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# ELECTRONIC SUPPLEMENTARY INFORMATION (ESM) FOR THE EVOLUTION OF CULTURAL ADAPTATIONS

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## TABLE OF CONTENTS

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Table of Contents.....	1
Theoretical Background .....	2
Model-based biases in cultural learning.....	2
Emergence of cultural adaptations.....	6
Representational content .....	7
Representational reconstruction and extension.....	9
Ethnographic Background for Yasawa Island.....	10
Methodological Approach used in Project .....	11
Table S1: List of Primary Data Collection Instruments Used in this Study.....	13
The Adaptive Problem: Toxic Fish.....	14
Fish Poisoning in Yasawa.....	14
Table S2. Ciguatera Symptoms Checklist .....	16
Species in reported cases.....	17
Figure S1. Types of fish associated with reports of <i>ika gaga</i> .....	17
Craving and the Drop in Reported Taboos.....	17
Figure S2. Comparison of cravings during pregnancy and breastfeeding ( $n = 70$ and $n = 61$ , respectively). The error bars are 95% exact confident intervals. ....	18
Free Response Data .....	19
Figure S3: Comparison of free-response taboos and checklist during pregnancy .....	19
Ciguateric Species are Important Food Sources.....	20
Table S3. Top 15 contributors by weight to diet from spear fishing catches.....	22
Fish Avoidances are Transmitted Principally via Cultural Learning .....	23
Figure S4. Answers to the question "How did you learn about these taboos?" for Bouwaqa and Bukama. The Fiji terms mix terms of references with terms of address. This is retained to preserve what our informants tended to actually say.....	23
Pathways of Cultural Transmission and <i>Yalewa Vuku</i> .....	25
Figure S5. Social networks of <i>yalewa vuku</i> . Arrows point toward person selected as <i>yalewa vuku</i> . Circles and squares represent males and females respectively. Red and blue indicate people from Teci and Dalomo, respectively. In Figure S5a (top) the size of the node (circle or square) represents the indegree. In Figure S5b the size of the node represents the eigenvector centrality. ....	27
Table S4: Regression analysis using Age and Plant Knowledge to predict indegree of <i>yalewa vuku</i> .....	28
Figure S6. Plot of Age in Decade vs. Indegree for <i>yalewa vuku</i> and Centrality.....	29
Biases on Meat, Freshwater Eels, Octopi & Porcupine Fish.....	29

Meat .....	29
Category-based Induction: Freshwater Eels and Porcupine Fish .....	30
Figure S7 shows the distances and estimated branching relationship for ten folk-species.....	32
Taxonomic Inheritance and Categorical Ambiguity: Octopi.....	33
Figure S8. Higher-level categorization for 8 folk-species. Error bars are 95% exact confidence intervals ( $n = 140$ ) .....	34
Are these Really Taboos? .....	34
Figure S9. The top figure shows the responses for pregnancy ( $n = 70$ ) and breastfeeding ( $n = 61$ ) for our question about how people would feel about a hypothetical taboo violator. The bottom figure S8B pairs the findings from Figure S8a (that the community will be angry) with the responses to our question of what the community would do. Error-bars are 95% confidence intervals.....	35
Other Reports of Pregnancy Taboos on Marine Species .....	37
References .....	37

This document supplements the main text by providing (1) greater theoretical background, (2) additional ethnographic details about the study populations, (3) methodological details about the research process, (4) data substantiating the presence and dangers of marine toxins, (5) results showing the differences in reported food cravings between pregnancy and breastfeeding, (6) taboo reports based on our free response methods, (7) data showing the contribution of tabooed species to the diet (of people not pregnant or breastfeeding), (8) additional findings on how taboo beliefs are acquired, (9) greater details on our analyses of prestigious *yalewa vuku* (wise women), (10) analyses of the lower-frequency reports of avoidances of land-animal meat (*lewe*), octopi (*sulua*), porcupine fish (*sokisoki*), freshwater eels (*duna*) and spices (*boro*), (11) analysis of reactions to hypothetical taboo violations, and (12) additional information on reports of pregnancy taboos on toxic marine species in other parts of Fiji and elsewhere in Oceania.

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## THEORETICAL BACKGROUND

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Understanding cultural evolution and the evolution of cultural adaptations requires considering both how cognitive processes influence the micro-level details of cultural transmission and how these micro-level processes aggregate up to generate population-level patterns of cultural variation (Richerson & Boyd 2005). In this section, we first summarize work showing how evolutionary theory can be used to develop hypotheses about the kinds of cues people use to figure out from whom to learn. Then, we briefly discuss how formal models allow researchers to cobble up from these psychological learning biases to broader patterns of cultural variation. With an eye to our main empirical findings, this second subsection emphasizes how evolved biases in our cognitive mechanism for cultural learning can give rise to population-level patterns of cultural adaptation.

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## MODEL-BASED BIASES IN CULTURAL LEARNING

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The application of evolutionary theory to understanding who learners should pay attention to for cultural transmission and how they should integrate information from different people has generated a wide range of hypotheses about human cognition, many of which have found empirical support (reviewed in Henrich & McElreath 2006). Hypotheses about *model selection biases* propose that learners should preferentially attend to those individuals in their social world

(“models”) deemed most likely to possess adaptive information that can be acquired by learners. To locate these *preferred models*, learners should give weight to a variety of cues that indicate which individuals are most likely to be worthy of imitation (i.e., possess adaptive information that could be learned). Sets of proposed cues include (1) skill, knowledge, success and prestige, (2) health and happiness, (3) age and (4) self-similarity (e.g. sex, ethnicity, personality, physical attributes). We deal with each of these in turn.

Acquiring skill, knowledge, and success in locally important behavioral domains is crucial for survival in small-scale societies (Henrich 2008; Hill & Hurtado 1996; Kaplan et al. 2000). Learners can use a variety of cues to figure out who in their group is likely to have the best acquirable skill or knowledge. To assess skill or knowledge, learners can directly observe it (e.g., a hunter adeptly shooting an arrow and bringing down a fast moving prey) or assess it indirectly with cues of success (e.g., the amount of meat the hunter brings back to camp) or prestige. Using cues of prestige here means that learners exploit the fact that others are also evaluating potential models based on observations of skill and success. By observing the ethological cues (including verbal expressions) associated with prestige evaluations, and prestige-biased imitation, learners can use others’ behavior to improve their own estimates of who is a good model. Extensive field and laboratory evidence from across the social sciences supports these hypotheses. Theory and evidence are laid out in Henrich and Gil-White (2001).

An important aspect of these predictions—that individuals will preferentially focus their cultural learning efforts on models deemed higher in skill, success, and prestige—is that such models will impact domains well beyond those obviously directly related to the model’s success or skill. This occurs for two reasons. First, it’s often difficult to tell what makes someone successful or skilled in some arena. If a learner seeks to imitate the best hunter he knows, does he copy (1) how the hunter makes his arrows, (2) the fact that the hunter gets up earlier than others, (3) the hunter’s taste for carrots, or (4) the meditative prayers the hunter says before departing on the hunt. Any or all of these may contribute to the hunter’s success. Thus, assuming they aren’t particularly costly to imitate, the learner should be inclined to acquire as many of the model’s traits as possible. Second, being highly successful in an important domain, especially in small-scale societies where a lack of division of labor prevents substantial specialization, may be a cue of being a good cultural model in general (Henrich & Henrich 2007: Chapter 2; Johnson 1995), or of having strategies or practices that favor success across many domains. People unconsciously think that if a model is good to copy in one domain then they’re probably good to copy in other domains.

Health is also obviously related to genetic fitness. Healthier individuals in ancestral environments could have more children and invest more heavily in their offspring. If being healthy reveals itself in appearance or activity, learners ought to be sensitive to this, such that, *ceteris paribus*, they differentially attend to, and prefer to learn from healthier models. If nothing else, learners should avoid learning from sickly-appearing models. Since positive affect, or more simply happiness, correlates with health outcomes (including long life (Pressman & Cohen 2005)), learners may use positive affect as a cue of whom to learn from (for evidence, see Rushton 1975). Of course, we do not mean to suggest a simplistic or general equation of fitness with long-term health or happiness.

Age provides an important cue for learners for two reasons. First, and most relevant for our arguments below, age is a good cue of possessing useful/adaptive information because (1) merely by getting to be old (and not dying) these individuals are demonstrating an ability to survive and

(2) they have had more years to acquire adaptive information, both culturally and via individual experience. *Ceteris paribus*, learners should prefer senior members of the community. Since old age may bring reduced mental faculties, learners will likely show a decline in preference for very old community members (if any are still around), due to a decline in mental alertness.

Second, at the other end of life history spectrum, children can scaffold themselves up to increasingly complex skills by focusing on same-sex models who are somewhat older than themselves. Using our hunting example, a six year-old would likely not learn particularly much by imitating the best hunter in the community, since the difference in skills is too great. Instead, this child would do better to focus on learning from the most successful eight to ten year old. By continually focusing on somewhat older models, learners are more able to tune their cultural input to their relevant level of skill. This is particularly true in the small-scale societies of human evolutionary history (Fiske 1998; Lancy 1996). For simpler skills, children can learn from anyone who is available and knowledgeable.

Since learners have evolved to seek and acquire those cultural traits most likely to be adaptive for them in their own attributes and their likely future roles in society, learners should also weight some assessment of the similarities between themselves and their potential models. Candidate dimensions of similarity, which have likely been relevant for a long time, include sex, ethnicity (using cues of language or dialect), personality and physical attributes.

- 1) Sex: if there has been a division of labor between males and females during much of human history then humans should have evolved a tendency to learn from people of their same sex (i.e., males copy males). This gives learners the best chance to acquire those mental representations (practices, skills, and beliefs) suitable to the role they are likely to occupy later in life (Henrich & Gil-White 2001).
- 2) Ethnicity: culture-gene coevolutionary models predict that learners should focus their learning efforts on models who share their 'ethnic markers' (cues of dialect, language, dress) because this gives them the best chance to acquire the mental representations (social norms, values, and expectations) that will permit them to effectively coordinate, exchange and cooperate with others in their social group (Henrich & Henrich 2007: Chapter 9; McElreath et al. 2003). Recent laboratory work with children and infants supports these predictions (Kinzler et al. 2007; Shutts et al. 2009), as does field evidence from the Ituri Forest (Aunger 2000).
- 3) Personality and physical attributes: provide cues that permit learners to select models likely to possess mental representations that are suited to the learners' endowments.

The accurate acquisition of some mental representations from preferred models (those selected based on success, age, prestige, etc.) will sometimes require the cooperation, or at least the consent of the model, and may require substantial time with the model. The consent and cooperation of the model may be the only way to guarantee that learners will observe or understand key elements of behaviors, beliefs or practices. The model may also facilitate learning by modifying their behavior in a manner that facilitates effective transmission.<sup>1</sup> In many cases

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<sup>1</sup> There is also the possibility of active teaching. However, since current evidence suggests that active teaching appears rarely in ethnographic record of small-scale societies, it may not be an important element of ancestral human environments (Fiske 1998; Lancy 1996; Lancy 2009). Active teaching, however, must be

these *access costs* may be high when preferred models (1) don't care much about the learner (no kinship or reciprocal ties, etc.), (2) don't live in the learner's immediate locale, and (3) are preferred by many other individuals such that learners end up competing for access to the most preferred models.

Theory predicts, and the empirical record supports, that learners deal with the problem by, essentially, paying for access with what we call prestige-deference (Henrich & Gil-White 2001). Prestige-deference is all the small benefits that learners pay, often continuously, to their preferred models. This includes responsiveness to requests (for help), small gifts and public praise. Learners' tendencies to pay prestige-deference are generally unconscious and driven by feelings of respect, admiration, and a desire to affiliate, or remain in proximity to their preferred model(s).

This line of evolutionary reasoning suggests that learners, before submitting to paying the access costs to the preferred models, ought to first learn as much as they can from models that (1) live in proximity and are easily accessed, and (2) care about the learner, or are otherwise incentivized to aid the learner. Candidates are family and household members, especially older siblings, parents, and grandparents. Even among family members, the above model-based cues will still apply, so learners will learn from older, more similar (e.g., same sex), more skilled family members.

Then, having learned what they can from these low-cost models, learners must decide (unconsciously) whether to "update" their mental representations from their preferred models, or stick with what they acquired from their low-cost models. This decision should depend on (1) the relative difference in preferences between the low-cost models and the preferred models (based on the model-based cues), (2) an assessment of one's self using the cues (having acquired representations from the low-cost model) vis-à-vis one's preferred models, and (3) any readily-observable cues that indicate whether preferred models hold different mental representations than those acquired from the low-cost models. If the available observations indicate that the preferred models hold similar mental representations (i.e., employ similar practices or expresses like beliefs) or if little difference exists in the relative degree of preference between low and high cost models, then there may be no need to update.

This line of reasoning leads to a modification of the *grandmother hypothesis*, an explanation for the long postmenopausal life span found in the human species (Hawkes 2002; Hawkes 2003; Hawkes et al. 1998). The standard form of the grandmother hypothesis proposes that by initiating, in a sense, an early menopause, natural selection has extended the lives of women in order to permit them to invest in their grandchildren. The emphasis has always been on investing material resources, like calories (e.g., tubers) in their grandchildren. However, with the evolution of high-fidelity cultural transmission grandmothers can invest in their grandchildren by transmitting adaptive information. Grandmothers are ideally suited for this because (1) access costs for the learners are low due to relatedness by common descent (kinship), (2) age, as explained above, demonstrates ability to survive and permits the accumulation of both direct experience and culturally-transmitted knowledge, and (3) by virtue of being a grandmother, these models have demonstrated their abilities to rear at least one offspring to adulthood and reproduction.

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distinguished from the existence of non-verbal communicative ("pedagogical") cues (Csibra & Gergely 2009).

This *information grandmother hypothesis* has several advantages over the standard form. First, it has some *prima facie* plausibility in that, in the knowledge intensive niche inhabited by humans, older females might have something to contribute to their grandchildren besides their physical labor and calories. Second, it makes a cross-species prediction that sophisticated cultural abilities ought to be associated with a long post-reproductive lifespan. Supporting this, both tooth whales and elephants appear to possess more sophisticated cultural abilities and long-post reproductive life spans (McAuliffe & Whitehead 2005; Rendell & Whitehead 2001). In Fiji, this work suggests that grandmothers transmit important fitness-relevant information about food avoidances to their granddaughters.

## EMERGENCE OF CULTURAL ADAPTATIONS

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For our purposes here there are three forces that can combine with vertical transmission (or familial transmission) to construct cultural adaptations: (1) model-based cues, (2) individual learning, and (3) natural selection acting on cultural variation. By using model-based cues, individuals acquire mental representations that, over successive generations, move the overall population toward those cultural patterns that maximize the cues for success, health, skill, etc. (Boyd & Richerson 1985; Henrich 2004). To understand how this can occur, consider only the above-discussed success and health biases. Suppose a person's dietary choices influence his energy level, longevity, ability to work (and accumulate skills and success), mental acuity, and the health of his children. Further, imagine that an environment provides 20 potential foods in addition to a local staple. Assume that half of these foods should be eaten to optimize success and health ("good foods") and half should be avoided. Each of the good foods incrementally increase an individual's likelihood of being selected as a model by an amount  $\beta_e$ , while eating each of the bad foods decreases an individual's likelihood of being used as a model by an amount  $\beta_a$ . Under these conditions, cues of success and health will move the entire population, *ceteris paribus*, to the optimal combination of preferences for good foods and avoidances of bad foods, over generations. We'll call this optimum the culturally adaptive equilibrium (10 good foods all eaten, 10 bad foods all avoided). The noise inherent in any such learning or transmission process will cause increasing amounts of variation for foods that are "less good" (more people will mistakenly adopt avoidances for them) than other foods, and more variation for foods that are "less bad" (more people will mistakenly adopt preferences for them).

In the second way, called *guided variation* (Boyd & Richerson 1985), individuals learn from their parents and then, through direct experience, add to or correct the information acquired from their parents. Over generations, this can lead a population to the adaptive optimum.

Theorists have recently argued that learned adaptations could be acquired entirely based on individual learning (Lehmann et al. 2008). While we think one could devise clever mathematical models to show it, little evidence from the laboratory or ethnographic record supports it. When given a chance to imitate others, children and adults usually make use of that information, especially when costs and benefits are uncertain, problems are difficult, or when environments are spatially or temporally changing (Boyd & Richerson 1985; Henrich & Gil-White 2001; Henrich & Henrich 2007). If humans were primarily individual learners, cheating would not be such a problem in schools.

In the third approach, natural selection can act on vertically transmitted cultural repertoires (McElreath & Strimling 2008). If offspring learn only from their parents, and parents with more

adaptive cultural practices rear more kids to adulthood, then natural selection can construct a cultural adaptation.

The routes to adaptation are not mutually exclusive. Vertical transmission likely often combines with model-biased transmission, individual learning, and natural selection on cultural variation. However, our data suggest that individual learning is relatively weak compared to model-based cues. Even if people did try to use direct experience (more than reported), this would likely not help much as an adaptive force, since for this problem (toxic fish effects on fetus and infants) the information available is both rare and noisy. Natural selection's direct effect on cultural variation is likely playing a small role, since women who deviate may rear fewer healthy kids to adulthood. But, given that people are updating from more knowledgeable older individuals, these effects on adaptive evolution are likely much faster than the effects of natural selection, and will dominate the cultural evolutionary process (both of which can operate at the same time). That is, if model-biased selection is operating effectively, there's little variation for natural selection to act on.

### REPRESENTATIONAL CONTENT

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In addition to the above forces, we expect the final distribution of variants in a population to also be influenced by two other aspects of our cognition for cultural acquisition, representational content effects and representation reconstruction. Evolutionary approaches to cultural transmission also provide a rich set of cognitively-informed hypotheses regarding how the content of representations influences their transmission (Boyd & Richerson 1985: Chapter 5; Sperber 1996a). The general insight here is that learners should pay particular attention to and remember representations likely to contain adaptively useful information. Specifically, cultural learners should be more likely to pay attention to and store representations when these are judged, *ceteris paribus*, more (1) fitness relevant, (2) potentially actionable, and (3) plausible or compatible:

*Fitness relevant:* natural selection should favor more attention and recall for representational content of greater relevance to fitness, at least in ancestral environments. Such content is often emotionally evocative, which provides a measure of fitness relevance, at least in ancestral environments, and provides a proximate means of biasing storage, recall and, potentially, subsequent transmission. Some research suggests that when representations are initially encountered they are spontaneously analyzed via mental simulation "as if true," resulting in immediate emotional responses (Gilbert 2007). If such simulations readily deliver affective reactions such as disgust, fear, etc., more cognitive resources are devoted to analyzing and storing the relevant information, leading to biases in cultural evolution. Evolutionary approaches regarding the origins of emotional or affective reactions to particular stimuli or content lead to a wide range of more specific hypotheses.

*Potentially actionable* means that the content of a representation leads to inferences that can readily influence subsequent actions, including additional inferences (Inferential Potential: Boyer 2001). Representations, for example, in which the causes of unpleasant circumstances (e.g., storms or illnesses) are random with respect to the actions of those afflicted don't lead to useful or helpful inferences or actions, and thus are not easy to maintain. Evolutionarily non-actionable representations need not be stored because they can't help you even if you do remember them. Instead, representations that involve believing that illnesses are caused by the jealousy of others

(e.g., the “evil eye”) can lead to inferences about who might be causing a particular illness and how one can avoid such illnesses in the future.

*Plausible or Compatible* involves a variety of expectations that a learner might have about how the world works and, consequently, what is more and less likely to be true. Some expectations rely heavily on our reliably developing intuitions, including cognitive processes related to such domains as mechanics and biology. Such plausible or compatible content biases can also be culturally acquired, such that the possession of one mental representation biases the acquisition of others. That is, having acquired a particular idea via cultural transmission, a learner may be more likely to acquire another idea, because the two “fit together” in some cognitive or psychological sense (Henrich 2009).

Hypotheses generated by an evolutionary approach to representational content biases are finding a wide range of empirical support. For example, Barrett (2007) has shown that children from both the Ecuadorian Amazon and Los Angeles recall experimentally-transmitted information about the danger of novel animals better than name-labels (e.g., peccary) or diet information (e.g., herbivore). Information about danger is fitness relevant (and emotionally evocative—fear), actionable (one can avoid these animals), and plausible (actual images of these animals were used so teeth, size, etc. cues would not violate plausibility). Other research on how the content of stories (e.g., rumors and urban legends) influences their differential cultural transmission shows that successful stories are both more plausible and more emotionally evocative than less successful variants: see work on rumors (Rosnow 1980), urban legends (Heath et al. 2001), and social information (Mesoudi et al. 2006).

Relevant to the empirical work below, an evolutionary approach to the acquisition of representational content related to food leads to several predictions. First, food is likely receive greater interest from learners vis-à-vis other domains (e.g. shoe laces) for obvious evolutionary reasons—food and food choice was critical to survival and reproduction. Second, consistent with evolutionary approaches under the rubric “error management,” people should be more likely to adopt culturally transmitted food avoidances than food preferences, since eating something poisonous, contaminated, or unhealthy often has a bigger downside (sickness and death) than not eating one choice among many potential food sources. Of course, the adoption of food avoidances should be balanced against the perceivable loss of calories and nutrients. We should also expect this tendency to vary during critical periods of the life course. Pregnant women, to protect developing fetuses, may be more susceptible to adopting such food avoidances than at other times, assuming they are supplied with sufficient calories and nutrition (Fessler 2002). On the other hand, lactating women, given their increased caloric demands and the offsprings’ decreased susceptibility to pathogens ingested by the mother (vis-à-vis the fetus), ought to be less likely to adopt food avoidances. Third, since meat, among other foods, is more likely to carry pathogens and parasites dangerous to humans than other foods, evolutionary researchers have predicted that the adoption of culturally transmitted meat avoidances should be more prevalent than the adoption of other food avoidances. Consistent with this, extensive analyses of cross-cultural data have shown that meat (including fish) are by far the most tabooed category of food (Fessler 2003). Moreover, since meat from animals more closely related to humans (phylogenetically) is more likely to carry pathogens and parasites harmful to humans, we predict that the tendency to avoid certain meat and fish may depend on their perceived similarity to humans.



Below we deploy these ideas to explain the presence of some food avoidances to a non-trivial degree among pregnant and breastfeeding mothers.

## REPRESENTATIONAL RECONSTRUCTION AND EXTENSION

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Cultural learning processes require that learners observe others in their social world and reconstruct the mental representations underlying their models' behavior. Since these public representations, whether they involve manual skills (carving a statue) or verbalizations of beliefs ("God will spite nonbelievers"), necessarily provide only incomplete information, the learner must assemble his mental representation from only fragmentary inputs. During this reconstruction process, a variety of cognitive processes must be drawn upon to supply input, to help "fill in the blanks." This supplied content will influence the patterns of mental representations observed across populations. It may, as is the case with some religious concepts or other representations, explain recurrent or universal aspects in the distribution of representations (Boyer 2001; Sperber 1996a). Alternatively, the cognitive process that fills in blanks may have been influenced by cultural transmission or development in a culturally-evolved environment, which may result in reconstructed or "filled-in" content that varies across cultural environments.

Many aspects of human cognition may influence these reconstruction processes in ways that impact cultural transmission and cultural patterning. Here we limit our discussion to folkbiological cognition, since this domain is crucial to understanding the empirical patterns observed below. Folkbiology represents a set of cognitive processes associated with learning and reasoning about living kinds (Medin & Atran 1999; Medin & Atran 2004). Broadly, findings from decades of work on this domain, drawing from both anthropology and psychology, demonstrate that all human societies organize the natural world in hierarchically ranked taxonomies with a privileged taxonomic rank that corresponds roughly to the biological genus in scientific taxonomies (at least land animals). Category-based induction allows information acquired about one individual or category to be systematically extended through the taxonomic hierarchy to other individuals and categories with decreasing degrees of confidence. These features facilitate the acquisition, storage, and extension of information acquired both individually and culturally. For example, this category-based induction permits observations of the behavioral patterns of one particular lion to extend to all lions, and possibly (with decreasing confidence) to all cats, to all mammals, etc. Similarly, lower ranked categories inherit, without explicit cultural transmission, all of the properties of the higher level categories. Lions are mammals, so we know they have blood, breathe air, bear live young, need to eat, lactate, etc. Category membership is both essentialist and primordialist. Essentialism means that the properties (known and unknown) of category members are thought of as resulting from some underlying essence or essential nature that remains unchanged by superficial transformations over the life course (caterpillars and butterflies). Privileged taxonomic ranks, folk generic species (e.g., trout, maple and tapir) are (1) the most commonly used labels for life forms, (2) usually linguistically monographic (Berlin 1992) (e.g., grouper, not squaretailed coral grouper), (3) the first learned by children (Stross 1973), and (4) the most inductively powerful (Coley et al. 1997; Coley et al. 1999; Medin & Atran 1999). In a world of cumulative cultural evolution in which information about the biological world continually amasses over generations, this reliably developing aspect of human cognition allows learners to effectively acquire, organize, store, retrieve and extend this potentially fitness-relevant information.

From the perspective of food avoidances and evolutionary theory, if learners know from direct experience or cultural learning that one folk-species is dangerous (e.g., poisonous), they should tend to use category-based induction to extend these properties to related living kinds (just as they would other properties), especially when direct experience or input from cultural learning is lacking or weak. In our empirical analysis below we explain how the low frequency reporting of avoidances for freshwater eels and porcupine fish may represent category-based inductions from knowledge about moray eels and puffer fish.

## ETHNOGRAPHIC BACKGROUND FOR YASAWA ISLAND

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The research presented here was conducted in three villages on the eastern coast of Yasawa Island, which lies in the northwest corner of the Fijian archipelago (177° 32'E 16°48'S). This island is roughly 20km long and 2km wide at its widest point. The island experiences distinct wet-hot (Oct.-March) and dry-mild seasons (April-Sept.) and is probably the driest island in Fiji. There are 6 villages on the island, with between 100 and 250 people per village. Most of our data collection was done in the villages of Teci and Dalomo, at roughly the mid-point of the island, though our main pregnancy, breastfeeding, and fish poisoning interviews were also conducted in the village of Bukama.

Politically, the villages of Teci and Dalomo comprise a single kinship-based political unit (called a *yavusa* in Fijian), while the village of Bukama is its own *yavusa*. *Yavusa* are the largest kin-based political units in the Fijian system. *Yavusa* are typically composed of several *mataqali*, or clans. A hereditary chief, in council with the senior male members of his *mataqali* and the senior male members of each of the other *mataqalis*, govern the community. For each village, an elected *turaga ni koro* is charged with handling relations with government ministries and external organizations (those outside the traditional systems of chiefs, clans, etc.). This elected leader may have important influences in political decision-making within the villages; however, he is usually subservient to the Chief and his council. Christian churches in these villages, and their pastors, often influence political decision-making, although in these particular villages at this time, churches play only a minor role in political decisions.

Economically, households subsist principally on horticultural production, littoral gathering, fishing, and some purchased foods (e.g., flour, sugar, tea). Male members of households maintain subsistence gardens that supply yams, cassava, bananas, coconuts and other fruits, which supply the bulk of the calories consumed. Men also fish, using hook-and-line, nets, and both surface and underwater spears. Underwater spear fishing is a primary source of male prestige. Fish plus other marine species supply the bulk of the protein. Women collect fire wood, prepare food, clean, fish with hook-and-line, and gather shellfish, mollusks, and the like on the littoral. In Teci and Dalomo most cooking is done on open kitchen fires, while some in Bukama use gas stoves.

The two *yavusa* are economically distinct because Bukama leases some of its land to an exclusive luxury hotel (the only one on the island at the time of the study), which employs many of its villagers. Teci and Dalomo, in contrast, supply only 3-6 workers to the hotel at any one time, and these jobs are ephemeral. In Teci and Dalomo, there is one radio phone, which works occasionally, no electricity, no vehicles, and no commerce (except for in-home “stores”). Most houses in Teci and Dalomo are made from traditional materials and there are only two small motorized boats. Bukama has mostly concrete block houses, and is serviced by a mini-bus from the hotel (to pick up

employees). Hotel workers can access a small, expensive hotel store. Some houses in Bukama have limited electricity, which is generated by the hotel.

Social and economic life is largely organized by a complex kinship system that extends the nuclear family into an *itokatoka* (extended household) and governs more distant relationships with a cross-parallel distinction. Each clan, *mataqali*, is composed of two or more *itokatoka*. The system expands the nuclear family by extending parental and sibling relationships while creating linkages of various kinds to other *itokatoka* (Toren 1990).

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## METHODOLOGICAL APPROACH USED IN PROJECT

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This work was conducted as part of an ongoing research project on Fijian life ways and cultural transmission. The project mixes in-depth ethnographic observation and participation with extensive interviews and experiments. The project was initiated on Yasawa Island in 2003, and most of the research presented here was done in 2005-2007, while Joe (PI) and Natalie Henrich were living in the community. The project employs a full time Fijian Project Director (Mr. Samisoni Nanavu) and an Assistant Project Director, who collect data on demographics, fish catches, time allocation and other survey data year-round. All the data used in this paper were collected by trained Fijian interviewers (fluent in Fijian and English), most of whom were recent graduates from the University of the South Pacific (Suva, Fiji) and do not have kin in these communities. During field seasons in 2003, 2004, 2005, 2006, and 2007, the PI (JH) has spent over 9 months living in the villages and has developed a working understanding of the unwritten local Fijian dialect.<sup>2</sup> He personally trained the Fijian interviewers and checked all the major categories of data described below. Much of the primary data presented here was collected and checked while he was living in Teci.

Since all villagers above about the age 7 are fluent in both standard Fijian and the local village dialect (the vocabulary of these dialects do overlap substantially, but are not readily intelligible), we conducted these interviews primarily in standard Fijian, but inserted local vocabulary wherever necessary (e.g., names of fish folk-species vary substantially across Fiji so we used local terms).

All interviews done with women on the topics of pregnancy and breastfeeding were done by female Fijian interviewers, one-on-one, in private (save for infants and young children: Becker 1995). The PI was only present during a series of training interviews. All interviews were prepared using the method of back-translation. Moreover, each interview was reviewed by the PI soon after completion, and interviewers were sent back if anything was incomplete or ambiguous.

Table S1 below lists the primary data collection instruments used for this study, provides a brief description of the goal and method of data collection, the initials and gender of the Fijian interviewers (column RA – “research assistant”), the sample size, and sample selection. The initials in RA reference a name in last row of the table. Under sample selection, we use T, D, and B

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<sup>2</sup> The project also has two other co-PIs not involved in this component of the project: Rob Boyd and Joan Silk have lived and worked in these communities in 2003, 2005 and 2008. One of the project leaders has been on Yasawa every year since 2003.

for Teci, Dalomo, and Bukama, respectively, to indicate the communities from which our participants or samples were drawn. If there is not T, D or B, it means we used all three communities.

**Table S1: List of Primary Data Collection Instruments Used in this Study**

#	Instrument name	Main goals of instrument	Samp. Size	Sample Selection	RA	Interviewer Sex
1	Pregnancy Interview	Establish if pregnancy sickness exists: get name, duration, symptoms, aversions, taboos. Use freelist and checklist for aversions and taboos.	70	All moms	NN	F
2	Breastfeeding Interview	Establish length of breastfeeding period, supplemental foods, problems, aversions in mom, and taboos	65	All moms	NN	F
3	Fish Poisoning Interview	Establish existence and nature of any marine food poisoning, establish pattern of symptoms, duration, effects, treatments, etc.	60/10	Random adults/male See text	SV	M
4	Fish Catch Measures	Done weekly to assess amount and type of marine species caught during underwater spear-fishing.		Fishermen (T)	Various	M
5	Social Networks Interview	Interviewees free list and then rank people according to whom they would go to for advice on various issues and who are <i>yalewa vuku</i> .	166	Everyone 7+ (T, D)	AM, SV, SU	M,F
6	Demographics Interview	Obtain basic demographic information of each member of a household: birth year, age, education, place of birth, etc.		All, updated annually	Various	
7	Marine Triads	Measure perceived similarity among fixed sets of living kinds.	101	Random, ages 7+	Paula, SN	M, F
8	Nurse Interview	Establish what information and advice medical personnel, who have contact with villagers, give about food during pregnancy and breastfeeding.	2	All Nurses on Yasawa	SN	M
9	Non-mother Pregnancy Interview	Establish what non-mothers, including girls 10 and up and men, know about pregnancy and breastfeeding.	76	Random non-moms	NN, LF	F
10	Fish Poisoning during Pregnancy and BF	Establish precisely when moms have experienced fish poisoning, with the aim of finding cases that occurred during pregnancy or BF.	69	All moms	NN	F
11	Taboo Follow-up	Obtain more detailed information about what women believe will happen if tabooed species are consumed during pregnancy and BF.	82	All moms	TR, NN, MB	F
12	Success Ranking	Have people freelist those individuals whom they consider the best, most successful, or most proficient in various domains (fishing, weaving, village history, etc.).	121	Random, ages 10+ (T, D)	SN, JK	M
13	Domains of Success	Establish the domains of knowledge, skill, or know-how that are considered most important for being a successful and respected adult.		Random, adults	SN	M
14	Reproductive History I	Established number of offspring, length of breastfeeding, and miscarriages.	45	All Moms (Teci, Dalomo)	LF	F
15	Reproductive History II	Checked number of offspring, length of breastfeeding, and miscarriages; added occurrences of fish poisoning during each pregnancy and each period of breastfeeding, as well as all other episodes of fish poisoning. Asked also about the whereabouts of each offspring.	75	All Moms	AT	F
16	Higher Level Classifications	Asked people to categorize 17 different folk-species as fish, mammals, shellfish or rocks.	140	Random, age 7+	SV, SN	M

Research Assistants (RA): SN=Samisoni Nanovu; JK=Joape Kuruyawa; LF=Letila Fono; NN = Naomi Nanovu; PT=Paula Tekei; TR=Tepola Rabuli; SV=Semesa Vanalagilagi; SU=Susan Utoni; AT = Asinate Tavaga; AW = Alanieta Waqa

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## THE ADAPTIVE PROBLEM: TOXIC FISH

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Ciguatera poisoning is the most common form of fish poisoning and afflicts populations dependent on marine resources throughout the tropics. Ciguatera toxins are produced by a marine dinoflagellate associated with macroalgae (usually found on dead coral), and accumulates up the food chain, achieving dangerous levels in large, often predatory, fish (Hokama & Yoshikawa-Ebesu 2001). Symptoms include both neurological (e.g., transient paralysis) and physical (e.g., diarrhea and vomiting) effects, which can be severe and endure for months or even years (Bagnis et al. 1979). In rare cases, poisoning can be fatal, even in otherwise healthy adults. Research also indicates that ciguatera toxins can harm fetuses (Geller et al. 1991; Pearn et al. 1982; Senecal & Osterloh 1991; Thoman 1989) and can pass to infants through breast milk (Bagnis et al. 1987). Toxic fish are undetectable without complex and costly laboratory tests (Ting et al. 1998), which are often unreliable. With coral bleaching caused by global warming, rates of ciguatera are likely increasing (Lehane & Lewis 2000).

Fish poisoning occurs among people who eat reef-dwelling fish throughout the Caribbean, Indian and Pacific oceans, including Fiji. Since many, and sometimes most, members of potentially toxic fish species do not contain any, or only subclinical levels, of toxins, and the presence of these toxins vary both temporally and geographically, our first step was to establish whether fish poisoning is a problem on Yasawa Island. Ecologically, since the village of Teci sits in front of a substantial stretch of dead coral reef, which is thought to fuel the production of these toxins, there was reason to suspect that ciguatera might be a problem.

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### FISH POISONING IN YASAWA

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Informal ethnographic observations and interviews indicated that “fish poisoning” (termed *ika gaga*) has some local prevalence. To explore this, our team conducted a random sample of 60 interviews among adults in the *Yavusa* Bouwaqa ( $n = 30$ , includes Teci and Dalomo) and Bukama ( $n = 30$ ). We added to this a non-randomly selected group of 10 males between the ages of 20 and 40 in an effort to explore the relationship between alcohol consumption and ciguatera poisoning.<sup>3</sup> From the random sample, 60% (CI95%: 0.41-0.77) and 56.6% (CI95% 0.37-0.75) of people from Bouwaqa and Bukama, respectively, reported having experienced at least one instance of *ika gaga* in their lives. Of those who have experienced at least one incident, the mean numbers of episodes is 2.4 (Bouwaqa) and 1.7 (Bukama). One person reported 9 episodes, and ten people reported four or five episodes. Our sample was 42% male, with a mean age of 37. A series of generalized linear regression analyses using a negative binomial link function with age, sex, and village as predictors of a person’s total number of poisoning episodes indicates that being male increases a person’s number of lifetime episodes by 0.8. Neither village nor age had a significant coefficient.

Since these data are reports using the local term, *ika gaga*, we sought to examine whether *ika gaga* corresponds to the clinical manifestation of ciguatera poisoning. To accomplish this, we (1)

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<sup>3</sup> Since few villagers ever drink alcohol, we added individuals who we thought were mostly likely to have both experienced ciguatera poisoning and drank alcohol (i.e. thirty-something males).

asked the same sample to free list the symptoms they experienced during these episodes, and then (2) went through a checklist of symptoms drawn from the medical literature on ciguatera. Table S2 presents the mean proportions of the samples reported on both our freelist task and our checklist data (the range in parentheses is an exact 95% confidence interval), as well as clinical data from health posts in French Polynesia and New Caledonia, from Bagnis *et al.* (1979). The symptoms in this table come exclusively from our checklist, which was composed from the symptoms commonly associated with ciguatera poisoning as described in the medical literature. Since it was not constructed specifically using the data from the French Polynesian-New Caledonia clinical evaluations, we matched up categories and included data from those sources wherever possible. While most of our categories matched one-to-one, two problems in symptom correspondence arose. First, our checklist separated the experience of numbness (in fingers, toes, etc.) from a tingling, crawling or burning sensation on the skin, while the Bagnis *et al.* dataset grouped these under paresthesia. Moreover, Bagnis *et al.* do not report on paresthesia in general, but only report by body part. This means we cannot extract the total percentage that experienced these symptoms overall. To deal with this, we have drawn the highest percentage reported for any particular body part from Bagnis *et al.* (1979) and paired this with our symptom of tingling, crawling or burning sensation. This highest percentage for any particular body part sets the lower limit for the overall percentage of those who experienced the symptoms anywhere on their bodies.

These data indicate that *ika gaga* in Yasawa corresponds closely to the clinical diagnoses of ciguatera fish poisoning. First, note that since our checklist itself was composed of symptoms associated with ciguatera poisoning, and gave particular emphasis to those symptoms known to be most diagnostic (#2 and #3 in bold), the high frequency of reports for these symptoms (96%) and the generally high frequency of all symptoms (including sensations of loose teeth at 22%) indicate that *ika gaga* corresponds to clinical ciguatera poisoning. Second, comparing this to the distribution of symptoms based on clinically diagnosed cases of ciguatera, there is a high degree of correspondence ( $r = 0.65$ ), especially given the differences in data collection methods and populations. Most importantly, there is high agreement on the most diagnostic symptoms. Finally, as a methodological check, the free listed symptoms, which were elicited *before* the checklist, show several of the high frequency symptoms, including the diagnostic sensation of tingling, crawling or burning sensation on the skin. Save for a couple of idiosyncratic mentions, all the freelisted symptoms were found in the checklist, so our checklist was not missing any key symptoms that might indicate an alternative diagnosis.

<b>Table S2. Ciguatera Symptoms Checklist</b>	Yasawa Freelist* (n = 70)	Yasawa Checklist Symptoms** (n = 70)	Clinical Fr. Polynesia* (n = 3009)
Pain in your joints	60	100 (96-100)	85.7
<b>Tingling, crawling or burning sensation of the skin</b>	<b>40</b>	<b>96 (88-98)</b>	<b>89.1</b>
<b>Sensation of hot-cold reversal</b>	<b>0</b>	<b>96 (88-98)</b>	<b>87.6</b>
Weakness	60	93 (86-98)	60
Numbness in fingers, toes, around lips, mouth or throat	0	89 (80-95)	----
Diarrhea	36	84 (75-92)	70.6
Nausea	0	84 (75-92)	42.9
Pain in the mouth area	0	80 (69-89)	
Vomiting	44	73 (62-83)	37.5
Pain in the legs or arms	0	69 (69-89)	----
Itchiness on skin	0	64 (52-74)	44.9
Stomach pain	0	56 (43-66)	46.5
Muscle cramps	0	38 (27-50)	81.5
Difficulty breathing	0	36 (25-47)	16
Sensation of loose teeth	0	22 (14-33)	24.8

\* Data in columns are % of sample with the symptom.

\*\* Data in the column are % of sample with the symptom and the exact 95% CI in brackets.

Interestingly, our data show greater consensus for ciguatera symptoms than the larger dataset from French Polynesia and New Caledonia. There are three possible reasons for this. First, our population is culturally, environmentally, and genetically more homogenous than the other populations. Second, our populations eat reef fish regularly—often daily—so many people probably maintain subclinical levels of ciguatera toxin in their bodies all the time. Perhaps this results in more intense episodes and more regular appearances of symptoms. Third, since these are recall data, it's possible that local cultural notions of what symptoms are *usually* associated with *ika gaga* have influenced the recalled symptoms, leading to a greater consensus on the most



prevalent symptoms. This third possibility does not detract from our primary claim that *ika gaga* appears to pick out ciguatera poisoning and that this intoxication is quite prevalent on Yasawa Island. Overall, however, the third explanation seems unlikely as people described specific incidences of the symptoms, vivid sensations, and particular events. For example, in discussing symptoms #2 and #3 people often described a specific memory of the burning sensation created by cool water touching their skin during bathing (there are no hot showers in these villages).

### SPECIES IN REPORTED CASES

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To further assess the nature of *ika gaga*, we asked those who reported at least one incident of poisoning the kind of fish responsible for their most recent incident. Figure S1 summarizes the reports from 43 people who recalled the fish implicated in the poisoning. All of the reported fish are, to some degree, associated with ciguatera. The top four represent the most notorious ciguatera carriers from the medical literature.

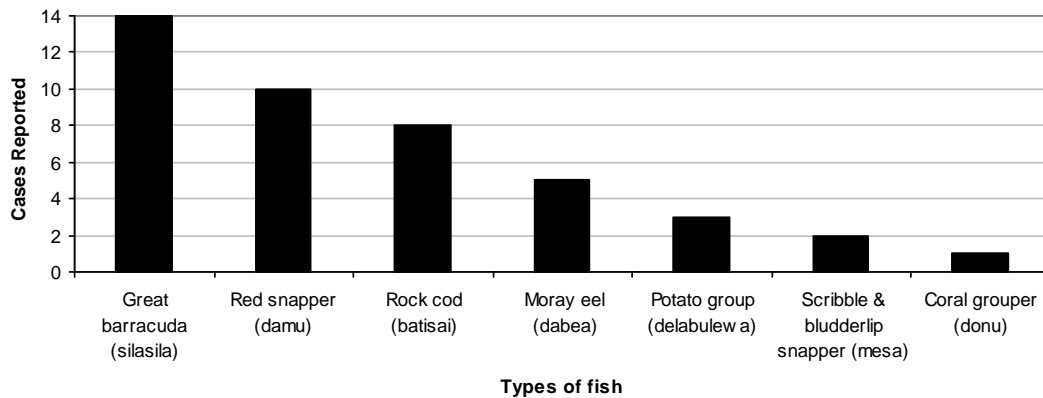


FIGURE S1. TYPES OF FISH ASSOCIATED WITH REPORTS OF *IKA GAGA*

To assess the impact of these poisoning episodes, we asked people how long they were sick. Many of our informants had trouble estimating this, but 33 people felt confident in recalling how long the worst of the symptoms lasted. These estimates yield a mean of 6.67 days (1 week). Fourteen people reported that some symptoms remained for a mean of 28.2 days (1 month), and sometimes recurred in milder manifestations.

While the above data show that ciguatera is an endemic health threat, and does have an impact on village life, people do not generally avoid potentially toxic fish. Most fish in these species do not cause acute health problems, and all are regularly eaten in these villages.

### CRAVING AND THE DROP IN REPORTED TABOOS

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Results presented in the main text show that the frequency of taboo reports for sharks and sea turtles drop from 87% to 52% and from 90% to 30% (respectively) as we move from pregnancy to breastfeeding. We speculate that these drops in taboo rates result from the combined facts that (1) sharks and sea turtles are the least toxic (or the least likely to be toxic) so their relative effects on health and success are the lowest; and, (2) nursing substantially increases women's caloric

demands—thus, these women are really hungry and crave a wide variety of foods (including fish) compared to pregnant women. This means that cultural evolution, driven by selective model-based learning, will first drop the taboos on the least toxic species as caloric demands increase and outweigh the negative impact of potential poisoning. It is also possible that breastfeeding infants are less susceptible to ciguatera toxins than fetuses.

Evidence for the increased demands of lactation come from (1) medical research showing the increased caloric demands of breastfeeding women (Ngo & Cervera 2001; Reifsnider & Gill 2000), and (2) our data comparing cravings reported during pregnancy vs. breastfeeding. Figure S2 illustrates this, showing that reported cravings increased in every category of food we studied.

However, since the Fijian translation of “crave” (*garova* in Standard Fijian or *garovia* in Yasawan) indicates in this context something one desires and would eat if given the chance, the tabooed fish (those in the consensus grouping) were reported extremely rarely or not at all—only by people who did not report them as tabooed. Ninety-seven percent of women reported craving *ika* (fish), in general, and would have reported the normally prized catches, like the moray eel, had it not been for the taboo.

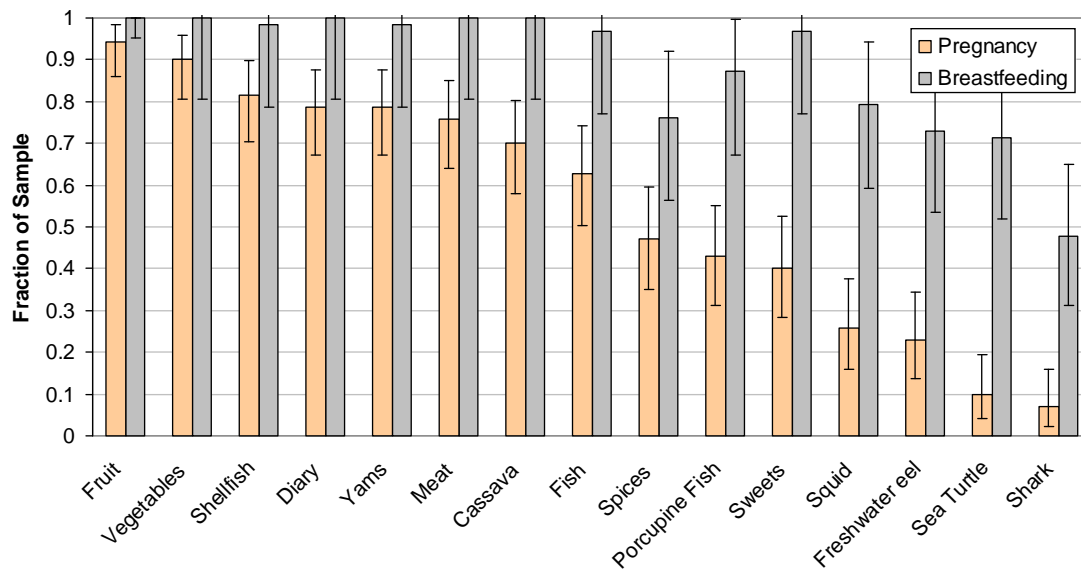


FIGURE S2. COMPARISON OF CRAVINGS DURING PREGNANCY AND BREASTFEEDING ( $N = 70$  AND  $N = 61$ , RESPECTIVELY). THE ERROR BARS ARE 95% EXACT CONFIDENT INTERVALS.

Within our category “meat,” which includes chicken, pork, and beef, we note a divergence from the taboo data presented above. When women mentioned taboos on meat, they specifically noted pork. However, for cravings, when women mentioned craving meat, they all specifically wanted beef. This is consistent with Fessler’s (2002: 35) suggestion and ethnographic evidence that women may also be using this special period to access particularly prized resources (which beef is, in Yasawa).

Consistent with the effects of increased demands for calories and nutrients, the reports of taboos for octopi, porcupine fish, and freshwater eel all dropped substantially. Octopi fell from 37% to 13%. The porcupine fish and freshwater eel fell from 20% to 7% and from 19% to 5%,

respectively. As all three remain significantly above zero, we suspect that these drops result from two cognitive effects that generate avoidances toward these particular folk species, keeping their rates above zero, pitted against the increased nutritional demands of breastfeeding. We discuss these two cognitive effects below.

## FREE RESPONSE DATA

The advantage of the checklist approach is that it minimizes the impact of individual differences in recall and reporting effort during the interview. The problem is that it may miss important foods. To address this, we asked our participants—prior to the checklist task—to first list all foods that they avoid during pregnancy. Figure S3 displays the overall response frequencies from both the free listing and the checklist. Here the first two paired bars (“Any/B-P Fish”) presents the checklist data for the item (“Any fish”, addresses whether the person tabooed at least one kind of fish) and the free listing bar gives the frequency of respondents who gave the ad-hoc categories of (1) poison fish (*ika gaga*) or (2) big fish or sliced fish (*ika lelevu* or *ika tavatava*, *ika tava*). We discuss this more below.

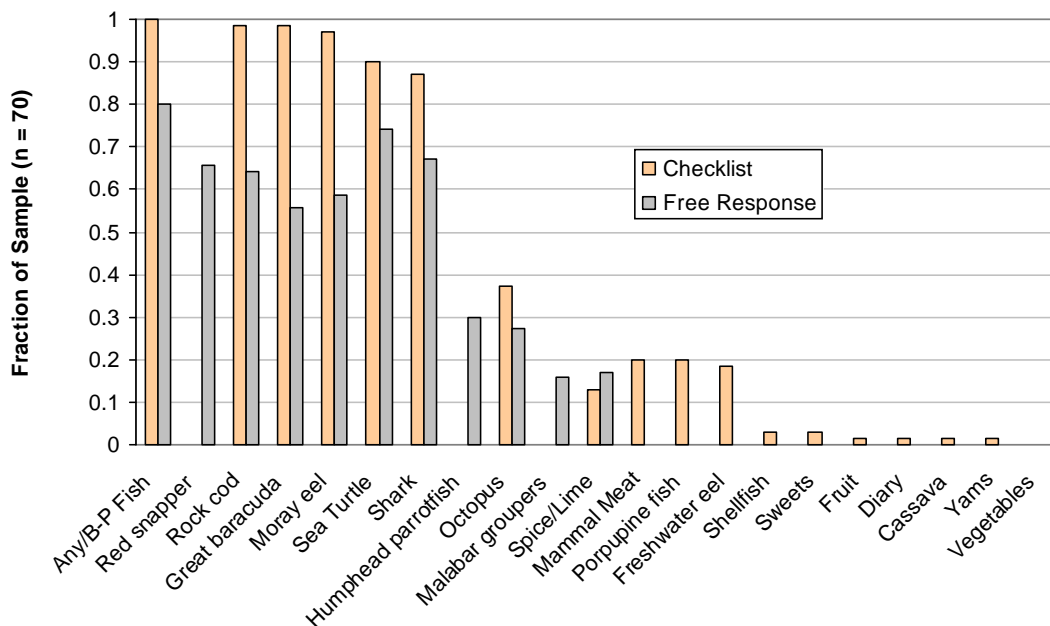


FIGURE S3: COMPARISON OF FREE-RESPONSE TABOOS AND CHECKLIST DURING PREGNANCY

The free response reveals the same general pattern observed in the checklist data: High response rates for taboos on known-to-be-toxic fish (from the medical/scientific literature) and lower rates for all other foods. As is typical, free listing yields lower frequencies than checklist formats. People probably tire after naming a few foods and forget others, unless motivated and cued by a direct question. Those items in the consensus grouping from the checklist (those with reported frequencies exceeding 87%) were freelisted by between 56% and 74% of the sample. Only one other fish that was not on our checklist was reported in this range: red snapper (*damu*). This fish is well known to be one of the most toxic (Lehane 2000). At lower frequencies in the free lists, two other folk species emerged, *kelia* (humphead parrotfish) and *votosiga* (malabar grouper). Both of

these species are occasionally associated with ciguatera poisoning in the literature, although they appear substantially less often than those in the consensus grouping. Except for spices (*boro*, see main text), none of the other foods emerged as taboos in the freelisting.

One key finding from the freelisting task is that *most* folk species of fish are not tabooed during pregnancy and breastfeeding. To see this clearly, note that the top 7 most frequently speared fish (see Table S3, next section) are never mentioned during freelisting.

As noted, the freelisting of food taboos also revealed the existence of two ad-hoc cultural categories whose members are folkbiological generic species. In 80% of our freelists, women referred to either (1) “big fish” (*ika lelevu* or *ika yalevu*) or “sliced fish” (*ika tavatava*, *tava*) or (2) poison fish (*ika gaga*), with many women listing both categories. We translate *tavatava* (or *tava*) as “sliced”, but in this context it refers to fish that are sufficiently large that they must be cut with the long bush knives that villagers routinely use in agriculture. This category acts as a heuristic for some to determine which fish not to eat during pregnancy and breastfeeding; this category generally includes sharks and sea turtles, and some also include *kalia* (green humphead parrotfish), *tavaga* (humphead wrasse) and rays (*vai*). *Ika gaga* principally includes moray eel (*dabea*), red snapper (*damu*), great barracuda (*silasila*), and rock cod (*batisai*), and sometimes blubberlip snapper (*mesa*), bluestripe herring (*daniva*), malabar grouper (*votosiga*) and potato grouper (*delabulewa*).

This distinction is important because it demonstrates that taboos are not merely coterminous with the category *ika gaga*, but includes other, less frequently caught, potentially toxic, species. That is, while we included sharks (*iko*) and turtles (*vonu*) in our checklist because they are known to be responsible for poisoning, Yasawans do not recognize sharks or sea turtles as *ika gaga*, but nevertheless taboo these during pregnancy and breastfeeding. Moreover, while they do not include sharks and turtles as *ika gaga*, women do report that a mother’s consumption of these during pregnancy or breastfeeding could damage the health of fetuses and infants. Although there is consensus that the consumption of any of the tabooed foods will damage the health of the fetus or infant, there is little agreement on precisely what form this will take. As expected, adaptive cultural transmission processes work to generate adaptive behavioral patterns, and not on getting the symptomology, causal details, or the “backstory” correct.

The freelisting of food taboos during breastfeeding yields findings that parallel those on the checklist. Because the breastfeeding interview was a second interview involving extensive questioning about food avoidances, and we were concerned about boring our participants, we did not push them to keep listing items, after their initial list, as we did in the pregnancy interview. For example, if a woman said *ika gaga* initially, we did not press her to list all *ika gaga* she could think of, as we did in the pregnancy interview. Despite this, the freelist results correspond to the patterns seen on the checklist results. *Ika gaga* (poison fish) were mentioned initially by over 80% of respondents, with rock cod, great barracuda, and moray eel all spontaneously mentioned most. Red snapper was again among the most freelisted avoidances, showing the same frequency of reporting as moray eels. Consistent with our breastfeeding checklist results, and different from the pregnancy findings, sharks, turtles and “big fish” were all mentioned infrequently.

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## CIGUATERIC SPECIES ARE IMPORTANT FOOD SOURCES

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To establish the relative importance of the tabooed foods vis-à-vis other marine species, we draw data from our measurements of actual fish catches in the villages of Teci and Dalomo. Over the course of one year, we recorded the folk species and sizes of the catches from all fishermen. In gathering these data, we took advantage of the fact that on Saturdays most of the fishermen in the villages go spear fishing (underwater) as a group. Once they are in the water, they separate and don't see much of each other until they go ashore 2-3 hours later. These data come from measurements of 1082 fish (66 different folk generic kinds) caught by 26 fisherman on 12 different Saturdays between July 7<sup>th</sup>, 2005 and July 1<sup>st</sup>, 2006 (including measurements in the months of July, Aug, Nov, Dec, April, and May). Since these data are principally from underwater spear fishing, they do not represent an accurate picture of all the species consumed in these villages, as some species are only taken by hook and line or in nets. Specific to our interests, underwater spear fishermen—armed with only slender metal rods and thick rubber bands (not spear guns)—expressly avoid both sharks and barracuda (which are taken by hook and line), so we don't expect these to be represented.

Based on these data, Table S3 shows the top 15 contributors to the overall catch, as measured in kilograms.<sup>4</sup> We recorded these marine species using the local generic Fijian names, so columns 3 and 4 represent our efforts to match these with the common and scientific taxonomies.<sup>5</sup> The letters in parentheses next to the scientific classification indicates at what level of the scientific taxonomy these generics match up. Columns 5 and 6 give the total weight (kg = kilograms) for each and its contribution, as a percentage of the overall catch. These are the top 15 of the 65 different folk species that we recorded. These 15 contribute 81.3 percent of the total weight of all fish caught.

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<sup>4</sup> These measures are raw kilograms and do not include adjustments for differences in the amount of edible materials contained in different species.

<sup>5</sup> Matching the local folk taxonomy up with the scientific taxonomy involves extensive interviews with local experts, and represents an ongoing process that is not yet fully complete.

Rank	Folk generic Name	Common names	Approximate match with scientific classification <sup>6</sup>	Total kg in sample	Percent of total kg
1	dridri	many surgeonfish and tangs	Some Acanthuridae (f)	61.66	19.30
2	ulavi	parrotfish	Scarus (g)	32.03	10.02
3	vai	rays	Rajiformes (o)	20.07	6.28
4	ika yalewa	unicorn fish	Naso (g)	17.61	5.51
5	yaro	lined surgeonfish	Acanthurus lineatus (s)	15.51	4.85
6	kasala	various groupers	Epinephelus (g)	13.72	4.29
7	damudamu	squirrelfish	Sargocentron (g)	13.69	4.28
8	<b>batisai</b>	rock cod	Plectropomus lanceolatus (s)	13.47	4.21
9	sokisoki	porcupine fish	Diodontidae (f)	13.18	4.13
10	<b>vonu</b>	sea turtle	Chelonioidea (sf)	12.70	3.97
11	<b>dabea</b>	moray eels	Gymnothorax	11.94	3.73
12	<b>damu</b>	red snapper	Lutjanus bohar & argentimaculatus	10.57	3.31
13	qitawa rilau	sweetlips	Plectorhinchus lessonii & lineatus (2s)	9.81	3.07
14	donu	coral groupers	Plectropomus (g)	7.29	2.28
15	<b>votosiga</b>	Malabar groupers	Epinephelus malabaricus (s)	6.63	2.08

These data indicate that the fish tabooed during breastfeeding and pregnancies are normally important contributors to the local diet. All of the tabooed fish that are caught by spear-fishing appear in the top 15 contributors. Cumulatively, summing up all of the folk species in bold, these tabooed fish contribute 17.3% of the total catch, a non-trivial portion of the diet. Moreover, this measure does not include sharks and barracuda, which are caught with hook and line, or the sea turtles caught in nets.

<sup>6</sup> The parenthetical letters give the approximate taxonomic level covered by the local Fijian terminology, so f = family, g = genus, s = species, o = order, and sf = superfamily. The "2s" means that that term seems to cover two species, but not the entire genus.

## FISH AVOIDANCES ARE TRANSMITTED PRINCIPALLY VIA CULTURAL LEARNING

Having argued that food taboos during pregnancy and nursing are a cultural adaptation that differentially targets toxic marine species, we now examine our hypotheses about (1) how these avoidances are learned (individually or culturally) and (2) from whom they are learned. By showing that these avoidances are influenced by selective attention to particularly knowledgeable or successful individuals (selective model-based cultural learning), we lay the necessary groundwork for the emergence and maintenance of a culturally-evolved adaptation.

To explore the acquisition of food taboos for pregnancy we asked our sample, “How did you learn about what foods to avoid while pregnant?” Note, we did not ask, “From whom did you learn about which foods to avoid?” People could have answered our question by referring to direct personal experiences, but they mostly did not. We recorded whatever women said and coded them straightforwardly into nine categories. Figure S4 summarizes our findings for the two *yavusa* studied. The main text presented only the Bouwaqa findings for reasons explained below.

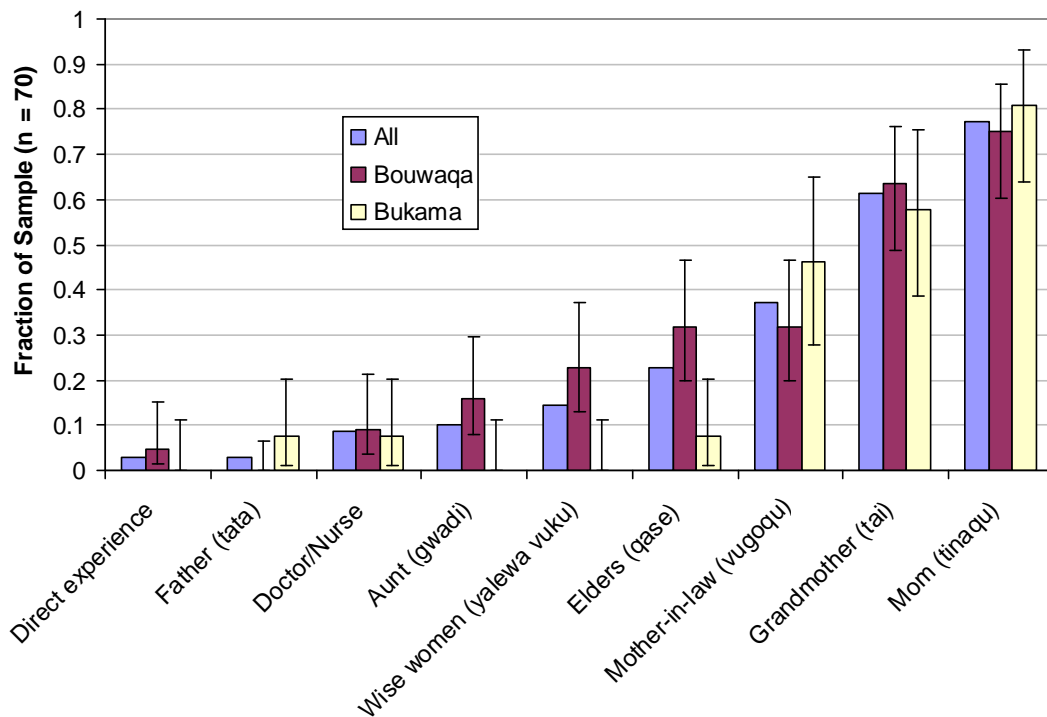


FIGURE S4. ANSWERS TO THE QUESTION "HOW DID YOU LEARN ABOUT THESE TABOOS?" FOR BOUWAQA AND BUKAMA. THE FIJI TERMS MIX TERMS OF REFERENCES WITH TERMS OF ADDRESS. THIS IS RETAINED TO PRESERVE WHAT OUR INFORMANTS TENDED TO ACTUALLY SAY.

The results presented in Figure S4 are consistent with our theoretical expectations in three principle ways. First, only 4% of participants mentioned acquiring food taboos from direct experience or individual learning, and no one mentioned *only* direct experience. Other parts of our interview show that while 68% of mothers can name a case or two in which violating a food taboo did harm a fetus or baby, these represent a handful of isolated incidences. Many informants

reported the same incidence (often with different details) and it was often unclear if informants actually saw events first hand, or were reporting second hand (that is, culturally transmitted) information. Finally, if someone had observed, or otherwise knew about only the reports we recorded, they would not have avoided rock cod, sharks, or red snappers.

Second, Figure S4 indicates that most learners took advantage of the low-cost (easily available) models who share a kin-based incentive that the future pregnant woman should acquire the best eating practices. Overall, 77% of women said they learned from mom (*tinaqu* or *nene*), 61% from their grandmother (*tai*), and 37% from their mother-in-law (*vugoqu*).

For those interested in explaining the origins of a long post-reproductive life in human females, we observe that grandmothers are an important source of fitness-enhancing culturally-transmitted information for their granddaughters. This supports the Information Grandmother Hypothesis described above.

Learning from mother-in-laws is not surprising, especially in this case. Since newly married women often move into their husband's parents extended household (*itokatoka*), first-time expectant mothers will find themselves around their mother-in-laws when they become most interested in pregnancy related food taboos. Moreover, while women are not genetically related to their mother-in-laws, mother-in-laws have a kin-based incentive in their daughter-in-law learning appropriate eating behavior—the fetus is genetically related to the mother-in-law and this partially aligns their interests. Across all three villages, 40% of adult females grew up in a different village from where they live now (exogamy rate). This percentage is remarkably close to the percentage of women who reported learning from their mother-in-laws.

Third, central to cultural transmission's ability to generate and sustain adaptive behavioral repertoires, are the effects of model-based biases, such as prestige, success, knowledge, and age. Once a cultural system has reached a stable equilibrium in a certain domain, most individuals will only learn from the available low-cost models, and will not need to update from preferred (prestigious) models. Theoretically, this occurs as learners compare their acquired cultural representations (acquired from low-cost models) with those of their preferred models, and assess differences in perceived cues of prestige, knowledge, success, etc. If these representations appear similar and the differences in success or the degree of model preference (the cues) is not too large, learners will stick with what they learned in the family (low cost models) and never update. Thus, since the distribution of food avoidances during pregnancy appear near the optimal response with regard to marine toxins, we expect a small but non-trivial degree of transmission from models deemed highly successful.

In Bouwaqa, a non-trivial fraction of women report learning from senior and/or prestigious women, not including their mom, grandmother or mother-in-law. Figure S4 shows 23% and 31% of women in Bouwaqa report having learned about food taboos from “wise women” (*yalewa vuku*) and “elders” (*qase*), respectively. Both *qase* (elders) and *yalewa vuku* suggests learning from senior women other than their immediate family members, and *yalewa vuku* carves out a select group of senior women known for their knowledge, particularly about medicinal plants, birthing, and traditional remedies.

In Bukama, no one mentioned *yalewa vuku* and only 8% mentioned elders (*qase*). We lack the data at this point to say precisely why we do not see this same pattern in Bukama, given the similarity between Bukama and Bouwaqa on their other responses in Figure S4. However, our approach to



cultural learning provides a hypothesis. In 1992 an exclusive resort was started on Bukama's territory and about 75% of the adults in this village work in the hotel. It may be that the substantial social and economic impact of the hotel, on both people's income and their ability to allocate time to traditional pursuits, has shifted the domains of prestige from those that include traditional knowledge to ones based around income generation, business, and commercial advancement. In Bouwaqa, our work has already shown that excelling in traditional domains (e.g., fishing, house construction, medical plant knowledge, etc.) remains the principle means for acquiring respect within the community, although business acumen is making some inroads. Ongoing research will comparatively explore the differences in prestige domains between these communities. If this hypothesis is correct and the villagers of Bukama have shifted from the traditional domains of prestige, we should expect the consensus response on prophylactic taboos in Bukama to drift away from the current adaptive consensus over the next few generations.

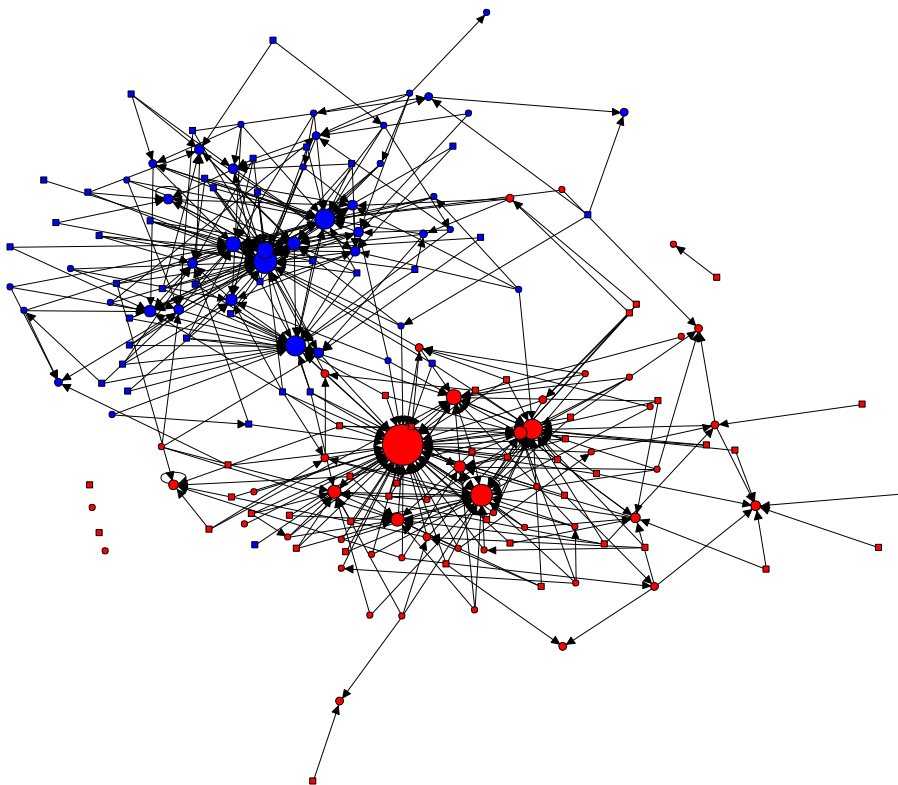
Finally, we note that the responses reported in Figure S4 do not look like those one gets when an adaptive response has been evoked by environmental circumstances (as opposed to being culturally transmitted or individually learned). As part of this same investigation we also examined two non-cultural evolutionary hypotheses about the nature of pregnancy sickness and found that most women were disgusted by the same local foods (and not the tabooed foods) during their first trimester in a manner consistent with an evoked response to environmental conditions. When we asked how they learned to be disgusted by these foods, they looked at us like we were crazy (*lialia*), and seemed baffled by the question. In contrast, when we asked about the tabooed foods, women readily answered the question, without confusion. This is merely a hint, but it does indicate that our participants did not merely feel inclined to give an answer to a wacky question.

## PATHWAYS OF CULTURAL TRANSMISSION AND YALEWA VUKU

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We hypothesized that the distribution of fish taboos in these populations, and in particular the local consensus of those avoidances, is a cultural adaptation driven by model-based selective cultural learning. This is supported in part by the tendency of women to report having learned their avoidance from a *yalewa vuku* (wise woman). To further examine this specific proposal while at the same time testing some of the more general hypotheses about model-based selective cultural learning, we present two analyses. First, we examine who villagers believe are the current *yalewa vuku* in Bouwaqa and assess the degree of agreement about who these women actually are. If the above hypotheses are correct, and *yalewa vuku* represent knowledgeable and prestigious transmitters in this domain of culture, the social network created by *yalewa vuku* nominations will be highly centralized: people will agree on who the *yalewa vuku* are. This need not be the case: we might have found, for example, that women said that they learned from a *yalewa vuku*, but no one agreed on who those women are, or everyone believed their mother is a *yalewa vuku*. Second, we regressed a measure of each person's prestige as a *yalewa vuku*, based on social network data (with most having zero prestige in this domain), on measures of age, perceived knowledge of medicinal plants, education, and clan membership. If the evolutionary hypotheses laid out above are correct, both age and expert knowledge or skill in a related domain should predict being selected as an *yalewa vuku*, thus making one more likely to influence the transmission and distribution of food taboos.

*Yalewa vuku* represent a social category of women respected by community members for their expertise in areas that women are supposed to know something about, including Fijian medicine (the use of medicinal plants), mat weaving, cooking, and reproduction (e.g., pregnancy, breastfeeding, and infant care). As part of our investigation, we asked every person over age 7 in Bouwaqa to name the *yalewa vuku*. Participants could name as many people as they wanted but everyone spontaneously listed between zero and 5 names. We also did not specify that the *yalewa vuku* had to be in Bouwaqa, but all the people named were in Bouwaqa. Figures S5a and S5b graphically illustrate the network. The nodes represent villagers, with the circles indicating females and the squares males. Each arrow points from the person interviewed to one of the individuals named by that participant. The overall orientation of the network is arbitrary, although the distances between nodes are calculated by “spring embedding” algorithms that pull the nodes closer together that have more interconnections (arrows) between them. The color of the nodes distinguishes the two villages, with blue indicating Dalomo and red Teci. In Figure S5a, the size of the node is proportional to its indegree centrality (hereafter “indegree”). Indegree is merely the total number of individuals who selected the node (individual) as a *yalewa vuku*. In Figure S5b, the size of the node gives the in-eigenvector centrality. An individual’s eigenvector centrality is calculated by weighting each nomination (each incoming arrow) by the eigenvector centrality of the nominator (the originating node of the arrow). Individuals with the highest eigenvector centrality are those who tend to be most frequently nominated by those who themselves are frequently nominated. For our purposes here, eigenvector centrality (hereafter “centrality”) measures an individual’s potential importance and impact on cultural transmission and evolution. The mental representation held by those with high centrality will have a disproportionate impact on cultural evolutionary dynamics.



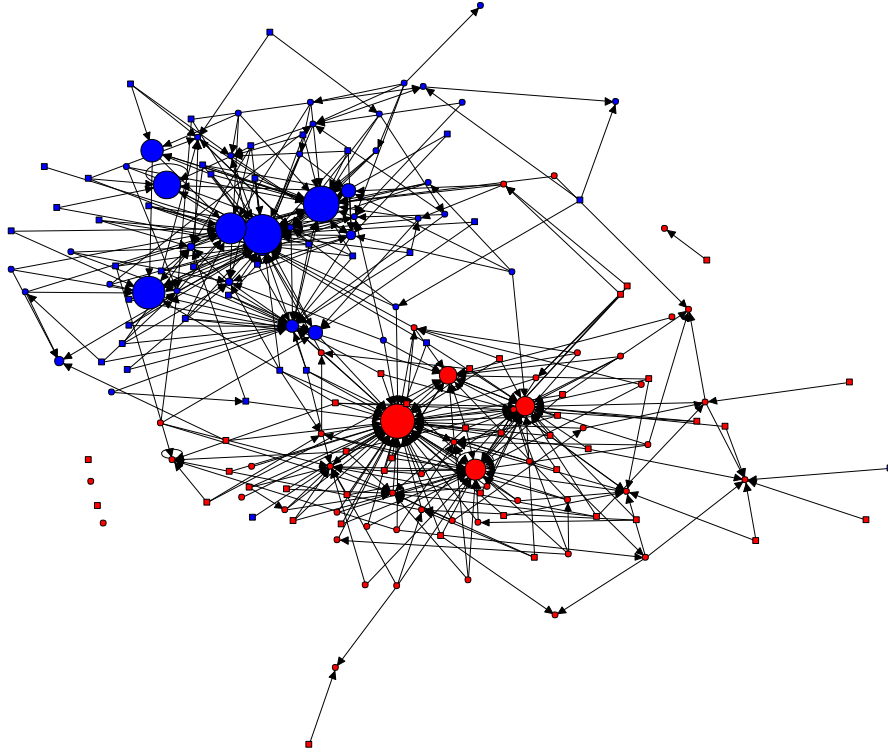


FIGURE S5. SOCIAL NETWORKS OF *YALEWA VUKU*. ARROWS POINT TOWARD PERSON SELECTED AS *YALEWA VUKU*. CIRCLES AND SQUARES REPRESENT MALES AND FEMALES RESPECTIVELY. RED AND BLUE INDICATE PEOPLE FROM TECI AND DALOMO, RESPECTIVELY. IN FIGURE S5A (TOP) THE SIZE OF THE NODE (CIRCLE OR SQUARE) REPRESENTS THE INDEGREE. IN FIGURE S5B THE SIZE OF THE NODE REPRESENTS THE EIGENVECTOR CENTRALITY.

Graphically, Figure S5 shows that there is substantial agreement on who are the *yalewa vuku* (the network is centralized) and that a handful of individuals likely has a disproportionate impact on cultural evolution. For indegree, only 61 individuals were nominated at all (so 111 individuals were never nominated). Of these people, only 25 people received more than five nominations and only three received more than 25 nominations. One person received 60 nominations, nearly twice as many as the number two ranked person. Our centrality measure narrows things even further: Of the 61 people who received any nominations, only 18 had centralities higher than zero (many people were only nominated by people who themselves were not nominated). However, at the top end, eigenvector centrality is much flatter than indegree. The person with by far the highest indegree (60) also has a high eigenvector, but no longer dominates (showing the third highest eigenvector centrality). There are five people with centrality scores between 0.60 and 0.85. Indegree and eigenvector centrality are correlated 0.73 (bootstrapped BCA 95% CI 0.57-0.84).

Before analyzing the relationship between being selected as a *yalewa vuku* and the hypothesized predictors of age and knowledge/skill, we need to describe how these measures of perceived knowledge were obtained. We asked a randomly selected group of 121 *yavusa* members (over age 8) to name the people who know the most about medicinal plants. These lists allowed us to calculate an aggregate measure for each person in the community, assigning anyone not named by these 121 people a measure of 0.

Building on the link established above between the cultural transmission of food taboos and *yalewa vuku*, we tested our hypothesis that learners will use cues of age and of perceived expert knowledge (or skill) to select whom to learn from by regressing the indegree for all women on their age and their knowledge of medicinal plants (as measured by other villagers' nominations as "most knowledgeable"). Indegree is merely the number of nominations each woman received.

Since the dependent variable is bounded and has a mode at zero, we used a generalized linear model with a negative binomial link function. In addition to age and perceived knowledge, we also included each woman's years of formal education (varying from 0 to 12) to control for any effects of education on perceived knowledge of local practices. All three coefficients are significant at conventional levels. For age (varies from age 8 to 82), each additional decade of life increases the number of nominations one receives as a *yalewa vuku* by about 0.7. For knowledge, every additional ten nominations as "most knowledgeable about medicinal plants" increases predicted *yalewa vuku* nominations by 0.5. The pseudo- $R^2$  for this regression is 0.15. Table S4 summarizes the analysis.<sup>7</sup>

**Table S4: Regression analysis using Age and Plant Knowledge to predict indegree of *yalewa vuku***

Variable	Coef.	Asymptotic <i>p</i> -value
Age (yrs)	0.066	7.2E-13
Knowledge (nominations)	0.052	0.001
Education (yrs)	0.2	0.002

As a check for possible confounding influences, we added *mataqali* (clan) membership to the above regression and re-estimated it. Clan was included to address the problem that people may be picking members of their own clan, and clans vary in size, so those from larger clans may be selected more frequently. The coefficients and significance for Age, Knowledge and Education do not change appreciably and AIC (Akaike Information Criterion) for this model is higher than for the previous model.

Figure S6 graphically shows the relationship between age and the two measures of centrality. As a lone predictor variable, age appears to have a non-monotonic relationship with centrality or prestige as a *yalewa vuku*. However, we performed a series of segmented regression analysis using knots between ages of 50 and 62 and found that—when perceived knowledge is controlled for—age always has a positive (and significant) effect on one's likelihood of being selected as a *yalewa vuku*. Thus, the drop observed in Figure S6 captures a drop in perceived knowledge.<sup>8</sup>

<sup>7</sup> The analysis was implemented in software package R using the generalized linear model with a negative binomial link function (`glm.nb`) from the MASS library.

<sup>8</sup> Elsewhere, Henrich and Gil-White (2001) have discussed how the prestige and influence of elderly individuals should decline in rapidly changing (out of equilibrium) circumstances. If the current circumstances are substantially different from that experienced by older individuals of their lives, learners should devalue them as models. Since we are arguing that, with regard to this cultural domain (not the society in general), things appear to have been stable, we will not deal with this here.

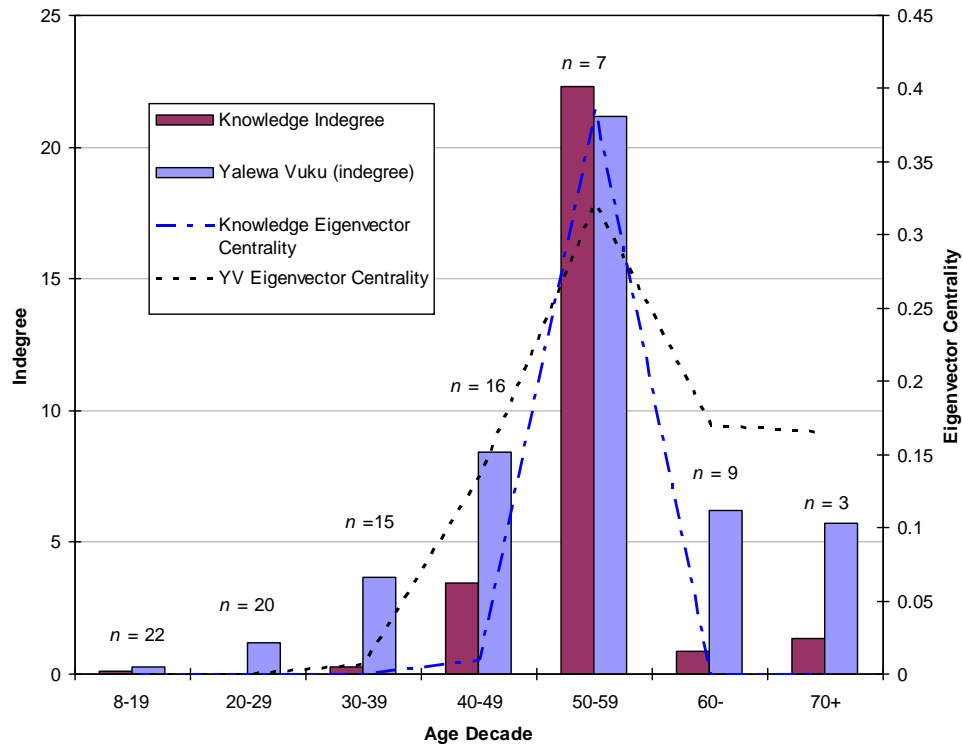


FIGURE S6. PLOT OF AGE IN DECADE VS. INDEGREE FOR *YALEWA VUKU* AND CENTRALITY

## BIASES ON MEAT, FRESHWATER EELS, OCTOPI & PORCUPINE FISH

So far, we have sought to explain the prevalence of the taboos in the consensus groupings as the adaptive products of selective model-based cultural transmission. Here, we aim to explain the foods in the intermediate category (porcupine fish, octopi, freshwater eels, land animal meat). This is important because if selective model-based forms of cultural transmission favor tabooing only toxic foods then some other processes or cognitive biases must be maintaining the frequency of the taboos on these non-toxic foods significantly above zero in all three villages. We propose that a non-trivial tendency to taboo each of these foods arises as a byproduct of an evolved aspect of human cognition.

### MEAT

In the checklist reports of pregnancy taboos, land-animal meat, freshwater eel, octopus and porcupine fish were all reported between 19% and 37% of the time. For breastfeeding, three of these four dropped in frequency (as did most items), but all remained significantly above zero. Notably, however, of these food categories, only octopus appeared in the freelisting. An evolutionary approach to learning suggests that our cognitive machinery for culturally acquiring eating preferences and practices ought to be influenced by error management biases aimed at meat, and particularly at mammalian meat, given its tendency vis-à-vis other foods to carry

parasites and pathogens dangerous to humans. Such a learning bias will favor the adoption of practices that help avoid pathogens and parasites. As a byproduct, such a bias will tend to maintain positive frequencies of meat avoidances, and occasionally spread such avoidances to consensus (Fessler 2002; Fessler 2003). Given this, it is not surprising that—except for spices—our top 12 most avoided foods in Fiji are *all* animal foods. Even shellfish maintained frequencies significantly different from zero during both pregnancy and breastfeeding.

Consistent with this, meat from mammals (pigs and cows) maintains a solid frequency of avoidance at about one-fifth of the sample during both pregnancy and breastfeeding. Our initial work on Fijian folkbiology indicates that these land mammals are considered more similar to humans than any other animal food typically eaten. Interestingly, however, every person recorded in this meat category noted that it applied only to pigs (*vuaka*). Only one person cited anything else in addition to pigs (cows or *bulmakau*). Taboos on pigs re-emerge across many cultural contexts and some speculate that pigs are particularly targeted because they consume garbage, feces, etc. (Fessler 2003), or because of the perceived similarity to humans. In contrast, in the craving data discussed above, everyone who reported craving meat cited cow as their meat of choice.

#### CATEGORY-BASED INDUCTION: FRESHWATER EELS AND PORCUPINE FISH

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While it likely has some contributory effects, the impact of a meat-based learning bias seems insufficient to explain the low frequency taboos on freshwater eels, octopi and porcupine fish, since these had avoidance frequencies similar to, and even higher than, land-animal meat. During at least the later portions of human evolutionary history, our ancestors likely relied on vast bodies of culturally-transmitted knowledge about plants and animals, and aspects of our evolved cognition reveal some specializations in this regard (Atran 1998). Two aspects of this folkbiological cognition are relevant here. The first aspect, category-based induction, permits inferences from knowledge about a single instance or category to be extended more broadly. For example, when one learns something about one particular lion (it climbed the tree), she can with decreasing degrees of confidence extend it to all members of the subspecies, the species, and beyond. The second aspect, taxonomic inheritance, permits learners to infer a number of characteristics about a folkspecies by learning in which higher-level category it resides. For example, merely by finding out that a robin is a type of bird one can infer that robins fly, lay eggs, build nests, etc.

With this as background, we hypothesize that in addition to the meat-based biases, two other cognitive forces were at work on this cultural variation. For freshwater eels, uncertain learners may have extended “known” properties from moray eels to freshwater eels. Moray eels are recognized by over 97% of people as tabooed. If the incoming cultural information on freshwater eels was uncertain, learners may automatically extend taboos (and toxicity) from morays to freshwater eels. To see this concretely, imagine a learner who gets strong cultural learning input that moray eels are taboo: everyone in the village says it, no pregnant women ever eat it, and prestigious women (*yalewa vuku*) are particularly vocal on the issue. However, this same learner gets mixed cultural information on freshwater eels. The learner’s mother (*nene*) and her mother’s older sister (*nene levu*) say freshwater eels are fine to eat, but the learner’s father’s sister (*gwadi*), who is mildly respected for her knowledge of medicinal plants, says freshwater eels are taboo and dangerous. Under such ambiguity in cultural information, the learners’ folkbiological category-based induction combined with error management on meat may overpower the ambiguous

cultural information and favor the inference that freshwater eels are also taboo (note, freshwater eels were never mentioned in the freelisting). Thus, the low frequency of taboos on freshwater eels may be a combination of three forces (1) adaptive model-based selective biases (e.g. success, health) driving the taboo frequencies to zero, (2) powerful folkbiological inferences (and the cultural transmission of moray eel taboos) and (3) error management in the domain of meat.

To examine this proposal we constructed a test with the following logic: learners who—due to their position in the networks of cultural transmission, their own cultural learning skills, or their life history—received weak (ambiguous) culturally transmitted information about freshwater eels (thus permitting a category-based induction to override) are also likely to have received ambiguous information on other items in the checklist. To analyze this, we compared the vectors of responses across all food categories with the consensus response (modal answers) for those reporting taboos on freshwater eels against those who did not (first, we removed freshwater eels and recalculated the matching correlations with the consensus response). If our proposal is correct, those who reported freshwater eel avoidances should have a lower mean agreement with the consensus response. The mean agreement for those citing freshwater eels as taboo was 87% while those who did not showed a mean agreement of 93% (one-tailed *t*-test,  $p = 0.016$ ).

Following the same reasoning, our informants may have extended a general avoidance of puffer fish (*vocivocia*) to porcupine fish (*sokisoki*), although the story is more complicated since both fish are toxic in a manner that has nothing to do with ciguatera. Most members of these species carry lethal dosages of tetrodotoxin, principally in their internal organs and eyes. In our sample of 23 people (not pregnant or breastfeeding), 91% reported always avoiding puffers while 0% reported avoiding *sokisoki*. Some explained that while *sokisoki* could be safely prepared, *vocivocia* could not always be rendered safe. We suspect that there is ecological variation in the dangerousness of the two species, and in Fijian waters puffers are more toxic than porcupine fish. These fish appear similar, and both inflate to several times their normal size when threatened. When cultural information is weak, pregnant women may combine a category-based induction from their beliefs and avoidances about puffer fish to porcupine fish. We performed the same test described above to test this hypothesis. The mean agreement for those citing porcupine fish as an avoidance was 84% while those who did not report it had a mean agreement of 94% (one-tailed *t*-test,  $p = 0.0002$ ). These analyses are consistent with the idea that when some members of a social group receive weak, contradictory, or ambiguous culturally-transmitted information about food taboos, they will increasingly rely on category-based induction from species they do know about.

The above line of reasoning depends on the assumption that our Fijian participants perceive moray eels and puffer fish as particularly similar to, in a folkbiological sense, freshwater eels and porcupine fish, respectively. To examine this we gave a random sample of 55 adults in our three villages 60 triad combinations containing the following ten concepts: moray eel (*dabea*), freshwater eel (*duna*), human (*tamata*), surgeonfish (*balagi*), shark (*iko*), sea turtle (*vonu*), barracuda (*silasila*), lobster (*moci*), porcupine fish (*sokisoki*), and puffer fish (*vocivocia*). We used an incomplete block design with lambda set to 4, so each pair of folk-species concepts appeared four times in the 60 triads (Burton & Nerlove 1976).<sup>9</sup> In each triad (e.g., shark—barracuda—porcupine fish) the informant had to pick the one most different from the other two. We performed two analyses on these data.

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<sup>9</sup> This was designed and processed using Anthropac .

To first establish that we could sensibly aggregate the individual-level data into a proximity matrix, we performed a cultural consensus analysis (Romney et al. 1986). Cultural consensus analysis is a widely used tool in cultural anthropology that extracts a single best-fit underlying model (set of responses) and assesses a groups' degree of shared beliefs or understandings (cultural models) in a particular cultural domain. This analysis confirmed a high degree of agreement, with a ratio 10.5 for the first and second eigenvalues, the first factor (the consensus responses) capturing 86% of the variation in responses, and no negative competencies. We have local consensus on these data.

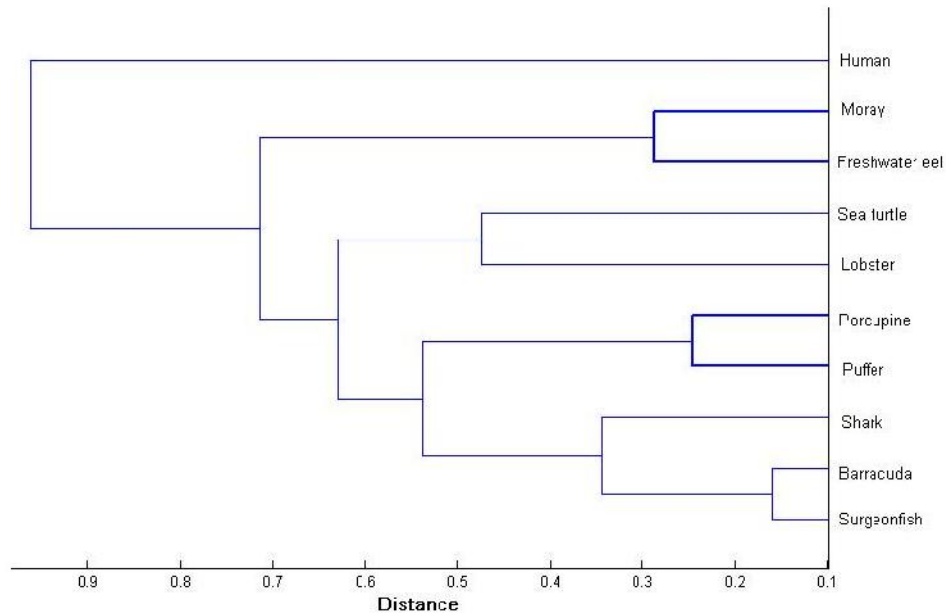


FIGURE S7 SHOWS THE DISTANCES AND ESTIMATED BRANCHING RELATIONSHIP FOR TEN FOLKSPECIES.

With this degree of agreement, we then performed a hierarchical clustering analysis on the aggregate proximity matrix, which is a weighted average degree of similarity for each concept pairing, derived from each individual's concept-by-concept similarity matrix (this is a symmetric 10 by 10 matrix for each person). Our results, shown in Figure S7, indicate that these Fijians do indeed perceive moray eels to be more similar to freshwater eels, and puffer fish to be more similar to porcupine fish, than to the other 8 folk species (7 marine species and humans). Figure S7 was derived using average linkage clustering, but both single linkage and complete linkage clustering yield nearly identical findings. Since for practical reasons we used only eight other species to contrast with, these results do not show that our informants perceived the moray-freshwater eel and porcupine-puffer pairing as maximally similar, though they do take an important first step in that direction. The analysis could have shown, for example, that freshwater and moray eels were dramatically different, since they inhabit completely different ecosystems.



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 TAXONOMIC INHERITANCE AND CATEGORICAL AMBIGUITY: OCTOPI
 

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For octopus, we hypothesize that the meat-avoidance bias combines with a salience possessed by organisms that are not readily identified as members of high-level categories in the local folkbiological taxonomy (Douglas 1966; Sperber 1996b). In common parlance, these categorically ambiguous animals would seem weird or unusual, compared to other living kinds. Cognitively, this salience may be adaptive: because our folkbiological cognition relies on taxonomic inheritance from higher level categories (like bird, fish, or mammal) to supply individuals with a wide range of information about generic animal kinds (like robin), animals that cannot be identified with a higher level category do not get the benefit of taxonomic inheritance. Knowing only that a robin is a kind of bird immediately tells one that robins likely breathe, have blood, can be killed, lay eggs, and are probably edible. Lacking taxonomically inherited information, such animal kinds are mysteriously salient compared to other animal kinds. Combining this with the downside of eating something toxic, learners may be biased to taboo categorically ambiguous things.

In an initial exploration, we sought to establish whether *sulua* (squid and octopi) are actually more categorically ambiguous than other folkspecies on our checklist. In one-on-one interviews, we asked 140 adults in Teci, Dalomo and Bukama to state whether each of 17 folkspecies are a kind of (a) *ika* (glossed as fish), (b) *manumanu* (non-fish, non-shellfish animal<sup>10</sup>), (c) *vivilli* (roughly, shellfish), and (d) *vatu* (stone). For each of these four higher-level categories we went through the entire list of folkspecies before moving to the next higher-level category, so answers were not forced to be mutually exclusive (people could have said, for example, that sharks are *ika* and *manumanu*). People were all spontaneously mutually exclusive in their assignments (even when they did not agree with each other).

Figure S7 shows that *iko* (sharks), *batisia* (rock cod), and *dabea* (moray eels) are unambiguously *ika* (fish), with over 90% citing them as *ika* and only *ika*. Thus, these taboos cannot be explained by categorical ambiguity. *Vonu* (sea turtle) shows some categorical ambiguity, with only 79% citing it as an *ika*, and the rest putting it as a *manumanu*. The categorization of turtle as “fish” (*ika*) is common throughout Oceania (Pawley 2007)). *Sulua* (squid and octopus), however, emerged as totally ambiguous, with 44% saying they are a kind *ika* (of which sharks and groupers are near perfect exemplars), 39% going for *manumanu*, and 1.6% saying *vivili*. *Sulua* are a categorically ambiguous animal food that cannot be readily identified with a life-form category. This may make them easy to taboo.

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<sup>10</sup> *Manumanu* is used in several ways and its meaning depends on context. It can be used for all “animals” save humans (and corals), and it can be coupled with adjectives, like *qwaqwa* (hard) or *vuku* (flying), to refer to large crustacean (or insects) and birds, respectively. But, in this context, people interpreted it as something we can gloss as non-fish, non-shellfish animals. Land mammals are likely the prototype in this category. If they had interpreted it as “all non-humans” we would not have found all mutually non-overlapping assignments to our categories.

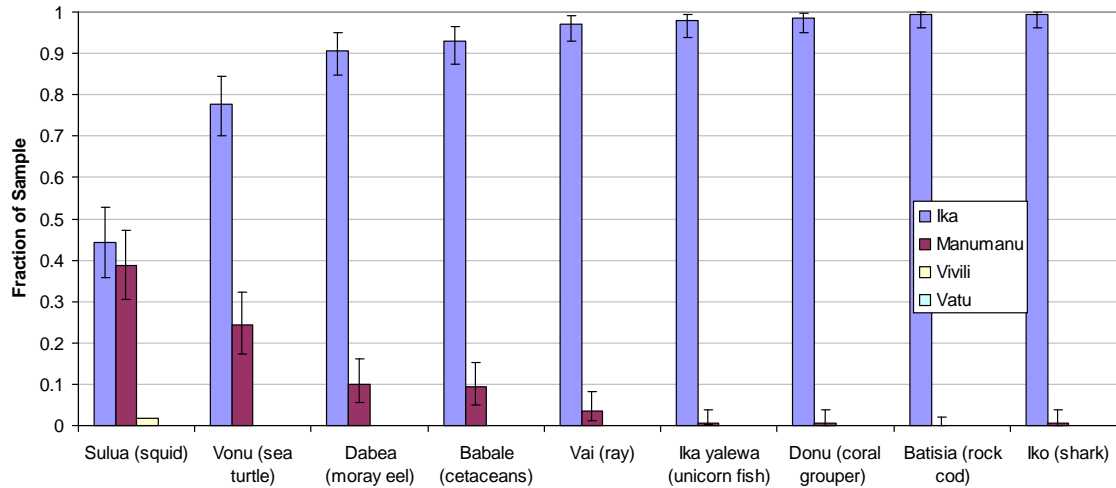


FIGURE S8. HIGHER-LEVEL CATEGORIZATION FOR 8 FOLKSPECIES. ERROR BARS ARE 95% EXACT CONFIDENCE INTERVALS ( $N = 140$ )

## ARE THESE REALLY TABOOS?

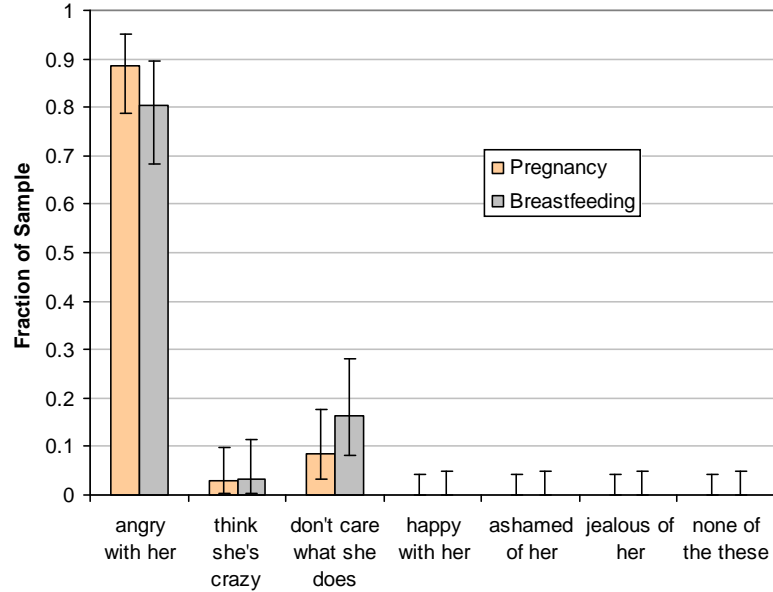
We have been calling these food avoidances during pregnancy and breastfeeding “taboos” in part because we used the word *tabu* in asking about them in Fijian. The English word “taboo” comes from the Austronesian word *tabu* (Fijian dialects are part of the Austronesian language family). The anthropological concept of a taboo usually includes a moral connotation such that third party observers of a taboo violation would react negatively even if the violation does them no material harm. The word *tabu* in the Yasawan Island dialect (and elsewhere) also often carries a moral association, with connotations of a community sanction for violations. This is, in fact, the first definition listed for *tabu* in the comprehensive dictionary for the Wayan islands, which lie at the southern end of the Yasawan archipelago (Pawley & Sayaba forthcoming). However, *tabu* can mean simply “be prohibited” in the sense of a conventional rule or personal restriction.

To explore whether these food avoidances have been moralized into taboos in the anthropological sense, we asked two parallel questions during our pregnancy and breastfeeding interviews. First, we asked: suppose a woman goes ahead and eats these tabooed foods during her pregnancy [or while she is breastfeeding], will people in the community (a) be happy with her, (b) feel ashamed of her, (c) be angry with her, (d) not care what she does, (e) be jealous of her, (f) think she is crazy, (g) none of the above.”<sup>11</sup> The meaning of “tabooed food” in the context of the question referred

<sup>11</sup> It might seem odd to ask multiple choice questions like this. In earlier interviews we tried asking first, in an open ended format, about how people would feel if someone did something (usually violating a norm), and then asked what people would do (contrasting “feel” vs. “do”). We found that people usually answered the second question when they were asked the first question. That is, they said what people would “do” not how they would “feel”. When we pushed a bit, many seemed hesitant or even unwilling to speculate about others feelings. However, while developing earlier interviews, we experimented with multiple choice questions when asking about “feelings”, and found that people readily responded to them. So, we asked the “feel” question in multiple choice format and the “do” question in an open-ended format (coding the answers).

directly back to either the freelisted food avoidances (in the breastfeeding interview) or to both the freelisted and checklist taboos. This question was followed immediately with: Will they do anything (regarding the woman who is eating the tabooed foods)?

A



B

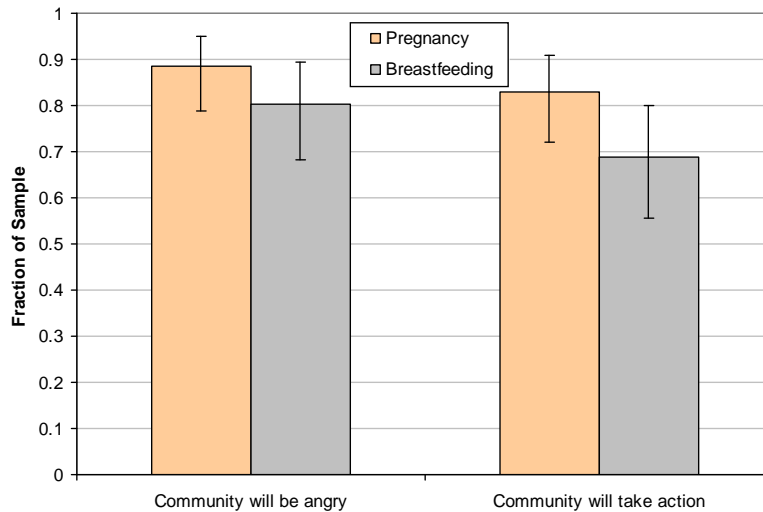


FIGURE S9. THE TOP FIGURE SHOWS THE RESPONSES FOR PREGNANCY ( $N = 70$ ) AND BREASTFEEDING ( $N = 61$ ) FOR OUR QUESTION ABOUT HOW PEOPLE WOULD FEEL ABOUT A HYPOTHETICAL TABOO VIOLATOR. THE BOTTOM FIGURE S8B PAIRS THE FINDINGS FROM FIGURE S8A (THAT THE COMMUNITY WILL BE ANGRY) WITH THE RESPONSES TO OUR QUESTION OF WHAT THE COMMUNITY WOULD DO. ERROR-BARS ARE 95% CONFIDENCE INTERVALS.

Since no differences emerged between the *yavusas* in these questions, Figures S8A and B display the aggregate responses from both. Figure S8A shows that most participants (all women) agree

that people in the community would be angry with someone who violated a food taboo during pregnancy or breastfeeding. There is a slight, non-significant, trend toward less severity for breastfeeding taboo violators (vs. pregnancy taboo violators). Figure S8B shows that most people believe that these negative feelings would turn into action. Consistently, women explained that community members would go to the taboo violator and “advise” (*vakasalataki*), “tell her straight” (*tukuna vakadodonu*) or “scold her” (*vosatakinia, cudruvia*). More than half the time, people would say they, or whoever was doing the advising, would explain to her that this behavior could hurt the baby. No one suggested anything beyond a good talking to. Everyone seemed to believe that this would bring any such taboo violator into line.

We also performed extensive interviews on what would happen to a fetus or infant if the mother consumed one of the tabooed fish during pregnancy or breastfeeding. A majority of women suggested negative health outcomes, which ranged from the infant getting “rough skin” if the mother consumed shark to “smelly joints” if the mother consumed a moray eel. Many women also said they did know what would happen since they have never known anyone who had eaten a particular fish during pregnancy or breastfeeding. Some women even said “nothing” would happen to the infant or fetus. So, despite the high consensus on the taboos themselves and on the anger towards violators, the explanations of the consequences for the infant or offspring are highly variable, though clearly biased toward negative outcomes. This suggests that the cultural transmission of these taboos does not work principally by first learning about negative outcomes or empirical cases, and then deciding to avoid certain fish. Such a pattern suggests instead that first women acquire the taboo, and then encounter a variety of stories about what happens when violations occur (which are probably biased by having pre-existing beliefs in the taboos). To underline this point, we asked every mother to describe incidences in which a tabooed fish was eaten. We did get a few stories (and the same stories from many people), but we found no cases for most of the tabooed species. Thus, neither women’s taboos, nor their anger at violators, can be understood as pragmatic responses to observationally or socially acquired information about the costs and benefits of consuming various species. The information to make this evaluation is simply not available.

Importantly, however, our work also indicates that these are not the kind of taboos for which people believe that violations will directly result in harming others (besides the offspring) by angering the gods, or through some non-specific form of supernatural sanctions. In Yasawan communities there are other cultural domains for which this is the case, but these particular food taboos are not in this sacred category. We suspect that this is because compliance with the taboo is pretty high (threats of social sanctions or of harm to one’s infant seem sufficient to maintain them), so threats of supernatural sanctions may be unnecessary to sustain the adaptive behavior.

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## OTHER REPORTS OF PREGNANCY TABOOS ON MARINE SPECIES

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Ethnographic evidence suggests that these taboos may be old, stable, and widespread. In the early 1930's at the opposite end of the Fijian archipelago in Lau, Thompson reports (1940), using virtually the identical Fijian words we now hear in Yasawa, pregnancy taboos on *ika tava* (fish that must be sliced), and specifically cites sea turtles and moray eels. Currently, in Yasawa, the phrase *ika tava* would add sharks and the aforementioned large species to the list of Lauan taboos. The taboos also included *yalewa matua* and *uluburu* (types of scorpion or lion fish). Since neither of these is eaten in Yasawa at all (by anyone), it is not surprising they are not tabooed during pregnancy or breastfeeding. Like Yasawans, Thompson reported that people say that if a woman eats these tabooed food, the baby will be sick (specifically having sores, which was one of the things we also recorded).

The correspondence is important given the separation in time and space, and the fact that Thompson was not focused on such taboos. Note that Thompson did not provide translations of the Fijian words (*yalewa matua* and *uluburu*) in her text, so members of our team went to native Lauan speakers from the same islands that Thompson worked on and had them translate Thompson's words.

In New Guinea, Malinowski reported that while pregnant women can eat most fish (and meat), they must abstain from species that "live in the submarine holes of the coral" and fish with poisonous fins (Malinowski 1929). This would include moray eels, as well as scorpion and lion fish.

In some places in Oceania, moray eels are tabooed for everyone, not just for pregnant and breastfeeding women. In Tikopia, archaeological evidences indicate that moray eels were consumed for a substantial period after initial colonization, but then dropped out. Currently, island residents taboo moray eels for all (Dalzell 1998).

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