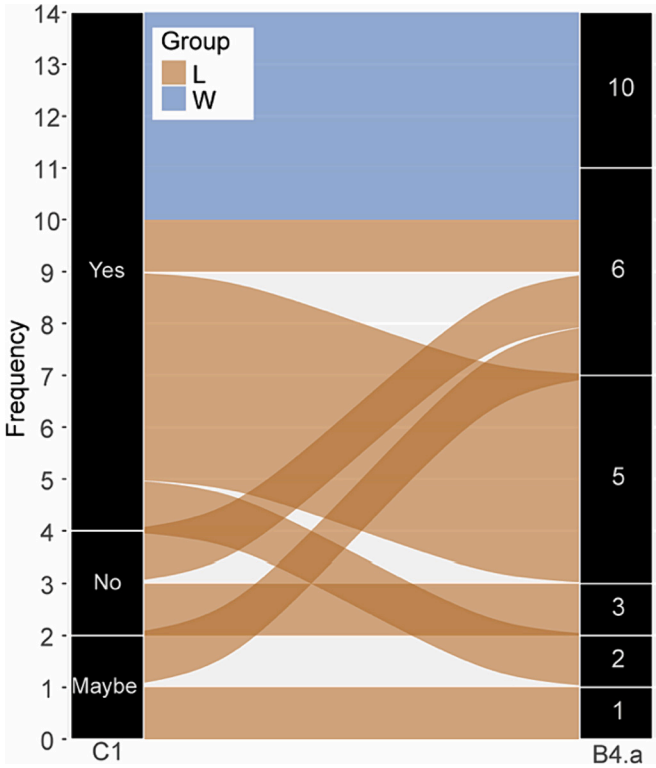

Fig. 6. Alluvial plot illustrating the relationship between the acceptability of experimentation on reefs (question C1) and the need for genetic restoration (question B4.a). Responses to B4.a range were reported on a 10-point Likert scale from 1, representing "no need" to 10, representing "it was very needed" per TO group. Each bar represents one participant's answer to question C1 and their associated answer to question B4.a (L - Lama Lama: n = 10 and W - Woppaburra: n = 4). All respondents from Woppaburra said it is acceptable, with a high to very high need. This contrasted with Lama Lama, who were more varied in their perception of acceptability and need, with respondents who did not think it was acceptable or unsure acknowledging the need for action, and vice versa.

need for AGF and the perception of abundance of coral (B2.a) and diversity of coral (B3.a) before restoration. We did not find this relationship to be significant (Figs. S8–S9).

When looking further at the relationships between responses (risk: D3.a,b, D4.a,b,c, D5 vs. benefit: C5.a,d,e,f), a number of relationships emerged. On average, Woppaburra perceived a much greater need for AGF on their reefs when compared to Lama Lama (B4.a: W = 9; L = 4.4; Fig. 6). Alternatively, Lama Lama had, on average, greater concerns about using both adult corals (D.3a: W = 3.75, L = 4.6) and coral offspring (D.3b: W = 6, L = 7.9). When asked about the greater good, Woppaburra respondents had a greater feeling that losing adults to help the Reef would balance out the loss (C5.e: W = 7, L = 5.75), whereas both groups had a similar feeling of balance knowing losing their coral offspring could help the reef (C5.f: W = 4.75, L = 4.89). Interestingly, Woppaburra reported the use of their coral for restoration of the reef as slightly more equitable compared to Lama Lama (D5: W = 5, L = 4.11). Spiritual connections to the adult corals (D4.a: W = 8, L = 8.4) and to the coral offspring (D4.b: W = 8, L = 7.8), were, on average, similar between the two groups. Although both groups reported on the importance of spiritual connections, we found that Woppaburra demonstrated a greater sense of spirituality, relative to Lama Lama, if their corals were mixed with corals from other reef regions (D4.c: W = 8, L = 6.1).

To better understand these responses, alluvial plots were constructed to explore the relationship between those who responded positively or negatively to whether it was acceptable to experiment on reefs (C1) with the need for AGF (B4.a; Fig. 6). All respondents from Woppaburra (100 %; n = 4) said it is acceptable, with 75 % of those expressing a perceived need for restoration as a 10 out of 10 (very needed) and 25 % perceived it to be a 6 out of 10. There was more variation in both responses within respondents from Lama Lama (n = 10). 60 % answered "yes" to experimenting on the reef, and of those, 40 % rated the need for restoration as a 5 out of 10, with fewer people either responding there was a high need (6) or much lower need (2). Some were unsure if it was acceptable (20 % "maybe"), and of those 10 % rated the need for AGF as 6 out of 10 and the other 10 % rated it a 1 out 10. Of those that responded that it was not acceptable to experiment on reefs (20 %, "no"), 10 % rated the need for AGF as a 3 out of 10 and the other 10 % rated it a 6 out of 10. The remaining 20 % of Lama Lama answered "maybe" to experimenting on the reef, of which 10 % rated the need for restoration as a 1 out of 10 and the other 10 % rated it 6 out of 10.

The relationship between the implementation of genetic action (here, AGF) and a change in the perception of "beauty" due to the restoration practice was also assessed. To do this, participants were asked to rate the overall perceived beauty of their reefs as well as score the diversity of corals, fishes, and other organisms (examples given were seagrasses, dugong, turtles). This included responses as to how they perceived it currently (before AGF, questions B1, B2.a, B2.b, B2.c) and how they would perceive each category after AGF (questions D7.c, D8.a, D8.b, D8.c; Fig. 7). On average, both groups perceived beauty to decrease, although by a much larger degree for Woppaburra (−66.7 % decrease) compared to Lama Lama (−7.5 %; Fig. 7). Within each group, Lama Lama perceived the diversity of each group to decrease after AGF (corals: −11.4 %, fishes: −23.8 %, others: −29.4 %), whereas Woppaburra perceived that on-average, diversity of these groups would increase overall (corals: 25 %, fishes: 17.6 %, others: 5.3 %; Fig. 7). When

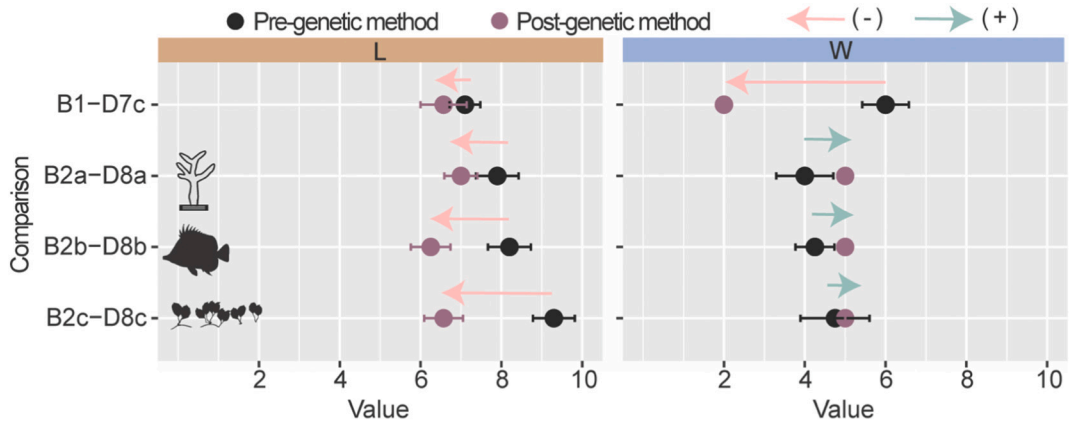

Fig. 7. The change in perception (positive or negative) of value between pre-genetic methods compared to post-genetic methods on coral reefs. Comparisons made before and after the application of a genetic conservation or restoration method (e.g. Assisted Gene Flow) included questions surrounding the perception of the overall "beauty" (B1, D7.c), coral abundance (B2.a, D8.a), fish abundance (B2.b, D8.b), and abundance of other marine organisms like seagrasses and dugongs (B2.c, D8.c). The value (x-axis) represents the average answers provided on a 10-point Likert scale (e.g., 1 = less abundance and 10 = most abundant). Overall, both groups perceived that the values of the reef across multiple categories would change, and mostly decrease, with the application of genetic conservation methods on reef, although by a much larger degree for Woppaburra (W) compared to Lama Lama (L). This accompanied contrasting patterns in the increase or decrease of abundances of different categories of organisms.

asked "why", answers included:

> *"At least you have something, but anything natural will outweigh what we have man made…"*
>
> (W4)

> *"Heated sea water may impact coral abundance" and "Fish dependent on coral may be impacted"*
>
> (LL9)

4. Discussion

The aim of our research was to better understand TO perceptions of genetic based conservation strategies on coral reefs. Whilst ample research now exists on the integrated involvement of Indigenous peoples and knowledge in conservation and management and applied ecology, by both Indigenous and non-Indigenous authors (Hill et al., 2019; Housty et al., 2014; Polfus et al., 2016; Jessen et al., 2022), we demonstrate a gap in marine genetic conservation and then examine it in depth using mixed-method interviews. We found that similarities and differences between TO groups exist, in which, on average, the differences outweigh the similarities. Overall, we found the main distinctions were surrounding the perceived need for genetic conservation action, the openness and receptiveness to experimentation on the reef, the perception of risk, and equity between groups around benefits sharing. In contrast, similarities occurred surrounding concerns toward the use of coral offspring for experimentation and the perception that beauty of the reef would, in general, decrease after genetic action. Importantly, both groups displayed a large spiritual connection toward the corals found within their Sea Country.

4.1. Diversity with common ground exists

Our main result, summarized above, highlights that diversity with common ground exists among Indigenous groups and that they should be included in marine genetic management. An important (and broader) point should also be made here about why this variation among Indigenous groups is important. This includes the harm associated with treating all Indigenous peoples as a monolith. The danger is immediately apparent when policy is applied broadly across protected areas, as it often is. If variation exists between groups, blanket policies will likely either not acknowledge or may even harm different groups (see discussion of potential sources of harm in Jessen et al., 2022). The diversity reported here across Sea Country has also been noted in terrestrial systems as well, where groups across regions communicated a range of opinions, beliefs, and practices (Polfus et al., 2016; Jessen et al., 2022). These results might be relevant to researchers dealing with other taxa, geographies, or people facing equally complex decision-making processes across rich ecological and social seascapes.

The literature search completed in this study confirmed the substantial gap in documenting or understanding TO perspectives toward the use of genetic conservation methods in the marine environment. This highlights an opportunity for managers to involve First Nations people in science and management processes as early as possible. At a minimum, TOs should not be discouraged from participating in environmental decision-making due to different knowledge systems and collaboration between Indigenous and western science needs to be prioritized (Gibbs et al., 2021; Ban et al., 2018). Indeed, there are now clear mandates for FPIC to be incorporated as standard practice into research planning (UNDRIP, Guidelines for Ethical Research in Australian Indigenous Studies 2012; AIATSIS, 2012). Science partnerships should aim to move beyond even beyond FPIC to the inclusion of TO aspirations and co-development into planning, involvement and leadership opportunities in governance frameworks to ensure better equity, participation, and resourcing for long-term support. The need for this could be clearly seen in responses in Table 1 (D11b and D11c). Therefore, although discussions around including Indigenous knowledge have begun, further developments to include Indigenous perspectives alongside scientific knowledge are urgently required (Waters, 2022).

4.2. Equity of conservation benefits

This study allowed us to better understand TO perceptions of equity in relation to the use of genetic methods on Sea Country. This is particularly relevant for conservation practices like AGF, which, by definition, requires the movement of corals, with or without their offspring, to another location (Aitken and Whitlock, 2013). Therefore, AGF naturally sets up the possibility for inequity in resource sharing, and in this case example, the sharing of genetic material. AGF can generate inequity because it involves extraction of resources from one location (collection of corals or their offspring from warmer reefs) and moved to another location (cooler reefs), potentially across sea country. Inequity in resource sharing, especially as it relates to First Nations resources, has been identified as an international priority within the

Convention on Biological Diversity, outlined in the Nagoya Protocol. As these practices are further applied and matured in marine sciences, lessons may be learnt from other translocation projects from other regions of rich and diverse socio-cultural contexts, including assisted colonization of western swamp turtles in south western Australia (Bouma et al., 2020) or the assisted gene flow of multiple tree species across Canada (Aitken and Whitlock, 2013).

At the start of this study, we expected that the northern TOs would feel disadvantaged as most of the AGF proposals have thus far involved "taking" corals from the warmer northern GBR to the cooler central and southern GBR, setting up the perception that northern TOs would not receive any direct benefits from AGF. However, contrary to what was anticipated, Lama Lama respondents showed a greater reef-wide perspective and openness to contribute corals from their Sea Country for the "greater good." They also reported the benefits at the reef scale: taking coral from their Sea Country will help the GBR as a whole and therefore benefit them, not only as individuals but as a group, as Lama Lama people.

As the oceans continue to warm due to climate change, this perception of inequality described above will likely only become more relevant as more and more corals may be taken from the northern regions of the GBR (or other reef regions), where heat tolerance has historically thought to be more pervasive, and moved down to central or southernly, cool regions (Quigley et al., 2019) – setting up an escalating cycle of inequity. Indeed, the GBR remains one of the healthiest reef systems globally. If degradation persists, translocation from the GBR to other regions around the world may be sought. This scenario further highlights the inequities created by climate change impacts (Pörtner et al., 2022) for both people and nature. Coral reefs are on the climate frontline (Pörtner et al., 2022) but these challenges will be faced by other at-risk groups in the future due to habitat destruction from warming, including amphibians, mammals and birds (IUCN, 2022).

Finally, when queried about whether TOs wanted to be included in these conservation decisions, 100 % of all TOs from both groups responded "yes", highlighting that they wanted to be involved in some, if not most, aspects of science and research undertaken on their Sea Country (Table 1; Fig. S10). It is therefore imperative to consider social equity and justice throughout the development of future genetic projects (Ban et al., 2018), such as AGF corals. This can be done by incorporating recognitional equity and procedural equity – defined by Bennett (2022) as the acknowledgment and consideration of local rights, values, knowledge, and needs into policy and practice, and the inclusiveness and participation in decision-making, respectively. Funding and support are also needed during research planning for relationship building. This has been highlighted as an essential first step before research begins, in order to build trust, relationships, and identify what and how research questions First Nations groups would like to be prioritized (Sidik, 2022). TO participation, knowledge sharing, and guidance in all aspects of the process is key to the development of sustainable and socially just conservation practices. These results underscore the interest to be involved and their inherent rights, interests, and knowledge must be considered at the start of decision making.

4.3. Receptiveness to genetic conservation methods

We also found that openness to genetic practices and experimentation on reefs differed between the TO groups. We expected those who perceived their reef as more pristine would be less open to restoration because of a perception of less need or potentially more concern for unintended damage from the genetic methods. However, we found evidence of a more nuanced relationship. Those who were more open to restoration from Woppaburra TOs for example, perceived their reef as more beautiful and more diverse, whereas those who had a greater perception of beauty and diversity within the Lama Lama TOs were less open to the application of genetic methods. This difference could be due to the perception that corals are generally tougher in the northern GBR and historically this region has been thought to be more "pristine" due to potentially less anthropogenic impacts on the coastline. Hence, northern TOs may be more hopeful, with less perceived need for restoration and more uncertainty toward experimenting on their Sea Country. However, southern reefs have a history of degradation due to local stressors and there is a greater perception of the risk of the loss of the reefs and therefore more concern surrounding the impacts of climate change, potentially creating the perception of being more open to restoration. Most protected areas are in pristine locations with low human influence (Vimal et al., 2021), potentially suggesting that legislations to protect these locations are easier to pass given higher appraisals of economic or ecological value. These results again strongly suggest that perceptions are context dependent and highlights that as many TO groups as possible should be involved in decision making and not to simply assume that one group's perceptions will be identical across all Sea Country.

It is also important to highlight that although both TO groups displayed a great concern toward using coral offspring (larvae or juveniles), feelings of spirituality toward both adults and offspring were important. The greater concerns toward offspring may be explained by this age group representing a future hope, and therefore the loss of offspring from the reef may affect the continuation of the reef through time. Taking offspring away from Sea Country may potentially disrupt this time continuity and thus have flow-on impacts for many generations to come. The concerns for future generations were identified as a theme throughout the approach which is not surprising when seeing TO concerns toward using coral offspring. Indeed, other First Nations groups report similar sensitivities to fine-scale population structure within species, including caribou from the Sahtú Region in Canada (Polfus et al., 2016), underscoring their detailed nuances and depth of knowledge of ecological systems. Spirituality and the sense of place, belonging or attachment to a location are important cultural values that need to be incorporated with care in decision-making and have a role to play in increasing public support of ecosystem conservation (Marshall et al., 2018). Therefore, it is important to consider spiritual connections and cultural values when planning any future work with corals, especially when restoration includes moving or removing offspring from Sea Country.

The discussion around AGF implementation has also created ethical concerns surrounding whether a "restored" site is more or less natural compared to the previous ecosystem (Filbee-Dexter and Smajdor, 2019). This led to the question of whether a coral reef restored using AGF is perceived as more or less natural compared to its previous state. This approach identified similarities and differences between TO groups in response to whether a reef post-AGF is less natural than a reef without it. Importantly, both groups perceived the reef post-AGF to be less natural and less beautiful. Like the example above, this again demonstrates previously "intangible" aspects of ecosystems (Polfus et al., 2016) may unintentionally be perceived as lost as a result of conservation action. However, it is important to note the nuances between groups and that perceptions differed, with northern TOs expecting a decrease in diversity across all coral reef organisms after AGF compared to southern TOs. This again underscores the importance of understanding perceptions across the reef given this initial diversity of responses.

Finally, concerns around genetic conservation techniques on coral reefs often revolve around AGF corals out-competing local stock, either through higher growth rates or high survival (Quigley et al., 2021). When asked to elaborate about risk, TO responses included concerns about whether AGF corals might out-compete native corals or other unintentional damage due to uncertainty over methods or if enough information was available to make informed conservation decisions. These responses are directly in-line with global concerns around genetic conservation (see risks outlined in Aitken and Whitlock, 2013), highlighting that TOs are already very much at the forefront of conservation thinking. This underscores that as conservation actions are being considered and developed, TOs must be involved in the discussions and their concerns heard and incorporated in risk-management planning.

5. Conclusion

Here we show that historically and overall in publications, there has been a lack of acknowledgment of Traditional Owner perceptions in coral reef restoration, especially around genetic techniques. We also show that perceptions of equity, benefits, and risks are group specific. This is concerning given the wealth of planning documents that Traditional Owners have put together outlining their knowledge needs and science priorities (e.g., Yirrganydji Sea Country Plan, Bardi Jawi Indigenous Protected Area Management Plan 2013–2023). To our knowledge, this study is the first to survey TO perceptions of genetic conservation practices on coral reefs, and we hope that the approach itself and results presented here will provide an initial baseline for further dialogue between TOs, scientists, and conservation practitioners. Finally, the unanimous call for inclusion recorded for all interviewed participants should be a clear sign that Traditional Owners want and must have a voice in this process.

Data accessibility statement

https://github.com/LaserKate. As per the Data Management Plan_AIATSIS and the Data Storage section on the Participant Information Sheet, all de-identified raw data will be lodged with AIATSIS.

Ethics statement

This research has been granted approval by the Australian Institute of Aboriginal and Torres Strait Islander Studies (AIATSIS) Research Ethics Committee to Quigley (REC Reference Number), including COVID variation extension until December 2021 and the inclusion of the above student co-authors (T. Venkatachalam, A. Siddiqi, M. Hatayama) onto the Ethics permit (EO173-14042020). All documents have been uploaded to the system (EO173-14042020 Variation Approval letter.pdf).

The AIATSIS Participant Information Sheet and the Informed Consent Form is available (participant_information_sheet_and_informed_consent_form_FinalKQ.pdf).

CRediT authorship contribution statement

Kate M. Quigley: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Taruna Venkatachalam:** Writing – review & editing, Formal analysis. **Mina Hatayama:** Visualization. **Aliya Siddiqi:** Visualization, Formal analysis.

Declaration of competing interest

The authors have no competing interest to declare.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.biocon.2024.110545.

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