Drivers of nutrient intakes from fisheries in French Polynesia

Hamilton et al., 2024

Supplementary material

Résumé

Les pêcheries artisanales fournissent des nutriments à des centaines de millions de personnes dans le monde et leurs rendements dépendent de l'état d'habitats marins tels que les récifs coralliens. La pêche artisanale est une source alimentaire particulièrement importante dans des sociétés souffrant de carences en nutriments et où des alternatives alimentaires beaucoup moins saines sont largement disponibles. En utilisant des données provenant d'études sur les récifs coralliens autour de deux îles de Polynésie française (Moorea et Raiatea), nous montrons comment la disponibilité des nutriments via les pêcheries a évolué en fonction de l'état de l'habitat corallien. La biomasse de poissons et la disponibilité des nutriments sont plus élevées lorsque la couverture corallienne est faible autour des deux îles, principalement à cause de l'abondance des poissons récifaux herbivores. Nous avons également étudié l'importance du poisson dans le régime alimentaire de la population, afin de déterminer si la consommation de poisson était en adéquation avec la disponibilité des ressources halieutiques sur les récifs proches et si les apports en nutriments provenant du poisson pouvaient être expliqués par les caractérisitiques socio-économiques de la population. La population consomme une plus grande diversité de poissons récifaux à Raiatea, mais les apports en nutriments provenant du poisson sont plus élevés à Moorea. La plupart des habitants des deux îles consomme plus de poisson que de viande, mais la consommation de poisson a diminué au fil des générations. Les membres des ménages pratiquant la pêche ont des apports en nutriments provenant des poissons récifaux et des poissons pélagiques plus élevés, et les membres des ménages pratiquant l'agriculture ont des apports en nutriments provenant des poissons récifaux plus élevés. La préférence pour la consommation de poissons récifaux plutôt que de poissons pélagiques est également associée à des apports totaux en nutriments plus élevés. Promouvoir les régimes alimentaires traditionnels riches en poisson pourrait être essentiel pour répondre aux besoins nutritionnels de la population de Polynésie française tout en réduisant les problèmes de santé liés à une alimentation trop riche en graisses.

Te Tautai

Ua riro te tautai 'ei faufa'a ora nō na hānerera'a 'ō na mirioni ta'ata nā te ao nei, tei te huru ato'a ra o te moana e tōna mau 'ī (mai te a'au, te mau to'a).

Te tautai, o te hō'ē ïa pātere mā'a faufa'a roa i roto i te mau tōtaiete e 'ere nei i te mau maita'i tino, e aore ïa, te 'amu nei i te mā'a 'e'ere i te mea au nō to tātou 'ea te ta'ata tāta'itahi.

Mā te fa'a'ohipa i te mau ha'amāramaramara'a nō roto i te mau mā'imira'a i ni'a i te ā'au e ha'a'ati ra i nā motu e 2 nō Pōrīnetia farāni (Mo'orea e Ra'iātea), te fa'a'ite nei mātou e, nāhea te rāve'a o te mau mā'a maitata'i nō te tautai i te tauira'a ia au i te huru tupura'a o te pu'a.

Rau huru ī'a e te mā'a e noa'a mai ia tāpo'i ri'i ana'e te to'a 'atiti'a a'e nā motu e 2, te tumu mātāmua, nō te rahi o te ī'a mai te pa'ati ānei, te pahoro e te vai atura.

Ua tuatāpapa ato'a mātou i te faufa'a rahi o te ī'a i roto i te parau o te mā'a a te mā'ohi, nō te hi'ora'a e, te tū'ati ra ānei tā tātou 'amura'a i te ī'a ia au i te mau 'ī e vai nei i roto i tō tātou nei moana e i te mau maita'i 'ato'a e vai nei i roto i te mau ī'a e te 'ite 'ato'a hia ra te rava'i 'ore o teie nūna'a ta'ata i te pae faufa'a moni.

Te 'amu nei te nūna'a nō Ra'iātea i te mau huru ī'a 'ato'a o te ā'au, 'are'a ra to Mo'orea 'amu 'oia i te mā'a e au i te ī'a.

I roto i nā motu e 2, te rahi ra'a, mea 'amu a'e rātou i te ī'a i te 'i'o, 'are'a i teie nei, varavara roa te ta'ata i te 'amu i te ī'a.

Te mau 'utuāfare e ora nei i te 'ohipa rava'ai e 'amu 'oia i te ī'a tua e te ī'a nō roto atu, 'are'a te mau 'utuāfare e fa'a'apu nei o te mau ī'a piri ā'au ïa i te mea au e rātou.

Te aura'a i roto i te 'amura'a i te ī'a nō te tai roto e te ī'a tua, nō te fa'aterera'a mā'a, te fa'atū'a'atiti ra'a ïa i te minamina ra'a.

Te fa'atīaniani ra'a i te mau mā'a tumu (e ī'a tō roto) nō te maita'i o te tino, o te tahi ïa rāve'a nō tātou te nuna'a nō Pōrīnetia farāni e 'oia 'ato'a, i te tauturu ra'a ia tātou i te fa'a'iti ra'a i te 'amu i te mau mā'a hinu ia maita'i noa tō tātou 'ea.

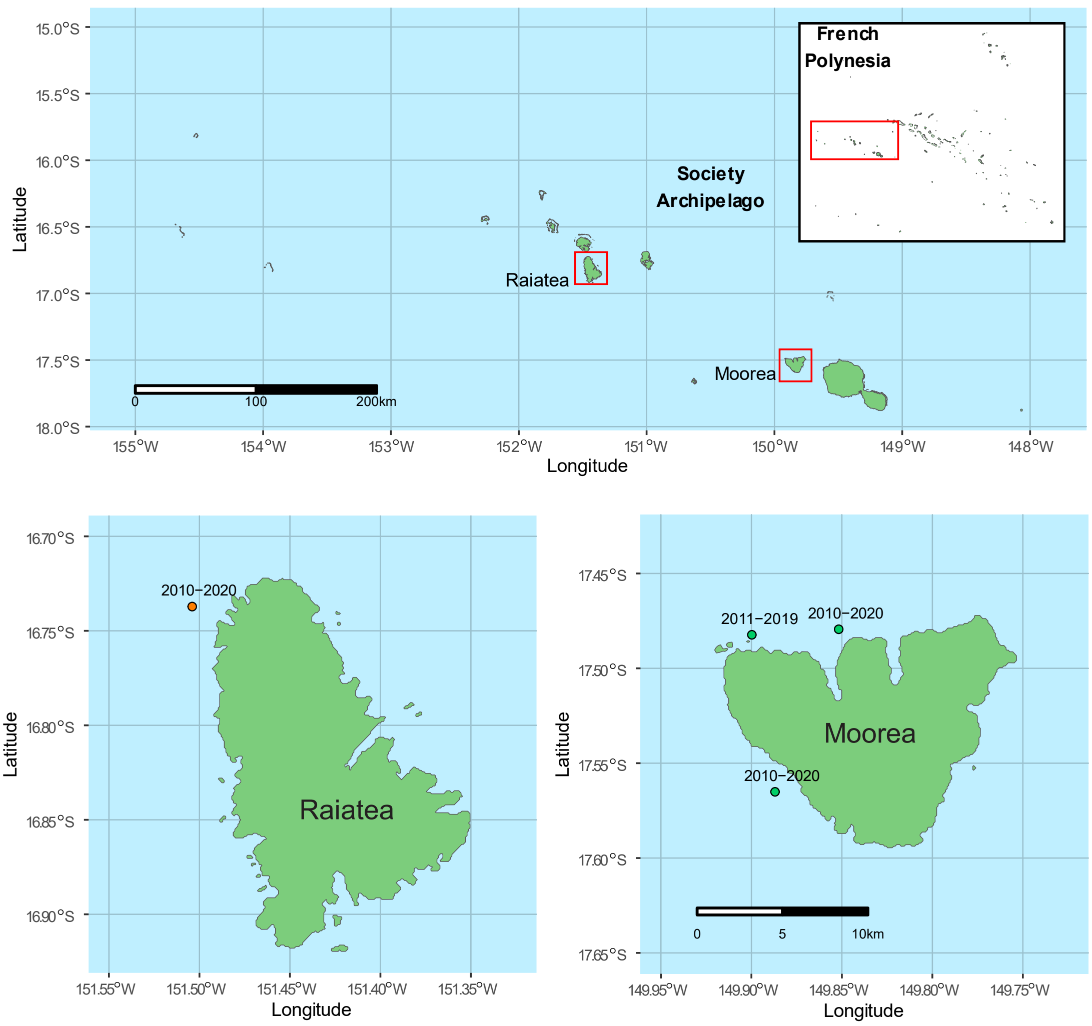

Figure S1: Map of Moorea and Raiatea within the Society Archipelago, French Polynesia (top). Reef survey sites are shown as points for each island (Raiatea: bottom left; Moorea: bottom right). Each reef site was surveyed every two years from 2010 to 2020, in even years except one site on Moorea which was surveyed in odd years, as shown by point labels. Bottom panels for each island are displayed at the same scale.

Methodology for underwater visual census surveys

Coral cover was estimated using photo-quadrats to record images along a 20 × 1 m section of the outer reef slope (between 7 and 13 m depth). Reef sites were sampled using a metal frame secured between two permanent metal stakes to ensure the same section of reef was sampled each year. Twenty replicate 1 m^2 photo-quadrats are completed along the frame, resulting in the entire 20 m^2 reef section being sampled. Photo-quadrat images were analysed using point intercept estimates, where 81 evenly spaced points are systematically overlaid onto each 1 m^2 quadrat image. Live coral at each point is recorded to genus level and coral cover is calculated as: 100 × number of points with live coral / 81. A total of 1620 points are analysed per 20 m^2 reef section. We estimated total live coral cover (%) by summing across all hard coral genera.

Fish data were collected along three belt transects of 50 × 5 m (250 m^2) at each site. All fish within the transect area were recorded to species level and their sizes estimated to the nearest cm. All three transects per site were conducted at the same depth, with one transect overlapping the coral photo-quadrat area and the other two 25 m away on either side, parallel to the first. Fish lengths were converted to weights using the formula $Weight = a \times Length^b$, where a and b are species-specific length-weight parameters (Froese, 2006).

Table S1: Fish species observed during reef surveys in Moorea and Raiatea, from 2010 to 2020, classified into three trophic groups: Herbivore (including microvores and detritivores), Mobile invertivore and Piscivore. Species are listed by family with the number of species given for each family. Only species with individuals ≥15 cm observed during surveys are listed. Tahitian/local fish names for some families and species are included below in brackets.

Herbivore	**Mobile invertivore**	**Mobile invertivore (cont.)**
Acanthuridae (*n* = 18)	**Balistidae** (*n* = 7)	**Lethrinidae** (*n* = 2)
Acanthurus mata	*Balistapus undulatus*	(oeo/bec de canne)
Acanthurus nigricans	*Balistoides viridescens*	*Gnathodentex aureolineatus*
Acanthurus nigricauda	(oiri)	(maene)
Acanthurus nigrofuscus	*Odonus niger*	*Monotaxis grandoculis*
Acanthurus nigroris	*Pseudobalistes flavimarginatus*	**Lutjanidae** (*n* = 4)
Acanthurus olivaceus	*Rhinecanthus lunula*	*Lutjanus bohar*
Acanthurus pyroferus	*Rhinecanthus rectangulus*	*Lutjanus fulvus*
Acanthurus triostegus	*Sufflamen bursa*	(toau)
Ctenochaetus binotatus	**Chaetodontidae** (*n* = 3)	*Lutjanus gibbus*
Ctenochaetus flavicauda	(korei)	(taea)
Ctenochaetus striatus	*Chaetodon lunula*	*Lutjanus monostigma*
(maito)	*Forcipiger flavissimus*	(tanifa)
Naso annulatus	*Forcipiger longirostris*	**Mullidae** (*n* = 5)
(ume/nason)	**Epinephelidae** (*n* = 3)	*Mulloidichthys vanicolensis*
Naso brevirostris	*Cephalopholis leopardus*	(vete)
(tatihi/tatii/herepo ti)	*Cephalopholis urodeta*	*Parupeneus barberinus*
Naso lituratus	*Epinephelus fasciatus*	(ahuru/takire)
(ume tare)	**Holocentridae** (*n* = 9)	*Parupeneus cyclostomus*
Naso unicornis	*Myripristis berndti*	(atiata)
Zebrasoma rostratum	(iihi/u'u)	*Parupeneus insularis*
Zebrasoma scopas	*Myripristis murdjan*	(atiata)
Zebrasoma velifer	(peti)	*Parupeneus multifasciatus*
Balistidae (*n* = 2)	*Myripristis violacea*	(atiata)
Melichthys niger	(iihi/u'u)	
Melichthys vidua	*Neoniphon opercularis*	
Chanidae (*n* = 1)	*Neoniphon samara*	**Piscivore**
Chanos chanos	*Sargocentron caudimaculatum*	**Carangidae** (*n* = 3)
Scaridae (*n* = 16)	*Sargocentron microstoma*	*Carangoides orthogrammus*
(pehoro/deng deng)	*Sargocentron spiniferum*	*Caranx melampygus*
Calotomus carolinus	(apai/rukeruke)	(paihere)
Cetoscarus ocellatus	*Sargocentron tiere*	*Scomberoides lysan*
Chlorurus frontalis	**Labridae** (*n* = 18)	**Epinephelidae** (*n* = 2)
Chlorurus microrhinos	*Anampses caeruleopunctatus*	*Cephalopholis argus*
(tegatega)	*Anampses melanurus*	(roi/merou celeste)
Chlorurus sordidus	*Anampses twistii*	*Variola louti*
(paati/ufu)	*Bodianus axillaris*	**Labridae** (*n* = 1)
Hipposcarus longiceps	*Cheilinus chlorourus*	*Cheilio inermis*
Scarus altipinnis	(papae)	**Lethrinidae** (*n* = 2)
Scarus forsteni	*Cheilinus trilobatus*	(oeo/bec de canne)
Scarus frenatus	(papae)	*Lethrinus olivaceus*
Scarus ghobban	*Cheilinus undulatus*	*Lethrinus xanthochilus*
Scarus globiceps	(Napoleon/tapiro)	**Lutjanidae** (*n* = 1)
Scarus niger	*Coris aygula*	*Aphareus furca*
Scarus oviceps	*Coris gaimard*	(paru)
Scarus psittacus	*Epibulus insidiator*	**Sphyraenidae** (*n* = 1)
(hou ninamu)	*Gomphosus varius*	*Sphyraena barracuda*
Scarus rubroviolaceus	*Halichoeres hortulanus*	(tapito)
Scarus schlegeli	*Hologymnosus annulatus*	
(kukina)	*Novaculichthys taeniourus*	
Siganidae (n = 1)	*Oxycheilinus unifasciatus*	
Siganus argenteus	*Pseudocoris aurantiofasciata*	
(marava)	*Thalassoma lutescens*	
	Thalassoma quinquevittatum	

Table S2: Descriptive statistics from interviews in Moorea and Raiatea. Interviews collected information from individual respondents, with some questions relating to their household (only one person per household was interviewed). Interviews took place on Moorea in September 2019 and on Raiatea from June to September 2019. Percentages relate to the total sample size per island.

	Moorea (*n* = 96)	**Raiatea** (*n* = 183)
Respondents per district*		
Taputapuatea	-	*n* = 55 (30.1%)
Tumaraa	-	*n* = 41 (22.4%)
Uturoa	-	*n* = 87 (47.5%)
Women	*n* = 64 (66.7%)	*n* = 126 (68.9%)
Median age	40.5	44
Minimum age	18	13
Maximum age	84	83
Men	*n* = 30 (31.3%)	*n* = 54 (29.5%)
Median age	45.5	42
Minimum age	20	18
Maximum age	77	81
Other gender	*n* = 2 (2.1%)	*n* = 3 (1.6%)
[Ages redacted for anonymity]	-	-
Household information		
Median persons per household	5	4
Fishing only	*n* = 42 (43.8%)	*n* = 93 (50.8%)
Farming only	*n* = 10 (10.4%)	*n* = 8 (4.4%)
Fishing and farming	*n* = 30 (31.3%)	*n* = 24 (13.1%)
Neither fishing nor farming	*n* = 14 (14.6%)	*n* = 58 (31.7%)
Easy access to the sea		
Yes	*n* = 93 (96.9%)	*n* = 125 (68.3%)
No	*n* = 3 (3.1%)	*n* = 13 (7.1%)
NA	*n* = 0	*n* = 45 (24.6%)
Highest education in household		
High school+	*n* = 62 (64.6%)	*n* = 110 (60.1%)
Lower	*n* = 33 (34.4%)	*n* = 71 (38.8%)
NA	*n* = 1 (1.0%)	*n* = 2 (1.1%)
Main language spoken with family		
French	*n* = 11 (11.5%)	*n* = 19 (10.5%)
At least one Polynesian language	*n* = 85 (88.5%)	*n* = 162 (89.5%)

* Population sizes for administrative districts in 2017 were as follows: Moorea = 17,463; Taputapuatea = 4,792; Tumaraa = 3,721; Uturoa = 3,778 (Institute of Statistics of French Polynesia, 2017). Uturoa was considered an urban district, all other districts were rural.

Table S3: Food groups used in our study (right), based on groups according to the Global Individual Food consumption data Tool (GIFT; FAO, 2022) (left). GIFT food groups in grey text were not included in this study.

GIFT food group		**Food groups in present study**
1)	Cereals and products (rice, maize, wheat, sorghum, millet, other grains)	**1) Carbohydrates (Carbs)**
2)	Roots, tubers and products (potato, sweet potato, cassava, taro, yam, plantain, other starchy roots/tubers)	
18)	Savoury snacks (crisps, cereal-based, other)	
3)	Pulses, seeds, nuts and products (includes soybean)	**2) Legumes, nuts & seeds**
4)	Milk and products (yoghurts, kefir, cream, whey, cheese)	**3) Dairy**
5)	Eggs and products	**4) Eggs**
6)	Fish, shellfish and products (including pickled or dried)	**5) Fish (incl. other seafood)**
7)	Meat and products (offal, processed/tinned/dried meats)	**6) Meat (incl. chicken & tinned)**
8)	Insects, grubs and products (including spiders and worms)	-
9)	Vegetables and products (leafy veg/salad, fungi, canned/pickled/fermented veg, dairy/meat imitates)	**7) Vegetables**
10)	Fruits and products (dried, canned/jarred)	**8) Fruits**
11)	Fats and oils (vegetable/animal fat and oil)	-
12)	Sweets and sugars (sweet bakery/pastry products, chocolate, jams, syrups/honey, dairy-based sweets)	-
13)	Spices and condiments (herbs, sauces/relishes)	-
14)	Beverages (alcohol, water, tea/coffee, soft drinks)	-
15)	Foods for particular nutritional uses (weight loss, sport supplements, medical, other)	-
16)	Food additives (sweeteners/flavourings, additives, microbiological/yeasts)	-
17)	Composite dishes (meals based on foods listed above)	-

Table S4: Recommended nutrient intakes (and equivalents) per day for the five nutrients included in this study. Recommendations for adult, pre-menopausal women were used for all respondents in our study, regardless of age or gender.

Nutrient	Daily Recommended Nutrient Intake (RNI)	References
Calcium, Ca	1000 mg	WHO/FAO, 2004
Iron, Fe	19.6 mg[§]	WHO/FAO, 2004; FAO, 1988
Zinc, Zn	4.9 mg[‡]	WHO/FAO, 2004
Vitamin A	270 µg[†]	WHO/FAO, 2004; FAO, 1988
Omega-3 (DHA + EPA)	250 mg*	European Food Safety Authority, 2010

[§] Iron RNI estimate is for a dietary iron bioavailability of 15%.

[‡] Zinc RNI estimate is for a dietary zinc bioavailability of 30%.

[†] Vitamin A requirements given as retinol equivalents (RE): 4.8 µg per kg body weight.

* Adequate Nutrient Intake (AI) used for omega-3, as RNI cannot be defined.

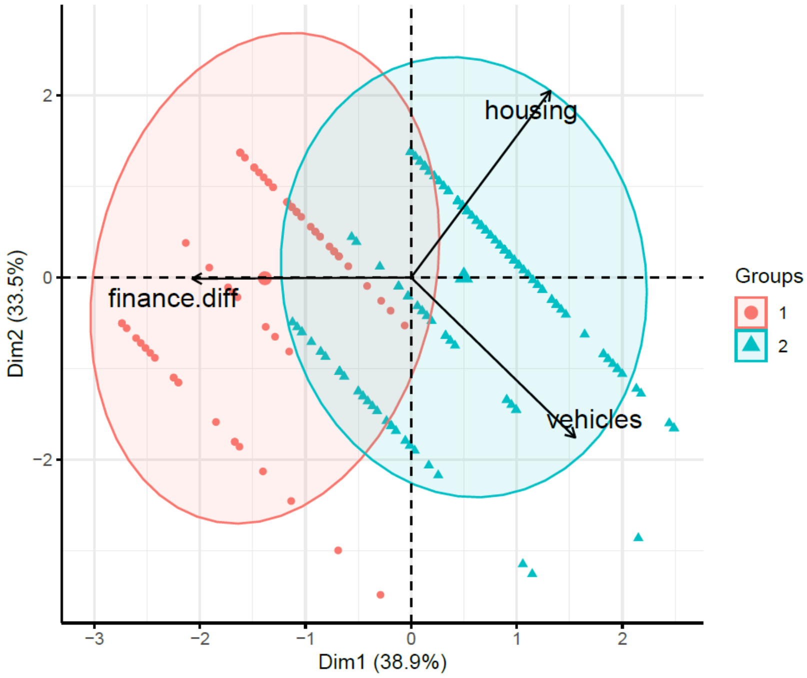

Figure S2: Principal component analysis (PCA) of variables used as a proxy for interview respondents' wealth ("finance.diff" = financial difficulties, "housing" = house ownership, "vehicles" = vehicle score). Arrows are loading vectors, representing the strength of each variable's association with principal components 1 (Dim1) and 2 (Dim2). Axis percentages correspond to the amount of variation in the data explained by each principal component. Values from principal component 1 were used to represent respondents' wealth in analyses. Points represent individual respondents, arranged into two groups: red (lower wealth on PC1) and blue (higher wealth on PC1), with large points indicating a typical respondent at the centre of each group.

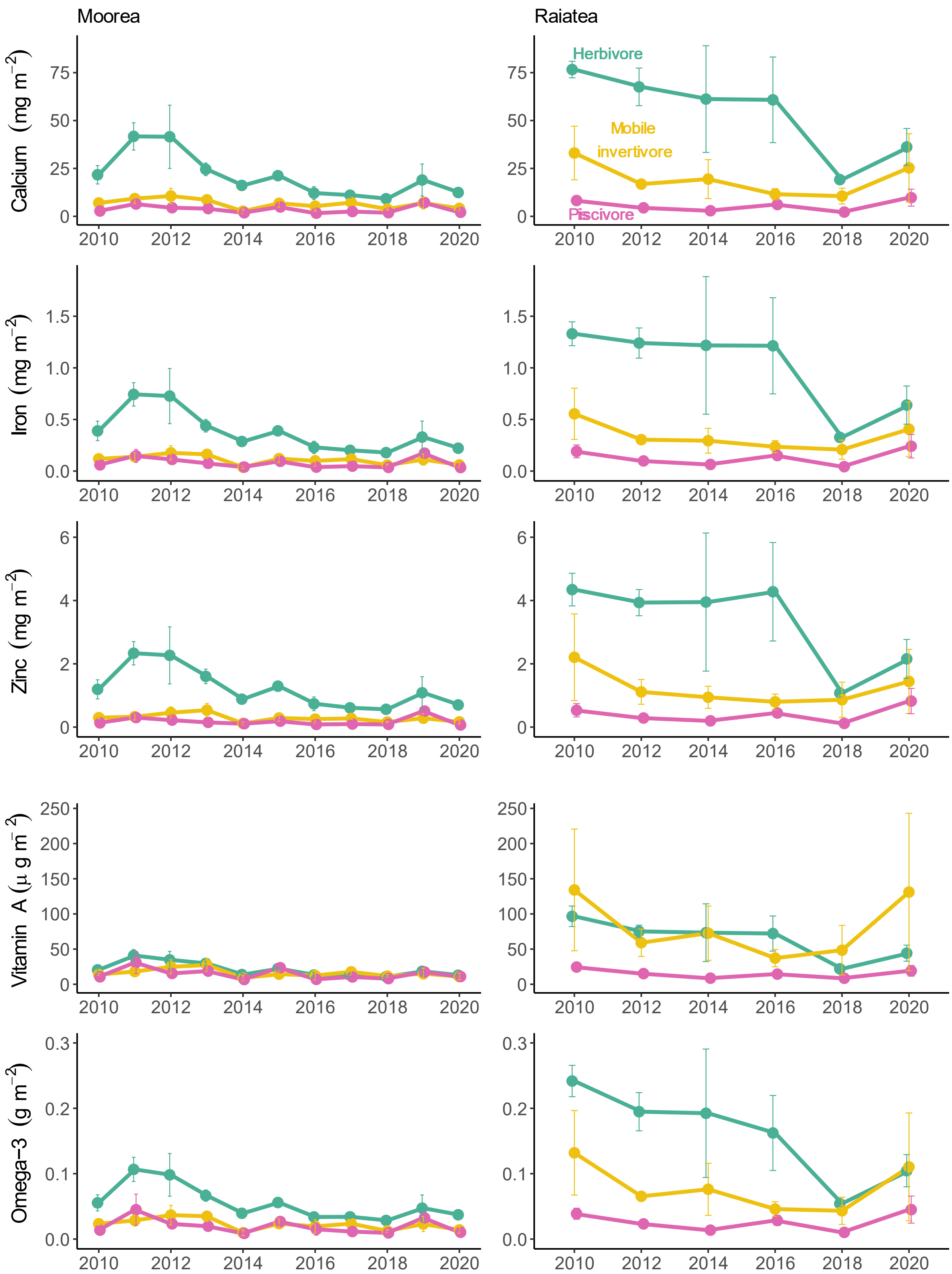

Figure S3: Estimated availability of five nutrients from fish on coral reefs around Moorea (left) and Raiatea (right) from 2010 to 2020. Only fish above the minimum fishable size (≥15 cm) with the potential to contribute to human nutrition were included, from three trophic groups: herbivores, mobile invertivores, and piscivores. Errors bars are the standard error of the mean across transects. Species nutrient estimates are from FishBase (Froese and Pauly, 2022).

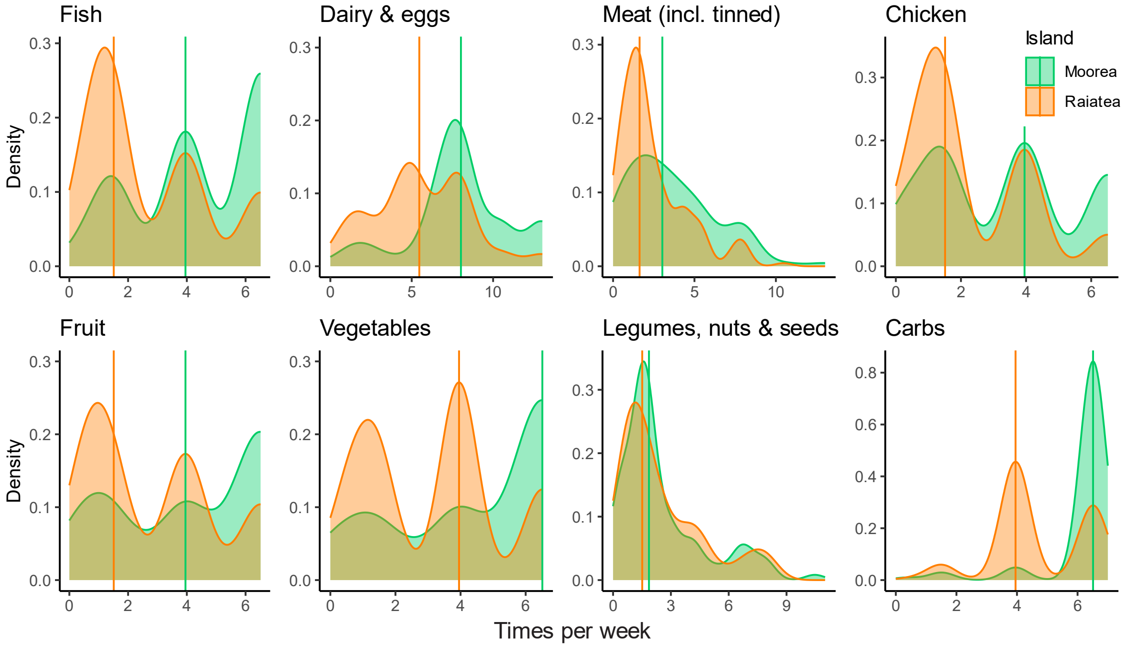

Figure S4: Frequency of consumption for each food group (times eaten per week) shown as the density of responses given by respondents during interviews in Moorea (*n* = 96) and Raiatea (*n* = 183) in 2019 (total density in each panel sums to 1 per island). Some food items have a maximum of 7 as the most frequent option was "every day" (fish, chicken, fruit, vegetables, and carbs). Other food items have values >7 as foods that were separate responses during interviews were combined: dairy + eggs, meat + tinned meat, legumes + nuts/seeds. Vertical lines display the median frequency of consumption for each island.