Science Advances
AAAS

advances.sciencemag.org/cgi/content/full/7/18/eabc7425/DC1

Supplementary Materials for

Fishers' response to temperature change reveals the importance of integrating human behavior in climate change analysis

Kathryn J. Fiorella*, Elizabeth R. Bageant, Naomi B. Schwartz, Shakuntala H. Thilsted, Christopher B. Barrett

*Corresponding author. Email: kfiorella@gmail.com

Published 30 April 2021, *Sci. Adv.* **7**, eabc7425 (2021)
DOI: 10.1126/sciadv.abc7425

This PDF file includes:

Extended Materials and Methods
Figs. S1 to S5
Tables S1 to S3

Supplementary Information

Extended Materials and Methods

Data

We used household data collected by WorldFish and partner NGOs that we matched to georeferenced satellite imagery and weather data. Household panel data were collected from 414 households over a three-year period from November 2012 through November 2015. Data were collected in January, March, May, July, September and November for a total of 19 time points, one in 2012 and six per year in 2013-15. A national election campaign forced a rescheduling of the July 2013 survey round until August 2013. We treat the August observations as if they were in July, as seasonal factors such as rainfall and temperature are similar from month to month from June through October. Data were collected in conjunction with monitoring of 40 Community Fish Refuges (CFRs), community-managed inland protected areas within the rice field fisheries. Each CFR has a "zone of influence", defined as the local area connected to the CFR by water in normal flood years (*41*) with a median area of 66 km^2 (min=9 km^2, max=539 km^2, mean=106 km^2).

One to three villages within the ZOI, and, where possible, within 1-2km of the CFR were selected. Within each selected village, 16 households were chosen at random from a complete listing of all households that met the inclusion criteria of participating in fishing, cultivating a rice field, and not planning to migrate seasonally. This initial sample was involved in a separate survey not used in this research, and it served as the sampling frame for the households included in the survey data used here. Within each CFR, ten households from the original 16 were purposively sampled to capture households with children <5 years of age (for project related reasons). Where more than ten households in a CFR had young children, households with the youngest children were prioritized; where fewer than ten households had young children, households with larger numbers of fishers were prioritized. Households that were lost to follow up over the project period were replaced by a household from the original sample of 16 households in their CFR. Sampling procedures are further described in a project report and research study *(28, 41)*. Of note, these households were located in a region supported to improve CFR management and aiming to improve fish habitat and buffer the impacts of environmental change broadly *(40)*. After attrition due to missing data in key variables, our current estimation sample consists of an unbalanced panel of 414 households, of which 308 (74%) are present in all panel periods. Our unbalanced panel includes households that were eventually lost to follow up as well as the households that replaced them, as long as these households were present in at least two time periods. We test whether attrition might bias our parameter estimates and find that it has no meaningful effect (see further detail below).

Information collected in the household survey includes details on fishing effort, fishing gear used and fish catch. Households estimated their total fish catch over the previous seven days, broken down by 104 fish species, 16 other aquatic animal species and 6 aquatic plant species. Households also report the amount of other aquatic animals (e.g., crabs, eels) and aquatic plants collected. Other key data include households' reported participation in fishing by each household member (number of days in the previous seven days), which we used to generate fishing effort in person-days, and what types of gear they used for fishing and collecting other aquatic animals in the previous seven days. Our metric of person-days spent fishing is limited in that it may fail to capture changes in the hours fishers spend to gain a sufficient catch. We use the gear data to generate a binary variable indicating whether a household used active gear types (e.g., cast nets or rakes) versus only passive types (e.g., fish traps that are set and left overnight) as an indicator of fishing labor effort per unit time spent fishing. Field staff supported the classification of gears as active or passive. Gears classified as passive included hand/pump, gillnet, cast net, three pronged barbed spear, plunge basket, bamboo basket, and eel rakes. Gears classified as active included horizontal cylinder trap for rice fields, hook and line, single hook set pole and line, cylinder trap with vertical entrance, tube trap for eel, eel clamp, and vertical rice field cylinder.

The use of household data was reviewed by the Cornell University Institutional Review Board (IRB) and granted exemption based on use of secondary data.

Air temperature data come from a combination of the National Oceanic and Atmospheric Administration National Centers for Environmental Information's Global Historical Climatology Network and the Climate Anomaly Monitoring System to create a data set known as GHCN_CAMS (*48*). Air temperature is computed for a 0.5° x 0.5° (approx. 55 km) grid and expressed in degrees Celsius. Rainfall data come from the Global Land Data Assimilation System Version 2 (GLDAS-2). Rainfall is computed for a 0.25° x 0.25° (approx. 27 km) resolution and expressed as monthly averages of three-hour running average rates in kg/m^2/second, which is a measure of rainfall intensity. We multiply the rainfall values by 1000 for ease of interpretation.

Average air temperature is 28°C (Table S1). Our analysis assumes that air temperature, households' perceptions of temperature, and water temperature covary positively and significantly. We verified the correlation between air and water temperature (Pearson's correlation coefficient = 0.29) in the CFR system using biomonitoring data collected by WorldFish. These data included water temperature, water clarity and fish species inventories collected every three months. We do not use the water temperature in our statistical models due their relative infrequency and their potential endogeneity to human behaviors in small inland ponds or lakes.

Flooding data come from the European Commission's Joint Research Center Global Surface Water Explorer (GWS), which maps seasonal and permanent surface water including rivers, lakes, wetlands, paddy fields, reservoirs, rivers and lakes using images from the USGS Landsat 5, 7 and 8 satellites (*42*). The data series run from December 1987 through September 2015 with observations every 16 days for the time period of this study. We calculate the monthly share of area within a 10km range of each CFR that is covered in water. We select a radius of 10km because this captures all households in the CFR zone of influence and approximates the maximum distance anyone might travel on foot in a day to fish. For the majority of cases (80%) where cloud cover is 75% or less, we have adjusted the flooded area by cloud cover (e.g., flooded area/(1-cloud cover proportion)). We drop observations for cases where cloud cover is >75% and impute replacement values using the mean of the prior and subsequent observations, weighted by cloud cover. If prior and subsequent observations both have >75% cloud cover, we drop the observation rather than impute, but if only one is <75% cloud cover we use that observation only. We conduct sensitivity analysis for cloud cover thresholds ranging from 55%-95% and the method of imputing missing values (simple mean versus weighted mean). The relationship between current period flooding and rainfall and flooding in prior periods is stable regardless of the chosen threshold or imputation approach.

Seasonal weather patterns are a major driver of the rice field fisheries system. Figure S1, panel (a), shows the annual temperature pattern, with higher temperatures in March-June, followed by increased rainfall from May through October in panel (b). Subsequently, flooding (Figure S3) peaks in September-November. Share of area flooded is, on average, low based on what one would expect in this system. We believe this is due to the nature of the surface water modeling approach, and the difficulties in detecting paddy fields. The model was designed to detect paddy fields, but under-detection is a noted issue (*42*). Without fail, we find the expected strong seasonal patterns and intertemporal correlations between surface water and rainfall that one would expect in this system (Figure S3). The key for our statistical analysis, given the estimators we use, is accurate capture of the intertemporal variation in surface water coverage within a given CFR, which we believe this data achieves.

Figure S4 shows the distribution of fish, aquatic animal and aquatic plant harvest throughout the year, which increases with the flood season, but remains high in January when flood waters are receding and fish are trapped in rice fields and ponds and therefore easy to catch. Aquatic plants are collected the most at the height of flooding. Figure S5 illustrates the variation in person-days spent fishing over the study period. While, on average, fishing effort peaks in July-November, during the flooded season, there is a lot of variation in fishing effort at any point in time and the seasonal patterns are not statistically significant.

Statistical Methods

We model two pathways through which temperature can affect fish catch. The first is the behavioral response of the fisher to temperature change. This could be due to physical discomfort with high or low temperatures, changing opportunity costs of time spent fishing under different temperature regimes, or fisher expectations of fishing conditions signaled by temperature. The second is an ecological effect via the availability of fish in the system, due to the effect of temperature on fish spawning and development, water quality and nutrient concentrations, and/or fish migratory responses (e.g., seeking deeper or cooler water).

We analyze the behavioral pathway by investigating whether fishers' participation, effort, and gear choice are affected by temperature change (Q1). We then investigate the composite effect of temperature on fish catch through both ecological and behavioral pathways together (Q2). Finally, we parse the behavioral and ecological (indirectly measured) pathways through which temperature relates to catch (Q3). Taken together, these analyses allow us to describe the causal effect of temperature on fish catch, and descriptively explore the ways that households employ adaptive strategies.

All models described below are estimated with model-specific fixed effects to control for time invariant characteristics in the cross-sectional units, as well as month fixed effects to control for seasonality common to all sample households. Household fixed effects are included in Q1 models. Community Fish Refuge (CFR) fixed effects account for the notable diversity of CFR types within this system in Q2 and Q3, where we control for a multitude of household characteristics using the Honoré correlated random effects estimator *(30)*, approximating a household fixed effect in a random effects Tobit model (*46, 47*). These fixed effects allow us to compare the relationship between a given household's temperature experience and its outcomes over time by identifying the causal effect of temperature off within-household variation in fishing effort and catch over time. We cluster standard errors at the CFR level, as that was the locus of the survey design.

We allow for the possibility that temperature has a non-linear, quadratic relationship with fish catch, as there are ranges over which growth and fecundity increase and others over which they decrease. Fish species in this system are understudied, providing very little information with which to build a hypothesis about the most relevant thresholds above/below which growth and fecundity change. Therefore, we opt for the more transparent, parsimonious specification using only a quadratic in temperature and de-meaning the data so as to center at the sample mean.

To determine the optimal set of lagged dependent variables in the model, we computed Akaike and Bayes Information Criterion (AIC and BIC) for each potential model. The AIC and BIC test results consistently favor an optimal specification of 1, 2 or 3 lags, with no substantive difference among those choices. In a model containing 2 or 3 lags, the one-period lag has the strongest explanatory power, while subsequent lags have limited or no additional explanatory power. So, we estimate the more parsimonious model with a single lag of the dependent fish catch variable as the statistically preferred specification.

Q1: How does temperature change affect fisher behavior?

To understand the causal effect of temperature change on fisher behavior ($Y_{i,j,t}$), we identify three ways that temperature might impact the behavior of fishing household *i* in CFR *j* at time *t*. On the extensive margin, a household may decide whether to participate in fishing (P_{ijt}=1 if any member of the household fished in past seven days, =0 otherwise). On the intensive margin, a household may vary how much effort it put into fishing, measured in person-days spent fishing in past seven days (E_{ijt}); and/or whether to devote more or less time to active (energy-intensive) approaches to fishing, measured by the share of total gear types used that require active fisher management (G^A_{ijt}), as distinct from passive gear types. We estimate regressions separately for each of these three outcomes using the general regression form:

$$Y_{i,j,t} = \gamma_0 T_{j,t-1} + \gamma_1 T^2_{j,t-1} + \gamma_2 T_{j,t-2} + \gamma_3 T^2_{j,t-2} + \gamma_5 R_{j,t-1} + \gamma_6 R^2_{j,t-1} + \gamma_7 R_{j,t-2} + \gamma_8 R^2_{j,t-2} + \delta_1 M_t + \mu_i + \varepsilon_{i,j,t} \quad (1)$$

The primary explanatory variables considered in this study are the average monthly air temperature T_j in CFR j one month prior to the current period ($T_{j,t-1}$), two months prior to the current period (($T_{j,t-2}$) and their squares. We also include the precipitation rate in the previous month ($R_{j,t-1}$), and two months prior ($R_{j,t-2}$), and their squares, in kg/m^2/s^1. We include fixed effects for month (M_t) to control for seasonality common to all sample households. Finally, we include a household fixed effect (μ_i) to control for time-invariant heterogeneity, including household-specific differences in non-fishing livelihood opportunities, skills, sociopolitical status, and access to private or common property resources. The temperature effects we estimate are therefore causally identified off within-household variation in fishing effort and catch over time, relative to interannual averages for any given month. We estimate this model for three different dependent variables, replacing the generic $Y_{i,j,t}$ with a binary measure of fishing participation ($P_{i,j,t}$), a continuous, non-negative measure of effort (E_{ijt}), and a binary measure of active gear use (G_{ijt}^{A}) indicating that a household used >50% active gear in the previous 7 days (equations not shown). We estimate a linear probability model for outcome $P_{i,j,t}$. For estimates of temperature effects on fishing effort (E_{ijt}) and active gear use (G_{ijt}^{A}), we restrict the sample to those who participate in fishing and estimate using Ordinary Least Squares.

Q2: What is the composite (ecological and behavioral) impact of temperature on fish catch?

After exploring behavioral temperature effects separately in Q1, we look at the composite behavioral and ecological effect of temperature on household fish catch, C_{ijt}^{f}, measured as the natural logarithm of total kilograms of fish reported caught by the household in the past seven days. Fish catch is the joint realization of human and ecological processes. The distribution of C_{ijt}^{f} is positively skewed with 48% of observations taking the value zero and no possibility of negative values. Therefore, we use a censored dependent variable model. In order to account for the unobserved household fixed effect, we use the Honoré Tobit estimator (*30*).

$$\begin{aligned} ln\,(C_{i,j,t}) = max\,(0, \beta_0 T_{j,t-1} + \beta_1 T_{j,t-1}^2 + \beta_2 T_{j,t-2} + \beta_3 T_{j,t-2}^2 + \beta_4 R_{j,t-1} \\ + \beta_5 R_{j,t-1}^2 + \beta_6 R_{j,t-2} + \beta_7 R_{j,t-2}^2 + \varphi \bar{X}_i + \omega ln\big(C_{i,j,t-2}\big) + \xi c_j \\ + \zeta M_t + \mu_i + \varepsilon_{i,j,t}) \end{aligned} \tag{2}$$

which includes the temperature and rainfall variables from (1) and incorporates within-household means of household characteristics ($\bar{X}_i$). To the extent that $\bar{X}_i$is correlated with μ_i, this corrects for any bias associated with unobserved time invariant household characteristics, such as fisher skill, sociopolitical status, and non-fishing livelihood opportunities. Household characteristics in $\bar{X}_i$ include household size, share of household members under 16 or older than 65, maximum educational attainment of any household member, household amenities index, livelihood asset index, livestock holdings by species, primary household source of income (fishing, farming, wage labor, skilled labor), land holdings (hectares), seasonally flooded land holdings (hectares), duration of seasonal flooding on own land (months), and whether the household experienced a health, asset or agricultural shock during the study period. The household amenities and livelihood asset indices are constructed using principle component analyses. The former includes improved wall materials (concrete, metal, wood); improved roof materials (concrete, metal, tiles, wood); improved wet season water source (well, rainwater, piped water); improved dry season water source (well, rainwater, piped water); clean cooking fuel (charcoal, electric, gas, biogas); connected to electric grid; and non-shared toilet, while the latter includes bagnet, bamboo barrage, bamboo rattan trap, barrel, boat, castnet, cooler, funnel trap, gillnet, hand net, harpoon, hook and line, fish jar, outboard motor, river trawl, scoop net, drag net, fish carry cage, smoke griller, tru, aquaculture cage, aquaculture pond, drum seeder, hand thresher, hand tractor, insecticide sprayer, motor pump, motorized thresher, ox cart, plow, rice miller, cart, and shovel. We include fish catch ($C_{i,j,t-2}$), from two months prior because fish catch is collected bimonthly. We include month (M_t) and CFR (c_j) so as to control for seasonality and for location-specific time-invariant features (such as accessibility, productivity, or proximity to other amenities such as rice fields or towns). If successful management of a CFR has buffered the ecological or behavioral effects of temperature, this would bias our findings towards the null. Taken together, the parameters $\beta_0, \beta_1, \beta_2$ and $\beta_3$represent the net causal effect of temperature *inclusive of* any adaptations fishers make, e.g., to fishing participation, effort and gear.

Q3: What is the ecological effect of temperature on fish catch (controlling for behavioral effects)?

Finally, in equation (3) we build on equation (2) to now include as controls the measures of fisher behavior so as to isolate the estimated ecological effects of temperature on fish catch, independent of endogenous behavioral responses, as reflected in the parameters θ_0, θ_1, θ_2, and θ_3 below.

$$\begin{aligned} ln\,(C_{i,j,t}) = max\,(0, \theta_0 T_{j,t-1} + \theta_1 T^2_{j,t-1} + \theta_2 T_{j,t-2} + \theta_3 T^2_{j,t-2} + \theta_4 R_{j,t-1} \\ + \theta_5 R^2_{j,t-1} + \theta_6 R_{j,t-2} + \theta_7 R^2_{j,t-2} + \lambda_0 P_{ijt} + \lambda_1 E_{ijt} + \lambda_2 G^A_{ijt} \\ + \alpha \bar{X}_i + \vartheta ln(C_{i,j,t-2}) + \sigma c_j + \rho M_t + \tau_i + \varepsilon_{i,j,t}) \end{aligned} \tag{3}$$

In this model, the coefficient λ_0 represents the partial correlation between the probability of fishing and fish catch, λ_1 represents the partial correlation between an additional person-day of effort and fish catch, while the coefficient λ_2 represents the partial correlation between using more labor-intensive fishing gear versus allocating less effort (i.e., using passive gear), all independent of temperature. Note that the λ_0, λ_1, and λ_2 coefficient estimates may be biased estimates of the true causal effects of these behaviors on fish catch because they are endogenous to the other explanatory variables; here we include them simply as controls so as to isolate the association between temperature and fish catch independent of any induced change in fisher behaviors. The inclusion of potentially endogenous controls in this equation means that the θ_0, θ_1, θ_2, and θ_3 parameters of primary interest represent associations and not necessarily strict causal effects.

Causal mediation analysis like that conducted in equation (3) raises some concern of bias due to intermediate confounders that are influenced by the exogenous explanatory variables, temperature and rainfall, and independently influence the mediator variable, in this case, fisher behaviors behavior) (*49*). A relevant example would be a non-fishing livelihood option that is influenced by temperature, such as rice farming, undertaken by virtually all sample households. Temperature-driven fluctuations in agricultural conditions could affect intrahousehold labor allocation to fishing as well as to the rice fields within which fishers often operate. To some extent, we control for household-specific rice production factors by including land and other agricultural assets. But we lack controls for intra-season rice production conditions more generally that might better capture the inter-annual variation in the returns to rice farming labor. However, such controls are do not guarantee that bias will be eliminated. The method proposed by Acharya, Blackwell and Sen (*49*) to correct for potential bias of this type has only been validated for linear and binary choice models, so we cannot implement it with the nonlinear, censored estimator our data require. However, our purpose in equation (3) is to illustrate that the causal effects of temperature on fish catch demonstrated in equation (2) may operate through multiple pathways. The estimates from equation (1) establish that temperature change causes fisher behavioral adaptation. The equation (3) estimates suggest that there may also be direct ecological effects of temperature on fish catch, independent of human fishing activity, that also merit exploration, even if we cannot fully disentangle the causal mediation in these data. The results from estimating equation (3) should simply be interpreted as an indicator that such multiple pathways exist; the estimated directions and magnitudes represent statistical associations only.

We assess attrition by modeling the household-and-period-specific probability of absence from the panel as a function of interview timing and baseline household characteristics (associated CFR, household size, maximum education attainment, housing amenities, productive assets, livestock, poultry, income source, landholdings, reported flooded landholdings, reported flood timing, and shock experiences). Attrition is associated with the interview months of May, July, September and November, relative to February and specific CFRs have statistically significantly higher probability of attrition than the reference CFR. Otherwise, attrition appears to be random. We show the attrition analysis results, estimated using logistic regression, probit regression and a linear probability model, in Table S3. Re-estimation of core models, adding in a control for the predicted probability of attrition yields virtually identical results as models that exclude attrition adjustment.

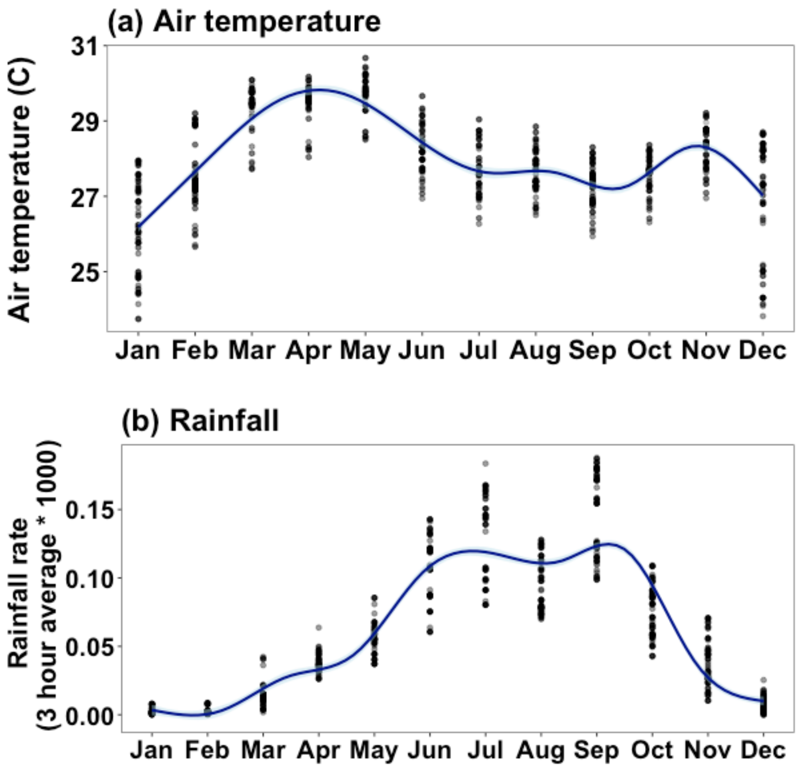

Figure S1. **Seasonal patterns of temperature and rainfall in Cambodian rice field fisheries.** Seasonal patterns in Cambodian rice field fisheries are shown with a) monthly average temperature and (b) monthly average precipitation (kg/m^2/second*1000, 2012-2016).

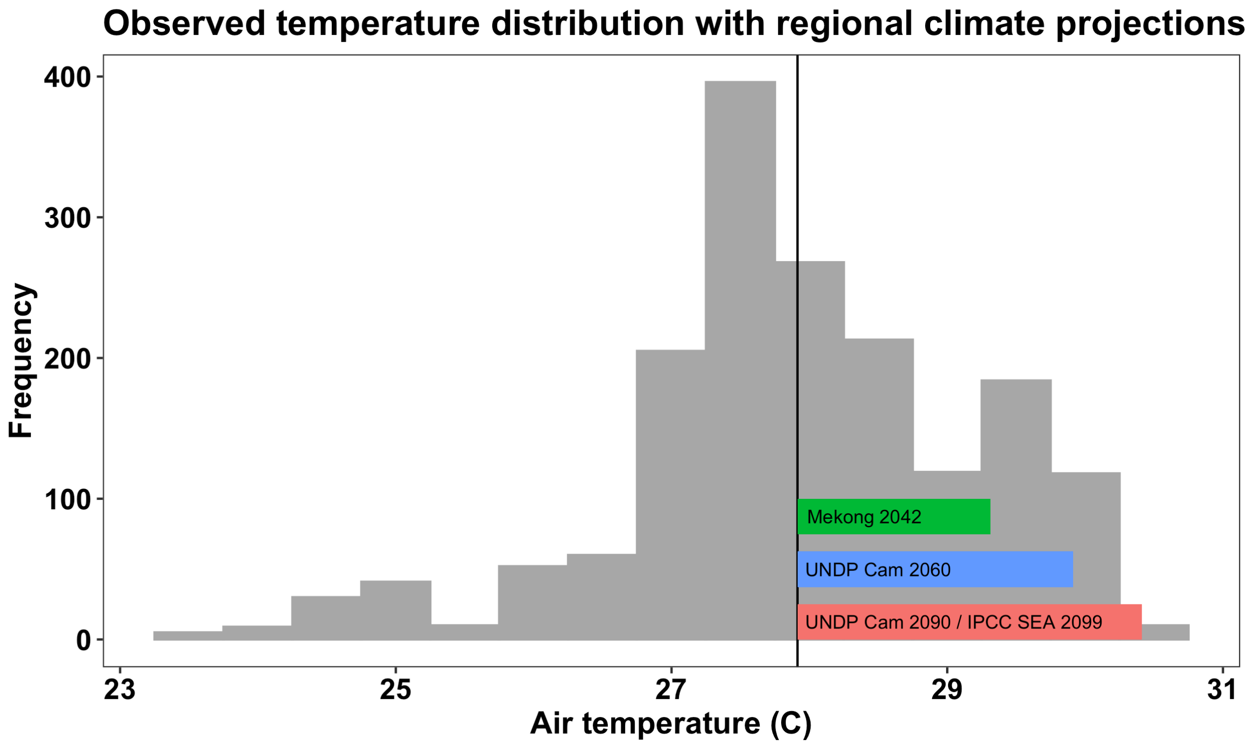

Figure S2. **Observed temperature distribution and regional climate projections.** Observed temperature distribution with overlays of three regional climate projections under A1B climate scenario. The histogram shows the distribution of observed temperature in our data, with a horizontal line at the mean (27.91C). The top horizontal bar indicates the 1.4°C rise in temperature projected for the Mekong river system by 2014 (*50*). The middle bar indicates the Cambodia specific 2.0°C rise in temperature by 2060 as estimated by the United Nations Development Programme (*32, 33*). The bottom bar indicates the 2.5°C increase estimated by UNDP for Cambodia (*32, 33*) and IPCC for Southeast Asia (*51*) by 2090 and 2099, respectively. The available regionally-relevant climate projections lie within the range of observed temperatures.

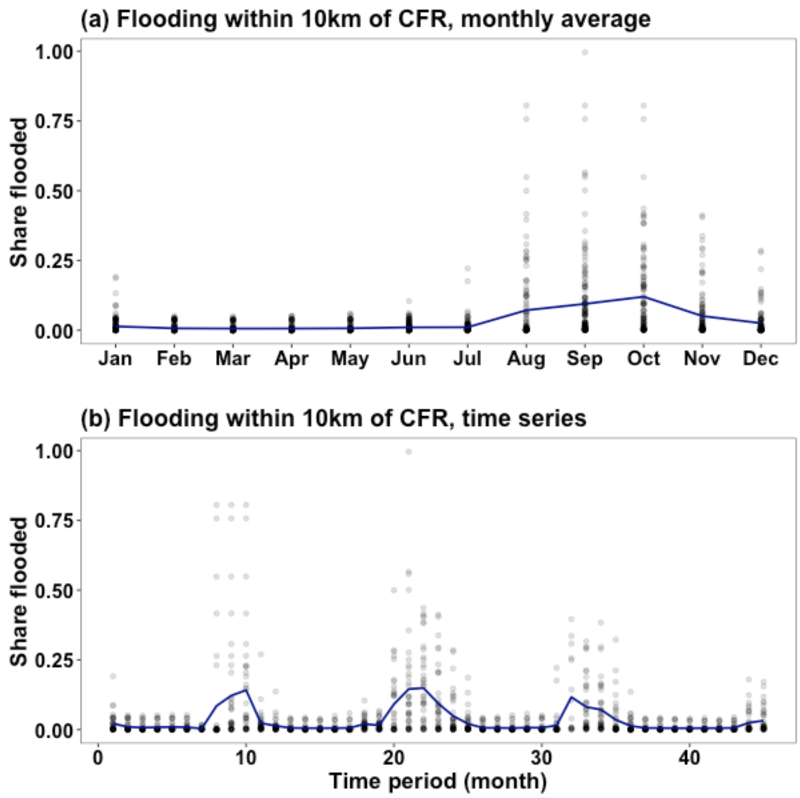

Figure S3. **Flooding dynamics around Community Fish Refuges.** Share of area within a 10km radius of each Community Fish Refuge that is flooded displayed (a) by month and (b) monthly across the three-year study period.

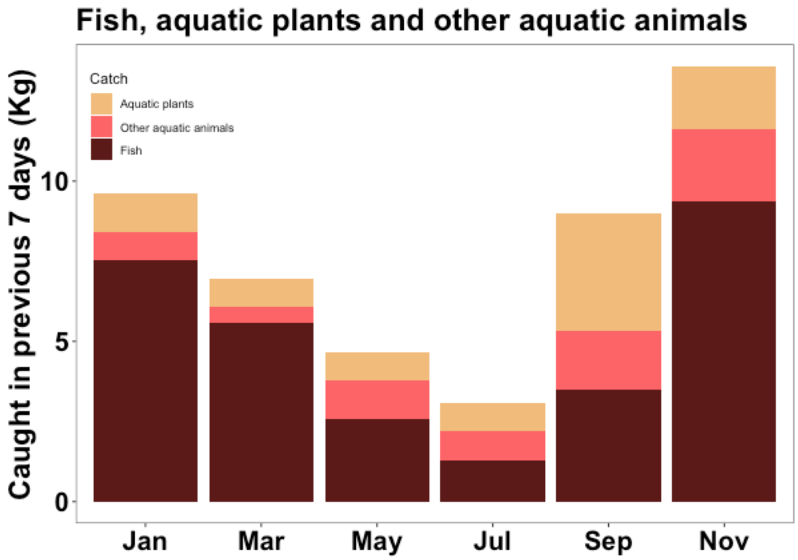

Figure S4. **Household harvest of fish, aquatic plants, and other aquatic animals.** Household average fish, aquatic plant and other aquatic animal harvest in previous 7 days by month.

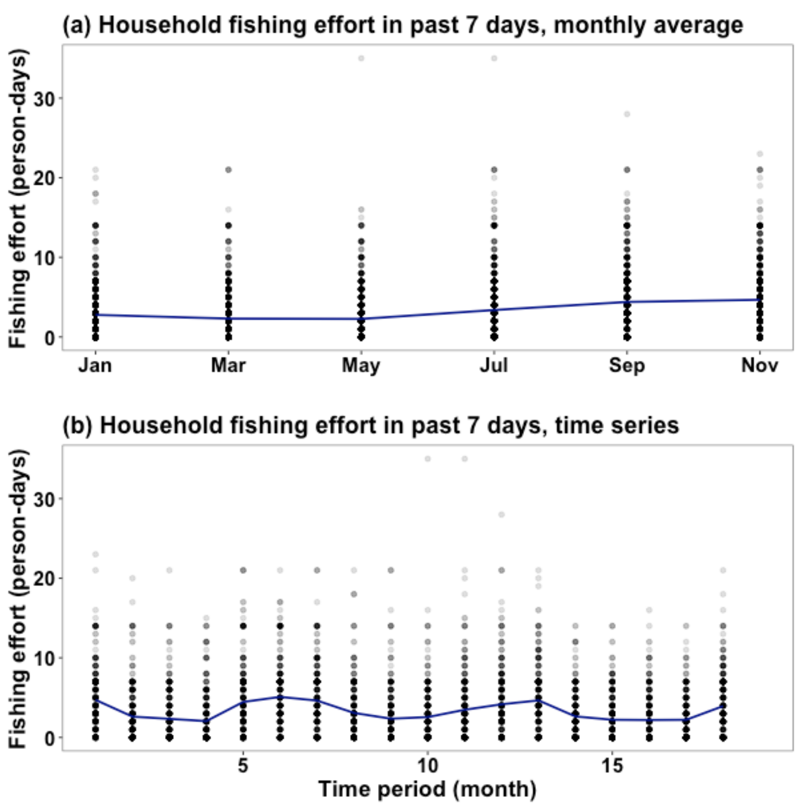

Figure S5. **Household fishing effort.** Fishing effort measured in person-days per household per week, aggregated by (a) month and (b) bimonthly across the 3-year study period.

Table S1. Descriptive statistics of key variables

	Overall mean	Overall SD	Within-household SD	Max	N
Household Fishing Panel					
Participated in fishing in current period (%)	64	47.9	40.7	100	6291
Participated in fishing in any period (%)	100	5.2	0.0	1	6291
Total fish catch in past week (Kg)	5	17.3	16.3	850	6291
Total other aquatic animals catch in past week (Kg)	1.3	4.2	3.8	145	6291
Total aquatic plant harvest in past week (Kg)	1.4	14.5	13.1	700	6291
Fishing effort (person-days)	3.2	3.7	3.1	35	6291
Share of households using active fishing gear	0.3	0.4	0.4	1	6291
Share of households using active OAA gear	0.2	0.4	0.3	1	6291
Air temperature (C)	0.0	1.5	1.4	3	6291
Rainfall (kg/m^2/second)*1000	57.4	51.8	51.5	184	6291
Area flooded within 10km radius of CFR (%)	2.9	8.0	7.3	100	5195
Area flooded within 10km radius of CFR--imputed using weighted mean (%)	3.4	8.4	7.5	100	6291
Area flooded within 10km radius of CFR--imputed using simple mean (%)	3.1	7.8	7.0	100	6291
Livelihood survey data					
Land area farmed (hectares)	2.4	2.4		25	811
Seasonally flooded land area (hectares)	1.9	1.9		15	811
Primary income from farming (%)	62.8	48.4		100	811
Primary income from fishing (%)	4.6	20.9		100	811
Primary income from wage labor (%)	16.5	37.2		100	811
Primary income from skilled labor (%)	8.6	28.1		100	811

Note: Only estimation sample households included in above statistics

Table S2: Regression output for all models.

	(1) Fishing participation	(2) Fishing effort in past 7 days (person-days)	(3) Used >50% active fishing gear (past 7 days)	(4) (ln) Total fish caught in past 7 days (kg)	(5) (ln) Total fish caught in past 7 days (kg)
Air temperature 1 month ago, centered at 28 C	-0.0457***	-0.224	0.0263	-0.334***	-0.104**
	(0.0173)	(0.146)	(0.0225)	(0.0672)	(0.0475)
Air temperature 1 month ago (squared)	-0.0102**	-0.0273	0.00612	-0.0721***	-0.0234**
	(0.00406)	(0.0350)	(0.00545)	(0.0157)	(0.0111)
Air temperature 2 months ago, centered at 28 C	-0.0159	0.191	-0.0241	0.329***	0.223***
	(0.0193)	(0.177)	(0.0236)	(0.0772)	(0.0541)
Air temperature two months ago (squared)	-0.000544	-0.0211	0.00399	0.0604***	0.0454***
	(0.00299)	(0.0263)	(0.00375)	(0.0119)	(0.00860)
Rainfall in previous month	0.526	18.72	-1.469	29.61***	21.30***
	(1.333)	(12.56)	(1.763)	(6.518)	(4.718)
Rainfall in previous month (squared)	-3.942	-66.06	1.574	-200.8***	-157.0***
	(6.504)	(62.32)	(8.886)	(32.17)	(23.21)
Rainfall two months previous	3.203***	35.66***	-6.756***	0.189	-14.66***
	(0.814)	(7.076)	(1.146)	(3.396)	(2.432)
Rainfall two months previous (squared)	-10.73***	-115.9***	22.87***	1.627	62.88***
	(3.108)	(28.38)	(4.536)	(14.13)	(10.01)
March	-0.0244	1.825***	-0.249***	0.312	-0.162
	(0.0598)	(0.533)	(0.0784)	(0.243)	(0.173)
May	0.0611	0.584	-0.127*	-1.133***	-1.373***
	(0.0528)	(0.470)	(0.0709)	(0.220)	(0.155)
July	0.0190	-1.022*	0.0824	-1.709***	-1.435***
	(0.0689)	(0.587)	(0.0899)	(0.313)	(0.227)
September	-0.00704	-0.647	-0.0384	-0.272	-0.274
	(0.0798)	(0.682)	(0.103)	(0.351)	(0.253)
November	-0.0145	-0.246	0.0457	0.0260	0.204
	(0.0787)	(0.688)	(0.101)	(0.357)	(0.258)
(ln) Fish catch two months previous				0.234***	0.128***
				(0.0202)	(0.0152)
Household fished in past 7 days					6.727
					(66.20)
Time spent fishing in past 7 days (person-days)					0.0879***
					(0.00482)
Used >50% active fishing gear (past 7 days)					0.332***
					(0.0354)
Flooding: Share of CFR flooded					-0.257
					(0.211)
Within-household means (2012-2015)					
Household size				-0.000315	-0.00908
				(0.0163)	(0.0139)
Share of household members <16 or >65				0.114	0.0789
				(0.365)	(0.315)
Maximum household educational attainment				0.0871*	0.0670*
				(0.0445)	(0.0376)
Household amenities index				-0.0247	-0.0225

				(0.0308)	(0.0257)
Livelihood asset index				0.0208	0.0397**
				(0.0230)	(0.0193)
Owns Buffalo				0.109	0.0817
				(0.0954)	(0.0800)
Owns Chicken				0.123	0.147*
				(0.101)	(0.0829)
Owns Cow				0.0305	0.0162
				(0.0688)	(0.0571)
Owns Duck				-0.0458	-0.0166
				(0.0686)	(0.0578)
Owns Pig				-0.0331	-0.0693
				(0.0741)	(0.0625)
Primary household income from wage labor (%)				-0.104	-0.103
				(0.139)	(0.120)
Primary household income from fishing (%)				0.0219	0.0420
				(0.187)	(0.157)
Primary household income from farming (%)				0.0509	-0.0582
				(0.128)	(0.108)
Primary household income from skilled labor (%)				-0.0801	-0.174
				(0.161)	(0.136)
Landholdings (Ha)				0.0374	0.0166
				(0.0242)	(0.0201)
Flooded landholdings (Ha)				-0.0857***	-0.0539**
				(0.0313)	(0.0263)
Months land is flooded				0.0156	0.0466
				(0.0630)	(0.0517)
Experienced a health shock				-0.0315	-0.0669
				(0.0652)	(0.0542)
Experienced an asset shock				0.00833	0.0737
				(0.0964)	(0.0829)
Experienced a crop-related shock				0.0597	0.128*
				(0.0931)	(0.0780)
Fishing effort (person-days)				0.298***	0.0596***
				(0.0166)	(0.0143)
Share of fishing gear used that is active (past 7 days)				1.007***	-0.273**
				(0.139)	(0.119)
CFR Fixed Effects	Yes	Yes	Yes	Yes	Yes
Household Fixed Effects	Yes	Yes	Yes	No	No
Constant	0.803***	3.039***	0.953***	-1.374***	-5.680
	(0.0393)	(0.345)	(0.0533)	(0.319)	(66.20)
Observations	7,200	4,892	4,447	6,291	6,291
R-squared	0.313	0.287	0.371		
Number of hhid				414	414

Robust standard errors clustered at the CFR level. *** p<0.01, ** p<0.05, * p<0.1. Reference month is February.

Table S3: Relationship between baseline household characteristics and panel attrition.

	(1)	(2)	(3)
	Linear Probability Model	Logistic	Probit
March	0.0118	0.242	0.100
	(0.0124)	(0.186)	(0.0935)
May	0.0211*	0.404**	0.183**
	(0.0124)	(0.181)	(0.0915)
July	0.0937***	1.269***	0.648***
	(0.0124)	(0.164)	(0.0841)
September	0.0195	0.376**	0.190**
	(0.0124)	(0.182)	(0.0911)
November	0.321***	2.727***	1.522***
	(0.0124)	(0.155)	(0.0790)
Household size	-0.00330	-0.0333	-0.0185
	(0.00250)	(0.0274)	(0.0150)
Share of household members <=15 or >=65	-0.0543	-0.597	-0.348
	(0.0573)	(0.643)	(0.350)
Maximum educational attainment by any household member	-0.00600	-0.0746	-0.0410
	(0.00627)	(0.0717)	(0.0389)
Household amenities index	0.00377	0.0365	0.0189
	(0.00479)	(0.0529)	(0.0290)
Livelihood asset index	-0.00341	-0.0410	-0.0220
	(0.00283)	(0.0338)	(0.0181)
Owns buffalo	0.00265	0.0396	0.0192
	(0.0122)	(0.141)	(0.0757)
Owns chicken	-0.00555	-0.0351	-0.0152
	(0.0142)	(0.160)	(0.0870)
Owns cow	3.08e-05	0.0147	0.00137
	(0.00911)	(0.1000)	(0.0546)
Owns duck	-0.0113	-0.137	-0.0798
	(0.00868)	(0.100)	(0.0544)
Owns pig	-0.00422	-0.0414	-0.0282
	(0.00933)	(0.111)	(0.0597)
Primary household income is from wage labor	-0.00628	-0.0713	-0.0255
	(0.0196)	(0.230)	(0.125)
Primary household income is from fishing sector	-0.00115	-0.0183	-0.00354
	(0.0243)	(0.278)	(0.151)
Primary household income is from farming sector (excl. wage labor)	0.00341	0.0257	0.0207
	(0.0170)	(0.193)	(0.106)
Primary household income is from skilled/salaried labor	-0.0176	-0.239	-0.108
	(0.0290)	(0.338)	(0.181)
Total area of land: paddy, chamka^, home garden, fallow (Ha)	0.00349	0.0332	0.0174
	(0.00287)	(0.0320)	(0.0172)
Total area of seasonally flooded land: paddy, chamka^, fallow (Ha)	-0.00440	-0.0373	-0.0175
	(0.00420)	(0.0476)	(0.0257)
Mean months flooded across all land types	0.0136	0.111	0.0620
	(0.00867)	(0.0885)	(0.0490)
Household experienced death, illness or health shock	-0.000236	0.00105	0.00406
	(0.00795)	(0.0894)	(0.0485)
Household experienced asset loss	0.0171	0.207*	0.109
	(0.0105)	(0.123)	(0.0671)
Household experienced crop loss	0.00830	0.0656	0.0446
	(0.0102)	(0.109)	(0.0592)

CFR Fixed Effect	Yes	Yes	Yes
Constant	0.263***	-1.365***	-0.775***
	(0.0408)	(0.419)	(0.229)
Observations	7,110	7,110	7,110
R-squared	0.185		

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Month reference category is February.
^Chamka refers to a diversified agricultural system involving simultaneous production of rice and vegetables on one plot of land.