Received: 13 April 2023 | Revised: 23 August 2023 | Accepted: 28 August 2023

DOI: 10.1111/fme.12651

ARTICLE

Fisheries Management and Ecology WILEY

Livelihoods and poverty in small-scale fisheries in western Amazonia

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Funding information
Japan Society for the Promotion of Science, Grant/Award Number: 18H05312, 18KK0042, 20K20332, 23243045 and 26245032; Social Sciences and Humanities Research Council of Canada, Grant/Award Number: 430-2016-00974 and 435-2015-0520

Abstract

Small-scale fisheries are vital to millions of rural people, but surprisingly little is known about the environmental and socio-economic factors that guide rural peoples' decisions to adopt a fishery-oriented livelihood. We analyzed data from a large-scale household survey of 3929 households in 235 rural communities in the Peruvian Amazon to develop multi-scalar quantitative models to explain engagement in fishing and the relationship between fishing livelihoods and poverty. Households harvested an average of 1000 kg of fish and sold 450 kg over the 12 months preceding interviews. The mean total annual income was 3119 USD per household and fishing contributed 27% to total income. Access to extensive floodplain habitat, geographical isolation, and an available workforce were important drivers of fishing activity, while poor market connectivity and limited financial capital restricted households from increasing the scale of market-oriented fishing. Wealthier households generally harvested more fish, whereas reliance on fisheries was greatest among poorer households who harvested less fish. Fisheries management and conservation initiatives in developing regions must consider the distinct drivers of fishing specialization across the full wealth spectrum with particular attention to "high reliance-high harvest" households.

KEYWORDS
artisanal fisheries, conservation, Peru, quantitative models, sustainable livelihood framework

1 | INTRODUCTION

Amazonia is home to the most diverse freshwater fish assemblages in the world and to several million inhabitants who rely on fish for food and their livelihoods (Pinedo-Vasquez et al., 2011; Sirén & Valbo-Jørgensen, 2022). Fish provide vital protein and micronutrients for rural as well as urban households in riverine towns and cities, and cash income for many rural dwellers (Barletta et al., 2010; Coomes et al., 2010, 2016; Guerrero et al., 2018; Hicks et al., 2019; McDaniel, 1997; McGrath et al., 1993; Sirén & Valbo-Jørgensen, 2022). Fisheries are also important for the rural poor to cope with shocks, such as illness (Coomes et al., 2010; McDaniel, 1997) and extreme floods (Coomes et al., 2010; Langill & Abizaid, 2020; Langill et al., 2022; Takasaki et al., 2010). Despite their importance, fish stocks have declined in many parts of the basin (Castello, Arantes, et al., 2015; Coomes et al., 2020) due to increased urban demand for fish, emergence of commercial fisheries, use of more efficient fishing gear, biological vulnerability of targeted species, limited governance and institutional capacity, and multiple forms of environmental degradation (Almeida et al., 2009; Castello, Arantes, et al., 2015; De Castro & McGrath, 2003; De Jesús, 2004; McGrath et al., 1993; Pinho et al., 2012). Fish stock depletion could directly compromise the food security of some of the poorest inhabitants of Amazonia and alter key aquatic and terrestrial ecological functions (Correa et al., 2015; Tregidgo et al., 2017, 2020). Further, subsistence and commercial small-scale fisheries are crucially important for the rural inhabitants of the Amazon and for achieving UN sustainable development goals in the basin, including poverty alleviation (SDG1), eradicating hunger (SDG3), and conserving aquatic ecosystems (SDG14) (de Andrade et al., 2021; Medina & Barbosa, 2023).

Whereas a growing number of studies have examined the management and governance of small-scale fisheries in Amazonia (see De Castro & McGrath, 2003; Goulding et al., 2018; Isaac et al., 1998; Lopes et al., 2018; McGrath et al., 1993, 2008, 2015; Pinho et al., 2012), surprisingly little is known about factors that shape rural household decisions regarding their engagement in fishing and the relationship between fishing and rural poverty. In particular, few have sought to identify which households rely most upon fishing and whom among them harvest the largest quantities of fish. This lack of understanding hinders efforts to manage and conserve fish stocks which depend fundamentally on informed targeting of programs and policies, and a clearer understanding of links between rural poverty and fishing (Allison & Ellis, 2001; Béné, 2003; Coomes et al., 2004; Guerrero et al., 2018; Lopes et al., 2011).

In early studies of fisheries exploitation, depletion of fish stocks was seen as a direct result of fisher poverty (Béné, 2003; Béné & Friend, 2011; Macfadyen & Corcoran, 2002; Pomeroy, 2016). The dominant narrative suggested that fisheries were quickly saturated because fishing had few barriers to entry, which led to a cycle of overfishing, impoverishment, and ever more intense exploitation (Allison & Ellis, 2001; Béné, 2003; Cinner et al., 2009). A more consensual perspective now challenges the view that poverty is both the cause and outcome of exploitation of fish resources. Empirical evidence for a correlation between poverty and fishing livelihoods is surprisingly limited worldwide (Macfadyen & Corcoran, 2002) and analyses of fishing as a rural livelihood reveal multiple barriers that prevent the poorest from entering fisheries (Béné, 2003). Recent studies that examine links among livelihood diversification, poverty, and overfishing suggest that external socio-economic conditions provide a better explanation for why poverty may intersect with fishing (Allison & Ellis, 2001; Béné, 2003; Béné & Friend, 2011; Brugère et al., 2008; Cinner et al., 2009; Martin et al., 2013). Geographic isolation, lack of access to higher education programs, and absence of credit are among many factors that can trap people in fisheries-dependent poverty (Cinner et al., 2009; Daw et al., 2012; Ferrol-Schulte et al., 2013; Gray et al., 2015; Jentoft et al., 2011).

Herein, we examined the role of contextual, environmental, and household factors that influenced engagement in small-scale fisheries and the relationship between fishing and poverty among riverine communities in western Amazonia. Specifically, we conducted a multiscalar analysis to assess the factors that influenced participation in small-scale fisheries, the quantity (kg) of fish harvested, and household reliance on fishing as a livelihood strategy in western Amazonia. We drew on the largest livelihood survey of rural Indigenous and mestizo households conducted in Amazonia to date (Coomes et al., 2016). We examined the role of fishing in Amazonian livelihoods and the relationship between fishing and rural poverty. Our findings support the importance of geographical, environmental, and socioeconomic conditions in fishing engagement and highlight the need to consider wealth inequality in the design of conservation initiatives in Amazonia.

2 | STUDY CONTEXT

2.1 | Study area

Our study area lies in the Departments of Loreto and Ucayali in Peru, including the Napo, Pastaza, Amazon, and Ucayali river basins (Figure 1). Loreto and Ucayali cover 117,681 km^2, 85% of the Peruvian Amazon, and consist of lowland humid tropical forests interspersed with extensive wetlands, floodplains, and lakes. The region was home to nearly 1,400,000 people in 2017, of which 71% lived in urban areas, mainly in Iquitos and Pucallpa (INEI, 2021). Both cities act as primary markets and administrative centers of their respective departments. Iquitos is accessible only by boat and air, whereas Pucallpa has been connected to the national capital of Lima by road since the 1940s. Napo and Pastaza basins, and regions of the Ucayali basin (hereby referred to as Lower and Upper Ucayali sub-basins) can only be reached after one or more days of travel by boat from Iquitos or Pucallpa. Communities in the Amazon basin and Middle Ucayali sub-basin can be reached within hours by river boat. Small towns with 5000 to 30,000 inhabitants are dispersed along rivers and serve as secondary markets and district capitals. The remaining populations live in small riverine communities, typically with 100–300 inhabitants.

Rural inhabitants in the region are primarily Indigenous peoples and mestizos of mixed Indigenous and Iberian ancestry (locally known as *ribereños*), with few colonist communities. Indigenous communities are more remote than mestizo communities. Both groups rely on agriculture, fishing, livestock raising, logging, non-timber forest product (NTFP) extraction, and hunting. Households are highly dependent on river transport to reach city markets with their products to earn income (Chibnik, 1994; García-Vasquez et al., 2012) and to procure basic goods. Other common economic activities include daily wage labor, small commerce, tourism, and petroleum extraction. Remittances from relatives in urban areas are also a significant source of income for rural households (Coomes et al., 2016; Gregory & Coomes, 2019).

2.2 | Fisheries of the Peruvian Amazon

In the Amazon basin, fishers range in economic orientation from a focus on subsistence to commercial exploitation (Isaac & De Almeida, 2011; Tello Martín, 1995). Subsistence fisheries commonly

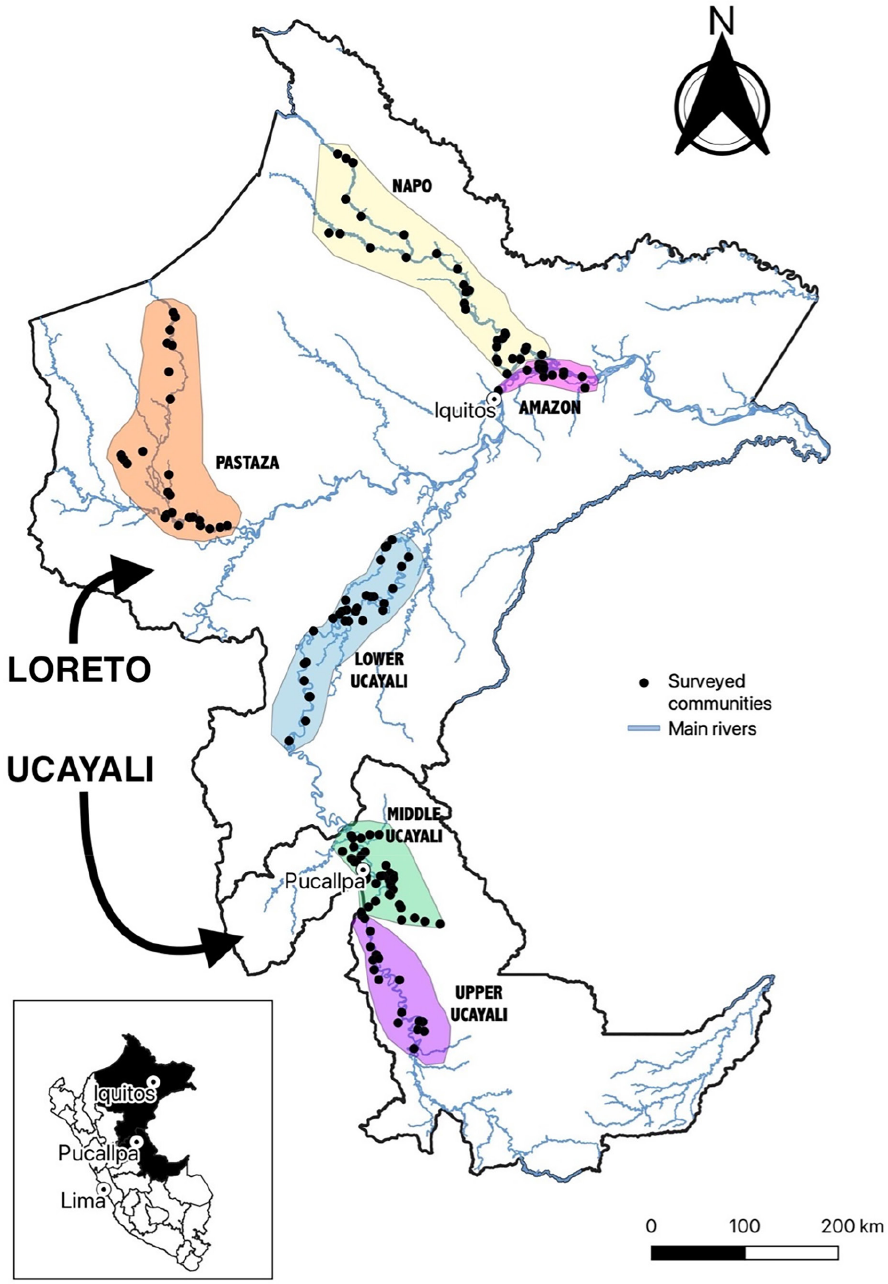

FIGURE 1 Study area and surveyed communities ($n=235$) between 2014 and 2016 in northeastern Peruvian Amazon. Colored areas represent basin and sub-basin units.

include activities that are not directed to profit maximization; that sustain a basic level of livelihood; and/or lack integration into the market economy (Schumann & Macinko, 2007). Subsistence fishing is for multiple species, mainly for food and occasionally to sell the surplus to earn income (Batista et al., 1998; Ruffino, 2011; Tello Martín, 1995). Subsistence fishers generally use simple fishing gear such as cast nets (known locally as *tarrafa*), hooks and lines, and trident spears (*flecha*), although plastic gillnets (*trampa*) have gradually replaced more traditional fishing gear (Tello Martín, 1995). Subsistence fisheries have been understudied because of their informality and remoteness (Batista et al., 1998). Fishers typically synchronize their fishing effort with seasonal floods and corresponding fluctuations in availability of other natural resources, such as game or suitable land for agriculture (Langill & Abizaid, 2020; McGrath et al., 2008; Smith et al., 2001; Tregidgo, 2017). Fishing is most productive during the low-water season when fish concentrate in lakes or rivers (Keppeler et al., 2020). During high water, fish disperse in flooded forests, thereby making fishing significantly more difficult and less efficient (Coomes et al., 2010; McGrath et al., 1993; Tregidgo et al., 2020). In the Peruvian Amazon, subsistence fisheries account for 49%–75% of the total catch (Sirén & Valbo-Jørgensen, 2022; Tello & Bayley, 2001, p. 124).

In contrast to subsistence fishers, commercial fishers rely almost exclusively on fishing as a source of income (Almeida et al., 2001; Ruffino, 2011). Commercial fishers travel along rivers and floodplains to find highly valued fish species in lakes, and conflicts with local communities that rely on fishing are common (Anderson et al., 2009; De Castro & McGrath, 2003). Expansion of commercial fisheries in

Amazonia began in the 1960s, a period of increased fish demand from a growing urban population and improved access to more efficient fishing technologies such as gillnets, trotlines and ice (De Jesús, 2004; McGrath et al., 1993). Commercial fishing initially concentrated on the most valuable species, such as the Zúngaro Dorado (*Brachyplatystoma rousseauxii*), Paiche (*Arapaima* sp.) and Gamitana (*Colossoma macropomum*). In Peru, as elsewhere in the Amazon, commercial fishing has caused a general decline of high-valued fish species, especially near urban centers like Iquitos and Pucallpa, and the number of commercially exploited species has expanded to include smaller, fast-reproducing, lower-value species (Coomes et al., 2020; De Jesús, 2004; Garcia et al., 2009; Hallwass & Silvano, 2016; Poissant et al., 2023).

Although an industrial fleet exists in Amazonian Peru (De Jesús, 2004), most of the commercial catch is increasingly harvested by small-scale fishers (Garcia et al., 2009; García-Vasquez et al., 2012). Small-scale fishers reside mainly in cities or rural communities, own a small boat and hire others to fish using a variety of fishing gears adapted to seasonal conditions (Batista et al., 2018; Castello et al., 2013; Tello Martín, 1995). The most common types of gear used in Peru are gillnets (*trampa*), circling nets (*hondera*), beach purse seine nets deployed from shore (*arrastradora*), and sturdy entangling nets for larger fish (*mallón*) (Tello Martín, 1995). In the study area, fishers typically sell their catch to middlemen living nearby who coordinate with passenger boats and markets in Iquitos and Pucallpa (Abizaid et al., 2022; Garcia et al., 2009). Some small-scale commercial fishers travel to sell to local or city fish markets, while others sell to community members for personal consumption, to local restaurants, or to buyers who offer competitive prices. Fish is traditionally salted for storage and transported to cities, although the use of ice boxes increased in frequency, even among remote communities where ice and salt can now be delivered by passenger boats from cities (García-Vasquez et al., 2012; Vela et al., 2013). In remote areas, informal creditors (*habilitadores*) loan or finance fishing equipment, household commodities, and sometimes money in exchange for a share or all of the catch. *Habilitadores* are important catalyzers of natural resource extraction, which also support the economic security of rural households, but may also keep households trapped in poverty (Ames, 2015; Kjöllerström, 2002). Fishing trips generally require substantial time away from home by men, whereas women are in charge of household tasks. Nevertheless, women sometimes fish for subsistence and most help in fishing-related tasks, such as cleaning, salting, curing, selling, and preparing fish for eating, and sharing among kin members (Espinosa, 2010; Langill, 2021).

Government authorities are responsible for recording landings at main river ports and enforcing fishing regulations. Governmental regulations prohibit predatory fishing techniques (e.g., using dynamite or poison) (Rodgers, 1987), protect sensitive areas (e.g., Pacaya Samiria National Reserve), restrict fish size for a limited number of species, and limit the fishing season (Ortega & Hidalgo, 2008). Commercial fishers are required to register with the *Dirección Regional de la Producción* and report catches to sub-regional offices, although the vastness of the area and limited human and monetary resources lead to many landings being unrecorded and fishers operating informally (Cavole et al., 2015; De Jesús, 2004; Garcia et al., 2009). In response to a perceived decline in local fish stocks and lack of capacity of the government to enforce fishing regulations, many riparian communities in Peru, as in Brazil, have implemented community-based fishery management (or co-management) initiatives underpinned by fisher ecological knowledge and participation, often achieving positive socio-economic and biological results (Anderson et al., 2009; De Castro & McGrath, 2003; Lopes et al., 2018; Queiroz, 2011; Reis-Filho et al., 2023; Smith et al., 2001).

3 | METHODS

3.1 | Data collection

Data were collected as part of the Peruvian Amazon Rural Livelihoods and Poverty (PARLAP) project (https://parlap.geog.mcgill.ca/). The PARLAP project collected the most extensive and comprehensive community and household dataset on rural livelihoods in Amazonia (Coomes et al., 2016). PARLAP field teams visited 919 communities between September 2012 and March 2014 in the Loreto and Ucayali Departments. Field teams identified the location of communities by the Peruvian national census, maps from the *Instituto del Bien Común* (IBC), Google Earth satellite imagery, and of unmapped settlements with the help of local communities. Field teams first sought permission from local authorities and then conducted focus group interviews that inquired about community market access, main economic activities, natural resource use, and settlement history (Coomes et al., 2016, 2020).

From August 2014 to July 2016, 235 communities were randomly sampled for follow-up surveys at the household level. Specifically, 20 households were randomly sampled from each community of more than 20 households, and all available households were surveyed in communities with less than 20 households. The household survey ($n = 3929$ households) sought information on household demographics, land holdings, production, resource extraction (over the previous 12 months), income, and non-land asset holdings (see Coomes et al., 2016, 2022). Qualitative information from fieldwork along the Lower Ucayali sub-basin by the lead author in 2019 aided to interpret the results of our statistical analyses.

3.2 | Analytical approach

3.2.1 | Description of fishing among surveyed households

Household engagement in fishing was examined for each of the four river systems in the study area, i.e., Napo, Pastaza, Amazon, and Ucayali (divided into lower, middle, and upper reaches). From the 3929 households surveyed, 3926 households provided complete information on the weight of fish harvested and sold, and

3906 reported observations for all other sources of income. Fishing incomes were estimated by multiplying the estimated catch by the local mean fish price (i.e., across species) obtained from a local market survey at the time of the household survey. Fishing reliance was then estimated by dividing household annual income from fishing (an aggregation of all fish harvested for sale and self-consumption) by total annual income (i.e., as the share of total income received from fishing). Distribution of fish harvested, sold, and consumed by households, and household economic reliance on fishing was assessed by basin/sub-basin using boxplots. A description of the different types of fishing gear among households can be found in Data S1.

3.2.2 | Models of fishing livelihoods

To estimate the influence of exogenous factors on household fishing activities, we first divided households into three groups: (1) households that did not harvest any fish; (2) households that harvested fish only for self-consumption (referred to as strictly subsistence-based households); and (3) households that harvested and sold fish (referred to as fish-selling households). Ninety-two percent of fish-selling households also harvested for personal consumption. Regression models were used to identify the factors that differentiated groups, economic reliance on fishing for groups 2 and 3, and the weight of fish sold by group 3.

The choice of predictors was guided by the sustainable livelihoods approach (SLA) (Scoones, 1998). The SLA is useful for depicting the complexity of poverty (Morse & McNamara, 2013); describing how and why people use, manage, and conserve natural resources (Ames, 2015); and understanding how ecosystems are overexploited (Ferrol-Schulte et al., 2013). Contextual features and three different forms of capital (natural, human-social, and physical) that operate at multiple scales (community and household) were used to predict specialization and concentration of fishing activity in household livelihoods (Aaron MacNeil & Cinner, 2013; Allison & Ellis, 2001; Ames, 2015; Coomes et al., 2004) (Tables 1 and 2).

Mixed models included community random intercepts nested within basins or sub-basins to control for differences among basins or sub-basins while keeping main estimates focused on regionally generalizable results. In addition, random intercepts were included for interviewers and the year and month of interviews. Non-normally distributed continuous predictors were log-transformed when judged necessary upon visual inspection to approximate a normal distribution and then standardized by subtracting the mean and dividing by the standard deviation. Logistic models were used to predict the household decisions to harvest and sell fish. Linear mixed models predict the quantity (kg) of fish sold within the previous 12 months ($\log_{10}$-transformed). Beta mixed regressions predict fishing reliance because parametric models based on the beta distributions are best suited for dependent variables expressed as proportions (Kieschnick & McCullough, 2003). Logistic and linear mixed models were estimated in R (version 4.2.1) with the lme4 package (Bates et al., 2015, version 1.1-30), and the beta regression model was estimated with the glmmTMB package (Brooks et al., 2017, version 1.1.4). Confidence intervals were calculated using the Wald method. Detailed estimation results including random effects estimates, intra-class correlation, and for unstandardized predictors can be found in Data S2, Table S2-1:5 and Table S2-8:12. Mixed logistic models explain the ownership of fishing gear, and linear mixed models explain the quantity (kg) of fish harvested for household consumption (see Data S1). To assess the robustness of findings, another similar series of models used clustered standard errors at the community level. Results of mixed and clustered error models were similar and consistent with each other (see Data S2, Figure S2-1:7). A correlation matrix between our predictors (Data S2, Figure S2-8) and the variance inflation factor (VIF) was examined in each model to assess multicollinearity.

3.2.3 | The relationship between poverty and fishing livelihoods

To assess the relationship between fishing and poverty, we examined how income from fishing (USD), participation in fishing (0/1), fish harvested for consumption and fish sold (kg), and fishing reliance (% of household income from fish) were related to current total annual income (USD), land holdings (ha), and non-land asset holdings (index). Annual income was calculated by summing incomes from all activities (subsistence and market production) of all household members. Land holdings included land in crop or fallow held by a household. Non-land assets were indexed as the first principal component based on possession (0/1) of the following goods: telephone, boat with outboard motor, motorcycle/motokar, generator, television, refrigerator, and propane stove (34% of total variance). Of the 3906 households for which total income could be calculated, 3778 households (in 235 communities) were available for analysis of land and non-land asset holdings (due to their additional missing values). Total income, land holdings, and non-land asset holdings were transformed into percentiles to normalize the effect of extreme values. Fishing income was summarized as the median, and harvest and fishing reliance were summarized as 0.1, 0.25, 0.5, 0.75, and 0.9 quantiles.

4 | RESULTS

4.1 | Engagement in fishing

Of 3926 households surveyed, 85% harvested fish (3324 households), 45% (1793 households in 223 communities) sold fish, 39% (1531 households in 225 communities) fished only for consumption (own household or shared catch), and 4% sold their entire catch during the previous 12 months. The average annual fish yield among surveyed households was highly skewed, with an average of 1000 kg and a maximum of 100 tons (Table 3). The average yield of fish sold by households was 450 kg. Household mean income from fishing was 904 USD

TABLE 1 Predictors of participation in small-scale fisheries in northeastern Peruvian Amazon collected during 2012–2016, within the sustainable livelihoods approach (SLA) framework for modeling fishing livelihoods.

SLA	Variable name	Description	Scale	Rationale for inclusion, hypotheses, and relevant sources
Context and trends	Distance to city	Network distance to nearest city (Iquitos/Pucallpa) (km)[a]	Community	Distance to city is a proxy for geographical isolation, reduced access to markets, healthier fish stocks, and usually associated with subsistence activities and diversified livelihoods relying on natural resource extraction (Ferrol-Schulte et al., 2013; Sirén & Valbo-Jørgensen, 2022).
	Located on main channels	The community is located on the main channel of a river (0 = no; 1 = yes)	Community	Communities located on main channels may have more transport options and increased integration to the market economy (Abizaid et al., 2022), may be more vulnerable to erosion and extreme flood events (Langill et al., 2022), and may suffer from increased fishing pressure from outside fishers (De Castro & McGrath, 2003; Silvano et al., 2014).
	Access to passenger boats	Community has access to passenger boats (*lancha*) (0 = no; 1 = yes)	Community	Passenger boats are a strong marker of market integration (Coomes et al., 2016) and have increasingly been used by remote communities to convey fish to city market (García-Vasquez et al., 2012; McGrath et al., 1993; Salonen et al., 2012).
	Access to informal creditor	Community members have access to a nearby creditor (*habilitador*) for aquatic resources (0 = no; 1 = yes)	Community	Informal creditor may loan or finance fishing equipment, making them important catalyzers of natural resource extraction (Kjöllerström, 2002; Ames, 2015).
	Access to phone communication	The community has phone communication (0 = no; 1 = yes)	Community	Access to phone communication may facilitate transactions and transportation of products, fish in particular, to the cities (Abizaid et al., 2022)
	Community age	Community age in current location (decades)	Community	The number of years since establishment of a community may affect the quality of available natural resources (Coomes et al., 2016).
	Number of households	Community size (no. households)	Community	The number of households within a community may influence pressure on local natural resources and household specialization (Cinner & Bodin, 2010).
	Indigenous community	Ethnicity of community (0 = Mestizo; 1 = Indigenous)	Community	Fish resources are especially important for Indigenous peoples in western Amazonia (Gray et al., 2015; Sirén & Valbo-Jørgensen, 2022).
Natural capital	% Forest cover	The percentage of land area within a 2 km radius around the community that[c] is classified from Landsat imagery to be forest with CLASlite v3.2[b]	Community	A proxy for terrestrial forest habitat. Abundant forest habitat may favor logging, hunting, or non-timber forest product for livelihoods (Coomes et al., 2016). Abundant forest may also be associated with productive fisheries in floodplains (Hurd et al., 2016).
	% Floodplain soils	The percentage of land area within a 5 km radius around the community that is underlain by Holocene parent material[c]	Community	A proxy for young alluvial soils in floodplains. Alluvial soils are fertile and can be associated with agriculture in floodplains (Coomes et al., 2016).
	% Main channel water	The percentage within a 5 km radius around the community that is determined from Landsat imagery to be comprised of open water along the main channel of a river[c]	Community	A proxy for river aquatic habitat and river fishing grounds.
	% Non-main channel water	The percentage within a 5 km radius around the community that is determined from Landsat imagery to be comprised of open water not along a main channel of river[c]	Community	A proxy for floodplain aquatic habitat and fishing grounds including lakes, abandoned side-channels, streams, and other forms of standing water.
	Presence of lake	Presence of a lake (0 = no; 1 = yes)	Community	Lakes are particularly productive for fisheries during the low water season when they become trapped in restricted area (Keppeler et al., 2020)

TABLE 1 (Continued)

SLA	Variable name	Description	Scale	Rationale for inclusion, hypotheses, and relevant sources
Human and social capital	Household formed in community	Household was formed in community	Household	Households coming from elsewhere may have restricted social networks, physical capital, access to natural resources, or local ecological knowledge compared to households that originate from the community.
	Number of elderly	No. of elderly (>=65 years) in household	Household	Number of household members may directly drive fish consumption and influence available workforce. As fishing is mostly men-dominated activity in the Amazon an abundance of female workers may decrease reliance on fishing (Espinosa, 2010; Langill, 2021). A higher number of household members may also favor within-households livelihood specialization, and thus also reduce dependence on a single activity, such as fishing (Coomes et al., 2004).
	Number of female workers	No. of females of working age (15–64 years) in household	Household	
	Number of male workers	No. of males of working age (15–64 years) in household	Household	
	Number of children	No. of children (<15 years) in household	Household	
	Head kin	No. of family members of household head living in community (including parents, brothers, sisters, children, uncles, aunts, and cousins)	Household	Household head's family members within the community is directly associated with social capital and access to extra-household workforce.
	Spouse kin	No. of family members of household head's spouse living in community (including parents, brothers, sisters, children, uncles, aunts, and cousins)	Household	Household spouse's family members within the community is directly associated with social capital and access to extra-household workforce.
	Sex of household head	Sex of head of household (0 = male; 1 = female)	Household	Fishing is mostly men-dominated activity in the Amazon (Espinosa, 2010; Langill, 2021).
	Age of household head	Age of head of household	Household	Older household heads may have had more time to diversify their livelihood portfolios and may lack the physical endurance for undertaking extended fishing trips.
	Education of household head	No. of years of education household head	Household	Higher levels of education of household head are generally associated with livelihood options other than natural resource extraction (Babulo et al., 2008; Guerrero et al., 2018).
	Household head born in community	Household head was born in community (0 = no; 1 = yes)	Household	We hypothesize that household heads born in the community may have more kin, more physical capital, and better access to natural resources than household heads from elsewhere.
Physical capital	Initial land holdings	Household total land holding at the time of formation in the current community (ha)	Household	Initial land holdings are the area held at the time of household formation. Used as a proxy for access to land for agriculture which is a predictor of current land holdings (Coomes et al., 2022).
	Initial non-land assets	Household non-land assets at the time of formation in the current community (first component of a principal component analysis based on possession of the following goods: a telephone, a boat/outboard motor, a motorcycle/*motokar*, a generator, a television, a refrigerator, and a propane stove) (*z*-score)	Household	Initial non-land assets are used as a proxy for initial wealth (physical and economic capital) at household formation. Greater wealth is associated with higher fish harvests (Gray et al., 2015), but its significance for household participation in fisheries remains controversial (Béné & Friend, 2011; Daw et al., 2012).

Note: All variables were derived from the PARLAP surveys unless specified.

[a]See Webster et al. (2016) for methodology.

[b]See Asner et al. (2009) for a description of the CLASlite system.

[c]A 2 km buffer was used for forest cover instead of 5 km for floodplain soils, main channel water, and non-main channel water because the 2 km buffer maximizes variations among communities and is a better representation of the spatial coverage needed for typical terrestrial orientated livelihoods (small scale farming, NTFP collection, hunting, etc.). A 5 km buffer was used for natural resources that are more easily accessible by the means of navigation. Methods for measuring open water can be found in Kalacska et al. (2022). The measure of floodplain soils is based on La Carta Geológica Nacional del Peru (1:100,000) published by INGEMMET (Instituto Geológico Minero y Metalúrgico, Lima), which is available online: https://portal.ingemmet.gob.pe/web/guest/carta-geologica-nacional-escala-1-100-000

TABLE 2 Descriptive statistics of predictors guided by the SLA framework for modeling fishing livelihoods, collected in northeastern Peruvian Amazon during 2012–2016.

	Variable name	*N*			Mean			*SD*			Min			Max		
	Household group	**NF**	**SS**	**FS**	**NF**	**SS**	**FS**	**NF**	**SS**	**FS**	**NF**	**SS**	**FS**	**NF**	**SS**	**FS**
Community level	Distance to city (km)	166	225	223	271	278	289	250	239	242	3	3	3	926	926	926
	Located on main channels	166	225	223												
	No	53	76	71	31.9%	33.8%	31.8%									
	Yes	113	149	152	68.1%	66.2%	68.2%									
	Access to passenger boats	166	225	223												
	No	74	99	93	44.6%	44%	41.7%									
	Yes	92	126	130	55.4%	56%	58.3%									
	Access to informal creditor	160	219	217												
	No	156	214	212	97.5%	97.7%	97.7%									
	Yes	4	5	5	2.5%	2.3%	2.3%									
	Access to phone communication	166	225	223												
	No	28	47	43	16.9%	20.9%	19.3%									
	Yes	138	178	180	83.1%	79.1%	80.7%									
	Community age (decades)	166	225	222	5.34	4.90	4.83	4.78	4.41	4.35	0	0	0	47	47	47
	Number of households	166	225	223	58.89	50.76	51.38	59.00	52.70	53.50	7	6	5	300	300	300
	Indigenous community	166	225	223												
	No	78	125	126	47%	55.6%	56.5%									
	Yes	88	100	97	53%	44.4%	43.5%									
	% Forest cover	166	225	223	72.81	75.72	75.82	19.15	17.79	18.06	12.04	12.04	12.04	99.14	99.14	99.14
	% Floodplain soils	166	225	223	62.747	62.39	63.43	30.53	30.14	30.30	0	0	0	100	100	100
	% Main channel water	166	225	223	8.323	7.961	8.32	7.98	7.25	7.73	0	0	0	38.87	34.21	38.87
	% Non-main channel water	166	225	223	1.75	1.66	1.70	2.4	2.28	2.31	0	0	0	10.24	10.24	10.24
	Presence of lake	166	225	223												
	No	32	41	36	19.3%	18.2%	16.1%									
	Yes	134	184	187	80.7%	81.8%	83.9%									

TABLE 2 (Continued)

	Variable name	*N*			Mean			*SD*			Min			Max		
	Household group	NF	SS	FS	NF	SS	FS	NF	SS	FS	NF	SS	FS	NF	SS	FS
Household level	Household formed in community	602	1531	1793												
	No	203	425	471	33.7%	27.8%	26.3%									
	Yes	399	1106	1322	66.3%	72.2%	73.7%									
	Number of elderly	602	1531	1793	0.41	0.26	0.19	0.72	0.59	0.50	0	0	0	4	4	4
	Number of female workers	602	1531	1793	1.17	1.31	1.44	0.91	0.86	0.90	0	0	0	6	7	6
	Number of male workers	602	1531	1793	1.09	1.16	1.23	0.80	0.73	0.73	0	0	0	4	5	5
	Number of children	602	1531	1793	1.75	2.33	2.76	1.78	1.88	1.95	0	0	0	8	9	11
	Head kin	598	1529	1790	4.93	6.65	7.74	9.81	9.93	9.75	0	0	0	89	100	75
	Spouse kin	597	1528	1786	5.65	6.20	7.28	10.41	10.41	10.71	0	0	0	98	137	97
	Sex of household head	602	1531	1793												
	No	74	48	42	12.3%	3.1%	2.3%									
	Yes	528	1483	1751	87.7%	96.9%	97.7%									
	Age of household head	599	1531	1793	49.96	45.43	43.64	15.76	14.64	13.41	17	17	17	90	94	93
	Education of household head (years)	599	1531	1793	6.56	6.22	6.26	3.58	3.14	2.98	0	0	0	13	13	13
	Household head born in community	600	1531	1793												
	No	359	884	955	59.8%	57.7%	53.3%									
	Yes	241	647	838	40.2%	42.3%	46.7%									
	Initial land holdings (ha)	598	1531	1791	1.74	2.30	1.41	4.45	6.38	2.99	0	0	0	51	105	58
	Initial non-land assets (*z*-score)	598	1531	1791	0.20	−0.02	−0.05	1.25	0.99	0.90	−0.46	−0.46	−0.46	7.59	7.71	7.79

Abbreviations: FS, Fish-selling; NF, Non-fishing; SS, Strictly subsistence.

TABLE 3 Descriptive statistics of incomes and fishing activities among households in northeastern Peruvian Amazon during 2014–2016.

Variable	Household group	Mean	*SD*	Min	25th percentile	Median	75th percentile	Max	*N*
Quantity harvested (kg)	NF	0	0	0	0	0	0	0	602
	SS	625	1362	2	130	262	700	34,200	1531
	FS	1663	4509	3	350	700	1500	100,000	1793
Quantity sold (kg)	NF	0	0	0	0	0	0	0	602
	SS	0	0	0	0	0	0	0	1531
	FS	985	3960	2	85	260	700	100,000	1793
Quantity consumed (kg)	NF	0	0	0	0	0	0	0	602
	SS	625	1362	2	130	262	700	34,200	1531
	FS	678	1281	0	140	335	700	20,000	1793
Income from fish sold (USD)	NF	0	0	0	0	0	0	0	602
	SS	610	1450	2	112	241	665	42,894	1531
	FS	1460	2837	2	321	723	1601	66,938	1793
Total income (USD)	NF	8274	16,682	0	1743	3933	9463	300,000	602
	SS	8566	10,296	19	3537	6150	10,045	142,546	1531
	FS	11,476	13,654	102	4528	7839	13,604	216,917	1793
Fishing reliance (%)	NF	0	0	0	0	0	0	0	602
	SS	24.96	23.94	0.06	6.45	15.32	38.13	100	1531
	FS	38.4	26.32	0.07	16.43	33.74	56.87	100	1793
Current land holdings (ha)	NF	6.95	21.6	0	0.69	2.00	5.40	239.12	539
	SS	5.99	13.81	0	1.2	2.65	5.53	254.51	1504
	FS	4.43	9.3	0	1	2.40	4.80	228.56	1746
Current non-land assets (*z*-score)	NF	0.27	1.23	−0.79	−0.75	−0.19	1.03	4.30	539
	SS	−0.03	0.98	−0.79	−0.76	−0.45	0.28	4.17	1504
	FS	−0.06	0.93	−0.79	−0.75	−0.46	0.23	4.22	1746

Abbreviations: FS, Fish-selling; NF, Non-fishing; SS, Strictly subsistence.

(1 S/ = 0.315 USD in 2015). Household reliance on fishing ranged from zero to 100% and averaged 27%. The average total income among all households was 3119 USD, although the median was 2074 USD.

Households along the Amazon and Middle Ucayali rivers harvested fewer fish than those in other basins/sub-basins (Figure 2). Fish sales were most common in the Pastaza basin and Lower Ucayali sub-basin, although households that sold large quantities of fish (i.e., 10,000 kg or more) were present in all basins and sub-basins. Households that sold the largest quantities of fish were found in the Amazon basin and Lower Ucayali sub-basin. Selling fish was relatively uncommon in the Middle Ucayali sub-basin. Fish consumption was similar among river basins, except for the Amazon basin and Middle Ucayali sub-basin, where household consumption was lower. Fishing reliance was generally higher in the Napo and Pastaza basins and lower in the Amazon basin, and households in the Middle Ucayali sub-basin relied less on fishing.

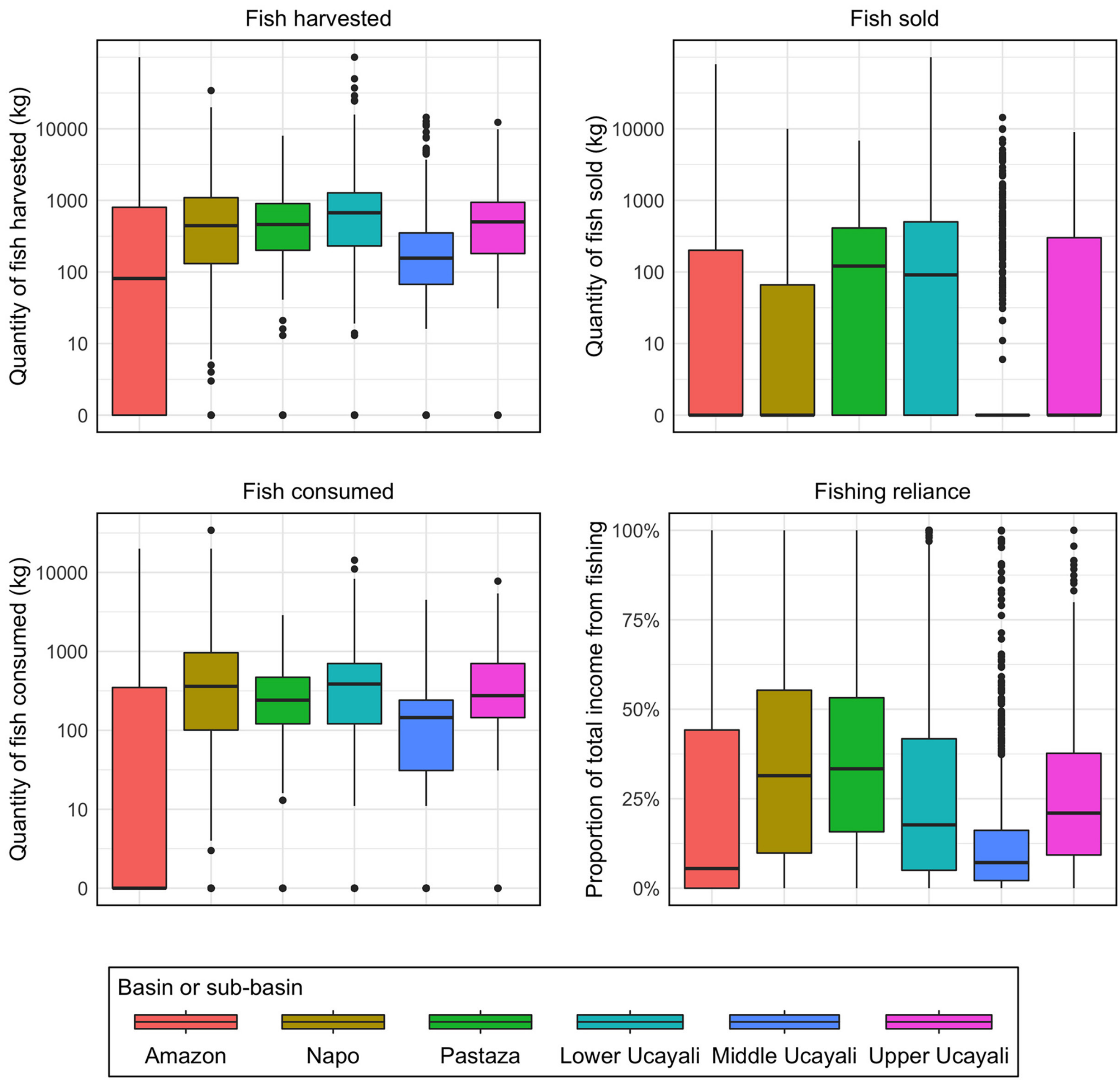

FIGURE 2 Fish harvested, fish sold, fish consumed, and fishing reliance for 3906 households in northeastern Peruvian Amazon: Amazon basin (n = 514, 63% harvested fish, 41% sold fish), Napo basin (n = 998, 92% harvested fish, 45% sold fish), Pastaza basin (n = 582, 92% harvested fish, 69% sold fish), Lower Ucayali sub-basin (n = 701, 80% harvested fish, 56% sold fish), Middle Ucayali sub-basin (n = 698, 82% harvested fish, 24% sold fish), and Upper Ucayali sub-basin (n = 413, 94% harvested fish, 41% sold fish) between 2014 and 2016. Lines within colored boxes represent the median. Edges of the box represent 1st and 3rd quartiles. Ends of the whiskers represent the 1.5 interquartile range.

4.2 | Household participation, fish sales, and reliance

4.2.1 | Context and trends

Distance to city and community indigeneity were strongly associated with household participation in fishing but not with the likelihood of selling fish, quantity of fish sold, or fishing reliance (see Figures 3–5 and Data S2: Table S2-1:5, for *p*-values). Communities located along a main river channel were less likely to sell fish and sold in lesser quantities. The number of households in a community was negatively associated with participation in fishing and not related to fish harvest or fishing reliance. Fishing reliance among strictly subsistence-based

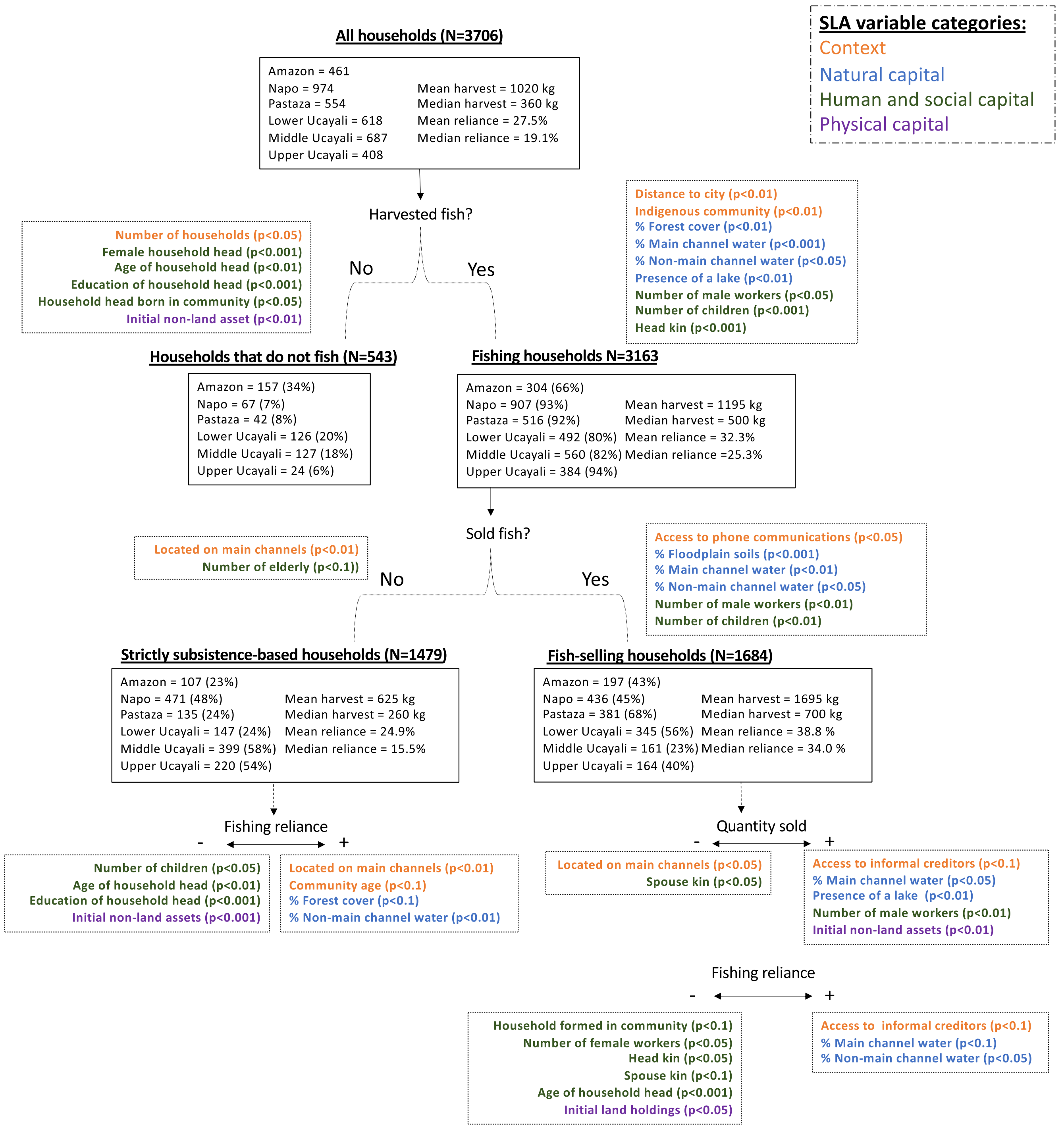

FIGURE 3 Synthesis of mixed model results of fishing activities among households surveyed in northeastern Peruvian Amazon between 2014 and 2016: (1) likelihood of harvesting fish (yes/no), (2) likelihood if selling fish (yes/no), (3) fishing reliance among strictly subsistence-based households, (4) quantity of fish sold (kg) among fish-selling households and (5) fishing reliance among fish-selling households. Only significant predictors ($p < 0.1$) are presented.

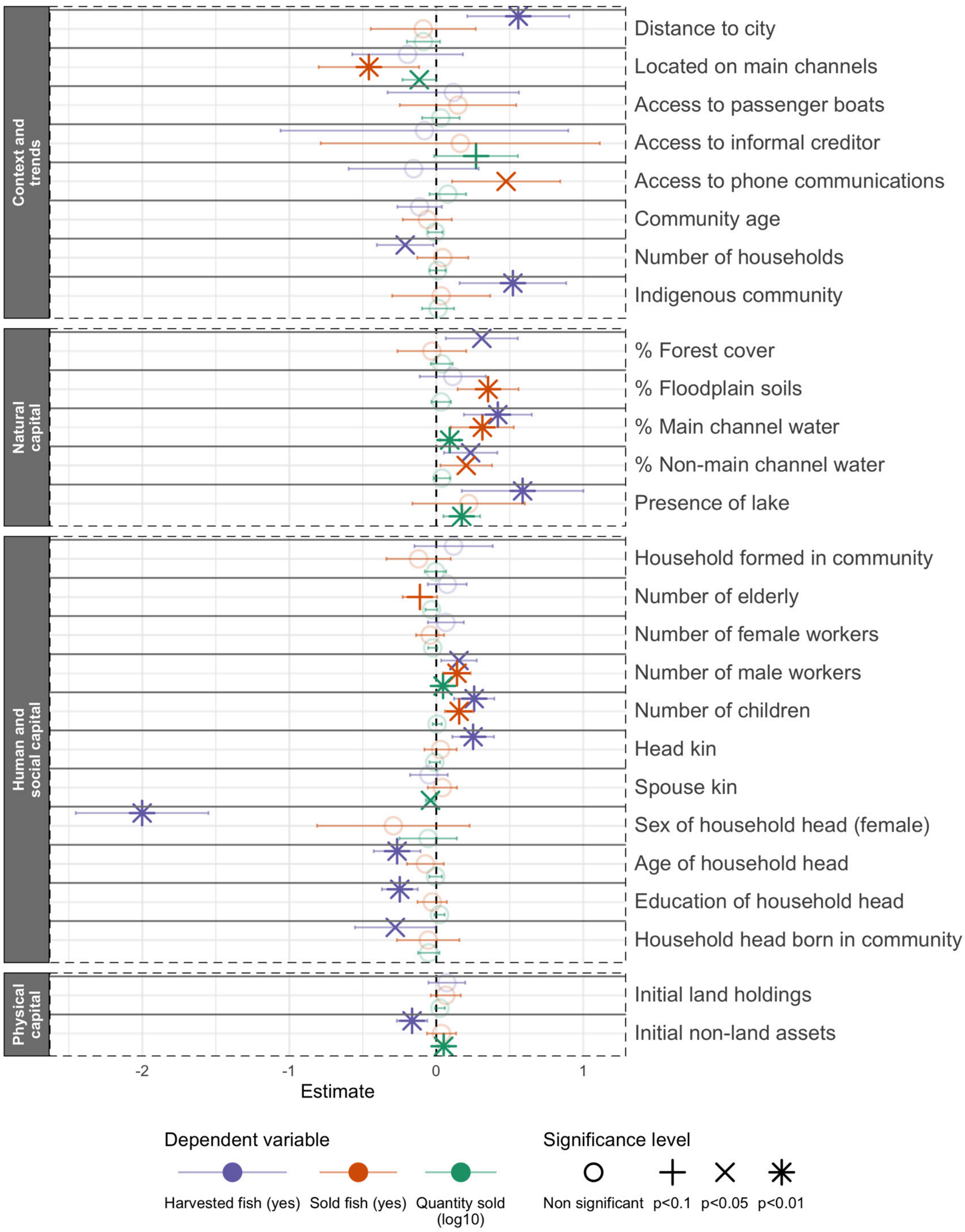

FIGURE 4 Mode estimates for the likelihood of harvesting and selling fish (log-odds), and quantity of fish sold (kg) among households surveyed in northeastern Peruvian Amazon between 2014 and 2016. The sample comprises 3706 households in 228 communities for harvesting fish (yes/no), 3163 fishing households in 227 communities for selling fish (yes/no), and 1684 fish-selling households in 215 communities for the quantity of fish sold. Coefficient estimates cannot be directly interpreted as they are derived from standardized predictors to compare effect size across predictors. Error bars represent the 95% confidence intervals. Transparent symbols are non-significant results.

households was higher among main channel communities. For fish-selling households, access to informal creditors was positively associated with quantity of fish sold and fishing reliance. Access to phone communication was also positively associated with the likelihood of selling fish.

4.2.2 | Natural capital

Households in communities with a nearby lake were more likely to participate in fishing and to sell larger quantities of fish (see Figures 3–5 and Data S2: Table S2-1:5, for *p*-values). Forest cover near communities

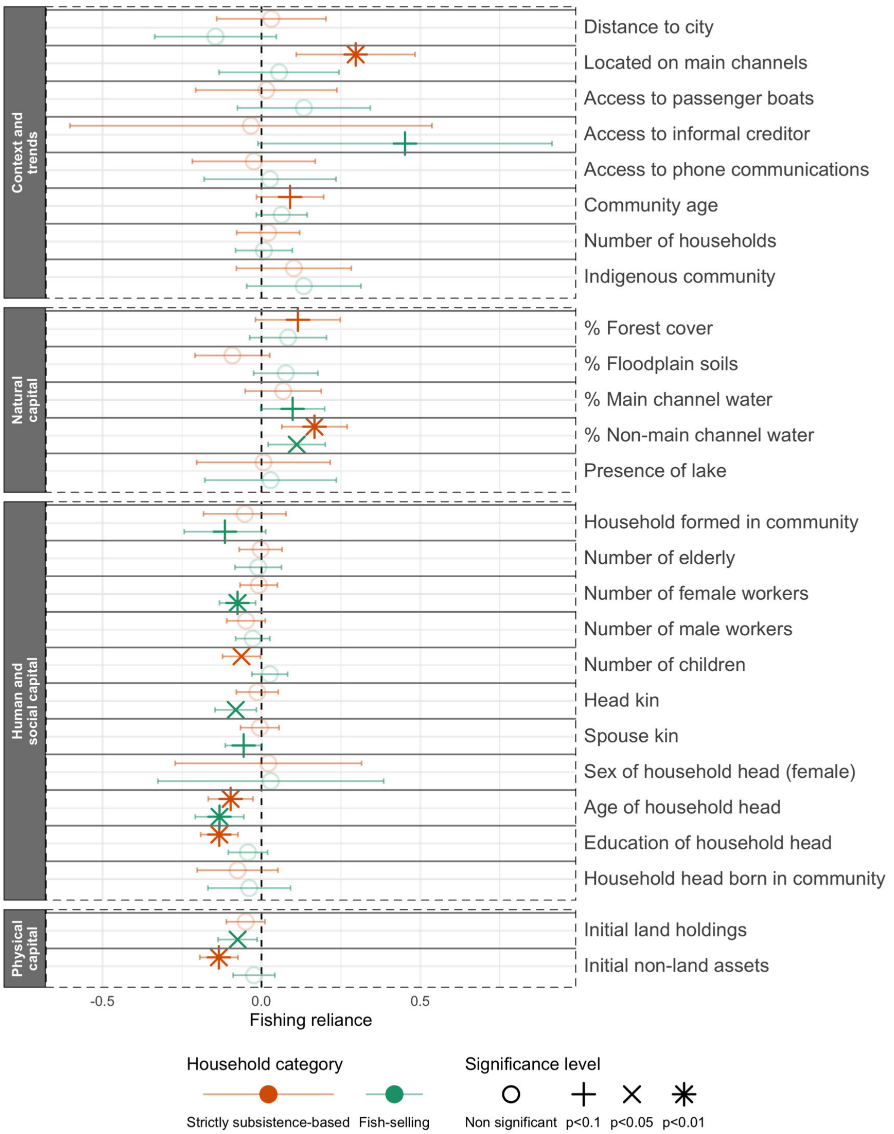

FIGURE 5 Model estimates for fishing reliance among strictly subsistence-based and fish-selling households among households surveyed in northeastern Peruvian Amazon between 2014 and 2016. The sample comprises 1479 strictly subsistence-based households in 217 communities and 1684 fish-selling households in 215 communities. Coefficient estimates cannot be directly interpreted as they are derived from standardized predictors to compare effect size across predictors. Error bars represent the 95% confidence intervals. Transparent symbols are non-significant results.

was positively related to household likelihood to fish. Households in communities with a greater share of main channel water were more likely to fish, sell fish, and sold larger quantities of fish. The share of inundated floodplain was positively associated with participation in fishing, selling fish, and fishing reliance. Households in communities with a greater share of floodplain soils also were more likely to sell fish.

4.2.3 | Human and social capital

Households headed by a male were more likely to participate in fishing than female-headed households (see Figures 3–5 and Data S2: Table S2-1:5, for *p*-values). Similarly, households with heads who were younger, less educated, and born outside the community were more likely to fish. The endowment of labor in the household was positively related to participation in fishing (i.e., number of male adults and kin group size of household head), whether a household sold fish, and quantity of fish sold. Households with more children were more likely to fish and sell fish.

Among strictly subsistence-based households, more reliant households had a younger, less educated head of household and fewer children. Fish-selling households that were more reliant on fishing also had a younger head of household, and both partners had fewer kin in the community. Such households also had fewer working-age females and were formed elsewhere than the community where they lived.

4.2.4 | Physical capital

Household asset holdings at the time of household formation in the community had a modest association with fishing decisions (see Figures 3–5 and Data S2: Table S2-1:5, for *p*-values). Households with small initial non-land asset holdings were more likely to participate in fishing but sold less fish than those that began their lifecycle with more non-land assets. Among fish-selling households, greater initial land holdings were associated with lower economic reliance on fishing. Among strictly subsistence-based households, initial non-land assets, rather than land assets, were related to reliance on fishing, with poorer households more reliant on fishing.

4.3 | Fishing and poverty

4.3.1 | Total income

Fishing was the second-most important income-generating activity among households in our sample, following agriculture (Figure 6a). Other activities, such as harvesting of game and NTFPs, logging and livestock made smaller contributions to income portfolios (Figure 6a). The percentage of households that harvested fish was lowest among low-income households (60%), and participation rates gradually increased with total income to 85%–90% for households above the 37th income percentile (Figure 6d). Similarly, the percentage of households that sold fish increased from 20% for the lowest income households to 60% for the highest income households. Fish harvest increased steadily with income (Figure 6g), whereas households with highest fishing reliance were at both extremes of income (Figure 6j). Median fishing reliance was unrelated to income for fish-selling households, but decreased for subsistence households.

4.3.2 | Land holdings

Income from fishing was unrelated to land holding size, but decreased relative to agriculture (Figure 6b). Participation in fishing was 70% among households with the least land holdings, and steadily increased to 90% for households between the 25th and 75th percentile of land holdings, before declining to 75% among the land-richest households. Participation in selling fish was similar and fluctuated between the 25th and 55th percentiles (Figure 6e). Participation in selling fish fluctuated greatly among percentile groups having very few households (e.g., 156 households that reported 1 hectare of land holdings were combined in a single percentile group, leaving neighboring percentile groups with fewer households). Quantities of fish sold were largely unrelated to land holdings (Figure 6h). In contrast, reliance on fishing declined as land holdings increased among households with median reliance or above (Figure 6k). Nevertheless, fishing remained a major share of income generated by fish-selling households, even among households with the highest land holdings (50% for the 0.75 quantile and 75% for the 0.9 quantile).

4.3.3 | Non-land assets

Fishing was the most significant source of income for non-land asset-poor households, followed by agriculture and other activities not related to natural resource extraction (Figure 6c). Participation rates in harvesting and selling were weakly related to non-land assets, both peaking at the 37th percentile (Figure 6f). The quantity of fish consumed was unrelated to non-land assets, whereas the quantity of fish sold increased with non-land assets (Figure 6i). Fishing reliance sharply decreased with non-land assets for fish-selling households, declined for subsistence-based households, and was relatively stable and high for top quantiles of strictly subsistence-based households (Figure 6l).

5 | DISCUSSION

Our findings that communities in floodplains had higher proportions of households fishing and selling fish, increased quantities of fish sold, higher reliance on fisheries, and greater ownership of fishing gear are consistent with floodplains being highly productive for fisheries (Almeida, 2004; Castello, Isaac, & Thapa, 2015; Garcia et al., 2009; Tello & Bayley, 2001). Floodplain lakes are important for fishing livelihoods by serving as reservoirs for fish resources when water levels recede (McGrath et al., 1993; Reis-Filho et al., 2023; Smith et al., 2001). Fishing is a widespread adaptation to the flood cycle in riverine Amazonia, especially when extreme flood events cause severe damage to crops in floodplains (Coomes et al., 2010; Langill & Abizaid, 2020; Langill et al., 2022; Takasaki et al., 2010).

We found that the proportion of fishing households was higher in communities far from the city, and that reliance on fishing was higher in remote basins (i.e., Napo and Pastaza, followed by the Lower and Upper Ucayali sub-basins), similar to other remote regions of Amazonia (Sirén & Valbo-Jørgensen, 2022), likely because of a lack of alternatives in remote areas that increase dependence on local natural resources (Ferrol-Schulte et al., 2013) or other food options (Tregidgo et al., 2020). We also found that households living in larger communities were less likely to harvest fish, a consequence of specialization and associated livelihood diversification among community members or increased competition for available fish resources (Cinner & Bodin, 2010). In communities along main channels, the likelihood of selling fish and quantity of fish sold were lower, but fishing reliance was higher for strictly subsistence-based households, possibly because more economic options are available in main channel communities due to increased connectivity to markets (Coomes et al., 2016). Also, in areas that are heavily fished, proximity to main rivers may accelerate fish depletion, because local lakes are more accessible to fishers from urban areas (Silvano et al., 2014). Consequently, commercial fishing may be less attractive to local communities that would need to compete with outsiders, whereas subsistence fishing would be necessary to supply protein. Alternatively, riverine households may turn to fishing for subsistence (Coomes et al., 2010) because they are more susceptible to severe flooding by their proximity to main channels (Langill et al., 2022), despite lower catchability of fish in flooded environments and reduced commercial prospects for households struggling to catch enough fish to meet their consumption needs (Tregidgo et al., 2020).

We found that market connectivity played an important role in commercialization of fish resources (i.e., quantity harvested was related to access to phones and informal creditors who acted as middlemen), likely because increased market connectivity is a

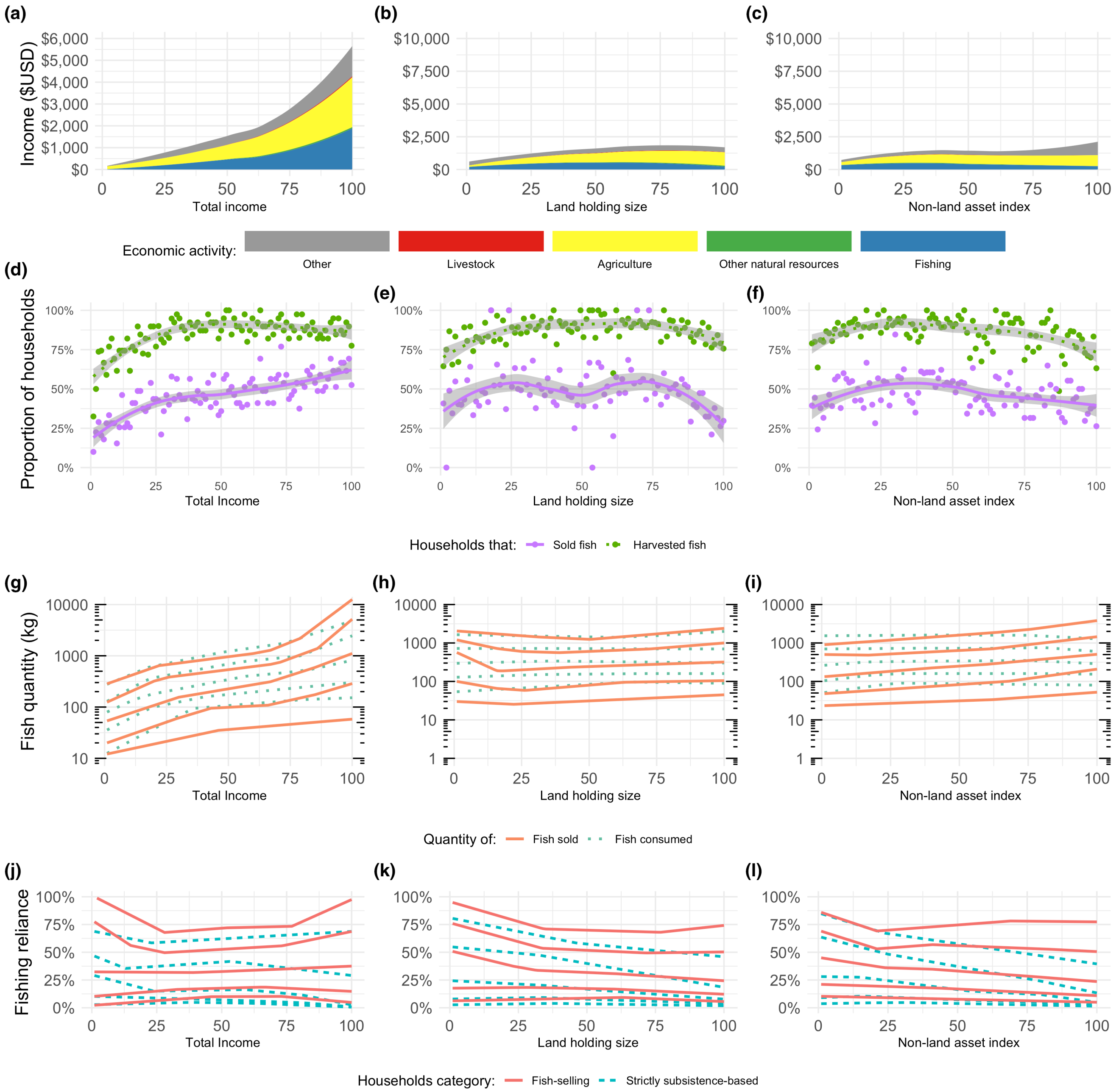

FIGURE 6 Relationships between fishing livelihoods and poverty among households surveyed in northeastern Peruvian Amazon between 2014 and 2016. The first column shows total income, the second column shows land holdings, and the third column shows non-land asset index. These three wealth metrics (*x*-axis) are compared with median incomes from different economic activities (a–c), participation in harvesting and selling among all households, with 95% confidence intervals (d–f), quantity of fish consumed among fishing households and sold among fish-selling households (g–i) and fishing reliance among strictly subsistence-based households and fish-selling households (j–l). The size for each sample in the first column is 3906 households; the size for each sample in the second and third columns is 3778 households, and is smaller than that in the first column due to missing values in land holdings and non-land asset index. All asset metrics are transformed in percentile ranks. “Other natural resources” includes incomes from logging, NTFP collection, and hunting. “Other” includes incomes from daily labor, salaries, commercial activities (operating a shop or another enterprise), remittances, and social programs (a–c). Regression lines represent 0.1, 0.25, 0.5, 0.75, and 0.9 quantiles (g–i).

driver of increased rates of natural resource extraction (Agrawal & Yadama, 1997; Porro et al., 2015). Informants from the Lower Ucayali sub-basin adopted fishing because of a lack of profitable economic alternatives and the ease of securing cash by selling to middlemen who coordinated with transport boats. An increase in the number of resident buyers over the past two decades has likely led to more favorable local prices for fish and higher returns to fishing (Poissant, 2021). *Habilitadores* accelerate the extraction of fish resources, in the absence of other easily accessible sources of credit, because rural people often have few other means to acquire assets, such as circling and large entangling fishing nets, and need to repay with valuable fish to offset debts (Ames, 2015; Kjöllerström, 2002). Widespread adoption of cellphones over the last decade facilitated transactions and transportation of fish to cities (Abizaid et al., 2022), and other impacts of cell phones on fishing livelihoods (Salia et al., 2011) warrant further research. Different from other studies, access to passenger boats was not significantly associated with any dependent variables in our study (Garcia et al., 2009; García-Vasquez et al., 2012; McGrath et al., 1993), possibly because passenger boats may have facilitated other livelihoods, were only one of many ways to transport fish to city markets, and other alternatives were available where passenger boats are absent. In any case, increased fishing pressure across the Amazon basin is often attributed to commercial fishers from cities traveling long distances to fish local lakes (McGrath et al., 1993), although our findings and observations indicate that increased market connection via phone access and informal creditors facilitated marketing of fish and commercial fishing by households in riverine communities (Abizaid et al., 2022; García-Vasquez et al., 2012; Vela et al., 2013).

We found that household access to labor was a major factor associated with an increased likelihood that households harvested and sold fish, consistent with other studies that found larger households extracted more fish resources (Coomes et al., 2004; Gray et al., 2015). Households whose heads had more relatives living in the community were also more likely to harvest fish, which reflects the need for available labor to fish jointly, share fishing gear, and finance fishing, although larger households were generally less reliant on fishing, likely because of livelihood diversification beyond fishing, especially when female workers and spouse kin were numerous. In that regard, our analysis confirms that fishing is an activity largely undertaken by men, although women undertake fishing-related tasks invisible in our analysis (Espinosa, 2010; Langill, 2021). The absence of women in fishing may be due to the burden of household-related tasks and communal labor (Langill, 2021), and higher vulnerability in social and physical capital (Appiah et al., 2021; Tindall & Holvoet, 2008). The sex of the head of the household was the most important factor explaining household decisions not to fish in our study, which highlights the importance of understanding the role of and barriers faced by women in the fishery sector (Harper et al., 2013).

We found that households whose heads were younger and less educated were more likely to harvest fish and relied more on fishing for subsistence, perhaps because such households had few lucrative alternatives available, so they turned to fishing (Coomes et al., 2004; Nguyen & Flaaten, 2011). Households with older heads and more elders generally avoided fishing as fishing is a physically demanding activity and/or because older folk secured other sources of income with time (Coomes et al., 2004; Poissant, 2021). Finally, we found that households living in Indigenous communities were more likely to harvest fish, which highlights the importance of fish resources in household economies of Indigenous peoples (Gray et al., 2015; Sirén & Valbo-Jørgensen, 2022).

We found that the highest levels of fishing reliance among households were at both extremes of the income spectrum, and as in the Ecuadorian Amazon, wealthier households also harvested more fish (Gray et al., 2015). Our finding that fishing was undertaken by all wealth groups, but that poorer households were more reliant on fishing, while harvesting less fish, is consistent with observations from the Mekong basin (Martin et al., 2013).

The disjuncture between fish harvests and reliance on fishing between relatively poorer and better-off households has important implications for fisheries management. We found that reliance on fishing was greatest among the asset poor, less educated, and younger, whose potential to generate substantial income from fisheries by harvesting large quantities is constrained by difficulties in accessing fishing gear and urban markets. Market connectivity increases with innovations in transportation and communication, so access to physical and human capital will likely become a more influential constraint on fishing, by providing an advantage for better-off households (Damasio et al., 2022). Inequality among rural households is well recognized as impeding collective action to protect local natural resources, especially when households with larger endowments cannot internalize benefits and have more economic alternatives (Aaron MacNeil & Cinner, 2013; Baland & Platteau, 1999; Crona & Bodin, 2010; Ostrom, 2007). In Amazonia, conflicts over access to lake resources by outsiders are frequent (De Castro, 2013; De Castro & McGrath, 2003). In the Lower Ucayali sub-basin, as elsewhere in the Peruvian Amazon, many communities have sought to establish regulations to ban or limit fishing practices that are seen as problematic by most of the community, but have often been unable to enforce them either because of opposition by wealthier fishing households that take the lion's share of fish or the formidable effort and organization needed for keeping trespassers at bay (Poissant, 2021). Successful collective action is needed not only to facilitate fisheries management but also to reduce poverty in small-scale fisheries (Jentoft et al., 2018).

Efforts directed towards poverty eradication and conserving fish stocks within small-scale fisheries should promote livelihood diversification and avoid the professionalization of fishers, which results in high dependency on fisheries (Allison & Ellis, 2001; Jentoft et al., 2011). Future policy interventions should be informed by our finding that the drivers of fishing specialization were distinct across the wealth spectrum. Among the asset-poor who depend heavily on fishing to take modest quantities of fish, most do so for lack of alternate economic opportunities, as demonstrated by increased reliance on fisheries associated with initial assets, lower education levels, and lower land holdings. Pathways for assistance to asset-poor fishers include investment in education, vocational training, micro-credit programs to displace informal debt contracts offered by middlemen, and support for equitable collective management of local lakes and rivers (Aaron MacNeil & Cinner, 2013; Cinner et al., 2009; Jentoft et al., 2011; Torell et al., 2017). Whereas most asset-rich households relied less on fishing for income, quantities harvested were much larger than “high reliance-low harvest” poor households. This finding highlights the importance of understanding the role of fisheries for asset-rich households with high harvests and low fishing reliance, and crucially, to find strategies that avoid or limit the use of alternative sources of income to subsidize increases in fishing efforts (Roscher et al., 2022). Further, asset-rich households who specialize in fishing because of higher returns afforded by more capital-intensive operations may be more likely to resist initiatives to collectively manage local fisheries and to invest beyond the fishery sector (Coomes et al., 2004; Poissant, 2021). Engaging effectively with these "high reliance-high harvest" households represents an especially difficult challenge in efforts to conserve and manage fish stocks so local fisheries remain a reliable source of food and income for all households.

ACKNOWLEDGEMENTS

We are most thankful to our two teams that conducted the survey work, in Loreto (Carlos Rengifo Upiachihua, Iris Anelís Arevalo Piña, Judiht del Castillo Macedo, Jacob Gonzales Bardales, Kathicsa Naydu Mendoza Montalván, Norith Paredes Salas and Inelza Zumbilla Ajón) and Ucayali (Luis Angel Collado Panduro, Claudio Sinuri Lomas, Santiago Nunta, Diego Fernando Dávila Gomez, Eduardo Carlos Perea Tuesta and Segundo Jorge Vázquez Flores). This study would not have been possible without their formidable efforts and commitment to the project. We are also particularly grateful to the visited communities and their support throughout the region. Finally, we thank the Editor-in-Chief, Dr. Michael Hansen, for his very helpful editorial comments and suggestions on the final manuscript. This study was supported by grants from the Japan Society for the Promotion of Science (23243045; 26245032; 18H05312; 18KK0042; and 20K20332) and the Social Sciences and Humanities Council of Canada (435-2015-0520 and 430-2016-00974).

CONFLICT OF INTEREST STATEMENT

Authors have no competing interests.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request and subject to privacy/ethical restrictions.

ETHICS STATEMENT

The PARLAP research project was approved by the McGill University Research Ethics Board (File number 290-0114) and by the University of Toronto Research Ethics Board (File number 29795).

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Poissant, D., Coomes, O.T., Robinson, B.E., Takasaki, Y. & Abizaid, C. (2024) Livelihoods and poverty in small-scale fisheries in western Amazonia. *Fisheries Management and Ecology*, 31, e12651. Available from: https://doi.org/10.1111/fme.12651