Moorea Lagoon Fishers' Mental Maps: An Exploratory Analysis of Polynesian Spatial Knowledge

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Moorea lagoon fishers' mental maps: An exploratory analysis of Polynesian spatial knowledge

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Abstract

This empirical study builds upon prior research concerning cultural influences on spatial mental representations in Oceania. A comprehensive examination of 93 mental maps sourced from 59 lagoon fishers of *Moorea* (French Polynesia) reveals interesting facts about the way they organize and share their spatial knowledge. Firstly, consistent with previous studies across Oceania, Polynesian fishers exhibit a preference for the allocentric perspective when representing their environment. Secondly, they generally rely on marine landmarks for navigation, with a particular emphasis on four entities: the reef barrier, maritime beacons, coral outcrops, and a key chromatic marker — *Moana* (blue in Tahitian) — indicating the depth of the lagoon. Finally, the factor analysis we conducted highlights two significant facts: (1) a geographical self-censorship, demonstrated by the low presence or even the absence of landmarks useful for locating their fishing spots; (2) a continuum between the surface and the depths of the lagoon, showing that surface fishers (line, net, troll, etc.) have a proven knowledge of seabed topography, whereas underwater speargun fishers also rely on landmarks located above the water.

KEYWORDS

frames of reference, geographical self-censorship, marine landmarks, mental maps, spatial cognition

INTRODUCTION

Cognitive anthropology delves into the ways human cultures conceptualize and interpret the world by examining the patterns of thought, symbols, and mental representations shared among individuals within a given society. A significant part of cognitive anthropology is dedicated to spatial orientation and wayfinding (Shore, 2014). Recent scientific developments in this domain underscore the unique processes through which Oceanian cultures acquire and recall spatial knowledge, emphasizing distinct variations across cultures. Notably, unlike Indo-European languages, Austronesian languages adopt specific frames of reference when describing object locations (Palmer, 2002). This distinction extends to the ways Oceanians convey their understanding of the environment onto tangible mediums such as paper, sand, or other material surfaces. In our endeavor to advance the field of cognitive anthropology in Oceania, we studied the organization of spatial knowledge among Polynesians — particularly the lagoon fishers of *Moorea* — by analyzing the way they externalize it through sketch maps. Before discussing the motivations driving our research, we will present an overview of the existing state of art on spatial cognition, touching on its broader implications, Oceanian specificities, and the distinct case of *Moorea* (Section 1). Subsequent sections will detail our methodology (Section 2), highlight our findings (Section 3), situate our results in the context of current scientific developments (Section 4), and conclude with a general synthesis (Section 5).

Cognitive maps, spatial knowledge, and mental maps

Following on from Trowbridge's "imaginary maps" (1913), Tolman (1948) postulated the existence of a "cognitive map" enabling human beings to find their way and navigate in space. Thirty years later, the seminal work by O'Keefe and colleagues (O'Keefe & Dostrovsky, 1971; O'Keefe & Nadel, 1978) showed that the hippocampus partially houses this cognitive map as a network of *place cells* which are activated when individuals are in a specific place. The development of cognitive maps also involves two complementary types of cell located in other parts of the brain: (1) *grid cells* — found in the medial entorhinal cortex (MEC) — which, together with place cells, form a grid-like representation of the environment; and (2) *head-direction cells* — found in the MEC, the thalamus, the posterior parietal cortex, and the lateral mammillary nucleus — which express wayfinding (i.e., the mental ability to establish a route to get from point A to point B) (Nadel, 2013). More recently, Jacob et al. (2019) showed that unlike place cells, whose activity is essentially based on information from the external environment, grid cell activation is primarily guided by internal information generated by the body movement.

To a certain extent, Tolman's use of the term "map" implicitly suggests that cognitive maps look like conventional maps (e. g., paper topographic maps). He questions the nature of the cognitive map in humans, asking whether it is a narrow strip-map or a comprehensive map, and leans more towards the first option of a sketch map to which detail is gradually added. He does not, however, question the cartographic nature of the cognitive map. Nearly 75 years later, research in neuroscience and cognitive psychology showed that the internal organization of spatial knowledge is not necessarily Euclidian. For example, Tversky (1993) likens the cognitive map to the cognitive collage, that is, an assembly of spatialized information that could take the form of a relatively comprehensive map, depending on the individual's familiarity with the environment. Ultimately, we retain Nadel's definition (2013; 156):

> "*A cognitive map is best defined as a mental representation of the environment that captures, in some specifiable way, the spatial relations among things in the world. Such a mental representation can be used to recognize places, to compute distances and directions, and in practical terms, to help an organism find its way from where it is to where it wants to be. […] the mental representation and neurobiological substrates that underlie a cognitive map act like, rather than literally look like, a map*".

In other words, cognitive maps contain spatial knowledge — that is, information about the external environment stored more or less permanently in memory. More specifically, Siegel and White (1975)

distinguish three types of spatial knowledge: (1) declarative (landmarks corresponding to fixed places); (2) procedural (routes linking landmarks together to get from A to B); and (3) survey (based on an Euclidean arrangement of landmarks and routes). Siegel and White's Landmark-Route-Survey (LRS) theory is intrinsically sequential: survey knowledge of space can only be developed after knowledge about landmarks and then routes has been acquired. Although the sequential nature of LRS theory is disputed (see Moeser, 1988 and Montello, 1998), the triptych introduced by Siegel and White — that is, landmark, route and survey knowledge — remains commonly used.

Furthermore, direct experience of the environment (i.e., without any medium) is usually considered as the "primary" means of acquiring spatial knowledge, while "secondary" means of acquisition being actual mapping tools (GPS, mapping platforms, etc.), oral descriptions (e.g., navigation instructions), and to a lesser extent, textual information (Kitchin & Blades, 2002). Conversely, acquired spatial knowledge can be retransmitted by exactly the same means. To this day, mental maps remain the most common tool for accessing individual and collective spatial knowledge. To avoid any confusion, we will now consider the term "mental map" as a material medium (paper, digital or otherwise) on which spatial knowledge stored in the memory (i.e., cognitive map) has been externalized.

Space and spatial knowledge in Remote Oceania

Our review of literature in cognitive anthropology shows that culture plays a decisive role in the acquisition and the transmission of spatial knowledge. Remote Oceania — that is, island territories located to the east of Solomon Islands (Polynesia, Micronesia, and a part of Melanesia including *Vanuatu* and New Caledonia) — is no exception to the rule. The Oceanian relationship with space is an issue that has often been addressed through the prism of linguistics. In their recent comprehensive meta-analysis, Pappas and Mawyer (2022) reveal that the topic of space and place holds significant importance within Oceanian linguistics research. They categorize this research interest into nine primary areas, referred to as "coupled language-space domains". Several of these categories have direct relevance to our study, including the cognitive framework, which encompasses frames of reference (FOR), orientations, allo-egocentric perspectives, and spatial conflicts. Further relevant categories include environmental relationships, such as wind and celestial systems, as well as navigation-at-sea, social spatiality as seen through spatially organized speech, and placemaking *via* place-naming and landscape terminology. More specifically, Ozanne-Rivierre (1987) showed in the 1980s that geographical spatial references in Kanak languages (*nemi* and *nengone*) relied on external physical landmarks, revealing in particular the double complementarity Land-Sea/Up-Down. The related spatial orientation is not based on cardinal points or an egocentric approach (right/left/front/back) as is usually the case in Indo-European languages. The Kanak people seem to prefer the Land-Sea axis in enclosed spaces such as houses and villages, and absolute references to prevailing winds for larger spaces (Bearune, 2013). The conclusions from Ozanne-Rivierre's (1987) work are in line with Oliver's (1974) synthesis of Tahitian culture and practices from the pre-colonial period. With particular reference to this period and Polynesian navigation, the latest studies by Eckstein and Schwarz (2018) on *Tupaia*'s cartography revealed that the Oceanian people had a conception of space and a spatial orientation that was at the time — late 18th century — quite different from that of Europeans. Nevertheless, the extraordinary map drawn by the Tahitian navigator on Captain Cook's HMS *Endeavour* shows that these two visions can be combined on a single cartographic document.

Research conducted after Ozanne-Rivierre's work reinforces the idea of an Oceanian cultural specificity regarding spatial cognition. We refer in particular to the work of Peltzer (1996) in Tahiti, Palmer (2002) in the Solomon Islands, Cablitz (2006) in the Marquesas Islands, and François (2015) in the Torres and Banks Islands of *Vanuatu*. Geography certainly plays an important role here. Bonnemaison's pioneering work in the Pacific (1989, 1992, 1994) shows that Oceanians have a conception of space that is very different from that of Western societies. He believes that the Western "geographical ideology", which reduces space to a geometric plane in which the idea of spatial enclosure is materialized through sharp boundaries, is overrated. The Oceanian understanding of space is fundamentally different. For the people of Oceania, space is intrinsically topological. It is based on the primacy of a relationship in which the notion

of border is associated with buffer spaces and fuzzy limits. This meaning stems from the cultural principle of a threefold continuity between Nature and Culture, Land and Sea, and Humans and Non-Humans (animals, ancestors, and deities). It contrasts with the Western cadastral system, where the registration of a delineated land parcel is equivalent to owning it. This reasoning comes from the principle that the land is a "thing" that human beings are entitled to possess. However, in the Oceanian spirit, the idea of *belonging* overrides ownership: the land belongs to humans just as much as humans belong to the land. This particular relationship with the land, but also with the sea, is expressed in many different ways. In French Polynesia (FP), it is, for example, still customary to bury the placenta — *Pufenua* in Tahitian — of a newborn child. *Pufenua* literally means "the centre/core (of) the land", "*as if it were naturally meant to be put into the ground, or as if it were itself a parcel of land included in the woman's body […] the child's first anchoring with the land within this marine environment of the amniotic sac enclosed by the membranes of the womb*" (Saura, 2003).

In addition, the rise of cognitive sciences has led a part of the academic community — anthropologists in particular (Kronenfeld et al., 2011) — to address the issue of Oceanian spatial cognition through the concept of FOR. According to Levinson (1996), an observer can describe the location of an object in relation to another one in three ways: (1) *relative FOR*, focusing on her/his own position (e.g., "*from my point of view, the pirogue is located to the left of the fisher*"); (2) *intrinsic FOR*, referring to an object using another one within the scene (e.g., "*the pirogue is located to the fisher's right*"); and (3) *absolute FOR*, using external cues (e.g., "*the pirogue is located to the west*"). The literature shows that usage differs significantly between Westerners and Oceanians: the former tend to use relative and intrinsic FOR to describe a restricted space, including the body itself, while the latter generally use the absolute FOR (Palmer, 2002). In this respect, Bennardo (2002a,b) showed that Tongans favored a particular FOR — termed "radial" — when designing mental maps of their village and island. Individuals using this subtype of absolute FOR start from a central landmark — deemed significant (e.g., *Neiafu* in the case of Bennardo's study) — from which they gradually move away centrifugally as they transcribe their spatial knowledge. Bennardo's radial FOR fits with the Oceanian geographical ideology described by Bonnemaison (1989), and also the spatial orientation models of both Shore (1996) (center-periphery) and Lehman and Herdrich (2002) (point-field), which consider space not as a container with sharp and fixed boundaries (discrete understanding), but as an unlimited field emanating from a central point (continuous understanding). Like Shore (2014), we believe that these models do not challenge the traditional binary categories of front-back and seaward-landward. Binary and radial models are mutually constitutive, and not independent. Finally, research by Feinberg et al. (2003) lies on the periphery of the above studies, but is interesting nonetheless. From a long series of anthropological studies of the inhabitants of *Anuta* (Solomon Islands) started in the 1970s, Feinberg et al. created a "collective mental map" of the lagoon. This rich map (300 entities spread over a 6- by 4-inch sheet) includes reef, coral, and sandy elements.

French Polynesia and the island of *Moorea*

Apart from linguistic work on space (e.g., Cablitz, 2006; Peltzer, 1996), very little research in the field of spatial cognition has been carried out in FP. In the early 2000s, the study conducted by Troadec (2003) showed that children of *Moorea* developed a mental representation of space that is not egocentric (right/left) — like children living in a rural environment in mainland France — but geocentric (towards the sea/towards the mountain). More recently, research by Mawyer (2014) in the Gambier Archipelago suggests that this same binary category follows a dialectical logic rather than a purely Aristotelian bivalence (i.e., A vs. non-A). To the best of our knowledge, no study has been undertaken on the analysis of Polynesian spatial knowledge drawing explicitly on the sketch mapping methodology.

Of the 75 inhabited islands of FP, we decided to conduct our research in *Moorea* because of the socio-ecological issues associated with the management of its lagoon. In a nutshell, there has been a demographic explosion in the mid-1980s: in less than 20 years, the population of this island has doubled, rising from 7,059 inhabitants in 1983 to 14,163 in 2002, reaching 17,816 according to the last census of 2017. This rise led to significant anthropic pressure on the coastline and the lagoon, which resulted in an intensification of

fishing activities, physical degradation (embankments, urbanization of the coastline, and extraction of coral materials), and an increase in pollutant releases (wastewater, pesticides, etc.). The island also receives several thousand visitors each year. Although it has experienced a drop in tourist numbers in recent years, *Moorea* still ranks with *Tahiti* and *Bora Bora* as one of FP's most visited islands. Because of its proximity to *Tahiti*, visits peak at weekends and during school holidays, when the population can double. Recreational activities (diving, fishing, recreational fish feeding, excursions, etc.) practiced during these periods inevitably disturb the functioning of the lagoon ecosystem.

Faced with this anthropic pressure, the municipality of *Moorea-Maiao* began working on a Marine Space Management Plan (PGEM) in 1996, which was ratified on October 21 2004. The plan covers the whole lagoon, from the shore to the −70m contour line, that is, beyond the lagoon on the external slope of the reef. The 2004 PGEM[1] includes two main zones: Marine Protected Areas (MPAs) and Regulated Fishing Areas (RFAs). There are eight MPAs, and regulations are stringent, banning fishing entirely (some MPAs do allow gear-based exceptions such as line fishing). In addition, vessels are restricted to a cruising speed of five knots and are required to moor to a fixed buoy for the duration of their stay in the area. The two RFAs, located in the associated municipality of *Papetoai* and *Maharepa* in the north of the island, aim to regulate fishing practices. Shellfish harvesting is prohibited, and fish sizes are regulated (this varies according to species). The PGEM contains different types of zoning in smaller areas such as anchorage zones, cruise ship berths, areas for feeding rays, and sharks (a practice prohibited since 2017 by the Polynesian Environmental Code), and cetacean resting areas.

Nearly 20 years after its introduction, the PGEM of *Moorea* holds a mixed record (Bambridge et al., 2019; Calandra et al., 2022; Gaspar & Bambridge, 2008). From a human perspective, the PGEM has led to governance and social inequity issues as lagoon fishers do not support the zonings and regulations (Wencélius et al., 2022). This failure can be attributed to the combination of two main factors. On the one hand, discussions held during the PGEM revision period showed that fishers were underrepresented on the *ad hoc* management committee[2] (Vongue, 2018). They have since joined forces and formed local fishing committees[3] (LFCs) and a lagoon fishing federation. On the other hand, several studies (Gaspar & Bambridge, 2008; Herrenschmidt, 2016; Quesnot, 2010; Vongue, 2018) showed that fishers felt a real sense of injustice. For them, the PGEM is primarily an instrument favoring tourism activities over subsistence fishing.

Undeniably, our study is embedded in a multifaceted context that needs to be specified:

- **Political**: Despite having been designed by local authorities and stakeholders, many fishers perceive the PGEM as yet another expression of post-colonial imposition, and there exists a great deal of confusion regarding who precisely manages the PGEM and its environmental zonings (local municipality, French Polynesian government, or French State).
- **Socio-economic**: The cost of living in *Moorea*, as everywhere in FP, has continued to rise, exacerbating social inequalities between the poor, who presumably include a large part of the subsistence fishers, and the wealthiest individuals. The current situation only reinforces the fishers' mistrust towards the PGEM, which they perceive as a tool serving economic rather than social development. The previous government's attempt to bypass the municipality's environmental zoning proposals to favor the development of a resort near a public beach (*Temae*) has only worsened the situation.
- **Cultural**: There is a portion — unfortunately difficult to estimate — of fishers who would like to see the PGEM abolished and replaced by a *Rahui*, that is, a traditional resource management system based on a temporary ban on a portion of the lagoon (see examples from *Tautira* and *Teahupoo* in Bambridge et al., 2019 and Fabre et al., 2021). Advocates of the *Rahui* model are *de facto* in opposition to fishers who support the PGEM, which sometimes creates conflicts within the lagoon fishing community.
- **Research**: Due to the presence of both French and American research stations (CRIOBE and GUMP — University of California), many projects on the lagoon of Moorea are underway. Lagoon fishers have been heavily solicited in the past without receiving much in return. It is therefore crucial to initiate and conduct research whose benefits are useful to them. Otherwise, researchers and their institutions may find themselves sidelined.

Objectives, research question, and contributions

Fundamentally, the PGEM is a Western tool that conveys exogenous cultural norms, which in effect, overshadow the distinctiveness of Polynesian cultures. The zoning delineations of the PGEM, as they were conceived in the early 2000s, counteract the principle of the Oceanian triple continuum, which establishes a continuity between Land and Sea, Nature and Culture, and Humans and non-Humans (Gaspar & Bambridge, 2008). In fact, the maps from which they are derived are governed by Aristotelian principles where the identity of an object A is defined by non-A across a crisp boundary. Under such premises, MPAs and RFAs are meant to induce disruptions between fishers and their environment (including non-humans). Furthermore, because they are designed to be operational, PGEM maps remain superficial. They are static, lack verticality, and cannot fully reveal the depth of Polynesian spatialities which, as the ancestral practice of *Rahui* attests (Fabre et al., 2021), are deeply connected to the sacred. Bearing these considerations in mind, we carried out this empirical study with the aim of delving into the mental representations of the lagoon held by the island's fishers, placing particular emphasis on the organization of their spatial knowledge. Given the lack of research on this topic, we explored the following question: *What are the structuring elements of the mental representations of space among Moorea's lagoon fishers?* In the end, this research intended to make at least two contributions: (1) scientifically, by filling a knowledge gap on the understanding of spatial knowledge in FP and, more generally, by expanding the scant research on mental maps related to marine space; (2) on a societal and political level, by providing a collection of tangible maps that PGEM managers could use to align MPAs and RFAs more closely with the lagoon fishers' mental constructs, potentially fostering enhanced societal acceptance of this environmental conservation tool.

MATERIALS AND METHODS

Study area

Moorea is a volcanic island located 25 km north-west of *Tahiti* in the Society Islands archipelago of FP. The island has a surface area of 134 km^2, a maximum altitude of 1,207 m (Mount *Tohiea*), and a 70 km coastline. Its lagoon, whose depth does not exceed 5 m, stretches over approximately 49 km^2 and surrounds the island at an average distance of 800 m. *Moorea* has a total of ten main passes (i.e., entry and exit points between its lagoon and the ocean) and two large bays located in the north (*Cook* and *Opunohu*) (Figure 1). Administratively, this island includes five associated municipalities: *Afareaitu*, *Haapiti*, *Paopao*, *Papetoai*, and *Teavaro*. At the time of the last census (2017), the island had 17,816 inhabitants.

Participants

It is hard to estimate the number of lagoon fishers in FP, especially for subsistence fishing[4]. In the early 2000s, Yonger (2002) estimated that 23% of *Moorea*'s population were lagoon fishers, and that more than half of the catch was for personal consumption (58%). More recently, Rassweiler et al. (2020) have estimated that three quarters of households in *Moorea* have at least one member who practices reef fishing. The authors also distinguished three main fishing techniques: net, line, and spearfishing. Regarding the specifics of our study, we had a total of 60 fishers participate, of which 48 were men and 12 were women. Thanks to the Federation of Lagoon Fishers of *Moorea*, we first approached an initial group of 10 fishers that was progressively extended to 60. Men are over-represented in lagoon fishing in FP although throughout Oceania, women are particularly active in this field (Lambeth et al., 2014). As fishing by women supplements fishing by men, we attempted to reach as many women as possible. This was not an easy task as they operate on the fringes of community networks dedicated to local lagoon governance. Finally, in our classification of the participants, we made a distinction between fishers who mostly stay at the surface using nets, lines, and

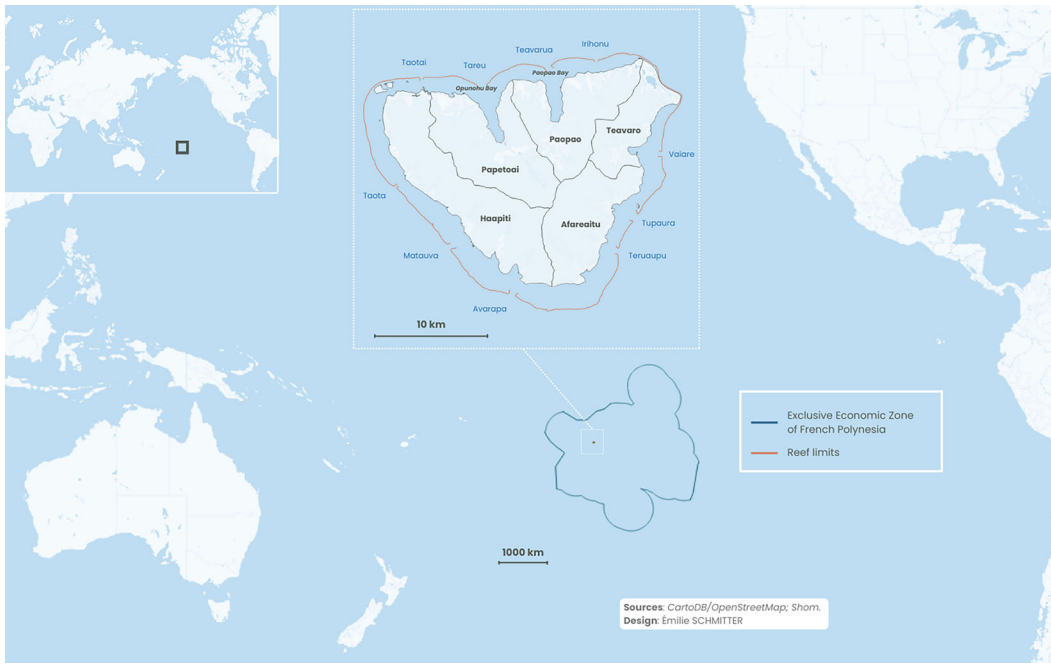

FIGURE 1 The island of *Moorea* and French Polynesia within the Pacific Ocean.

cages ($n = 23$), and those who exclusively fish under water with spearguns ($n = 30$). It is noteworthy that, of the 60 fishers we interviewed, only 6 alternate between these two techniques.

Data collection

The raw data for this study were collected in *Moorea* between April and July 2022.

Method

There are several ways of accessing mental representations of space, but the drawing of sketch maps is the most common method (Gieseking, 2013). To put it simply, it consists of asking people to represent a given space on a medium, typically paper or digital. While this method is relatively easy to implement, it does not take into account the fact that individuals will have different levels of drawing ability. The spatial reconstruction game (JRS) designed by Ramadier and Bronner (2006) overcomes the bias of the drawing skills, but makes it difficult to account for the diversity of physical elements to which the subject has access. Indeed, JRS users can only use a predetermined set of pieces associated with particular functions (e.g., a certain piece refers to a certain type of building). Given the lack of studies on mental representations among inhabitants of FP, we were not able to make an *a priori* identification of the category of physical elements salient to fishers. We therefore opted for the sketch map method, despite its skill bias. Also, it is worth mentioning that representing space through drawing is not completely extraneous to local fishers who, in informal discussions dealing with their fishing experiences, draw out their fishing spots or aspects of lagoon topography on the sand. In some rare instances ($n = 3$), when participants struggled to externalize their spatial knowledge on a blank sheet of paper, laminated satellite images of the island were made available[5]. Finally, it should be noted that using sketch maps and (potentially) satellite images limit the use of language (speech). This benefit is a determining factor insofar as Tahitian-speaking fishers

may unconsciously limit themselves because of a possible lack of French vocabulary (French and Tahitian languages co-exist).

Equipment

The following equipment was used to collect the sketch maps:

- White A4 sheets of paper;
- Pencils (grey and colored);
- Audio recording device;
- Laminated satellite images of the island (used as a fallback solution when necessary).

Procedure

After receiving the fishers' contact details from the Federation, fishers' friends, or family members, we phoned potential participants to introduce ourselves, explain the main objective of our study (i.e., to gain a better understanding of spatial knowledge among *Moorea* lagoon fishers), and to propose an interview, in a place of their choice, for collecting their mental map(s). If they agreed, we met at the chosen location — generally their home ($n = 32$), or less frequently a public place ($n = 22$) — to conduct the interview. Before participants started drawing the sketch map(s), we (1) reminded them of the study objective, and (2) obtained their oral consent for recording the session and using their mental map(s) in a scientific context. Once the participant's oral consent was obtained, we started the audio recording device before inviting them to draw the fishing areas they usually frequent. Sometimes, depending on how the drawing was developing, a verbal prompt was necessary to initiate and/or sustain the session.

Data analysis

The content of the mental maps was analysed at the individual and collective scales.

Individual content analysis

A content analysis was carried out. We first segmented each mental map according to the entities represented by the fisher. Sometimes, we went back to the audio recordings to refine this operation. We then annotated each sketch map by assigning a unique identifier to each entity recorded. All the identified entities were listed in a table containing the following fields:

- **Identifier**: unique identifier of the entity;
- **Entity**: name of entity, as named by the fisher, if applicable[6];
- **Toponym**: official place name of the entity, if applicable[7];
- **Sheet of paper**: sheet number associated with the map;
- **Map_code**: map identifier[8];
- **Description**: any clarifications about the entity.

Lastly, we harmonized the entities where necessary, as different names have sometimes been given to the same geographical object. For example, the "*Taotai* pass" (official name) was sometimes designated as "*Club Med Pass*", "*Tiahura* pass" or "*Park Royal* pass".

Cross-sectional content analysis

Once the segmentation and harmonization were completed, we carried out a cross-sectional analysis. This step resulted in a clustering of entities considered to be equivalent or similar within a supra-category. Clustering was initially carried out manually and separately by two researchers. The results were then pooled and discussed to create a final list of 55 supra-categories. We ultimately conducted a more in-depth statistical analysis on these clusters through a Principal Component Analysis (PCA) and a Bottom-up Hierarchical Clustering[9].

RESULTS

We met 60 fishers in 54 interviews. Out of the 60 interviewed, one 70-year-old fisher refused to draw a mental map. In his own words, following the Polynesian oral tradition, "*the spoken word, listening, and observation must be preferred to the solely written word*". In addition, three people used the laminated satellite images only to help them represent specific contours of the island. For some interviews, multiple fishers were interviewed at the same time. Some drew a single mental map, while others drew several, generally when they associated a mental map with a particular fishing area[10]. Specifically, 11 fishers designed 6 mental maps as a group (4 groups of 2 fishers, and 1 group of 3 fishers), and 48 fishers created 87 maps on their own. In the end, we collected a total of 93 mental maps. The shortest interview lasted 8 min, the longest 2 h and 41 min, and the average time was 55 min[11].

Map typology

We identified four types of mental map out of the 93 collected: *overview map*, drawn at the scale of *Moorea* (A); *allocentric map* specific to fishing areas (B1); *egocentric map* specific to fishing areas (B2); *both allocentric and egocentric map* (at the scale of the island and specific to fishing areas respectively) (C); *circular map* showing the fishing areas successively in a circular way[12] (D). Table 1 summarizes the basic information about this typology.

To create this typology, we examined every mental map one by one. We considered a map to be allocentric when the perspective adopted was that of an entirely top-down view (i.e., exclusively from above) (e.g., Figures 2 and 3). Mental maps with an oblique perspective (e.g., Figure 4, on which the beacons are seen from the front) or a first-person view (e.g., Figure 5) were classified as "egocentric". More specifically, an A map shows an allocentric perspective (i.e., based on a bird's-eye view) of the whole island of *Moorea* (Figure 2). The 6 fishers who exclusively created these maps depicted their fishing areas less precisely than the others. Among the maps focusing on daily fishing areas, a distinction can be made between B1 allocentric maps and B2 egocentric maps. It is interesting to note that two of the three fishers who produced an egocentric map positioned themselves facing the island of *Moorea*, as if they were actually fishing (Figure 5). In addition, two other types of map were collected: the C map, which features both *Moorea* and an egocentric perspective on the same sheet of paper (Figure 10); and the D circular map, on which the fisher described his fishing area in a circular manner along the edges of the sheet of paper (Figure 9). We also observed that some fishers started with an overview map that they then refined into a B1 ($n = 5$) or B2 ($n = 1$) map. Finally, out of the 60 fishers we met, only one produced separate B1 and B2 maps.

In addition, we paid close attention to the geographical context of the interviews. Indeed, we recorded that mental maps were most often drawn in locations far removed from the sea (land side — $n = 33$) than in locations near shore (sea side — $n = 26$). We also described the informant's bodily position while drawing, and fishers who faced the sea totally (front) or partially (side) largely outnumber those who had their backs to the sea (49 vs. 10).

TABLE 1 Map typology and related geographical information.

Type	Description	Spatial perspective	Fishers' location during the interview				Occurrences (number of fishers)	Average density of entities
			Side		Body position relative to the lagoon			
			Land	Sea	Open	Closed		
A	Overview map representing the entire island of *Moorea*.	Allocentric	4	2	6	0	6	27.5
B1	Allocentric map specific to fishing areas.	Allocentric	25	17	34	8	42	17
B2	Egocentric map specific to fishing areas.	Egocentric	1	1	1	1	2	83
C	Map showing both allocentric and egocentric perspectives.	Allocentric and Egocentric	0	1	1	0	1	47
D	Map showing fishing areas in a circular manner.	Allocentric and Egocentric	0	1	1	0	1	18
A and B1	Fisher designed separate A and B1 maps.	Allocentric	2	3	4	1	5	16.75
A and B2	Fisher designed separate A and B2 maps.	Allocentric and Egocentric	0	1	1	0	1	10
B1 and B2	Fisher designed separate B1 and B2 maps.	Allocentric and Egocentric	1	0	1	0	1	16

Individual content analysis

At the end of the segmentation process, 1,806 entities were identified from the 93 collected mental maps. Once the harmonization step was completed, 341 appeared to be unique (i.e., clearly distinguishable) among the entire set of mental maps. Specifically, we obtained an average of 34 entities per fisher for a standard deviation (SD) of around 23, and an average density of 19 entities per mental map[13]. Three outliers are present with average density values of 63, 77, and 118 entities. Furthermore, we note that B2 and C maps have the highest average density (83 and 47 respectively) (Table 1). These scores obviously need to be considered from the perspective of the low number of maps produced in each of these categories (2 and 1 respectively). Of the B1 allocentric maps — that is, those that were mainly produced — some are highly detailed, like that of fisher 13-RP (Figure 3), while others provide very little information, such as fishers 32-ME and 24-HH. The same applies to the A maps: fisher 15-C's map contains only 9 entities, whereas fisher 25-RF's map includes 77.

Cross-sectional content analysis

Identification and characterization of supra-categories

The 341 unique entities were grouped into 55 supra-categories. From the number of entities observed, eight categories stand out:

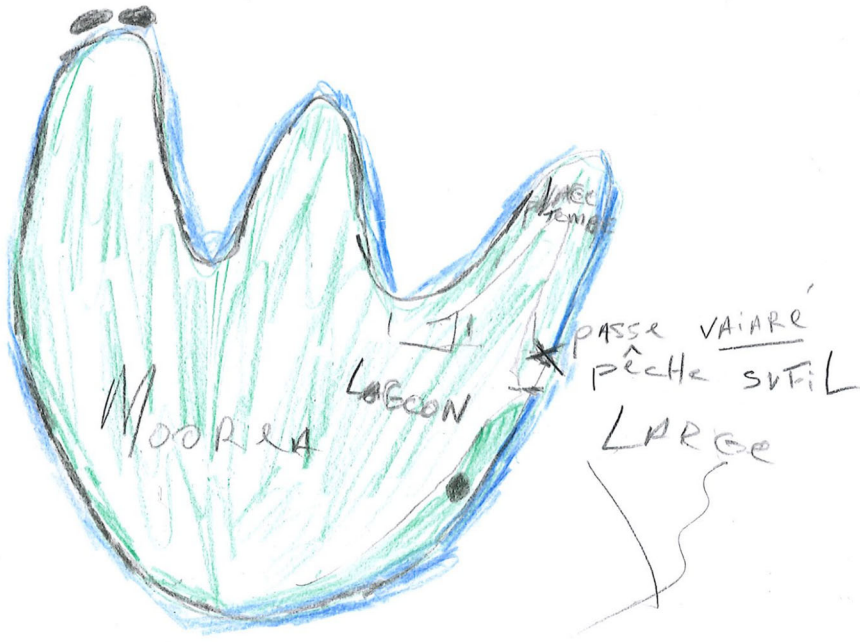

FIGURE 2 Allocentric overview map designed by fisher 15-C (A type).

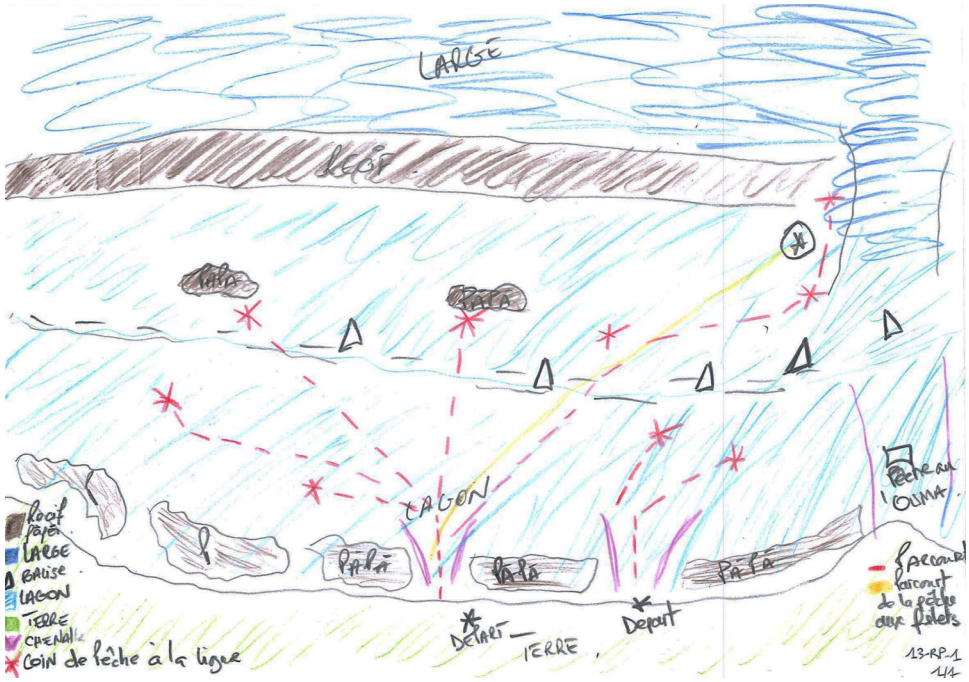

FIGURE 3 Allocentric mental map designed by fisher 13-RP (B1 type).

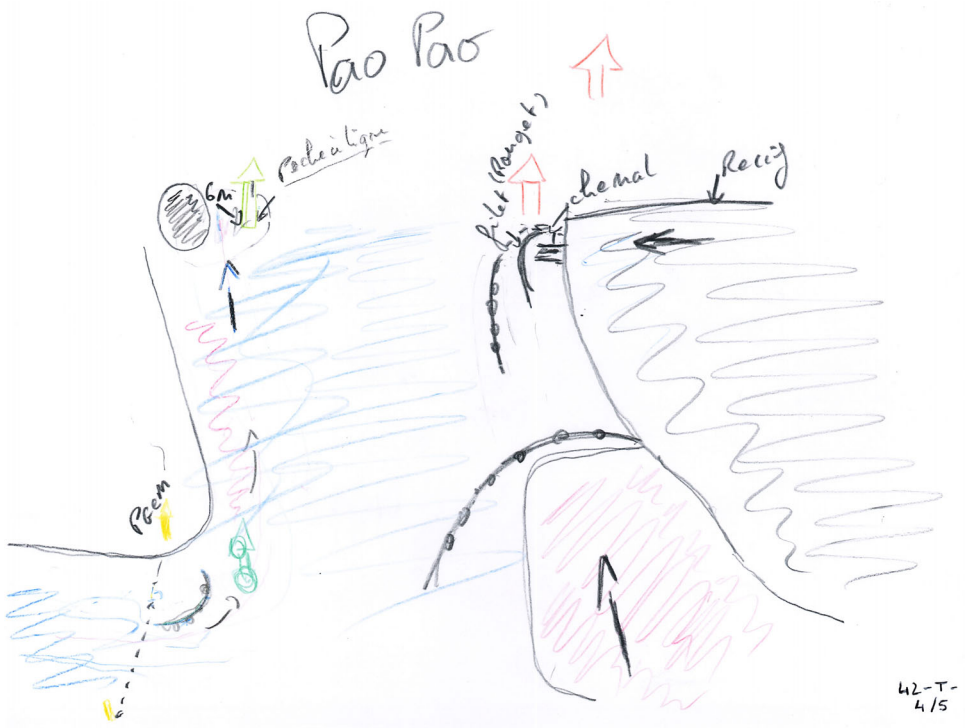

FIGURE 4 Egocentric mental map (oblique perspective) designed by fisher 42-T (B2 type).

FIGURE 5 Egocentric mental map (first-person view) designed by fisher 19-TO (B2 type).

- Fishing area ($n = 341$);
- Beacon ($n = 254$);
- Pass ($n = 151$);
- Orientation ($n = 102$);
- Reef ($n = 86$);
- Coral ($n = 68$);
- Blue (*Moana*) ($n = 62$);
- Seabed topography, to a lesser extent ($n = 45$).

The *Fishing area* category is the best represented, which is logical given the focus of our study. These areas are typically depicted by a polygon or a cross. Offshore *beacons* and *passes* — which represent the island's entry/exit points and transition zones for certain fish species — are in second and third place respectively. These elements can be considered as global landmarks that guide fishers in their activities, but also in the drawing of their mental map. Beacons and passes are useful for wayfinding, but can be distinguished from actual orientation indications that fall within the "*Orientation*" category. The latter contains a set of abstract entities indicating directions (e.g., an arrow pointing to a place that does not appear on the drawn area), cardinal points, or terrestrial landmarks for navigating by alignment. *Reef* and the associated category "*Coral*" stand behind "*Orientation*". These are also essential marine landmarks, like *Blue* (*Moana*), which is a special category referring to the color of the water on the surface of the lagoon. In practice, lagoon fishers distinguish different shades of blue depending on the depth of the water. These chromatic markers often correspond to fishing areas and/or markers leading to them. Some blues have special names, such as *Moana Menemene* (circular blue), *Moana Tarava* (longitudinal blue), or *Moana Oiro* (the blue specific to the *Oiro* species, a sea eel). Although it differs slightly from *Blue* in terms of frequency, we retained the "*Seabed topography*" category, because unlike the other seven, it involves an explicit description of the bottom of the sea. Conversely, there are poorly represented supra-categories, such as the island's *airport* ($n = 5$), the *schools* ($n = 3$), and the *Lake Temae* ($n = 2$).

Inter-individual differences

The small number of individuals who produced B2 ($n = 2$), C ($n = 1$), and D ($n = 1$) maps meant that we were unable to make a relevant statistical comparison of map types. We focused instead on the following two individual factors: (1) gender (female-male) and (2) fishing type, which was divided into *surface fishing* (net, line, harvesting, and troll) and *underwater fishing* (spearguns). For the gender comparison, two interviews conducted in pairs (female-male) were excluded, leaving 10 women and 45 men for comparison. More specifically, the Shapiro-Wilk normality test and Bartlett's test for homogeneity of variances show that conditions were not met for one-way ANOVA ($p < 0.05$). Given the size of our sample, it is impossible to know whether the robustness of the ANOVA test can compensate for the failure to meet the conditions for applying it. We conducted instead a Wilcoxon-Mann-Whitney test for each supra-category (occurrences), which turned out to be significant only for the variable "*Pass*": men drew significantly more passes than women. In the second comparison, we excluded individuals engaged in both surface and underwater fishing ($n = 6$). This resulted in a final count of 22 surface fishers and 25 deep-water fishers. As with the first comparison, the conditions for conducting an ANOVA (normality and homogeneity of variances) were not met. Therefore, we conducted another Wilcoxon-Mann-Whitney test, which proved to be non-significant for all supra-categories ($p > 0.05$), except for "*Seabed Topography*" (Table 2). Unsurprisingly, underwater fishers described the bottom of the sea more frequently than the surface fishers.

Factor analysis

We conducted a PCA to summarize the data and identify potential explanatory factors from the correlations observed between the supra-categories. Analyses were performed using the *FactoMineR* package under *R*. As the number of variables (supra-categories) ($n = 55$) was significantly higher compared to the number of individuals ($n = 53$), we substantially reduced it by retaining the eight salient supra-categories: *Fishing area*, *Beacon*, *Pass*, *Orientation*, *Reef*, *Coral*, *Blue*, and *Seabed topography* — along with the number of drawn entities by fishers for each of these categories. The PCA was conducted using a rectangular matrix, in which the rows denote individual respondents, the columns represent the eight most salient supra-categories, and the cells indicate the quantity of entities from a specific supra-category drawn by a particular fisher. Specifically, the preliminary analysis of the individuals' graphs does not show any single individual who could provide a major contribution to constructing the plans. Inertia distribution shows that the first

TABLE 2 Inter-individual comparisons (gender and fishing techniques) in terms of supra-categories (occurrences) using the Wilcoxon-Mann-Whitney test.

Supra-category	Women versus men (*p-value*)	Surface versus deep-water fishers (*p-value*)
Fishing area	0.40	0.29
Beacon	0.58	0.42
Pass	**0.04**	0.25
Orientation	0.55	0.86
Reef	0.56	0.36
Coral	0.32	0.20
Blue	0.86	0.37
Seabed topography	0.57	**0.01**

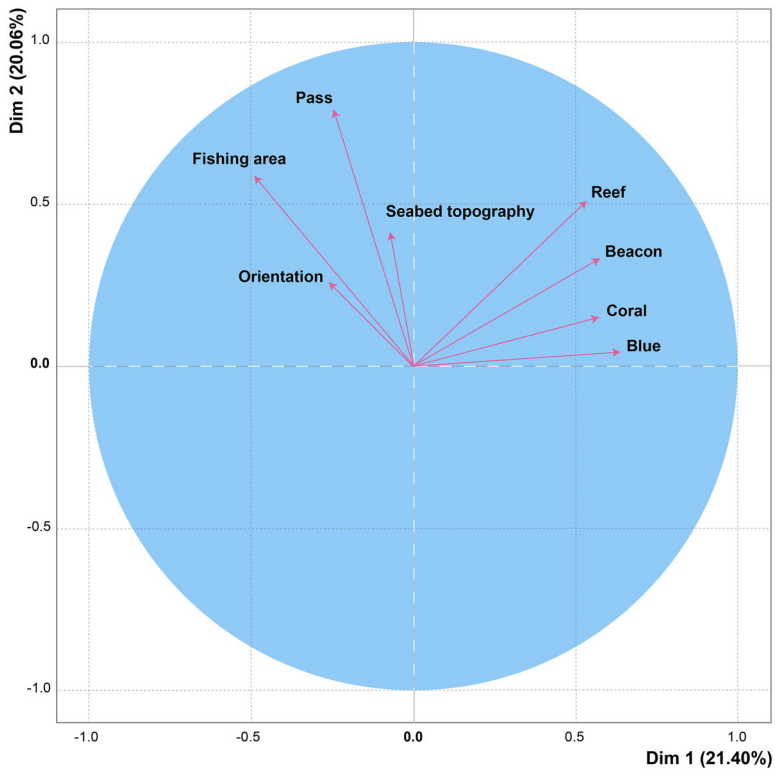

FIGURE 6 PCA: Correlation circle. PCA, principal component analysis.

two axes alone account for 41.46% of the total variability of the variables, which is higher than the reference value of 40.93% (0.95 quantile). Although relatively close, the inertia rate of the first component (or dimension 1) is lower than that of the 0.95 quantile (21.4% vs. 24.1%). We will therefore restrict our PCA analysis to the first two axes, but bear this information in mind when interpreting the results. The correlation circle and the individuals' graph (highlighting in pink the fifteen individuals with the highest contribution to the construction) appear respectively in Figures 6 and 7.

We observe that the variables "*Blue*", "*Coral*", and "*Beacon*" actively contribute to the construction of the first dimension, while the variables "*Pass*" and "*Fishing area*" significantly contribute to that of the

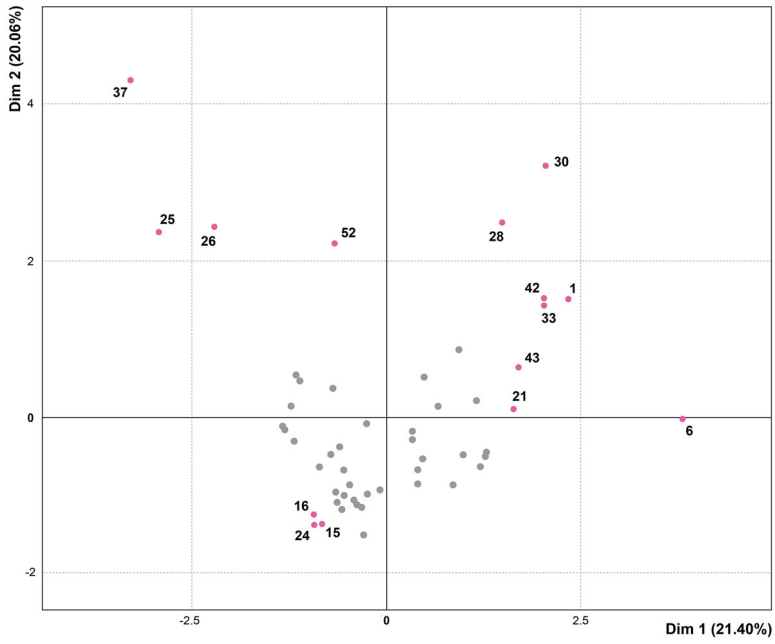

FIGURE 7 PCA: Individuals' graph. PCA, principal component analysis.

second dimension. The relatively short length of the arrows for "*Seabed topography*" and "*Orientation*" indicates that these two variables are poorly represented on the plot. Furthermore, the angle formed by the "*Blue*" and "*Fishing area*" variables suggest a slight negative correlation, which we confirmed using Kendall's coefficient (−0.20). Aside from this pair, it appears that the "*Coral*", "*Beacon*", and "*Reef*" variables are uncorrelated with the "*Pass*" and the "*Fishing area*". The four variables "*Blue*", "*Coral*", "*Beacon*", and "*Reef*" are in fact physical markers that allow fishers to orient themselves during a fishing session. These markers also geographically shape their mental maps. Given these elements, we can associate the first dimension with spatial orientation using physical landmarks. As previously specified, the second dimension is strongly related to the passes and fishing spots. The apparent correlation between passes and fishing areas confirms the importance of the pass habitats for fishers and particularly for men as indicated by the significant gender-based difference in the use of those landmarks in our sample (see Table 2). Given that men focused more on the passes than women, and that we have a clearly unbalanced female-male ratio (12:48), the importance of the "*Pass*" variable should be relativized. From our perspective, the second dimension can be associated with fishers' talkativeness about their fishing spots. Thus, as shown by the Bottom-up Hierarchical Clustering that was carried out automatically in *R* using a three-class breakdown (Figure 8), we have: (1) in blue, a first cluster of fishers who, like 25-RF, indicate their fishing areas without necessarily giving relevant landmarks precisely (see Figure 2); (2) in green, a second cluster of fishers like 42-T who are more willing to reveal their fishing areas (see Figure 4); (3) in purple, a last cluster that forms a middle ground, including individuals who, at the extreme, share little navigation information and almost none about their fishing spots (see Figure 3).

DISCUSSION

Spatial perspectives

Structurally speaking, most of the fishers exclusively relied on an allocentric spatial perspective (53 fishers). Only 2 fishers (one woman and one man) chose to transcribe their spatial knowledge from a

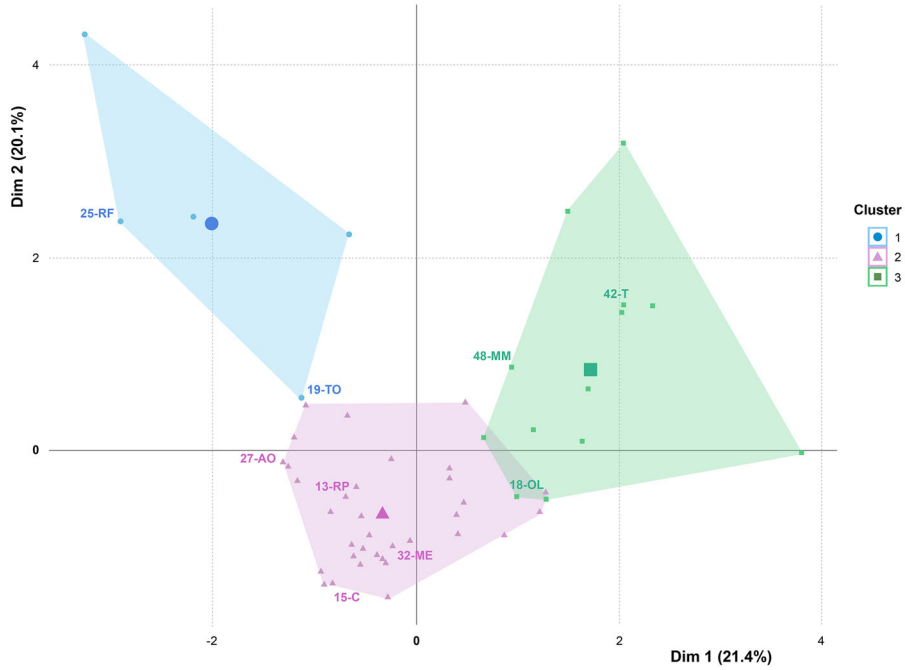

FIGURE 8 Bottom-up hierarchical clustering.

purely egocentric perspective. Although generalizing remains tricky given the low proportion of women interviewed, there does not appear to be a substantial difference between men and women in this respect. This initial conclusion is not in line with studies conducted on spatial orientation and navigation in the Western world; in which women are much more likely to prefer an egocentric approach than men (Lawton, 1994; Nowak et al., 2015; Quesnot & Roche, 2015; Quesnot, 2016). On the other hand, it is highly consistent with the study by Bennardo (2014) which shows that Tongan navigation instructions are mainly given from an allocentric perspective, in both small and large-scale spaces. The Oceanians' strong preference for the absolute FOR (Palmer, 2002) — principally the Land-Sea (*uta/tai*) axis for Polynesians (Cablitz, 2006; Feinberg et al., 2003; Mawyer, 2014; Peltzer, 1996; Troadec, 2003) — may explain why participants predominantly adopted the allocentric perspective to externalize their spatial knowledge. Furthermore, as suggested by the map legend that appears on some mental maps (e.g., Figure 3), it seems that some fishers — for whom the proportion is difficult to estimate — are accustomed to handling cartographic media. Undoubtedly, this factor contributes to explaining the high proportion of allocentric maps in our sample.

It is also worth considering C maps (both allocentric and egocentric representations on the same medium) and D maps (circular representation). More specifically, the latter type is very close to the radial FOR introduced by Bennardo (2002a,b) and the spatial orientation models formalized by Shore (1996) and Lehman and Herdrich (2002) (center-periphery and point-field, respectively). We have called it "circular" instead of "radial", because fisher 27-AO who created this mental map did not draw it "centrifugally". He started from a central point (himself in this instance) but unlike the radial approach, he described and drew a fishing area that was located in front of him, and continued in this way around the island, and by extension the sheet of paper. It is particularly interesting to note that the fisher did not go all the way around the sheet. He stopped at his last fishing area, which is located at the bottom of the paper (Figure 9). To a certain extent, the D map is a combination of egocentrism (starting from the fishing area in front of the individual) and allocentrism (using a bird's-eye-view perspective). The C map also combines two spatial perspectives in one drawing, but in a different way. The female fisher 18-OL who created it first drew an overview map of *Moorea* so as to locate her fishing area in relation to the whole island (south-west). She

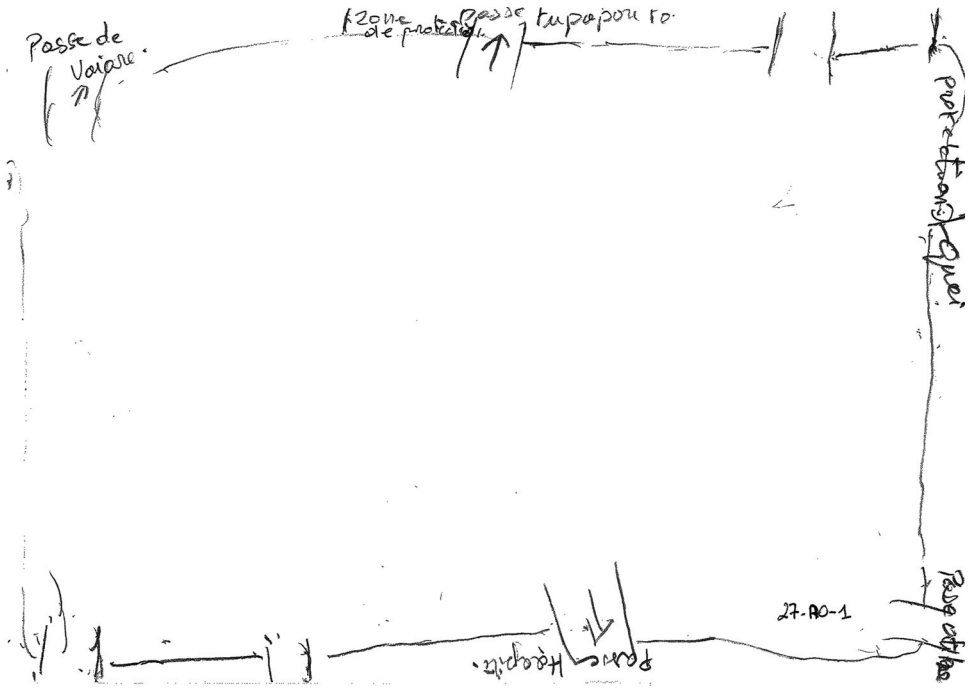

FIGURE 9 Circular mental map designed by fisher 27-AO (D type).

then represented it egocentrically by positioning herself on the shore, facing out to the sea (Figure 10). B2 egocentric maps are also specific: the 2 fishers who drew this type of map (19-TO and 42-T) positioned themselves facing the land, as if they were fishing (Figures 4–5).

Ultimately, despite the very high frequency of allocentric mental maps, the diversity of observable spatial perspectives highlights two aspects. Like Shore (2012, 2014), we believe that egocentric and allocentric approaches are in fact two modes of spatial expression that can be used — in the form of a mental map or even a navigation instruction — by one person. This also applies to the fishers we interviewed. In fact, several individuals, like 13-RP, orally described a fishing route (egocentric perspective) before retranscribing it allocentrically (Figure 3). It should therefore be kept in mind that the mental map remains a medium through which an individual shares her/his spatial knowledge with others. It is an intersubjective medium *per se*. In order to be understood, people have to mention meaningful references (landmarks, place names, etc.). Mental mapping is therefore a method that is highly context-dependent. On the one hand, the shared spatial knowledge may vary according to the interlocutor's spatial familiarity with the environment (Quesnot & Roche, 2015). Indeed, the fishers might have drawn more egocentric maps if they had been interviewed by people from the same extended family. On the other hand, we put forward a hypothesis which — to our knowledge — has never been formulated before: the location where the drawing session takes place, as well as the position of the interviewee's body, play a fundamental role, particularly in island spaces. Indeed, we think that the position of the fishers, open to the sea when the drawings were being made (83%), favored a land-sea orientation. Moreover, we might have collected more B2 maps if we had conducted our survey on a boat in the lagoon of *Moorea*.

Sharing spatial knowledge (?)

Individual and collective analyses of the collected mental maps show that eight supra-categories — *Fishing area*, *Beacon*, *Pass*, *Orientation*, *Reef*, *Coral*, *Blue*, and *Seabed topography* — appear much more frequently than

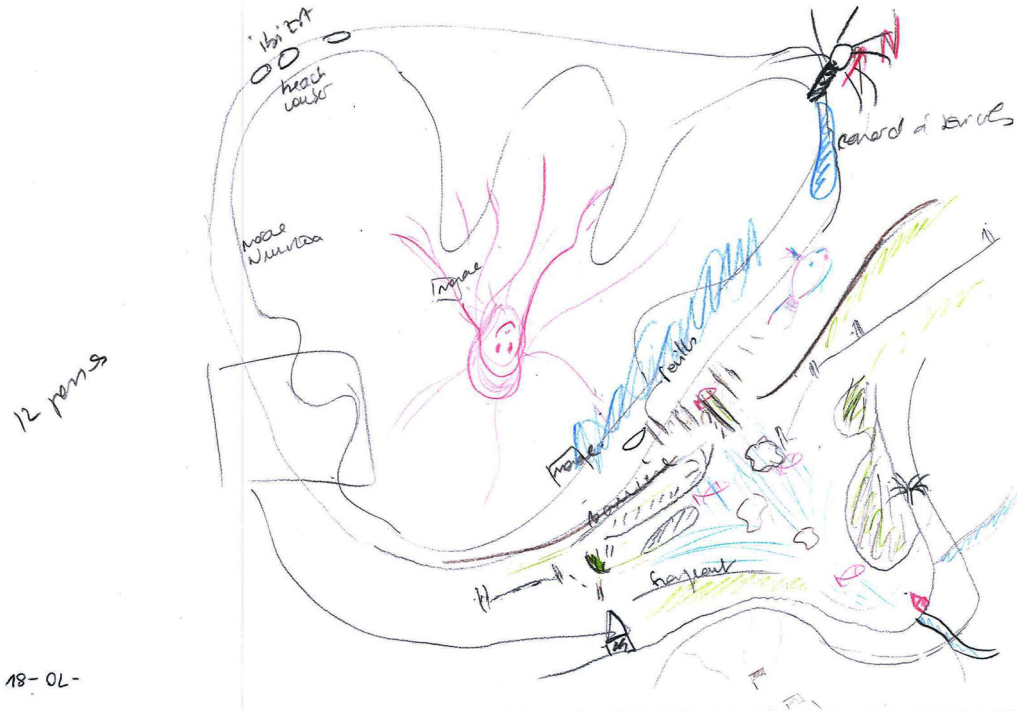

FIGURE 10 Mental map designed by fisher 18-OL, showing both allocentric and egocentric perspectives (C type).

others. However, the interpretation of these results is open to question. Firstly, it must not be forgotten that categorizing entities (i.e., creating categories and transferring an entity to a category) remains an arbitrary process, which is at the very least a subjective one. For example, we could have included the entities *Papa* (compressed and layered coral bed) and *Toopu* (coral clusters surrounded by "blue") in the "*Coral*" category, but we excluded this option because some fishers clearly made a distinction — both in their discourse and their maps — between *Coral*, *Papa*, and *Toopu*. This difference is, by the way, consistent with the study by Feinberg et al. (2003). Secondly, a low number of occurrences does not necessarily mean fishers attach less importance to the entities concerned. Apart from *Papa* ($n = 16$) and *Toopu* ($n = 12$), Polynesian cultural sites (*Marae*; $n = 8$) are of major importance, as are the categories of *Land* ($n = 5$), *Shore* ($n = 25$) and *Mountains* ($n = 16$) which, in the spirit of the Oceanian Land-Sea continuum (Gaspar & Bambridge, 2008), play a key role in fishers' orientation and navigation by alignment. Thirdly, it is worth bearing in mind that the first two dimensions of the PCA only explain 41.46% of the total variability of our dataset (limited to the eight main categories). While this percentage is still higher than the 0.95 quantile baseline score, it should be noted that a significant proportion of total variability is explained by factors other than those discussed here.

Having outlined these limitations, which are clearly difficult to avoid, we will now discuss the results returned by the PCA. As a reminder, the variables "*Blue*" and "*Coral*", and to a lesser extent, "*Beacon*" and "*Reef*", contribute to the construction of the first dimension of the PCA that we have associated with spatial orientation. These four elements are global marine landmarks used by fishers for navigating and locating their fishing spots. These are the same elements that are usually mentioned by them when they start to draw their mental maps. Blue areas, corals, beacons, and the reef barrier structure both their movements in the lagoon, and the externalization of their spatial knowledge. At first glance, it is interesting to note that these four markers — both material and cognitive — are rarely mentioned in the scientific literature dealing with Oceanian spatial cognition. This is particularly true for the chromatic markers *Moana* (Dye, 1983 being the only example we found in the literature), which are highly visible from the shore, but also from a boat sailing on the lagoon. By the way, it is interesting to note that in Tahitian, the term *Moana* (blue)

means both deep (adjective) and ocean/deep sea (common noun). Furthermore, we can observe that three of them are natural elements. It is highly likely that blue, coral, and the reef barrier were already relevant marine landmarks in the pre-colonial era. Green, red, and black beacons complete the picture, despite their artificial nature. The importance of navigation beacons in fishers' representation of space also stems from the fact that they provide highly visible landmarks for navigating at night when other landmarks are less reliable. The fact that this marine marking is used to signal channels clearly reinforces the idea that these four elements are primarily useful navigation landmarks:

> "*Two red **beacons**, one black, then one red. Then over there you pass a green, a green, and another green. Once you reach the third green **beacon**, you have a small **pass**. After that, it's the Maatea **pass**." (48-MM) "Here is the **blue** and here you see… you see these two red **beacons** opposite the quay, opposite the quay, you have two red **beacons**. […] You see here, as it's **blue**, you've got the red **beacons**, which will be useful for the boats, showing that there's a big rock here, lots of rocks over there." (41-S) "This is a place where we fish Operu [Decapterus macrosoma]. It goes like this. Because it eats the sand, the **blue** here and the sand here. You see it's like the **blue**, it's like that the deep one, it only comes this way […] And then in November, well, it's Maito [Ctenochaetus striatus] then. The whole month of November, they gather next door, they gather here, they gather there, at the **moana**, at the **moana tarava** too, they lay their eggs.*" (2-EM)

The second dimension, on the other hand, is strongly associated with the variables "*Pass*" and "*Fishing area*", while the contribution of the variables "*Seabed topography*" and "*Orientation*" is actually marginal. Straight away, it would be tempting to see this as an opposition between people who fish on the surface (net, line, harvesting, and troll) (first dimension) and those who practice underwater fishing (second dimension). Although there is a significant difference between them in the description of the seabed topography (see Table 2), this shortcut must be discarded for two good reasons : (1) surface and deep-water fishers both appear in clusters 1 and 3 (respectively in blue and green in Figure 8); (2) the "*Seabed topography*" variable is poorly projected on the second PCA axis. In fact, there is a continuum between the lagoon's surface and its depths, since surface fishers rely on depth markers (e.g., chromatic markers), just as deep-water fishers use markers that are visible from the surface (typically beacons). In addition, the role of the "*Pass*" variable in the construction of the second dimension, and its association with "*Fishing area*", confirm the importance of passes not only as obvious landmarks, but also as highly prized fishing grounds (Breckwoldt et al., 2022):

> "*In general, there are quite a lot of fish in the **passes**. I know that the Taotaha **pass** is a small **pass**, with a lot of current, a lot of life, a lot of activity, and there you'll find parrots (fishes) aplenty.*" (52-T)

However, the prominence of the "*Pass*" variable (best represented in the PCA) should be put into perspective, as we have seen that the representation of passes was more present in maps drawn by men than in those drawn by women. Such a result highlights a historic gendered-division of fishing territories in Polynesian societies, which still seems to operate, with offshore fishing falling into the male domain, in contrast to the near-shore fishery dominated by female fishing and harvesting activities (Oliver, 1974).

From our perspective, the second dimension of the PCA essentially refers to the fishers' talkativeness about their fishing spots. As a matter of fact, a high number of fishing areas on a mental map does not necessarily mean that the fisher who created it is inclined to share his/her spots. This is where the cross-analysis of the two PCA dimensions becomes meaningful. Indeed, fishers from cluster 1 (see Figure 8), like 15-C, readily identify the areas where they fish, but without sharing the landmarks for locating them accurately (see Figure 2). Only a few fishers from cluster 3, like 42-T, share enough information to locate their favorite fishing spots precisely (Figure 4). In fact, most of the mental maps we collected are in between: fishers simply describe a few spots without associating relevant landmarks. We are therefore dealing with a form of "geographical self-censorship" which can be explained by at least three socio-political factors. Firstly, the introduction of MPAs and RFAs in 2004 completely changed the island's fishery geography. Some fishers found themselves excluded from their usual fishing areas (most often located in front

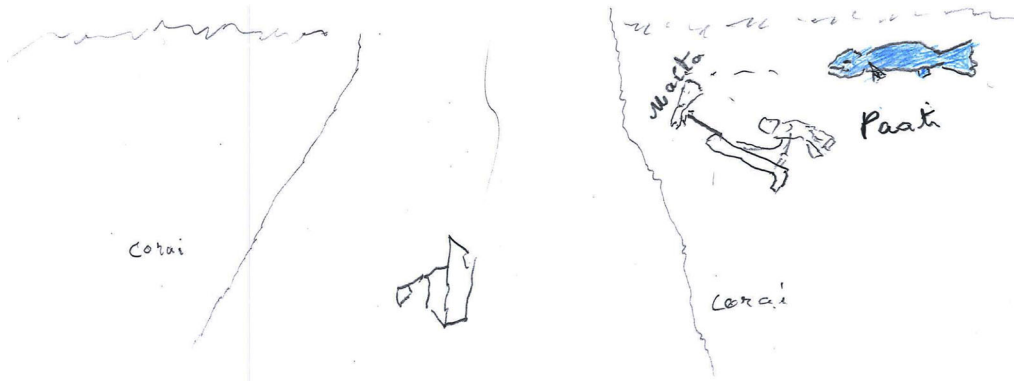

FIGURE 11 Allocentric mental map designed by fisher 32-ME (B1 type).

of their house) and had no choice but to "encroach" on their neighbours' fisheries, which sometimes generated conflicts. These people were therefore rather vague when describing their fishing areas so as to avoid tensions. Secondly, we should also consider the possibility that some of the interviewed fishers may engage in fishing within prohibited areas (typically MPAs). In this case, it would obviously not be in their interest to reveal this information, let alone on a map that is intended to be shared. The third and final explanatory factor relates to the competition between some fishers that may have resulted from resource scarcity. Some fishers were perhaps being deliberately vague when describing their environment in order to conceal their fishing spots as much as possible:

> "*Well, when I used to fish on the reef, I enjoyed fishing on the reef because in the morning [**hesitation**] it's stuff **you shouldn't tell the others** because [laughs] you see, when you search for a while and [**blank**] **if you give it to the others they'll come back** […] This is **my** spot. Let them look for it on their own, they can just look for it like I did. You see fishers like [inaudible] it's a bit like that. Well, **you're not going to tell them**.*" (43-AA)

Embodied, embedded, and extended cognition

The discussion will conclude with the embodied, embedded, and extended nature of cognition (Clark, 2012). In the Cartesian tradition of separating the thinking subject (*res cogitans*) from the material extent (*res extensa*), cognition was originally a matter of the mind alone. Varela's research on enaction contributed to the emergence of embodied cognition. In their collaborative work, Varela, Thompson, and Rosch demonstrated that cognition is not merely the internal processing of information within an isolated mind. Instead, it is a co-constructed phenomenon that emerges from the dynamic interaction between a living organism and its environment (Varela et al., 1991). Apart from the hypothesis we have raised regarding the importance of the fishers' position when designing mental maps, several elements reinforce the bodily dimension of Polynesian cognition.

For example, the map of fisher 32-ME (Figure 11) is much more informative than it first seems. Indeed, he did his best to translate his spatial knowledge in the form of an allocentric map showing the *Teruaupu* pass. The fish he drew — *Paati* (Parrot fish, in Tahitian) — is the species he prefers, along with *Maito* (Striated surgeonfish, in Tahitian). This fisher roughly drew himself and where he fished, explaining in detail the way he catches *Paati*. He had trouble summarizing his activity on a sheet of paper. Like many other fishers involved in this research, he offered to accompany us to the fishing area so that we could gain a better understanding of his environmental representation. Actually, most of the *Moorea* lagoon fishers felt the need to anchor their speeches and their mental maps in a physical (and thus situated) reality. The

map of female fisher 19-TO (Figure 5) is a working example of a person who intuitively puts her/himself (mentally) in a fishing situation — that is, in her boat and within the ocean in this case — to be able to represent her/his "vision" of the lagoon space more easily.

> "*I swim here, because I live here. Here here, my house is here" (19-TO) "Well, when you go out into the sea, eh, when you go out into the blue, there. You* ***see*** *the fish, when it stops [****gestures****], it turns [****gestures****]. You can be 50 metres deep, but that's what fish do. And that's it! There's more, it turns [****gestures****],* ***you see, you see the thickness of the fish*** *[****gestures****]." (46-JBA) "It's bloody hard to locate yourself in space like that, you know.* ***Now I'm in underwater hunting mode****, you see*." (52-T)

Ultimately, externalizing spatial knowledge in a sketch map is not sufficient in itself. The informal exchanges we had with the fishers clearly suggest that these media would need to be supplemented with observation of fishing practices. This is particularly relevant as fishing remains an activity which (1) engages the whole body and (2) is based on a set of dynamic elements such as the phases of the moon, the swell, the multiple trajectories of prey, or the flowering of certain terrestrial species. Cognitivism and its two main components — computationalism (i.e., equating the functioning of the mind with a machine) and representationalism (i.e., perceived objects represented by meaningful symbols) — reveal their limitations in this specific context. Without necessarily adhering to Varela's anti-representationalist and pro-phenomenological vision (Varela et al., 1991; Varela, 1993), it is important to recognize, like Ingold (2000), that the disembodied understanding of spatial knowledge through mental maps alone seems ill-suited to the Polynesian context. In this respect, the relevance of methods including the body and the five senses cannot be disputed.

Furthermore, we maintain that Polynesian cognition is also embedded and extended. The way fishers encode their knowledge is clearly inseparable from the physical environment, but also and above all from the socio-cultural milieu. As we have already mentioned, fishing in *Moorea* is a highly socialized activity. Fishers, including those who fish alone, are necessarily embedded in larger collectives (clans, fishing teams, families, social media groups, etc.) that influence their concrete practice of fishing and, therefore, their mental representations. Some groups tolerate or even appreciate each other, while others are in conflict for reasons we have already discussed (depletion of resources, reduction of the areas where fishing is allowed, etc.). Social media, predominantly used by those under 20 in our sample, have also a significant impact. Some users publicize their catches with photos and videos, encouraging others to target larger fish. As the latter are subject to increasing fishing pressure, they adapt their behaviors, seeking refuge in deeper waters. This phenomenon contributes to a transformation in spearfishers' spatial practices and the associated risks, as they explore deeper, more challenging territories to exploit a dwindling resource and to demonstrate their freediving prowess. The act of sharing images on social media also fosters a competitive environment in which fishers attempt to deduce each other's fishing locations, examining the background of posted images for any identifiable landmarks that could reveal a precise location. The activity of fishing is also shaped by family and religious contexts. For example, fisherman 12-HC, originally from the district of *Temae*, explained to us that he had completely modified his fishing territory after his marriage to a native of the *Maharepa* associated municipality. Lastly, the cognition of Polynesian fishers can also be considered as extended. In the spirit of the triple continuum between Nature and Culture, Land and Sea, and Humans and non-Humans, their minds and bodies are indeed extended by material instruments (pirogue, oar, rod, fishing gun, etc.) that allow them to refine their understanding and their behaviors to an eminently dynamic environment (swell, marine currents, prevailing winds, lunar cycles, routes taken by fish, etc.):

> "*Yeah, the tips, all the tips. Because… you know why? Because there's a current. There's* ***a current that changes all the time****. And the current brings the maa [food in Tahitian], the plankton and all that. That's why all these spots are full of fish." (26-H) "You need* ***outgoing current****. Outgoing, yes. When you're here, you'll see groups of Paraha [Platax orbicularis] like this in the current. In this way,* ***they're waiting for food****, you see,* ***they're waiting for what's coming****. Jacks [Caranx], Paraha, Ume [Naso unicornis]. That's it, and I put the net there*." (42-T)

CONCLUSION AND PERSPECTIVES

Our research contributes to the field of Polynesian mental representations through an unprecedented study of the mental maps of *Moorean* fishers. Analysis of their sketch maps reveals a clear preference for an allocentric spatial perspective; although they never used a radial perspective to portray their environment. The findings also suggest that the body's position and the place where the mental maps were designed played a significant role in the way of representing the island of *Moorea* and its lagoon. Indeed, conducting the interviews from the lagoon — facing the island — might have had the effect of inverting the ratio between the allocentric and egocentric perspectives depicted on the mental maps. In terms of content, we mainly (and logically) encountered entities useful for orientation such as the reef, coral outcrops, and beacons. An interesting and unanticipated element that often appears in the mental maps is the chromatic depth marker that fishers commonly refer to as "blue" (*Moana* in Tahitian). In addition, the factor analysis we conducted revealed a distinct form of geographical self-censorship (not all fishers are necessarily inclined to share their fishing spots precisely), as well as a rarely highlighted complementarity between the lagoon's depths and its surface. In short, although these elements allow us to learn more about Polynesian spatial knowledge, it is important to bear in mind that leaving the body and the socio-cultural background out of the equation when trying to gain a better understanding of local spatialities remains criticizable. In this respect, we believe that research in cognitive anthropology could be enriched by embracing the paradigm of embodied, embedded, and extended cognition (Clark, 2012; Varela et al., 1991) in its cultural approach to mental representations — at least in Oceania. Ultimately, the findings outlined in this paper fill an existing scientific gap regarding the mental representations of Polynesian fishers and their methods of sharing spatial knowledge through drawings. On a more pragmatic level, the mental maps that we have collected, along with the invaluable verbal information provided during interviews, offer an unprecedented perspective on the practice of lagoon fishing in *Moorea*. We hope this will assist local fishers in demonstrating the value and diversity of their practices to policy makers, particularly to the managers of the island's Marine Space Management Plan (PGEM).

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ENDNOTES

[1] Between 2015 and 2021, the *Moorea-Maiao* municipality revised the PGEM. Although the revised version was approved by the Council of Ministers on 2021/09/10 (Arrêté 2009 CM), the new regulations were not applied at the time of our study (i.e., between April and July 2022).

[2] The PGEM is managed by a permanent committee that includes the mayor of the municipality and various representatives (fishing, hotel industry, tourism professionals, voluntary sector associations, etc.).

[3] Each associated municipality now has an LFC. In parallel, a lagoon resource management committee for the whole island has been set up, which deals exclusively with lagoon fishing-related regulations.

[4] In FP, only professional lagoon fishers (i.e., those who sell their catch) hold a professional card. Subsistence fishers are therefore not affected by this scheme.

[5] We must point out that the laminated images were never shown before the start of the session. They were only taken out from the experimenters' car when the participant expressed the need for a spatial frame of reference to draw his/her sketch map (3 times).

[6] The labeling of the entities drawn by a participant was not systematic. However, what the objects corresponded to was always specified orally (e.g., "*This band is the reef*").

[7] The entities do not systematically refer to an official place name (toponym) (e.g., "*My fishing area*").

[8] This field is useful, because a single mental map can spread over several sheets of paper.

[9] Bottom-up Hierarchical Clustering (BHC) involves sorting statistical individuals into homogeneous groups. The clusters produced by the BHC differ from the supra-category clusters that we manually assembled earlier.

[10] A mental map can be made up of several sheets of paper, but the opposite is not true.

[11] The time stated above refers to the length of the entire interview, and not the time taken to draw the mental map(s).

[12] To facilitate the reading of the article, only a few examples of mental maps are presented. Additional illustrations will be provided upon request to the first author.

[13] NB: Fishers were able to draw more than one mental map. Aside from the two individuals who combined both spatial perspectives (A-B2 and B1-B2), fishers who drew multiple mental maps maintained the same perspective.

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