To estimate the potential for reserves to increase fish richness, density, and biomass, we surveyed 23 paired reserve and non-reserve locations during a single dry season between December 2017 and March 2018. Individual reserves were selected to represent a range in age, size, isolation, size of nearest village, stream order (1st – 5th), and network position. Non-reserve surveys were conducted downstream of reservesat all locations except one, to which there was only upstream access. Where stream segments were sufficiently narrow and shallow (19 of 23 sites), two researchers wearing dive masks and snorkels censused fish by swimming/crawling along 50 m transects from downstream to upstream and enumerating all fish within a 2-meter band centered on each observer.

In the 4 large mainstem sites (mean width > 20 m), one researcher surveyed 50-meter-long reaches by systematically counting fish while moving from bank to bank in an upstream direction. Each survey lasted 20 minutes, which approximated the average survey duration for shallow reaches. Additionally, to account for benthic or cryptic species in shallow water (< 80 cm) at these 4 sites, a second researcher conducted 4 lateral belt transects at each survey reach. Belt transects were demarcated with a chain placed on the substrate perpendicular to flow. To allow disturbance effects to dissipate, we waited 15 min after chain placement to begin surveys, then enumerated all fish within a 2 m band centered on the chain for up to 20 m of stream width. For each reserve/non-reserve site, a total of 4 surveys were conducted at two reserve and two non-reserve reaches.

To estimate site-specific biomass, each researcher estimated fish total lengths during each transect. When fewer than 10 individuals of a species were observed, lengths were estimated for each individual. For species with > 10 observations in a survey, researchers estimated 10 lengths representing the size distribution observed for that survey. Estimated lengths were cross-validated between researchers in the field using submerged measuring tapes as reference. We estimated site-specific biomass for reserve and non-reserve fish by evaluating the mean observed length for each site with a length–weight relationship developed from previous work in the Ngao River (Koning unpublished data) and supplemented with literature values. For the 4 large mainstem sites, we combined density estimates using count-weighted averages of both survey techniques for each survey location.

At each survey site we measured key aspects of reach habitats that could affect fish communities, then tested for habitat differences within (reserve vs. non-reserve) and among areas. At each transect location, we measured depth and substrate composition at 6 lateral transects corresponding with 0, 10, 20, 30, 40, and 50 m marks. Depth and substrate type were recorded at 10 evenly spaced locations across the stream width. Substrate types followed the Wentworth classification: silt (<62.5 *µ*m); sand (62.5 *µ*m–2 mm); pea gravel (2–8 mm); gravel (8–32 mm); pebble (32–64 mm); cobble (64–256 mm); boulder (> 256 mm); bedrock (>4000 cm). For mainstem sites where both snorkel and benthic counts were employed, we conducted 5 lateral transects from the chain counts and snorkel surveys for a total of 10 transects and 100 benthic point samples. To calculate median particle size at each site, we used the median size of each particle class for each observation, then calculated the median across all 60 point-samples. We also measured discharge at each reserve/non-reserve location to account for the effect of segment size on reserve outcomes using standard methods.

From these measurements we calculated mean depth, maximum depth, mean width, median substrate particle size, and three metrics of substrate diversity: Simpson’s diversity index of substrate types, and the loading scores for the first two axes of a principle component analysis of substrate types by site. We tested for differences in each habitat variable using mixed effects models with reserve protection as a fixed categorical variable and each reserve/non-reserve location as a random term. Across all variables, reserve habitats did not differ from non-reserves for our study transects (p > 0.05). Based on these results, we ruled out any potential contribution of habitat differences in our analysis of reserve/non-reserve effects.

*Reserve features*

To quantify those reserves features we considered potentially important for predicting reserve success, we either made direct field measurements, extracted data from digitized maps, or interviewed community members at each survey site. River size quantified as discharge (m3 sec-1) was measured in the field using standard methods. Reserve size was quantified using field measurements of river width, multiplied by reserve length determined as river length between upstream and downstream boundaries.

To evaluate spatial metrics of the reserve network, we digitized the Mae Ngao River network from Google Earth satellite imagery and mapped all potential stream courses regardless of the presence of visible surface water, as no existing hydrological maps were at sufficient resolution for our analysis. We used field observations to constrain the digitized stream network based on the presence of water in 20 tributaries during the height of dry season (early May 2016). Using our digital river network and a hydrologically conditioned digital elevation model of 90-m resolution, we extracted the upstream catchment area and average slope for each tributary, then estimated an upstream area threshold that best separated wet from dry locations. We estimated an upstream extent of 1.02 km2 to best delineate perennial flows (ROC-AUC= 0.89, n=20) and trimmed our digitized stream network accordingly to a total length of 827 km. We also delineated all roads and villages within the Ngao River Valley from satellite imagery, which allowed us to calculate Euclidean distances between each reserve and the nearest road and the nearest village as metrics of reserve isolation.

Considering these reserves as a network, we calculated three additional parameters from our digitized stream network that could influence ecological responses: river distance to the nearest reserve, river distance to mainstem confluence, and betweenness centrality. Distances among reserves and to the river confluence were calculated from reserve boundaries and measured along the river course. Betweenness centrality is an index used in network analysis that describes the relative importance of each node (*i.e.,* reserve) to overall connectivity within the network. Specifically, the standardized betweenness centrality for a node, *i*, is calculated as:

BCi = (2 × Σj<k gjk (i)/gjk)/((N – 1)(N – 2))

where i ≠ j ≠ k, gjk is the number of equally shortest paths between nodes j and k, gjk (i) is the number of these paths which include node i, and the denominator represents twice the total number of node pairs without node i.

We determined the reserve age (numbers of years since establishment), enforcement (explicit penalty for illegal harvest; yes or no), and village size (number of households in sponsoring village) from over 35 interviews with village leaders and community members.