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Spatial use of marine resources in a rural village: A case study from Qoma, Fiji

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Understanding the value of fishers' Indigenous and Traditional Knowledge (ITK) and of fishers' spatial use of customary fishing grounds is an important contributing factor to marine resource management. This study investigates and documents ITK of marine resources and the associated spatial knowledge of fishing areas in Qoma, a rural fishing village in Fiji. Using a sex-generational lens, our research combines theory and methods from Participatory Geographic Information Systems and ethnography. We document how fishermen and fisherwomen use geographic space in their traditional fishing grounds showing changes in the areas they travel to and fish. Targeted marine resources and knowledge of those resources differ between fishermen and fisherwomen, reflecting the traditional roles of men and women within Indigenous Fijian (iTaukei) culture. Fishermen and fisherwomen of ≥60 years have a richer knowledge of marine resources than younger fishers (men and women), measured by the number of unique species they could identify or describe using local taxonomic classification. Our ethnography findings highlight the importance of maintaining this ITK to preserve marine resources of significance for future generations. Our study concludes with insights into three knowledge gaps; the spatial use of traditional fishing grounds by fishermen and fisherwomen (including a statistical analysis and map), generational differences in fisher knowledge, and the distinctive differences in fishermen's and fisherwomen's ITK of fishing. This study also discusses how these three key insights when combined can contribute to improved local fisheries resource management.

KEYWORDS

customary/traditional fishing grounds, ethnography, Fiji, ITK, marine resources, PGIS

Introduction

Pacific Island fishermen and fisherwomen developed their Indigenous and Traditional Knowledge (ITK) through close interaction with their environment, and have since used this knowledge to systematically exploit their resource (Veitayaki, 1997; Kitolelei et al., 2021). The intimate fisher-environment interaction equips fishers with an understanding of the spatial distribution of their resources within customary fishing grounds. The location of marine resources and fishing areas are identified using features in the landscapes and seascapes (Calamia, 1999), such as reefs or island locations. For many coastal communities in the Pacific and Fiji, fishing provides resources for subsistence and commercial use for both men and women (Dakuidreketi and Vuki, 2014). Men and women participate in fishing and the ITK which the fishers develop is different due to the differences in fishing locality, perceptions of the environment and experiences during the harvest of resources (Ruddle, 1993; Omoto, 2004). The ITK of fishing in Fiji evolved since its documentation in the 1700s when the first explorers reported their observations of fishing rituals and knowledge of fishers in Fiji (Seemann, 1862; Pritchard, 1866; Toganivalu and Beauclere, 1917; Roth, 1959). Today, ITK is greatly influenced by the introduction of contemporary fishing gear and methods, commercialization of resources and diet preferences of community people (Kunatuba, 1983; Zug et al., 1988; Clarke and Thaman, 1997; Thaman et al., 2008).

The ITK of fishers is today endangered because some of the knowledge is forgotten by knowledgeable holders, elders pass away without sharing their ITK with the next generation, and some practices associated with ITK of fishing inevitably became redundant over time. Environmental knowledge which local and Indigenous communities possess gained recognition after the United Nations Educational, Scientific and Cultural Organisation published the *Traditional Knowledge and Management of Coastal Systems in Asia and the Pacific*, which brought together Indigenous peoples discussing the importance of ITK to marine resource and coastal management (Johannes et al., 1985). In 2022, the International Union for Conservation of Nature acknowledged that the applications of ITK into "scientific processes increases the likelihood that these processes are comprehensive and informed by the best available information" (IUCN, 2022:3). This means, that ITK has a significant role in informing conservation and regulations which are used to govern the spatial use of marine resources.

To achieve sustainable near-shore fisheries management in customary fishing communities, it is necessary to understand the ITK connected to marine resources and fishing grounds from which they are fished. Moreover, a successful application of ITK needs both fishers and scientists to have a mutual understanding of the strengths and weaknesses of their respective knowledge systems (Johannes and Neis, 2007).

In Fiji, the application of ITK with science is used in a number of marine conservation efforts. Some examples of ITK and science contributions to conservation include filling information gaps on the early life stages of sharks in seven riverine systems on Viti Levu and Vanua Levu (Rasalato et al., 2010), exploring opportunities and challenges in managing the spawning aggregations of groupers in the Kubulau District in Bua (Fox et al., 2012), exploring shifting baselines and conservation of mollusc populations of Nagigi (Bao and Drew, 2017), a species-by-species assessment of the collapse and recovery of tropical mollusc fisheries in Navakavu (Thaman et al., 2017), and the setting up of marine protected areas to restore food systems (Tawake et al., 2001). All these documented studies involved local communities and knowledgeable fishers, including customary fishers, who informed the work.

Customary fishing clans of Fiji, known as the gonedau, are led by their master fisher (Tunidau) and are equipped with specialized knowledge and skills passed down generations of customary fishers. These fisher clans play an important role for their chiefs by providing chiefly ceremonial marine resources such as sea turtles (Kitolelei et al., 2022). Gonedau clans are divided by speciality including the fishers and the boat builders, and both guilds play important roles in the Indigenous Fijian (iTaukei) community by using their expertise in the harvest of marine resources and the construction and use of specialized fishing canoes. In addition to the customary fishing clans, fishermen and fisherwomen in Fiji possess ITK suitable for harvesting resources such as knowledge on fish aggregation and spawning periods and locations, the seasonal environmental indicators, tidal, lunar and diurnal cycles and the weather (Kitolelei et al., 2021). Moreover, customary management and governance is part of the fishing culture in Fiji, and the chiefs worked with their community members to govern marine resource use (Veitayaki, 1997). Contemporary fishing gears widely used in Fiji include synthetic fishing nets and lines, spear guns, diving equipment, and modern baits. The use of contemporary fishing gear combined with ITK enables fishers in Fiji to overexploit their resources, leading to overfishing and the collapse of some marine resource populations (Thaman et al., 2017; Fache and Pauwels, 2020).

Although ITK as discussed can contribute greatly to learning, it also has its limitations which include: 1) the loss of ITK over time influenced by Western ideas and religious groups which displace or devalue some local language and practices; 2) change in the local understanding of the marine environment status which is influenced by a point in time, such as loss of resources through cyclones; 3) exploiting ITK for resource extraction rather than resource management as done in the 1950s by the Fisheries Commission (Van Pel, 1955); 4) ITK can be an obstacle for effective governance in a community, particularly when an elder who possesses the knowledge undermines the decision made by the leaders.

The documentation of ITK on fishing in Fiji is a slow process, with sporadic information reported on men and women's fishing. Much of the work documented on Fiji's ITK of marine species independently describe the differences between men and women's knowledge, connecting ITK with Western Science as the most relevant and practical basis for fisheries conservation and recovering the collapsed local fisheries biodiversity. Past studies have not made explicit comparisons between the ITK of men and women of different age categories. However, Thaman et al. (2017) briefly discuss the differentiation of men's and women's knowledge of molluscs and the temporal changes in mollusc populations over a span of 40 years. Bao and Drew (2017) study on molluscs does not differentiate between men and women but describes knowledge differences between different age categories.

To date, no study has explicitly explored the generational differentiation of fishermen's and fisherwomen's ITK. Therefore, the purpose of this study is to fill in the knowledge gap in Fiji's research on combining ITK with science while using the sex-generational perspective. Using a combination of ethnographic and Participatory Geographic Information Systems (PGIS), this study presents Qoma, a rural fishing village as a case study to investigate and document fishermen's and fisherwomen's ITK. This study contributes to the limited research focusing on differences in spatial use of marine resources, fishing practices, targeted species, and number of species known/identified by fishers' according to sex and age in the Qoma. Using the sex-generational lens, we explore fishers' daily interactions with resources and perceptions of these resources as well as of their (current and future) management.

Materials and methods

Study area

Qoma village (hereafter "Qoma") is spread across the three tiny islands of Nabulebulewa, Qoma Levu, and Qoma Lailai. Qoma is located approximately 70 km northeast of Suva, Fiji's capital city (Figure 1) and is part of Tailevu Province. The closest municipality is Korovou Town. The three islands comprise an area of approximately 35 ha. The village takes up the whole of Nabulebulewa, which is home to roughly 80% of the population, while the remaining 20% reside on the adjacent end of Qoma Levu. Qoma Lailai remains an uninhabited island. In 2018, Qoma had a population of 262 people with 82 families (Sailasa Vasua, pers comm to NQ, 26.05.2018). Sources of livelihood include subsistence agriculture (on Qoma Levu and Qoma Lailai), subsistence and commercial fishing, and paid employment. Qoma villagers are the gonedau for the Turaga na Ratu (Paramount Chief) of Verata, have customary fishing rights in two areas (Lot 4 and Lot 5 on Figure 2) designated

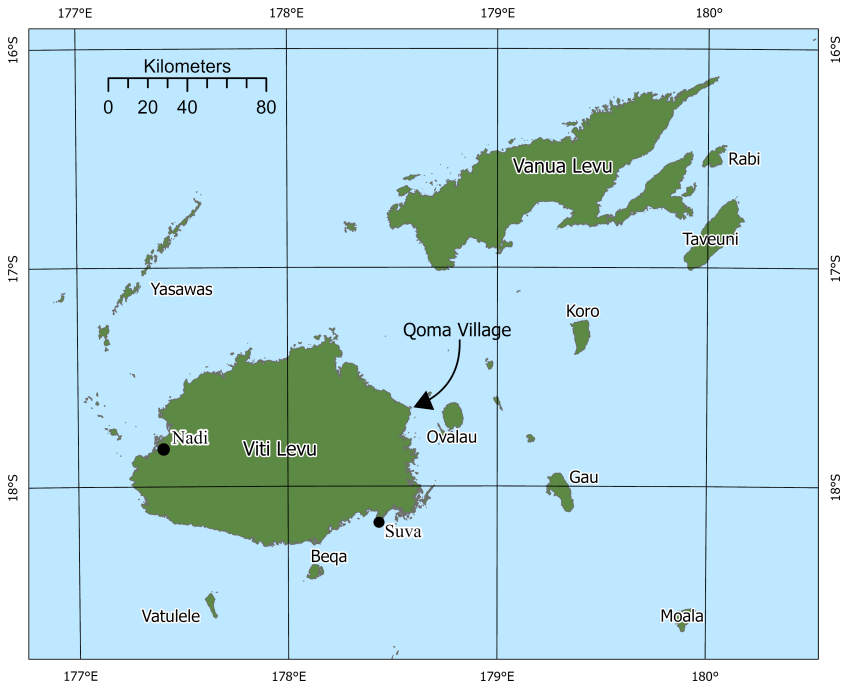

FIGURE 1
Fiji showing the location of Qoma village.

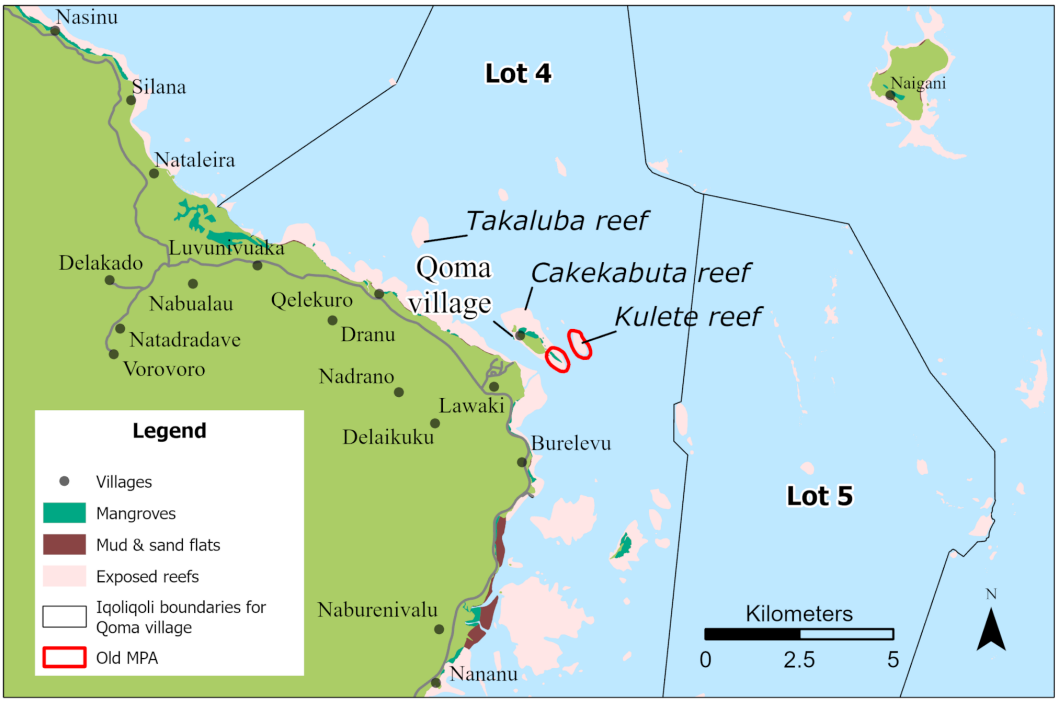

FIGURE 2
Qoma village with iqoliqoli boundaries and nearby marine habitats. The Lots labelled in these maps are the traditional fishing boundaries allotted and marked out by the Native Lands and Fisheries Commission between 1958 – 1967 and the records are kept with the Ministry of iTaukei Affairs office.

by the Native Lands and Fisheries Commission, with a combined area of 291 km^2. Within Qoma's traditional fishing ground (iqoliqoli) boundaries are mangroves, seagrass meadows, lagoons, mudflats, reef channels, extensive reefs, and the waters behind them (Figure 2). The fishermen are renowned sea turtle hunters (Kitolelei et al., 2022) and the women are skilled in gleaning on the intertidal flats and mangroves areas, catching smaller fish, crabs, and octopus (Veitayaki, 1994).

Fishing practices in Qoma have changed considerably over time such as customs associated with turtle harvest and customs associated with fishing gear preparation like net making. Some fishers still incorporate some old fishing practices such as the use of specialized nets made from beach hibiscus sinnet for fishing used in group fishing. Due to heavy reliance on marine resources, a locally managed marine area (LMMA) was set up in 2010 on the south of Qoma Levu, stretching from Kulete Reef and includes Qoma Lailai, an area believed to have held an abundance of resources in the past (Figure 2). This LMMA was discontinued after three years, its unsuccessful due to the lack of awareness on the proper local monitoring. Customary laws that govern fishing in Qoma include the practice of village rituals, respect for people's relationship with the sea, village/clan identification using totem fish[1], and the declaration of sacred fishing grounds (Vave, 2022).

Unpredictable weather conditions on account of El Niño-Southern Oscillation climate change, and oil pollution from the Natovi Jetty (an interisland ship anchorage located south of Qoma), are among the factors that affect marine resource health and abundance. In 2016, Qoma was devastated by Tropical Cyclone Winston which destroyed 70% of the homes and changed the structure of the reef by depositing rocks and coral debris on the reef. The community has since rebuilt their homes through communal effort and aid from the Fijian government (Sitiveni Tagi, pers comm to SK, 3.11.2020), while the damaged reefs are still slowly recovering.

1 Totem fish refers to one of three natural resources (fish, plant and animal) which the iTaukei communities in Fiji use to represent as a symbol of fertility and reproductive capability, usually iconic features of importance in the local custom. Sometimes the mere mention of a totem can lead to punishment of an individual such as drinking a large bowl of kava (GATTY, R. 2009). *Fijian-English dictionary: with notes on Fijian culture and natural history*, Suva, R. Gatty).

Data collection

Ethnographic methods

Ethnographic methods used in this study included participant observation (Jackson, 1983; Kawulich, 2005), informal interviews (Spradley, 1979), talanoa (informal conversation), and focus group discussions (Longhurst, 2016). NQ conducted research in 2017 – 2018 by living in Qoma for two three-week periods. During this time, NQ gained insights on beliefs and socio-cultural practices in the village. NQ focused on villagers' relationships with their marine environment and carried out 31 semi-structured interviews with individuals in the community who were actively engaged in fishing and reef gleaning (Table 1). While the interviews were open-ended, the structured part of the interviews addressed questions about participants' perceptions of the most important marine resources ('top five'), fishing/harvesting methods, personal demographic information (age, sex, occupation, etc.), and information on the sites from where the resources were taken. Length of each interview was 15 – 30 minutes on average. Interviews were conducted in homes of the interviewees or in the village hall, allowing interviewees to have a relax setting. NQ collected qualitative data by using semi-structured interviews, which encourages a two-way communication for both interviewer and interviewee to learn.

In 2020, a follow-up visit was conducted by SK, who presented a summary of the research findings of the 2017 - 2018 field work. SK worked separately with groups of men and women to verify research information collected through earlier PGIS mapping and informal interviews. SK also discussed management implications of the presented data. Data collection method included talanoa and in-depth interviews of selected individuals identified by the community as experts (older fishers who fished when they were younger and present day fishers). Fishermen and fisherwomen were interviewed separately to ensure that the fisherwomen could share their knowledge. The fishermen and fisherwomen were also separated during focal group interviews.

The talanoa sessions and in-depth interviews centred around temporal changes in fishing methods, resource abundance and size, local vernacular name(s) of resources, place names and fisher ecological knowledge. The focus groups of the talanoa sessions consisted of fishers from two age categories (18 – 35 years old and 36 – 59 years old), and discussions were stimulated through the interview questions used. This method also allowed knowledge transmission between the two age categories. The discussion also prompted interviewees to remember some 'forgotten' knowledge such as the Qoma local names of some fish and beliefs and taboos associated with some fishing locations. SK conducted a total of 36 interviews (Table 1).

NQ is a Solomon Island young woman who conducted field work in Qoma with MK, an iTaukei young man as her field assistant. SK is an iTaukei woman who was assisted by AS, an iTaukei young woman in 2020 and together they translated NQ's findings and verified them with the fishers in Qoma. Both researchers went through the Tailevu Provincial Office and contacted the turaga ni koro (government-appointed village spokesman) directly with regards to the logistics of their research. Due to the sensitivity of some information, the fishers were asked to confirm which information they allowed to be published. Ethical considerations were taken into account and a letter of permission to publish selected information was also given to the turaga ni koro and fish warden. The letter of permission was signed by the turaga ni koro on behalf of the fishers after he read the letter and, for even better clarity, SK translated the details of the letter.

Participatory GIS

Participatory mapping data of the Qoma fishers' knowledge was collected by NQ and verified by SK. Identification of areas from where marine resources were harvested was carried out using a tablet computer with GIS software or laminated 1:50,000 topographic maps, depending on which method participants found easiest to use (Figure S1). Although some participants had difficulties with using the tablet computer, most were able to identify the fishing sites—using reefs or rocks visible on the imagery or the topographic map. Participants mapped fishing sites individually using polygons. For the analysis, fishing sites identified by more than one participant were combined in the GIS into a single site to avoid double counting sites (See *Supplementary Information* for more details of PGIS methods).

Data analysis

Ethnographic data from talanoa sessions and in-depth interviews was entered into Microsoft Excel and coded to for qualitative and quantitative analysis. The coding of the ITK of

TABLE 1 Age and sex distribution of participants in PGIS mapping interviews (2017-2018) and ethnographic interviews (2020).

	PGIS Interviews (2017-18) Age				Ethnographic Interviews (2020) Age			
	18-35	36-59	≥60	Total	18-35	36-59	≥60	Total
Male	7	7	2	16	3	9	3	15
Female	7	5	3	15	6	10	5	21
Total	14	12	5	31	9	19	8	36

men and women was based on the type of information collected - ecological knowledge (spawning behaviour, feeding habits, aggregations), cultural significance, religious beliefs, resource use, estimated catches, Indigenous taxonomies. Information on target species was derived by tabulating the frequency with which each resource was mentioned by each participant. Results were combined in tables and are presented in this paper and the accompanying Supplementary Information (Tables S2–S6). Ethnographic data from participant observation was recorded in notebooks from which anecdotes and quotes are presented in this paper.

Data collected through PGIS mapping were input into ArcGIS software to create the marine resource maps in this paper and the large, laminated poster-size maps gifted to the Qoma community. A feature-based proximity analysis was used to calculate distances from Qoma to fishing sites mapped through PGIS interviews (See Page 2 of Supplementary Information for details). Non-parametric tests were used; differences in distance fishers of the three age groups (1-35, 36-59, ≥60 years old) travel to fishing sites were tested with the Kruskal-Wallis test, while the Mann-Whitney-Wilcoxon test was used to test for differences in distance travelled by fishermen and fisherwomen within each age group. The ethnographic information was analysed by age categories and separately documented fishermen and fisherwomen ITK per generation. The PGIS maps and data were documented separately for fishermen and fisherwomen.

Quotes used in this study were recorded by NQ in 2017 – 2018, translated from the iTaukei language by the Indigenous field assistant (MK), and later verified by SK and AS in 2020. SK also contributed translated quotes from the in-depth interviews conducted in 2020. The limitation of translating quotes from the iTaukei language is that some information is lost in translation.

Fishers is used throughout the manuscript referring to both fishermen and fisherwomen interviewed for this study.

Results

Fishing sites and use of space

Through the PGIS interviews a total of 138 fishing sites were mapped as polygons for 42 different marine resources (Table S1). Differences in how fishermen and fisherwomen utilise space in their traditional fishing grounds are markedly evident from the GIS data (Figure 3). Fishermen travel to the submerged reefs in waters up to 22 km from Qoma whereas 75% of the interviewed fisherwomen tend to fish on the intertidal flats and on the

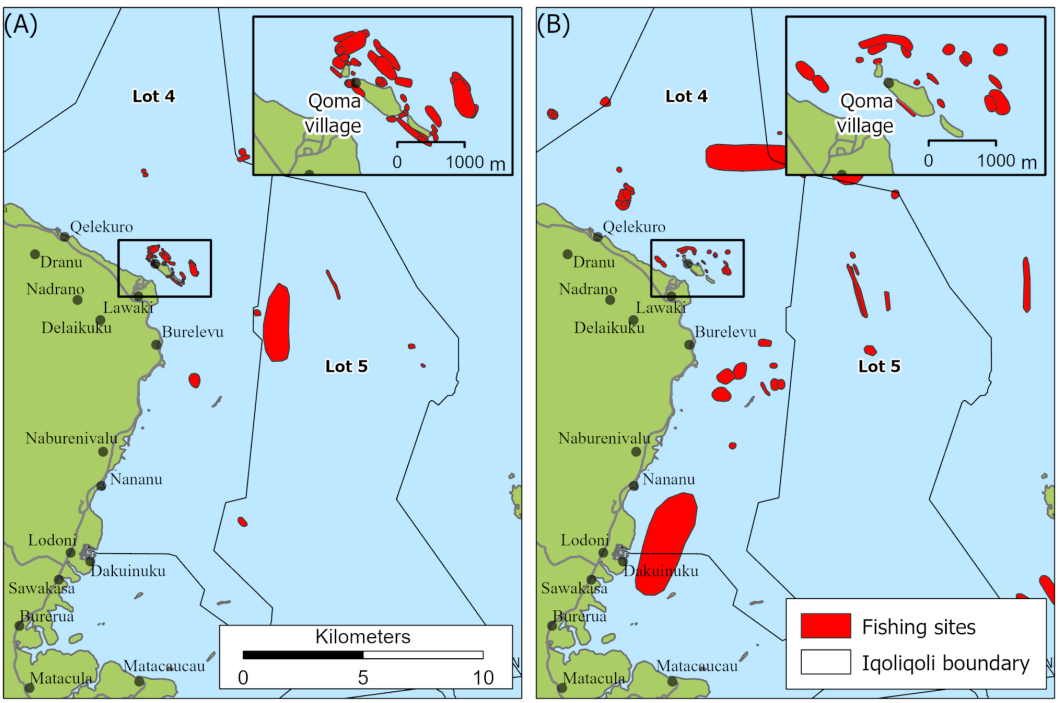

FIGURE 3
Fishing sites identified by female participants **(A)** and male participants **(B)** through PGIS mapping interviews. The Lots labelled in these maps are the traditional fishing boundaries allotted and marked out by the Native Lands and Fisheries Commission between 1958 – 1967 and the records are kept with the Ministry of iTaukei Affairs office.

fringing reef around Qoma. However, 25% of the fisherwomen travel further regularly, especially if they can fish with someone who owns a boat, as shared by this 46-year-old woman:

"I always go out fishing with [my] husband on a boat. My husband spear dives while I fish using hand lines from the boat."

The difference in distance travelled for fishermen versus fisherwomen was significant for all age groups (W=44, p=0.143 for 18-29; W=158, p=0.004 for 36-59; W=14, p=0.005 for ≥60) (Figure 4). The statistics show that there are no significant differences between the fishermen's age categories (H=4.61, df=2, p=0.100). However, the statistics show significant difference between two fisherwomen's age groups (H=8.17, df=2, p=0.017), demonstrate that women of 36 – 59 years old travel further than the ≥60 years old.

Of the 138 fishing sites identified, 101 fishing sites (73.0%) were associated with a single marine resource, 23 (17.5%) were associated with five marine resources, seven (5.0%) were associated with four marine resources, five (3.5%) were associated with three marine resources, and two (1.0%) were associated with two marine resources. Fishing sites associated with multiple marine resources are shown on GIS overlap analysis and include the area around Takaluba reef and the area on the fringing reef north of Nabulebulewa island (Figures 5, 6).

Important marine resources

The fishers identified 42 different marine resources in their local iTaukei names targeted for sale or subsistence use. Table 2 and Figure S2 offer a summary of the most important resources identified by the villagers according to four categories: economic importance, cultural importance, to be preserved for future generations, and of management concern. Of the 42 marine resources, ten resources were at the top of one or more of these categories, indicating that about a quarter of the resources are considered of high importance for one or more of these reasons (Table S2).

This data shows that donu (grouper, *Plectropomus* spp., high economic value and of management concern) is found at 12 locations, comprising approximately 400 ha and may be considered relatively abundant from a geographic perspective (Table 2; Figure S2). Both drekeni (many-spotted sweetlips, *Plectorhinchus chaetodonoides*) and kawakawa (several grouper species) are overfished. Drekeni is found in only two sites (45 ha) and kawakawa is found in four locations covering 265 ha. Resources such as sucuwalu (white teatfish, *Holothuria (Microthele) fuscogilva*, high economic value) is found in only two sites with a total area of 17 ha. Sici (turban/trochus shell, *Rochia nilotica*, preserve for future generations) are also harvested in two locations constituting only one ha, suggesting these resources are relatively uncommon geographically.

Of the two resources of cultural importance, vonu (sea turtles, *Caretta caretta*, *Chelonia mydas*, and *Eretmochelys imbricata*) is exclusively harvested by men and is presented alive as the head of ceremonial tribute (kakana vakaturaga). Matu (silver biddy, *Gerres* spp.) is exclusively harvested by women using nets and is eaten at important communal feasts where it is served to special guests. Table 3 presents the overall 'top five' resources identified by men and women. Two resources targeted by both men and women are donu and kuita (*Octopus cyanea*). Women catch octopus along the coast of Qoma, while fishermen travel to an uninhabited island to capture octopus and other resources from the nearby submerged reefs.

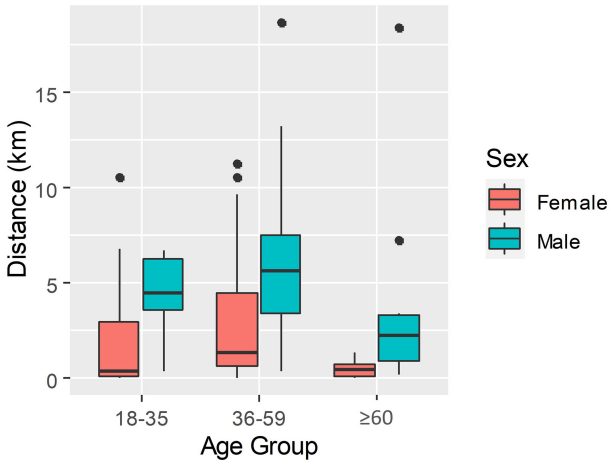

FIGURE 4
Distance fishers travel to fishing sites by age and sex.

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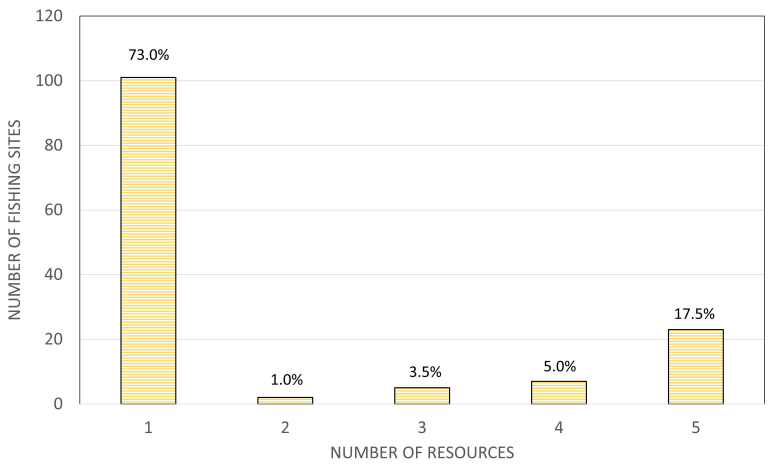

FIGURE 5
Number of resources harvested per fishing location.

Intergenerational transmission of knowledge

"I learned how to fish from my grandfather. He used to take me out fishing and taught me how and where to fish because here (Qoma), fish is the source of our survival".

This was shared by a 52-year-old fisherman as he described how knowledge of how and where to fish was passed on from the previous generation. Children in Qoma learn how to fish at a very young age, through imitation of their parents and extended families in the village. A 19-year-old fisherman said:

"I started fishing when I was 10 years old and since then after school, I would go around the island fishing."

Most boys start fishing at the age of eight by using bows and arrows in the mangrove areas and along the seawall. Young girls start at the age of nine using fishing lines from the seawall at high tide. However, there is also concern that not only are fishing practices changing— using spear guns, for example, is becoming more common—but interest in fishing among children is declining, as expressed by a 26-year-old fisherwoman:

"Nowadays young children are no longer interested in going out fishing as before because of television and other technology, which occupy them during their leisure time and substitutes for fishing. It is not like before when we were always excited to go out fishing every day after school and during the school holidays."

During the follow-up interviews in 2020 the number of marine resources identified by participants were described and recorded in greater detail than the PGIS mapping interviews. For example, sasalu, which was formerly identified in the PGIS mapping interviews as a single resource, was broken down in 2020 by a 66-year-old fisherman to 32 different species. These included several species of sea cucumbers, seaweeds, sea urchins, sea hares and sea grapes. An 84-year-old former fisherwoman who specialized in shell fishing (dauvivili) bemoaned the loss of expert shellfish collectors:

"*Today, I do not think any of the women younger than me know how to identify different shellfish, nor do they know the best locations for gleaning*".

In Qoma, very few people still retain the knowledge of the different types of gastropods that were present fifty years ago. This is because they have become scarce or extirpated from overharvesting and the effects of natural extreme events such as storm surges and cyclones. Of the 143 marine species discussed in interviews in 2020, fishermen over 60 years described 76% of the species and fisherwomen over 60 years described 46% of the identified species. This is due to the different fishing location preferences, fishing gear preferences and fishing purpose (subsistence or commercial use). The 18 – 59 year-old fishermen identified 108% more species than the fisherwomen in the same age category. This is because the men dived for sea cucumbers, lobsters, and fish while women catch fish and hand collect mangrove crabs (Table 4).

During these interviews, it became evident that in addition to the elders having a richer knowledge of marine species, many of the traditional fishing methods described by elders were unknown to the younger generations listening to the interviews. Some methods include cina saku – marlin fishing using coconut leaf torches. Moreover, changes in the fishing gears were noted by the elders. A 78-year-old fisherwoman described fishing in the 1960s:

"When I first arrived as a newly married woman into Qoma, I was taken fishing by the older women in the village. After I got accustomed to the fishing, I used to go fishing with two close

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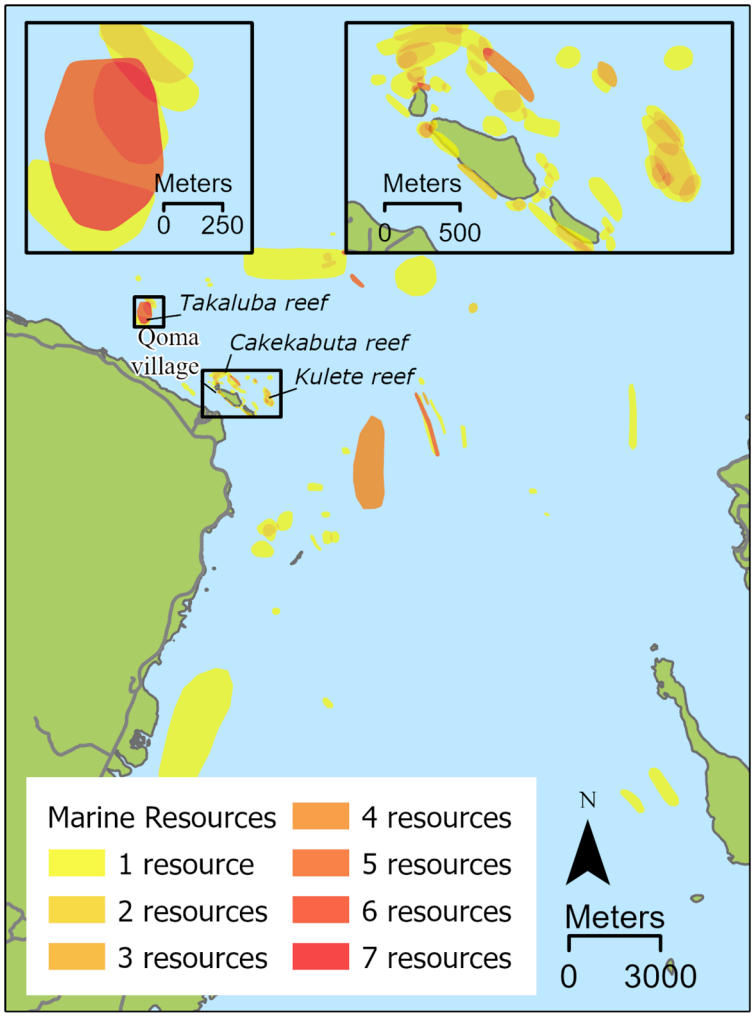

FIGURE 6
Spatial overlap of marine resources showing relatively high resource richness of Takaluba reef and the north end of Nabulebulewa island fringing reef.

friends. We used to sew store-bought sails together and hoisted them up on our boats to make it easier to travel around and fish. We used hand-held lines which we made from home using coconut sinnet and sometimes beach hibiscus."

Changes in the type of fishing gear used was described in detail by a 67-year-old fisherman who gave an example of the change in the materials used for making fishing nets:

"I remember my father told me that between 1930 – 1940 we made nets from coconut sinnet; in the 1950s, the coconut sinnet was replaced with cotton twine; in the 1960s the twine was replaced with nylon nets and the nylon nets were replaced by nets plaited from fishing lines in the 1980s."

Resource use and exploitation

Heavy reliance on the marine resources of Qoma is part of the fishing culture of the people. A 53-year-old fisherman described fisher perceptions on the abundance and unlimited resources and the reason why they heavily rely on the sea:

"Na neimami qele na waitui" – "the sea is our land and God will always provide for us."

People in Qoma maintain traditional ways of relating to marine resources and their iqoliqoli. These are revealed through people's actions and relationships within the village, as well as in their perceptions and fishing practices. On fishing trips, fishers

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TABLE 2 Summary of the most important resources identified as: 1) high economic importance, 2) high cultural importance, 3) to be preserved for future generations, and 4) of current management concern.

Fijian name	English name	Scientific name	No. locations	Hectares	% of total
1) Economic importance					
Donu	Grouper	*Plectropomus* spp.	12	397	9.0
Kawakawa	Grouper	(several species)	4	265	6.0
Sabutu	Pacific yellowtail emperor	*Lethrinus atkinsoni*	4	263	5.9
Sucuwalu	Sea cucumber, white teatfish	*Holothuria (Microthele) fuscogilva*	2	17	0.4
Urau	Spiny lobster	*Panulirus* spp.	7	375	8.5
Total economic importance			29	1317	29.8
2) Cultural importance					
Matu	Silver biddy	*Gerres* spp.	7	11	0.2
Vonu	Sea turtle	*Caretta caretta, Chelonia mydas, Eretmochelys imbricata*	16	1287	29.0
Total cultural importance			23	1298	29.3
3) Preserve for future generations					
Donu	Grouper	*Plectropomus* spp.	12	397	8.9
Sasalu	Collective term for edible seagrass and seaweeds, soft corals, jellyfish, algae, sea anemones, sea urchins, sea slugs, sea hares, and marine worms; this term is often used to indicate a "delicacy"	(several species)	7	493	11.1
Sici	Turban shell/Trochus shell	*Rochia nilotica*	2	1	0.1
Urau	Spiny lobster	*Panulirus* spp.	7	375	8.5
Vonu	Sea turtle	*Caretta caretta, Chelonia mydas, Eretmochelys imbricata*	16	1287	29.0
Total future generations			44	2553	57.6
4) Management concern					
Donu	Grouper	*Plectorhichus* spp.	12	397	9.0
Drekeni	Many-spotted sweetlips	*Plectorhinchus chaetodonoides*	2	45	1.0
Sabutu	Pacific yellowtail emperor	*Lethrinus atkinsoni*	4	263	5.9
Total management concern			18	705	15.9
TOTAL All marine resources*			138	4697	

*Breakdown for all marine resources comprising TOTAL is available in Supplemental Information.

TABLE 3 Overall 'top five' resources identified by men and 'top five' resources identified by women, with local iTaukei name and common English name.

Men		Women	
iTaukei	Common name (Scientific name)	iTaukei	Common name (Scientific name)
urau	lobster (*Panulirus* spp.)	kabatia	red-eared emperor (*Lethrinus rubrioperculatus*)
vonu	sea turtle (*Chelonia mydas, Eretmochelys imbricata*)	matu	silver biddy (*Gerres* spp)
saqa	giant trevally (*Caranx ignobilis*)	sabutu	emperor (*Lethrinus atkinsoni*)
walu	Spanish mackerel (*Scomberomorus commerson*)	busa	halfbeak (several species)
sasalu	echinoderms, seagrass, seaweed, jellyfish, sea urchins	kake	red-tailed snapper (*Lutjanus fulvus*)

The scientific names are noted in brackets.

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TABLE 4 Age and sex breakdown of number of species identified by fishers for different taxa.

Taxon	Total species	18-35 yrs		36-59 yrs		≥60 yrs	
		Female	Male	Female	Male	Female	Male
Sharks	8	0	0	0	2	0	8
Rays	10	0	0	2	2	0	7
Eels	1	0	0	0	0	0	1
True finfishes	34	7	13	13	29	17	17
Echinoderms	29	1	26	1	3	10	27
Crustaceans	22	3	11	2	19	10	12
Gastropods	16	1	1	1	3	15	16
Bivalves	8	1	0	0	1	8	8
Cephalopods	2	1	1	2	1	2	1
Sea turtles	4	1	2	1	1	0	5
Seagrass & seaweeds	9	1	0	3	1	4	7
Total	143	16	54	25	62	66	109
% of Total	100%	11%	38%	17%	43%	46%	76%

Species were identified by their local names and were matched against the scientific names with reference to work done in Qoma by Veitayaki (1990) and the iTaukei dictionary published in 2021 by the Ministry of iTaukei Affairs. Collectively 143 different species were identified by all age-sex groups.

use chants for fish calling, reflecting their connections with the marine resources and the surrounding environment (Box 1). During a fishing trip, an older woman who was calling out the names of the fish was asked why, and she replied:

"*The fish can be called to come closer to the hook.*"

This trusted fish calling rituals, demonstrating people's deep connection to their environment, the resources it yields, and their forefathers. The practice also shows that, to local fishers, fish are not just resources to be captured, but physical manifestations of relationships which can be influenced to assist fishers attain their goals of making a catch.

Through talanoa sessions, fishers identified resources they exploited, reasons for resource exploitation, and the conservation status of the marine resources. Resource exploitation over time, coupled with increasingly efficient fishing gears and the effects of natural and anthropogenic environmental changes have led to the decline of some resources. For instance, heavy exploitation of the giant triton (*Charonia tritonis* - davui) led to the species becoming rare in the late 1990s and triggered a crown of thorns starfish (*Acanthaster planci*) outbreak; which greatly affected the protected area established in 2010.

According to elders (≥60 years old), in the 1970s, spawning aggregations of the unicornfish (*Naso unicornis* - ta) used to occur around Qoma and caught in abundance. A 68-year-old fisherman described how the unicornfish was exploited:

"*Fishers who catch ta today target the fish outside of its traditional fishing season, which falls between November to January. In addition to this, many fishers dive and actively target ta at night while the fish is sleeping. Gillnets are part of the problem when used to catch all kinds of fish, including ta. For this reason, ta is rarely found or caught where it used to be abundant. And when it is harvested, the ta is no longer large or fat like it used to be when I was younger.*"

The coral reefs around Qoma are endangered by destructive fishing methods and oil spills from the nearby interisland ship anchorage (Solomoni Tabata, pers comm to SK, 03.11.2020). According to a fisherman, between 1986-87, fishers used to uproot coral where fish were hiding and used fish poison (*Derris trifoliata* – fish poison vine) to stun fish in those areas. This method enabled fishers to catch target and non-targeted resources and damaged the corals.

In addition to overfishing and destructive fishing methods, fishers mentioned that there has also been an increase in the number of fishers using the shared fishing grounds of Qoma leading to heavy declines in resources. Moreover, progressive introduction of new fishing gears in Qoma such as motorized boats in the 1950s and new fishing hooks, fishing lines, nylon nets, and diving gears replaced home-made fishing gears in the 1970s. Although these methods were efficient, they had damaging effects to the marine environment and resource populations.

Ecological knowledge

Men and women identified certain seasonal target resources which have seasonal peaks and are identified by seasonal indicators (Table S5). For example, octopus can be caught at any time during the year, however, fishers mentioned that octopus is abundant in July and August. Octopus abundance is signalled by the flowering of the coral tree (*Erythrina variegata* -drala) and the ti plant (*Cordyline fruticosa* – vasili). There is also an abundance of juvenile stingrays (draunivau) in the water at this time. Fishers call the phenomenon cabe na kuita (octopus

season), when octopi aggregate and fishers can catch up to 40 octopi per day.

Another aggregation mentioned by fishers is that of the gold-spotted rabbitfish (*Siganus punctatus* – nuqa) which aggregate to spawn and feed. According to a fisherman and fisherwoman,

"*The nuqa never fails to appear every year between December and January during the period known as Vula i Nuqa Levu and Vula i Nuqa Lailai in the iTaukei fishing calendar*".

During this period, fishers take note of the lunar and tidal movement before going out fishing, and can catch hundreds of nuqa in their nets. There is also an abundance of the upside-down jellyfish (*Cassiopea* spp. – drose) which is a chiefly delicacy for the paramount chief in Verata.

Brown land crabs (*Cardisoma carniflex* – lairo) are also abundant between December and January and their presence is signified by the fruiting of the breadfruit tree (*Artocarpus altilis* – uto). During this period, these berried crabs migrate to sea to spawn and are easier to capture when they return to land, fishers can hand-collect more than 50 in one night. Finally, according to fishermen, the narrow-barred Spanish mackerel (*Scomberomorus commerson* – salala) aggregate and spawn fromNovember to December. This is indicated by an abundance of the giant trevally (*Caranx ignobilis*), the fruiting of the mangoes (*Mangnifera indica* – maqo), and Malayan apples (*Syzigium malaccense* – kavika), and the native pineapple (*Ananas comosus* - balawa) fruiting.

Local management practices

Sacred spaces are often used in Fiji to cordon portions of an iqoliqoli for special use. For example, Cakau Davui reef is a sacred fishing ground (iqoliqoli tabu) that requires the invocation of a special ritual before villagers may fish there (Veitayaki, 2005). However, informal discussions with the villagers revealed that nowadays these rituals are rarely practiced as the villagers seldom fish in Cakau Davui. According to the fishers, the government-licensing system diminishes customary right and the value of their sacred spaces as it authorizes outside licensed fishers to access Cakau Davui for fishing.

Another common practice is the use of tabu areas (marine areas where fishing is prohibited for a certain period). The observation of a tabu was common when a high chief died but it can now be declared for other reasons as illustrated by this example provided by a 63-year-old fisherman:

A tabu was put in place in Qoma for a period of six months after it was found that little or no catch was coming from the fishing ground. The village elders and head of the mataqali [subclans] *agreed on a tabu period. Rules regarding the restricted access and the demarcated tabu areas were publicized to the people of the village. A ceremony involving the presentation of a sevusevu* [ceremonial kava offering] *to the chiefs and the ritualised sharing of kava after the elders agreed to establish the tabu period, formalises the arrangement. To lift the tabu, the villagers again presented a sevusevu to the Tui Nabulebulewa to seek his permission and blessing for the relaxation of the ban and the harvesting of the resources.*

During the 2020 talanoa sessions, the topic of existing or potential protected areas was discussed. At that time, there were no protected areas in place, though fishers indicated on the maps that an earlier protected area was setup on the southeast portion of the fringing reef near Qoma (see Figure 2). One of the fishers suggested a protected area could be established in the mangrove areas of Qoma Levu and Qoma Lailai because of their importance as fish nurseries and that few fishers go there for crabbing or gleaning. Overall, fishers believed a gazetted marine protected area would limit their access to fishing areas.

Moreover, Qoma fishers use cultural and religious customary knowledge to mark ecologically or culturally significant spaces for fishing and resource management. An 87-year-old former fisherwoman told a story of them capturing a totem fish, which was considered culturally sacred and forbidden (tabu) to catch:

"*When I was younger, we were fishing with a group of women using nets. When we lifted our nets out of the water, one of the women captured our totem fish/We all abandoned our nets and ran ashore leaving our nets and catch behind".*

Another belief was that in the past when out sea turtle hunting, the fishermen would capture as many turtles as they could with their nets until a sea turtle passed close to the net without being captured. They interpreted this as a sign that they had captured enough sea turtles for their purpose. A 58-year-old fisherman described the end of sea turtle hunting:

"*Our ancestors were sacred turtle hunters. We believe that sea turtles will continue to be captured until we have enough for our communal ceremony or ceremonial tribute. Once we capture what we need, all other sea turtles that come close to our turtle net will all pass through without being caught. This is when we stop our turtle hunting*"

Other cultural practices associated with sea turtle harvest included the presentation of kava to the traditional fishermen (gonedau) who prepared specialized nets, or for the traditional iTaukei priest (bete) to contact ancestral spirits before fishing (Table S6), and special chants. Due to heavy exploitation, sea turtle harvest is banned in Fiji through the Fisheries Act [Cap 159]. However, until 2018, Indigenous fishermen could apply for an "exemption for traditional use" license to capture sea turtles.

In the past, associations with spirits were an indirect way of managing resources as fishers revered their ancestral spirits and feared the punishments they would receive if they broke taboos (tabu) associated with them. Since the adoption of Christianity, fishers have moved away from traditional chants and rituals involving contact with ancestral spirits. New rituals such as offering a prayer before fishing are today adopted. Moreover, church leaders usually adhere to conservation advice from the

Government, NGOs, and Tertiary Institutes, and therefore call their church members to protect resources and fish sustainably for future generations (Table S6).

Discussion

Building on the gaps found in Fiji's research on the marriage between ITK and science, our study provides three key insights using Qoma as a case study. First, our study confirms that fishers develop their ITK through daily in-field experiences (Veitayaki et al., 2015) therefore the spatial use of the iqoliqoli depends on resource abundance, fishing gear, and the purpose of fishing (Kitolelei et al., 2021). Fishers in Qoma naturally revisit sites they capture a lot of marine resources. As a result, the revisited sites can be overexploited, confirming fisher perceptions that their resources have diminished over time. Although fishers are aware of the diminishing resource base, they continue to harvest the resources and thus keep changing the marine resource abundance of the iqoliqoli. Fishers' actions clearly state the need for awareness on the implications of overfishing. Knowledge exchange is an important platform for creating awareness on the different issues which policy makers, resource managers and the fishers face and provides opportunity for dialogue on past, present and future ways on improving resource use and attitudes of fishers.

In Qoma, changes in the spatial use of the fishing grounds are evident as fisherwomen are able to access fishing areas they had little or no access to. Accessibility occurs with the introduction of efficient fishing gears and transportation methods. In the past, majority of the women's fishing occurred in and around the intertidal areas. In 1986, Veitayaki reported that fishing played an integral part of Qoma and the communal division of labour was observed (Veitayaki, 1990); particularly for major ceremonies, where women participated in reef gleaning and men went turtle hunting (Kitolelei et al, 2022). Like many iTaukei communities, cultural roles "define and determine spheres of influence … and dictate roles and participation in various fisheries sectors" (Vunisea, 2014:9). Today in Qoma, although cultural roles are pre-defined, men and women work together to meet communal obligations and provide for their families. Some women modified existing fishing techniques such as nunu kuita in order to capture target resources faster, and travel further to fish. Moreover, rituals which used to be associated with the ancient beliefs are no longer practiced because they have either become redundant or forgotten.

Statistically, our results show a significant change in the distances travelled by the fisherwomen of 36 – 59 years of age, and this is because these fisherwomen join their husbands or men who go on fishing trips using outboard motor. Decline in fisheries resources within the shared iqoliqoli boundary is evident through the spatial use of preferred fishing locations as fishers travel as far as 22 km away from Qoma. Similar reports of traveling further to fish is reported by Golden et al. (2014) from Nagigi village in Vanua Levu, Fiji. Through our study, fishermen and fisherwomen were given a chance to map their fishing areas using PGIS. Beyond the sense of ownership, PGIS mapping has the potential to give indigenous peoples a sense of control over the resources they value and have stewardship over (Rambaldi et al., 2006; Sieber, 2006; Mukherjee, 2015).

The maps and spatial data produced from the PGIS effort not only offer a baseline inventory of marine resources, but also offer a foundation of data from which community/state hybrid marine resource management planning could be implemented. While people in the village do not have the expertise to utilise the GIS data directly, they can work with government and non-governmental entities that do, with the satisfaction of knowing they produced the data (Calamia, 1999; Aswani and Lauer 2006).

Second, our study provides insights into the generational differences in resource use, spatial use and management/exploitation activities. Changes in the transmission of fishing knowledge and skills between generations is interrupted by the changing attitudes of younger and older generations. As shown in the results, elders reminisce on the temporal changes in fishing gears, the way they were taught to fish, and the person teaching them how to fish. Temporal changes in the environmental setting in which ITK is transmitted is apparent from fisher quotes where intergenerational knowledge transmission occurred often with older fishers (50+ years old) during in-field experiences when compared to the younger generation. Culturally, fishers in Fiji grew up with a learning-by-doing attitude which is a practical method of passing knowledge and in most cases, the young fishers were 'thrown into the deep end' by their elders so they could quickly adapt and learn the fishing techniques. Being a proficient fisher in the past ensured that one could feed their family with protein sources from within their fishing grounds.

In contrast with the views that interest in fishing is diminishing, Fache et al. (2022) identified fishing as a recurrent theme in the children's drawings in Fiji. In Qoma, some young fishers fish for survival, therefore learn to fish at a young age. Some of the younger fishers are more knowledgeable of finfish, echinoderms (mostly sea cucumbers) and crustaceans (mostly lobsters) because these resources are highly valuable and actively targeted for sale. Associated spatial knowledge of where these resources can be found during the day and at night is also held by young generation fishers as they use their motorized boats and diving equipment and fishing gear to capture the resources.

A vital point highlighted in Qoma is the loss of knowledge transmission between generations. Villagers between 18 to 55 years of age are either in school, work or have moved into the urban areas. They have also opted to buy canned fish instead of spending time fishing because fishing is time consuming and dangerous. Due to this attitude, some elders are reluctant to

share their knowledge because they feel that fishing and its associated knowledge was their burden to bear and food is more accessible via supermarkets and shops.

Thirdly, the knowledge gap which shows similarities and differences in the ITK of fishermen and fisherwomen and how they can contribute to resource use and management is discussed. Fishing gears women use include hand held fishing lines and fishing nets which are used around the intertidal areas and along reef edges and from boats. The target resources they capture include small finfish, and these are used for daily household consumption. Men use spear guns, fishing lines for trolling, and occasionally use nets to capture sea turtles. Their fishing gears allow them to fish in different fishing location and to exploit a wider range of habitats as compared to women. In terms of conservation status of resources, fishermen identified the giant triton and white teatfish as vulnerable resources from within their fishing areas. The fishermen identified these resources as vulnerable because they actively targeted these two resources. Fisherwomen identified cowries and cone shells as vulnerable resources as the areas where they were abundant was destroyed by Tropical Cyclone Winston. The natural extreme event changed the fishing environment and affected women's target resources.

ITK which fishermen and fisherwomen both hold include the knowledge of seasonal spawning or aggregation of certain fish and crustaceans, seasonal flowering and fruiting of plants which coincide with absence or presence of resources. Fishermen and fisherwomen also possess similar knowledge of exploited habitats such as coral reefs because they frequented these areas to either break corals (in the 1950s) or use fish poisons for catching fish. They also recognise the health of coral reefs is linked to the pollution from surrounding waters. Resource exploitation is also attributed to the fact that the people in Qoma have very little land for planting, therefore, they harvest the resources from the sea instead of the land.

Fishers in Qoma possess ITK that can add to fisheries science research in Fiji. This is shown by the rich ecological knowledge they possess and indicator species such as plants which they use to identify the fishing aggregation periods for certain target species. Fisher knowledge of marine species, although is different between sex-generational categories still show that men and women have an intimate understanding and exploit marine resources they either eat or sell. Although fishing habits lead to exploitation, it is also a survival technique in Fiji's highly monetized society where the cost of living is increasing. It is critical to identify practical local institutions which can convert ITK of Qoma and iTaukei fishers into efficient management strategies by incorporating sex-age data. These strategies if successful, can be translated to the national level and then the regional level.

Education and social media or online platforms can progress knowledge transmission between generations. Incorporating interesting ITK into messages presented in on online platforms increase knowledge transmission by spreading information across a large audience in a short time span. A case of knowledge transmission using education *via* online platform is done by Dr. Tarisi Sorovi-Vunidilo in her *Talanoa with Dr. T* episodes which use both English and the iTaukei language. While our study shows significant ITK differences between age categories, this can be improved through education and learning from home. This means joining elders on fishing trips and in-field experiences within the iqoliqoli areas.

Decision making and leadership roles are important for monitoring and management of resource use. In pre-colonial times, a chief's word was the law. Today, the power of customary leadership has deteriorated through the slow influence of the Colonial and National government and replacing key leadership areas with government officials. Within an iTaukei community, some people are accorded respect according to their wealth, job and educational status rather than chiefly title. However, decisions to properly manage or exploit resources falls to chiefs. This is evident in Qoma, where fishers continually harvest sea turtles (with or without licenses) with approval from their chief (Kitolelei et al., 2022). Accepting the limitations and improving them so that they match the strength of ITK in communities can assist in resource management practices which are locally introduced into Qoma and other parts of Fiji.

Conclusion

Although Qoma village is small and relatively isolated, the ITK of this rural fishing village is relevant to broader understanding the differences in sex-generational categories of fishers. Through participatory approaches to resource management strategies, men and women of different ages can share their knowledge of fishing location importance based on the types of resources or marine environment interactions which occur in these areas. We argue that intergenerational knowledge exchange and documentation and linking of ITK with scientific knowledge encourages the participation of local communities in monitoring their fisheries.

Fishermen and fisherwomen, both young and old, possess unique ITK and experiences which can contribute to the exploitation or conservation of their resources. By incorporating their knowledge with scientific information, they can provide valuable information on which management strategies and policies can be used to target the challenges faced at the local level, which can also inform national biodiversity management plans. A better integration of ITK, management practices, policies and latest biodiversity knowledge can increase the resilience of the community and incorporate multi-disciplinary and well informed resource

management initiatives which fishers at the local level can understand, adopt, and monitor.

We strongly reiterate Fiji's current management strategies and policies for national conservation need to incorporate ITK correctly in order to bring the policies to the local-scale. There also needs to be a platform of knowledge sharing facilitated by open-access data sharing particularly for GIS based applications to improve visualization of ITK. Information needs to also be translated to community-friendly materials using local languages for knowledge transmission and loss protection. Moreover, sensitive information which can affect the resource base of communities need to be protected from publication if the knowledge is going to be used for exploitation by outside fishers.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material, further inquiries can be directed to the corresponding author.

Ethics statement

The research project was approved by USP Research Ethics Committee. Written informed consent was obtained from the individual(s) for the publication of data and quotes included in this article.

Author contributions

SK: Conceptualization, Data curation, Investigation, Formal analysis. JHL: Conceptualization, Data curation, Formal analysis, Funding acquisition, Supervision, Visualization. NQ: Data curation, Formal analysis, Investigation, Funding acquisition. JR: Funding acquisition, Investigation, Supervision. JV: Funding acquisition, Supervision. SP: Conceptualization, Funding acquisition, Project administration, Supervision. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

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