Using maps to communicate sea-level rise can undermine concern among risk-exposed populations

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May 7, 2024

Abstract

Sea-level rise caused by climate change poses enormous social and economic costs; yet, governments and coastal residents are still not taking the mitigation and adaptation steps necessary to protect their communities and property. In response, advocates have attempted to raise threat salience by disseminating maps of projected sea-level rise. We test the efficacy of this ubiquitous communication tool using a high spatial-resolution survey experiment that exposes households on either side of projected sea-level rise boundaries to individually-tailored risk maps. We find this common risk communication approach has the unintended consequence of *reducing* concern about future sea-level rise, even among households projected to experience flooding this century. By contrast, direct communications about impacts on traffic patterns increase concern about future climate impacts among coastal residents. Map-based risk information does increase support for collective spending on climate adaptation, but it does not increase individual intentions to contribute. Our results demonstrate the importance of empirically testing messaging campaigns for climate adaptation.

Climate change-induced sea-level rise (SLR) poses an existential threat to coastal communities across the planet and is projected to affect hundreds of millions of people in coastal areas by 2100 (1; 2). Risks posed by SLR include erosion, contamination of fresh water, and flooding, but the most extreme impacts of SLR come during extreme weather events, when increased storm surge can cause severe flooding that undermines infrastructure within a matter of hours or even minutes in low-lying areas. The gradual effect that climate change will have on coastal sea levels and the infrequent nature of extreme storms, however, lead many individuals to underestimate the likelihood, severity, and consequences of this threat. In the United States, public concern about SLR remains low, even in shoreline communities, where climate-related risks are still understood by many as spatially and psychologically distant (3; 4). Further, individual sea-level rise risk perceptions are often unrelated to either climate science acceptance (5; 6) or assessed flooding risks (7; 6). Even those who understand the risks of flooding believe government rather than individuals should be responsible for risk management and perceive themselves as being at low risk (8). While personal experience with storms and flooding events offers one potential proxy for the long-term welfare consequences of SLR, the effect of these experiences remains a topic of active debate. Some studies do find that experience affects climate attitudes and adaptation intentions (9; 10; 11; 12). However, other work finds that flood experiences have limited or no influence on climate attitudes or risk perceptions (13; 7). Despite these mixed results, it is clear that the framing of flood risk information can have a large effect on perceived risk (14).

Government officials and climate advocates have sought to address the gap between public risk perceptions and long-term threats through communication campaigns that raise the salience of future sea-level rise threats. Often, this has involved providing residents with individualized information about local flooding through maps. Such maps typically provide a birds-eye view of projected flood zones that allow the identification of individual homes. These efforts presume that, even if climate hazards have not yet been realized, concrete information about future hazard impacts can increase public support for necessary mitigation policies and adaptation investments. By reducing the "psychological distance" of a threat by providing specific, personally relevant information on projected harms, risk communications might induce more "experiential" processing of information that is faster and potentially more powerful than "analytical" processing in risk assessment and decision-making (15). In practice, increased risk salience in the climate domain has, in some limited circumstances, induced pro-environment individual and political behaviors (16). Yet, these effects are modest and tend to be localized to immediately impacted communities. For instance, the effect of wildfire exposure on climate voting is limited to more Democratic areas becomes insignificant beyond 15 km from the wildfire boundary (17). Moreover, reducing the psychological distance of climate risks has variable effects. Distance-reducing interventions shift the cognitive and affective processes that individuals use to make sense of climate change - but in ways that can leave overall issue engagement unchanged (18; 19). Thus, the effects of efforts to increase the salience of climate risks remains, ultimately, an empirical question.

In this article, we use two high spatial-resolution survey experiments to test the effect of a common visual risk communication device on household sea-level rise concerns in four US coastal areas with significant SLR risk exposure (San Francisco Bay Area, CA; Palm Beach County, FL; Norfolk, VA; and Ocean County, NJ; see Materials and Methods for details on sampling strategy and experimental protocols). We use an address-level mail-to-web sampling approach that allows us to identify respondents in the immediate vicinity of projected SLR boundaries and present them with customized treatments that highlight SLR impacts centered directly on respondents' own homes. In one experiment, we randomly assign all survey respondents to receive an individually tailored risk map (treatment condition) or no map (control condition). In a second experiment on our California sample only, we randomly assign individuals to receive information about the effect of SLR on future commute times in their neighborhood (treatment condition) or no commute information (control condition). By exploiting address-level differences in projected SLR exposure, we can distinguish between the effect of information in neighborhoods that are projected to be impacted by flooding in a changed future climate versus immediately adjacent unflooded neighborhoods. Our approach is an advance over existing research, which has relied on traditional survey providers that typically cannot provide geographic resolution below the zip code level. As a result, we are able to make comparisons across both our randomized information treatment and control groups, and across a geographic risk discontinuity (i.e., the flood zone boundary).

Contrary to expectations that sea-level rise risk maps will promote public concern, we find evidence that SLR risk maps generally *reduce* concern about future risks. Surprisingly, SLR risk perceptions are lower even among households whose properties are projected to flood by 2100. In a second experiment, we randomly assigned one set of our respondents to receive information about projected commute time increases in their neighborhood as a result of SLR through 2100. Here, in contrast to our map experiment, we find that traffic impact messaging *increased* concern among all coastal residents.

Our results highlight how untested climate communication tools can have unexpected effects that undermine advocates' intentions. The results also speak to the urgent need to empirically test public climate communication campaigns to ensure that targeted interventions shape behavioral intentions and risk perceptions in intended ways.

Results

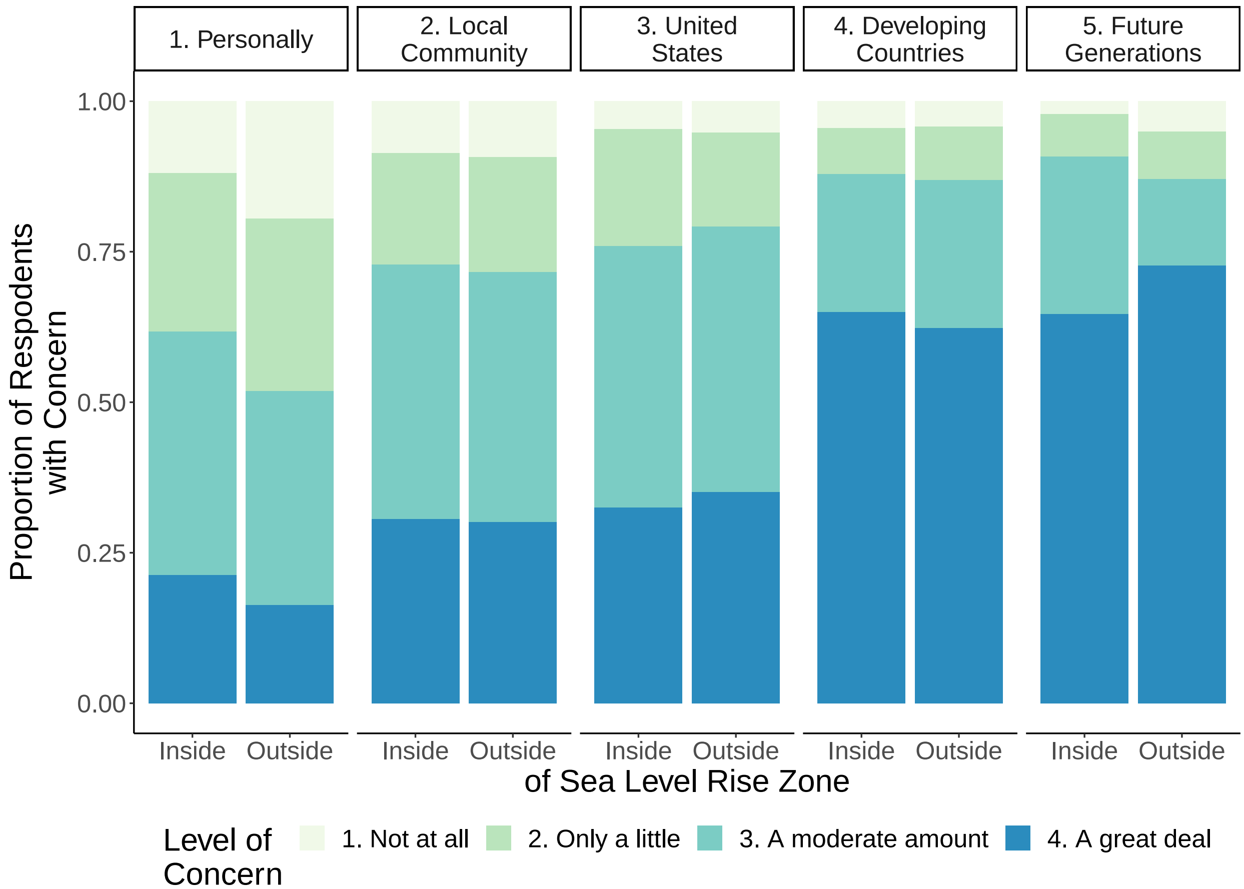

Figure 1—**Respondents believe sea-level rise is a threat to others, not themselves – even when they live in a projected sea-level rise zone**. Figure shows proportion of control condition respondents who indicated concern for each reference group across all study sites (CA, NJ, VA, FL). Respondents whose addresses are inside vs. outside projected sea-level rise zones report statistically similar levels of personal and distant concern (SI Table A1).

We find that even the Americans who would be the most impacted by SLR have low levels of concern about this existential risk. Consistent with previous work (c.f. 3), even respondents whose properties are vulnerable to projected SLR believe that SLR is more a threat to other people than it is to themselves. Fig. 1 shows SLR concern among control respondents who were not treated with SLR maps in areas projected to flood by 2100 (left) and the adjacent areas that are not projected to flood by 2100 (right). Concern is increasing in both spatial (beyond one's community) and temporal (future generations) distance. Despite these respondents living in locations that face significant SLR risk exposure, only about half of respondents believed that SLR posed a moderate amount or a great deal of risk. Even among respondents whose properties are projected to flood, respondents were more concerned about the impacts of SLR for others in their community than for themselves and believed SLR risks would be more severe elsewhere in the United States, in developing countries, and for future generations. Respondents whose addresses are inside and outside of the SLR projection zones have perceptions of personal and community risk exposure that are statistically indistinguishable.[1]

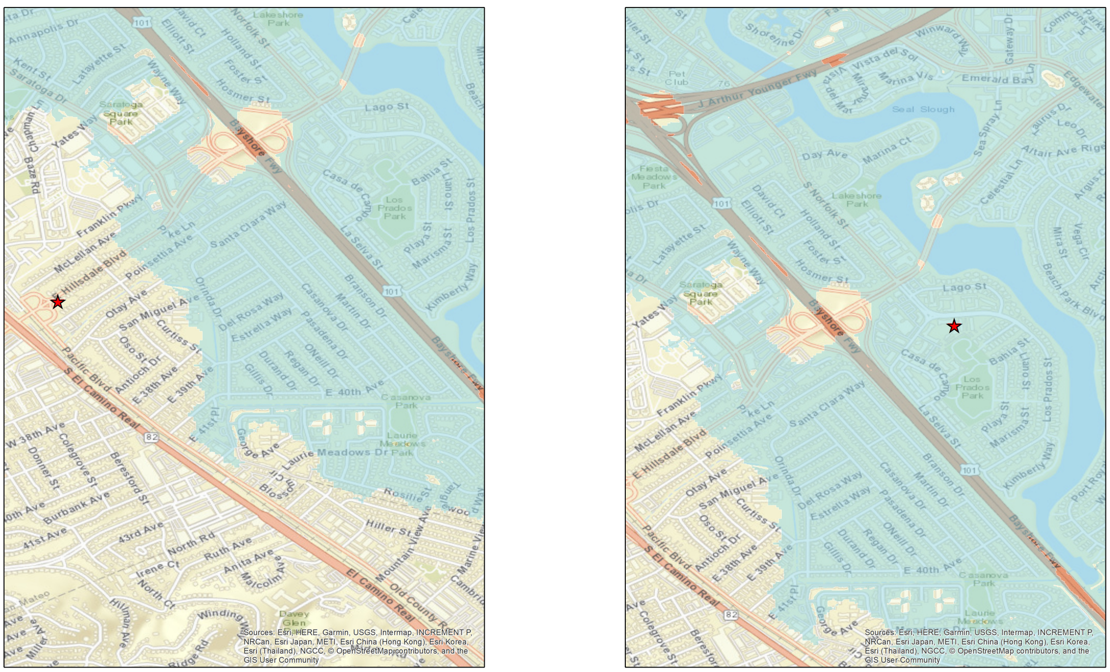

Figure 2—**Example maps shown to treated respondents just outside (top) or just inside (bottom) the projected sea-level rise boundary zone**. The red star (shown to respondents) visualized the location of each respondent's home address. Control group respondents received no map.

Can increasing the salience of future climate risks reshape respondent concern about future welfare? We test this ubiqituous risk communication approach by randomly presenting individuals with individually-tailored census-tract level maps of projected flooding around their home, highlighting each respondent's home in relation to projected flooding boundaries (Fig 2.) Respondents

[1] For the local community, US, developing countries, and future generations DVs, p-values for a t-test for a difference in means and for a Kolmogorov–Smirnov test for difference in distribution are all $p > 0.1$. For the sense of personal risk dependent variable, there is a difference of means of 0.22 ($p = 0.01$), but no significant difference in the distribution (KS-test $p = 0.14$).

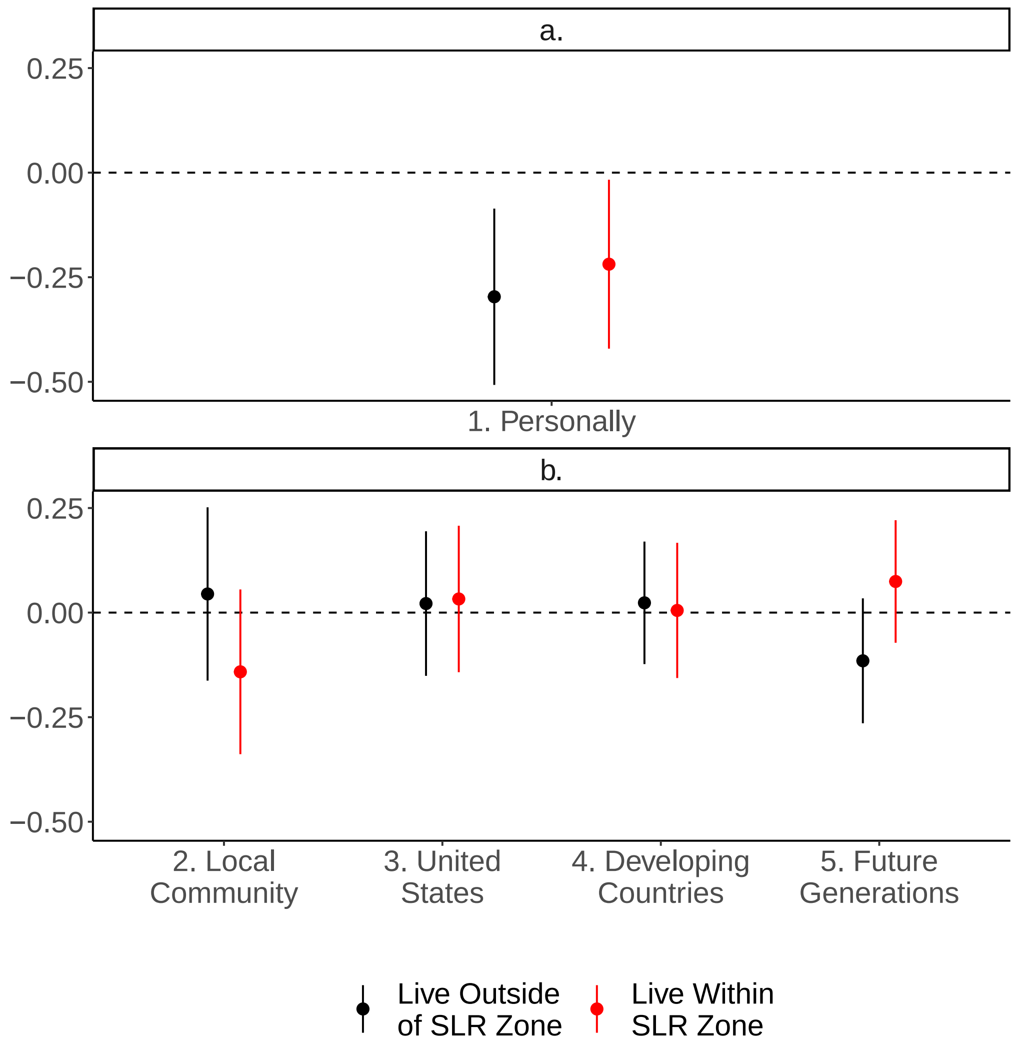

Figure 3—**Sea-level rise maps reduce perceptions that sea-level rise will harm respondents, regardless of whether home is located inside or outside the projected flood zone**. Figure shows treatment effects of being shown an individually-tailored sea-level rise map, including an indicator for the respondent's house, on the threat by sea-level rise to the respondent personally (pane A) or more distant groups of people (pane B). Points show regression coefficient and line segments show 95% confidence intervals, computed with HC1 standard errors. All regressions contain fixed effects for location (CA, FL, NJ, VA). Concern is measured on a 4-point scale. Respondents whose addresses are projected to experience flooding under a 1m sea-level rise scenario are labeled as "Live Within SLR Zone". Respondents whose addresses are projected to remain outside the sea-level rise zone under a 1m sea-level rise scenario are listed as: "Live Outside of SLR Zone". n = 737.

in the control group received no map. Among treatment units, 98% of respondents indicated that their home was correctly marked on their risk exposure map, including 98% of respondents whose houses were projected to flood. We disaggregate our sample between individuals living inside and outside projected SLR boundaries (Fig. 3). Contrary to policymaking goals and stakeholder expectations, maps experimentally *reduced* respondent perceptions that SLR would harm them. Among individuals located just outside projected SLR boundaries, map exposure decreased perceived personal harm by 0.50 points on a 4-point scale (equivalent to 0.58 standard deviations, $p < 0.01$). This effect, consistent with (3), might be expected when maps show a respondents' property just outside of direct flooding danger. However, we also find a similar reduction in personal concern among respondents whose homes are projected to experience flooding in the future. Among these respondents, whose maps explicitly marked their addresses with red stars within the shaded blue SLR zone, we still find a similar treatment with projected flood impacts lowering perceived levels of personal harm by 0.33 on a 4-point scale (0.37 SD, $p = 0.03$). While respondents inside the SLR zones had unchanged perceptions of local community risk as a result of flood impacts, respondents living outside the SLR zone also reported *decreased* perceptions that SLR would impact their local community, even as these respondents saw maps that showed homes in their immediate community or neighborhood flooded. Maps did not change perceptions of harm to more distant groups or future generations.[2] Although we report results pooled across all four study sites here, these effects hold in the four study sites individually and are directionally consistent (SI Section 1). The effects are also robust to covariate adjustment and the use of ordered logit instead of OLS (SI Section 2).

We examine these spatial effects in a more granular fashion in Fig. 4, where we bin respondents by 50 m of distance from the projected SLR boundary. Respondents to the left of the vertical dashed line live in addresses that are projected to flood and received maps indicating their property would flood. Even individuals living 200 meters within the flood zone significantly reduced (b=-0.64, p=0.01) their risk perceptions as a result of map exposure.

Despite the backlash in respondent risk perceptions, we still find that map exposure increases respondent support for some adaptation policies (Fig. 5). We consider four policy measures: limiting how development occurs in flood-prone areas; increasing the number of residents and

[2]The effect of the map treatment on concern for future generations is the only substantial positive effect at 0.09, however, the effect is not significant at $p = 0.16$. Due to the long time frame of the SLR projections, respondents who are planning to pass along their home may be concerned about their children's welfare.

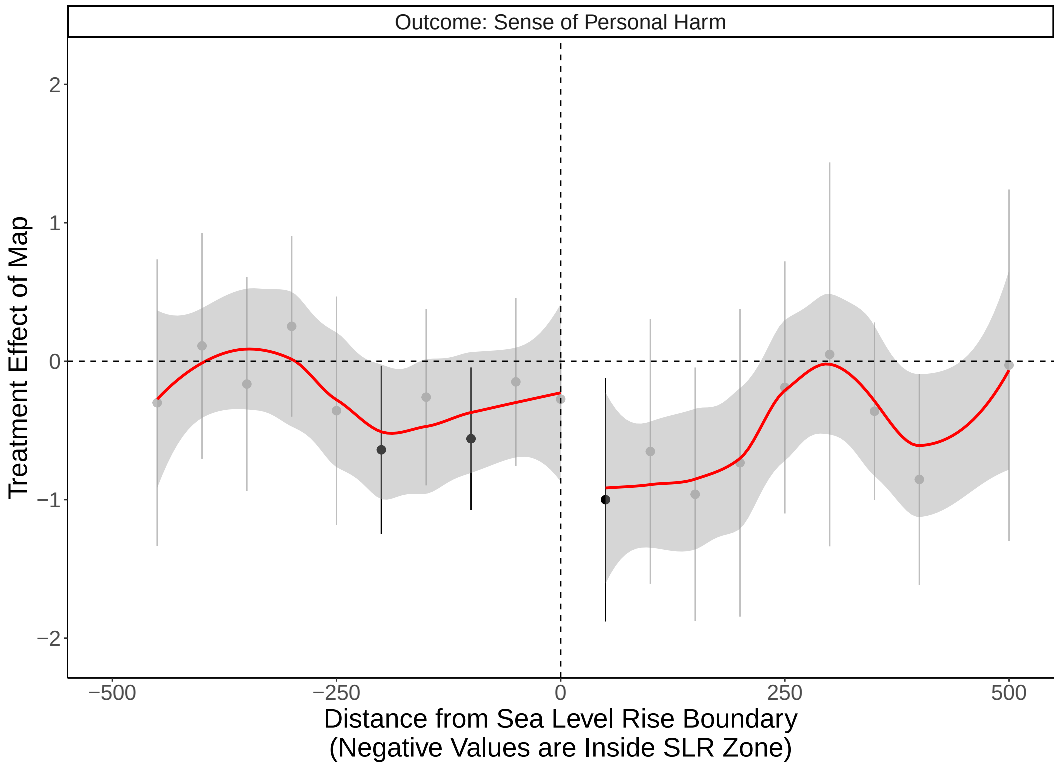

Figure 4—**Effect of map treatment does not vary significantly around sea-level rise cutpoint.** Figure shows effect of map treatment on personal concern, with separate regressions estimated at 50 m intervals, pooled across CA, NJ, VA and FL samples. Bins with less than 15 observations are dropped. Points show regression coefficient and line segments show 95% confidence intervals, computed with HC1 standard errors. Black bars show coefficient estimates that are significant at the $p < 0.05$ level. Red line is a LOESS curve fit to the regression estimates and shaded grey areas show 95% confidence interval around curve. n = 899.

business owners that invest in flood insurance, regardless of the property's location relative to a floodplain; removing existing structures from flood-prone areas; and constructing small flood control structures intended to prevent flood damage. In general, there is robust support for all of these policies; mean support for all policies on a 7-point scale is above the mid-point of the scale; the median response for increasing flood insurance and removing structures from flood zones is "Neither agree nor disagree" and for limiting development in flood zones and building flood controls is "Agree." In the control condition, there are significant differences between respondents who live within and outside of SLR zones for limiting development in flood zones ($b = 0.31$, $p < 0.01$) and for removing structures from flood zones ($b = 0.52$, $p < 0.01$).

We find that map exposure shapes some - but not all - policy preferences as a condition of an individual's projected exposure to flooding. Respondents whose homes are not projected to flood have unchanged preferences across all measures, despite their reduced personal concern. By contrast, respondents who received information that their own home would flood became significantly more likely to support collective management of SLR through increased flood insurance and support for more flood control infrastructure. However, receipt of information about individual risk exposure did not make respondents more likely to support policies that restrict behaviors (limiting development in flood zones and removing structures from flood zones). These results are consistent with patterns of public preferences for compensatory policies reported in (20).

If high-resolution spatial maps of risk exposure do not significantly increase respondent concern about SLR risk, how might policymakers better increase support for adaptive behaviors? We test a second approach to increasing SLR risk salience in a separate survey experiment on our California survey sample. Here, we randomly assign half of our Californian experimental sample to receive information about the increased average commute times in their census tract associated with a 1m SLR scenario by 2100. While this treatment also appeals to an individual's property, it presents information about a community-level infrastructure and economic activity threat. Fig. 6 shows the effect of the traffic treatment on levels of SLR concern. For a direct comparison, SI Section 4 shows results for the map experiment and traffic experiment on the same California sample that received both treatments.

Unlike the map treatment, providing information about SLR's effect on traffic commutes increases perceived harms both personally and for distant groups, even though the experiment still

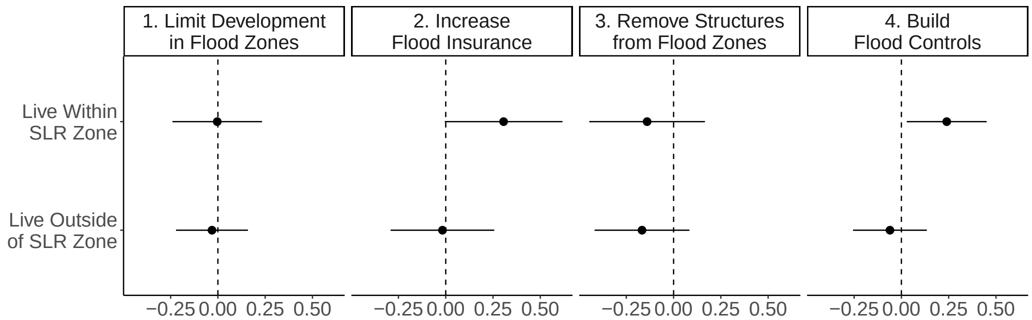

Figure 5—**Sea-level rise maps increase support for select adaptation policies among respondents projected to experience flooding**. Figure shows treatment effects of being shown an individually-tailored sea-level rise map, including an indicator for the respondent's house, on support for various policies. Points show regression coefficient and line segments show 95% confidence intervals, computed with HC1 standard errors. All regressions contain fixed effects for location (CA, FL, NJ, VA). Policy support is measured on a 7-point scale. Respondents whose addresses are projected experience flooding under a 1 m sea-level rise scenario are labeled as "Live Inside SLR Zone". Respondents whose addresses are projected to remain outside the sea-level rise zone under a 1 m sea-level rise scenario are listed as: "Live Outside of SLR Zone". n = 1,242.

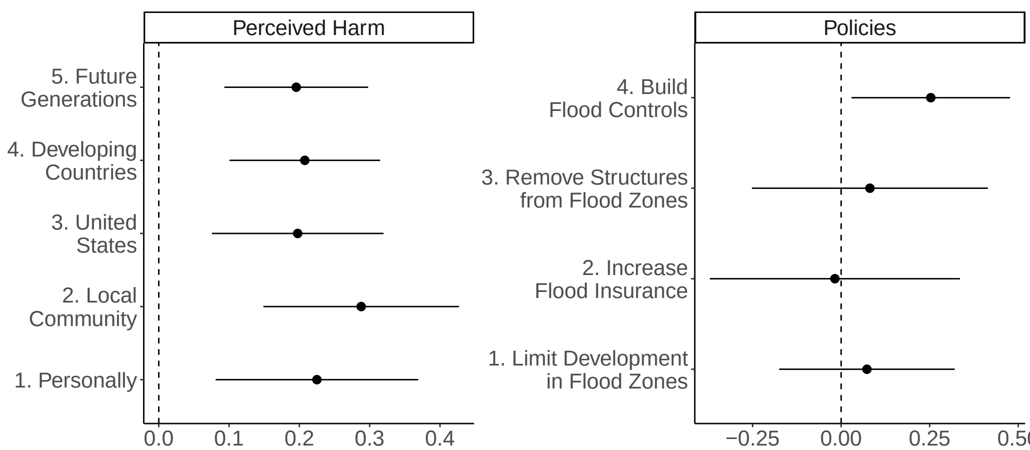

Figure 6—**Information about projected traffic delays due to sea-level rise increases perceived personal risks, perceived risk to distant groups, and support for flood controls**. Left panel shows treatment effects of projected 1 minute increase in census tract-level traffic due to SLR for 5 separate regressions of traffic treatment on levels of perceived harm (4-point scale). Right panel shows treatment effects of projected 1 minute increase in census tract-level traffic due to SLR for 4 separate regressions of policies to address SLR (7-point scale). Points show regression coefficient and line segments show 95% confidence intervals, computed with HC1 standard errors. Regressions control for whether respondents received map treatment. Sample includes only California respondents. n = 640.

presents information about future risks anchored around the same date (2100). Regression coefficients plotted in Fig. 6 show that being shown information about traffic commutes increases perceived harms from SLR by 0.23 points on a 4-point scale (0.22 standard deviations, $p < 0.01$). We find roughly similar effects on perceived harms to the respondent's local community, the US as a whole, developing countries, and future generations. The traffic treatment presents information about average traffic commutes for their broader census tract and primes individuals to think about the effects of SLR on transportation and infrastructure risks, not just risks to their individual property. Like the map treatment, the traffic treatment shifts respondents' views on policy remedies for SLR, but only for building flood controls (b = 0.215, p = 0.01). Unlike the map treatments, there are no effects on policy to increase the takeup of flood insurance.

As an alternative outcome measure, we also investigate the effects of both the map and traffic treatments on willingness to pay (WTP) for four other climatea adaptation policies. By randomizing the cost of policies across respondents, we can construct demand curves and compare the intercepts and slopes across the treatment conditions. Looking across four distinct policies—coastal restoration, preventing the impacts of SLR, buying out flood-prone properties, and building flood control infrastructure—we find no difference in the slope of the demand curves (SI Section 5). While the intercepts or base levels of support for these policies vary, the indistinguishable slopes indicate that these preferences are similarly responsive to price. When respondents are presented with either a map of their home near the SLR boundary or information about increased commute times, they do not appear to become more or less price-sensitive when evaluating policies. These null findings suggest that common methods of sea-level rise risk communication may not shift preferences for costly, ameliorative policies in desired ways.

Discussion

In this paper, we test the effect of a common climate risk communication strategy using a high spatial-resolution survey experiment in four US coastal communities. Unlike previous work that has relied on regional samples, we sample addresses immediately around projected SLR boundaries using a spatially granular mail-to-web survey technique. Our experimental results highlight how untested climate communication tools can have unexpected and sometimes counterproductive effects. Contrary to advocates' expectations, providing risk-exposed coastal residents with maps of projected sea-level rise can sometimes *reduce* individual concern. By contrast, an alternative type of risk communication that emphasizes infrastructure disruptions in the form of increased commute times increases concern among all coastal residents.

One potential explanation for this surprising result is that uncertainty in the estimates is not well communicated by SLR maps. Uncertainty has been shown to increase public acceptance of scientific predictions in some cases (21). We ask respondents about the credibility of the treatments in the experiment, and while 81% find the treatment somewhat or very credible, some of the results may be driven by a backfire effect among those who did not. Of the 19% who did not find the map treatment credible, only 37% were shown their home inside the SLR zone, indicating that it is not necessarily disbelief in the calculations behind the treatment, but the idea of SLR or risk projections itself. A related concern, that respondents could have rushed past the map without studying it closely and identifying their home, also does not appear to explain a lack of communication; the median time spent on the treatment page was 33 seconds.

Another potential explanation for the negative effects of SLR maps on risk perception is that the treatment is backfiring among partisans who do not believe in climate-change induced SLR. Presenting factual information that contradicts priors or partisan beliefs has been shown to backfire and increase beliefs in the opposite direction (22), although this effect is rare across the issue space (23). Our experiment differs from studies of such backfire, which frequently present false information then seeks to correct (we present just factual information) and measure beliefs (we measure concern and policy support). Examining heterogeneous effects among partisans and by belief in global warming, we see no evidence consistent with this explanation. SI Section 6 shows a statistically significant decrease in perception of personal risk from the map treatment among Democrats, Republicans, and Independents in our sample. Republicans, however, are more likely to decrease their perception of risk to their local community and other distant groups than Democrats or Independents. And SI Section 7 shows significant decreases in personal concern both among those who believe global warming is caused by humans inside and outside the SLR zone, moreso than those who do not believe in global warming or that it is caused by humans. We interpret this to mean a backfire is unlikely and that those who believe in global warming simply had worse priors about the extent of sea-level rise, leaving more room for the treatment to reduce their concern.

A related possibility is that we observe decreased concern because the map and traffic treatments trigger strong negative emotions. Particularly in the context of climate communications, apocalyptic, loss-framed messages that trigger strong negative emotions like fear and anxiety can be demobilizing (24; 25). However, the map treatments decrease concern but increase policy support, which indicates that the treatment is engaging political commitments over provoking an emotional response. Also, given the high level of credibility that respondents evaluated the treatment with, we do not seem to be provoking a shutdown or denial effect related to emotional backfire.

We also consider subgroup effects among homeowners vs. renters. Renters may have different time horizons in considering risks to local properties, and if the long-term nature of the threat (e.g. by the end of the century) is driving these results, we might expect a differential impact between the two subgroups as renters worry less about location-specific effects into the future. Yet, we show in SI Section 8 that these backlash effects to maps occur for both renters and homeowners. Suggestively, we find some evidence, however, that the traffic experiment is effective on homeowners but not renters (SI Section **??**). More generally, future work could further explore the potential mechanisms underlying this disconnect between treatment intent and outcome. For example, construal theory argues that the psychological mechanisms with which individuals process risk may be conditioned by the distance or abstractness of a threat

Overall, our results speak to the urgent need to empirically test all features of public climate communication campaigns to ensure that targeted interventions are able to shape behavioral intentions and risk perceptions in support of climate adaptation policies (26; 27). Our findings thus have important implications for advocacy and risk communication practices. Our experiments offer a high-resolution test of a commonly-used real world strategy to communicate climate risks. Practitioners, government officials, and activists should consider the limits of individualized communication about SLR as a method to build support for policy. It is in some ways understandable that respondents did not react strongly to the treatment given that the youngest person in our sample will be 99 years old when the SLR portrayed in our individualized maps is projected to occur. Our choice of treatment, designed to maximize external validity by matching existing communications from governments, sacrifices immediacy and therefore presents a conservative test of the psychological mechanisms undergirding reactions to SLR.[3] However, in illustrating the intertem-

[3]Respondents demonstrated high awareness of existing communications when asked about the flood zone that FEMA had assigned to their home. We asked respondents whether they lived in a flood zone and to categorize whether they were in a high risk, moderate risk, or undetermined risk area (72% of the sample was in moderate risk

poral problem posed by climate change, using projections in 2100 makes perfect sense; the effects of these consequences of climate change will be felt primarily by future generations and our failure to find effects on perceived harm for these future generations mean that respondents have already updated to a pessimistic view of their future, or cannot be convinced by this visual communication. Moreover, we found strong results on the commute time experiment despite this experiment having an identical future anchor date of 2100. This emphasizes that our results are not a simple function of discounting future risks, but also of the ways in which individuals understand and process the risk information presented to them.

Further research should examine whether other attitudes, e.g. towards managed retreat, may change in response to similar treatments. In addition, these results suggest that qualitative research may be useful in order to better understand how SLR maps and other major climate communication tools affect public risk perceptions and policy preferences. While our traffic experiment points towards emphasizing the infrastructure effects that climate change will produce, further study is needed in determining which types of collective risks threaten self-interest and shift attitudes. Research could also investigate whether information about depth of flooding induces a difference response than the spatial extent of flood exposure. Above all, our results emphasize the importance of conducting systematic empirical tests to determine and increase the efficacy of important climate risk communications.

Material and Methods

We use a spatially-explicit sampling method to layer a survey experiment on top of a geographic discontinuity to assess the affects of climate communications that pose a threat to individual's self-interest. Unlike existing research, which has relied on traditional survey providers that rarely provide geographic resolution below the ZIP code level, we use an address-level mail-to-web sampling approach that allows us to target respondents in the immediate vicinity of projected SLR boundaries and present them with customized treatments centered on their own homes.

We began with a spatially disaggregated sampling frame to target individuals in coastal com-

flood zones and 27% of the sample was in high risk flood zones). 40% of respondents correctly identified whether they were in high risk or moderate zones, 19% knew that they were in a flood zone but did not know which, 25% of respondents were in a moderate risk zone but did not think they were in a flood zone at all, and 6% were in a high risk zone but believed they were in a moderate zone.

munities who live on either side of projected SLR flood boundaries. We selected four coastal areas in the United States, choosing diverse communities with respect to recent flooding events and rates of belief in climate change, using data from (28). Our four communities were Ocean County (NJ), which was significantly impacted by Superstorm Sandy in 2012 and where belief in anthropogenic climate change (50%) is below the national mean (57%) despite being in a reliably Democratic state; Palm Beach County (FL), which has been impacted by numerous hurricanes and where belief in anthropogenic climate change (58%) is at the national mean, but is part of a largely Republican state; Norfolk (VA), which has not faced storm-based flooding over the past decade and where belief in anthropogenic climate change is at the national average (57%); and, finally, the San Francisco Bay Area, which has not had a flooding event but has very high climate science acceptance and has been the site of previous scholarship on local risk communication strategies (3). Community selection was done in partnership with senior policymakers working in the SLR space who have detailed knowledge about the relative complexity associated with spatial risks in US coastal communities. The four communities sampled, while not representative of all coastal areas in the United States, offer considerable variation across social, political, and economic contexts. At the same time, our survey sampling frame is representative of households within each of these areas. We also sought communities with non-obvious distributions of SLR flooding risks, for instance as a result of barrier peninsulas that exposed houses away from beachfront real estate to SLR risk. By choosing communities with complex SLR risks, we reduced chances that respondents had purchased their house with knowledge of flooding risks.

In each community, we began by identifying the spatial extent of projected flooding under a 1 meter sea level rise scenario. For the East Coast study sites, we utilized mapped flood boundaries for 1 m (3 ft) of SLR from the National Oceanic and Atmospheric Administration (NOAA). These projections use a linear superposition approach that adds SLR onto current water levels and overlays the new water level surface onto an existing elevation map to identify hydrologically connected areas that experience flooding (29). This approach does not account for dynamic interactions between higher sea levels and the local topography or shoreline infrastructure, which could affect the extent and severity of flooding (30; 31). This approach also does not account for storm or tide-based surges. Flood boundaries for the San Francisco Bay Area were based on a dynamic simulation of 1 m (3.3 ft) of SLR obtained from the U.S. Geological Survey's Coastal Storm Modeling System

(CoSMoS). CoSMoS uses downscaled global wind and tide data to define regional wave and water level conditions for future SLR and storm scenarios and accounts for interactions with the existing shorelines (32; 33).

We then overlaid these projections onto building footprints. Using Microsoft Building Footprints for California, Florida, New Jersey, and Virginia, we manually trimmed the data to overlap with the geographic areas of interest for each state and for Florida, New Jersey, and Virginia to match specific areas that are likely to be heavily impacted by SLR. These include the area east of the Garden State Parkway in New Jersey, the area east of Interstate 95 in Florida, and the area north of Interstate 264 in Virginia. In addition to the intersection of the flood projection and the building footprints, we drew a 2-km buffer around the border of each SLR map layer to capture areas that were adjacent to the flood zones but were not flooded themselves. This process yielded two distinct building groups: those inside a SLR zone and those outside (within 2 km) of a SLR zone.

From those areas, we sampled 5,000 non-flooded residential buildings within the 2km buffer zone in each of Florida, New Jersey, and Virginia and 15,000 buildings in California.[4] We extracted geographic centroids for each building and reverse geocoded using Google's reverse geocoding API to yield a complete list of street addresses. In some cases, multiple addresses were returned for a single building, sometimes corresponding to different types of dwelling units. When this occurred, we retained addresses corresponding to "premise" address types, as these correspond to residential units. If more than one premise location was returned for a single centroid, the first premise in the list of premise locations was retained.

In late 2020, we mailed individualized letters to the households in the sample, inviting one resident from each household to participate in an online survey on issues related to coastal life (see SI Section 10 for example recruitment letter). Each letter contained a customized URL so that we could tailor each respondent's survey to their specific address. Respondents who completed our survey received a $5 digital gift card by email that they could redeem at dozens of different online retailers or donate to a charity of their choice. This yielded 1,243 responses across all four sites (737 CA, 178 NJ, 116 FL, 212 VA). The average response rates inside and outside the projected SLR

[4]Buildings located in a flood zone were randomly sampled as well, but only if there were at least as many flooded buildings as there were buildings in the random sample of non-flooded buildings. For instance, in Florida and Virginia, there were fewer than 5,000 flooded buildings in the flooded zone. In both cases, a full census of flooded residential buildings was taken, totaling 2,200 buildings in Florida and 1,300 buildings in Virginia.

boundary are 2.6% and 3.1%, respectively. SI Section 11 shows the demographic characteristics of our survey respondents versus the general population in the census tracts from which they were sampled, to assess non-response bias, and of survey respondents within 250 m of the projected SLR boundary on either side of this boundary, to assess sampling bias. On the issue of sampling bias on observables, we find imbalances on race and ethnicity but otherwise find that levels of education and homeownership are well matched across these boundaries. SI Section 12 shows uniform density in the distribution of complete responses by distance to the projected SLR boundary. Non-response bias, as with many mail-to-internet surveys, is present on our observed characteristics; our sample is significantly whiter, more educated, and more likely to own a home than the general population of the census tracts that we draw our sampling frame from.

In the map experiment, respondents were assigned to a treatment condition of their census tract, showing their address and projected flooding in the surrounding area, or a control condition with no map. The respondent's home was marked with a red star on these custom maps, giving respondents a clear sense of their property's flooding risks from SLR. Fig. 2 shows example maps shown to respondents just inside and just outside the SLR boundary zone. Respondents were shown the following text alongside the map: "This is a map of your local neighborhood. The star represents the approximate location of your home. The transparent blue area represents projected sea level-rise and flooding by the year 2100 if no action is taken to reduce global warming." We do not provide respondents with information on the source of this data, and only provide information on the spatial extent of projected flooding, not the local depth of that flooding.

Households on either side of the flood boundary are similar on many observable characteristics of the families who live there and the built environment, but will have drastically different treatments: those inside the SLR boundary will see their house projected to experience flooding while those outside the boundary will see their house safe from projected SLR. We leverage both the randomization of being shown a map or not from the experiment as well as the comparability of households just inside or just outside the SLR boundary.

Our second experiment, shown only to the California sample, randomly provided individuals with information about a more systemic risk: increases in commute traffic from SLR-affected infrastructure. In addition to causing direct flooding of homes, SLR will also impact critical infrastructure systems like roadways. Disruptions to one link in the road network can cause additional delays for travelers throughout the system (34; 35). To examine how this effect would influence respondents' climate beliefs, we randomly assigned respondents in the San Francisco Bay Area to receive information about the average increase in commute time for their zipcode associated with the same 1m SLR scenario used to draw the individualized flood maps.

These estimates were generated using MATSim, an agent-based traffic assignment model (36). Given a travel plan of commuters and their daily activities and a connected roadway network, the model assigns commuters to specific roadways to complete their trips. The travel plan of commuters is based on real vehicular travel information from Bay Area cell phone users (37). For the 1m SLR scenario, a flood map was overlaid with the road network to determine which roads (links) were inundated and should be "cut." The model then reassigned commuters as needed. SI Section 3 shows the distribution of traffic delays at the census tract level; the median household in the sample was shown a traffic increase of 15 minutes. Respondents saw the following text treatment:

> If we don't take action to reduce global warming, sea level-rise and flooding by the year 2100 will have a big impact on road and highway infrastructure across the San Francisco Bay Area. For example, commute times will get longer in many parts of the Bay Area, even for people whose houses are not directly impacted by flooding. Using a recent traffic forecasting model, we've estimated that flooding will increase the commute time of average person in your neighborhood by [#] minutes every day.

We analyzed the map and traffic experiments as simple randomized experiments, presenting regression coefficients from a regression of the following form:

$$Y_{is} = \alpha_s + \beta T_{is} + \epsilon_{is}$$

where Y_{is} is level of concern or support for policy, T_{is} is an indicator for the map or traffic treatments, which are randomly assigned in the survey, and α_s is a state fixed effect (which controls for site-specific factors in our pooled estimates). We use Huber-White HC1 standard errors which are clustered at the individual level where treatment is assigned. For the map experiment, we ran separate models for those within and outside of the SLR zone and present results as two side-by-side experiments. As a robustness check, and to improve precision, we show covariate-adjusted models in SI Section 5, controlling for self-reported race and ethnicity, gender, homeownership status, party identification, and political ideology. Results are substantively identical. To examine heterogeneous effects across the SLR projection gradient, we also estimate a series of binned regressions at 50 m intervals from the SLR boundary. These regressions are estimated in a similar manner to the side-by-side experiments.

We also examined the effect of Special Flood Hazard Area (SFHA) designation on the responses. SFHAs are zones where the floodplain regulations set through the National Flood Insurance Program (NFIP) are enforced and where the purchase of flood insurance is mandatory. Respondents located in these zones may already have knowledge of flood risks through NFIP requirements, which could influence their responses to our SLR treatments. To test this effect, we overlaid the household locations with SFHA maps from FEMA's Flood Map Service Center and designated each household as within or outside of the SFHA. We then incorporated this in our regression model...

Finally, as a robustness check on the policy-dependent variables, we examine the results of the map and traffic treatments on an across-subjects willingness-to-pay (WTP) experiment. The WTP setup presents a policy option with a randomly varied price tag and uses many respondents' propensity to support the policy to estimate a demand curve for the policy. We randomly vary four different policies (supporting coastal restoration, preventing the impacts of SLR, buying flood-prone properties, and building flood control infrastructure) and seven different prices per year ($1, $2, $5, $10, $20, $50, $100) across respondents. We estimate the demand curves for policies using a linear regression with policy fixed effects. We then compare the slopes of the demand curves across experimental conditions in the map and traffic experiments.

Data Availability Statement

The underlying data used in this article will be deposited in a Harvard Dataverse repository to accompany publication of this article.

Code Availability Statement

The code and replication scripts necessary to generate the figures, tables and analysis reported will also be deposited in a Harvard Dataverse repository to accompany publication of this article.

Ethics Statement

This study was reviewed and approved by the University of California Office of Research as Protocol 15-19-0108. Respondent participation in our survey was voluntary, and respondents provided informed consent before taking the survey.

Correspondence

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Acknowledgements

We acknowledge funding from the United States Coastal Research Program Grant, and seminar participants at the University of Pennsylvania, the University of California Santa Barbara and Rutgers University for feedback on earlier drafts of this paper.

Contributions

M.M. participated in all stages of this study, including design, data collection, analysis and writing. A.S. participated in analysis and writing. J.M. and M.H. participated in design and writing. C.M. participated in data collection. M.L. participated in design.

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1 Results by Study Site

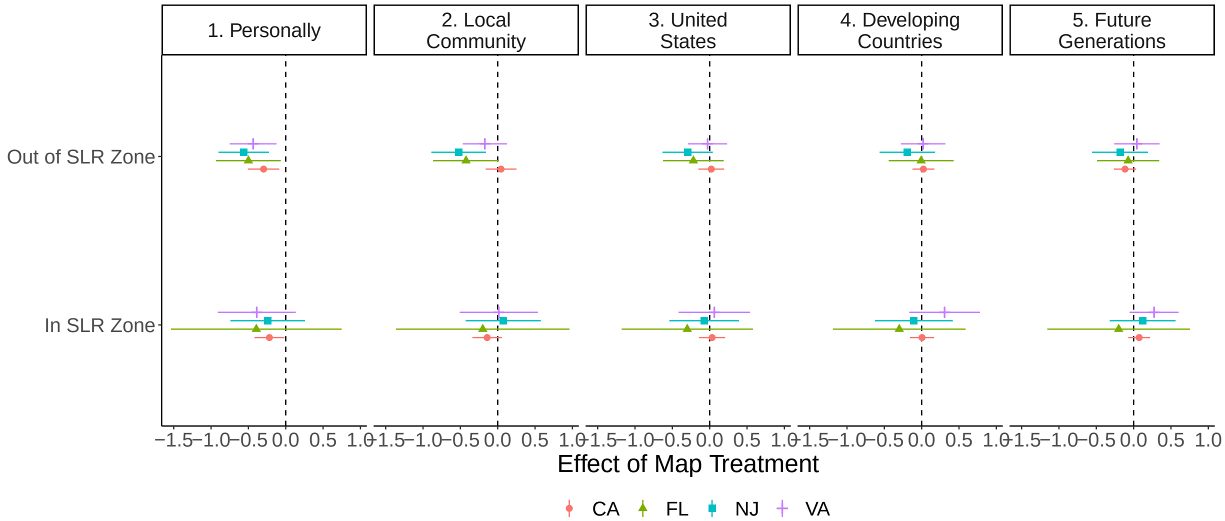

Figure A1—**Sea-level rise maps decrease personal concern for residents of all states; only FL and NJ residents decrease concern for local community and distant groups.** Figure shows treatment effects of being shown an individually-tailored sea-level rise map, including an indicator for the respondent's house, on the threat that sea-level rise poses to diverse categories of people, for respondents in four sample states. Bars show 95% confidence intervals. Respondents whose addresses are projected to experience flooding under a 1 m sea-level rise scenario are labeled as "Live Within SLR Zone". Respondents whose addresses are projected to remain outside the sea-level rise zone under a 1 m sea-level rise scenario are listed as: "Live Outside of SLR Zone". Points show regression coefficient and line segments show 95% confidence intervals, computed with HC1 standard errors. CA n = 737; FL n = 116; NJ n = 177; VA n = 212.

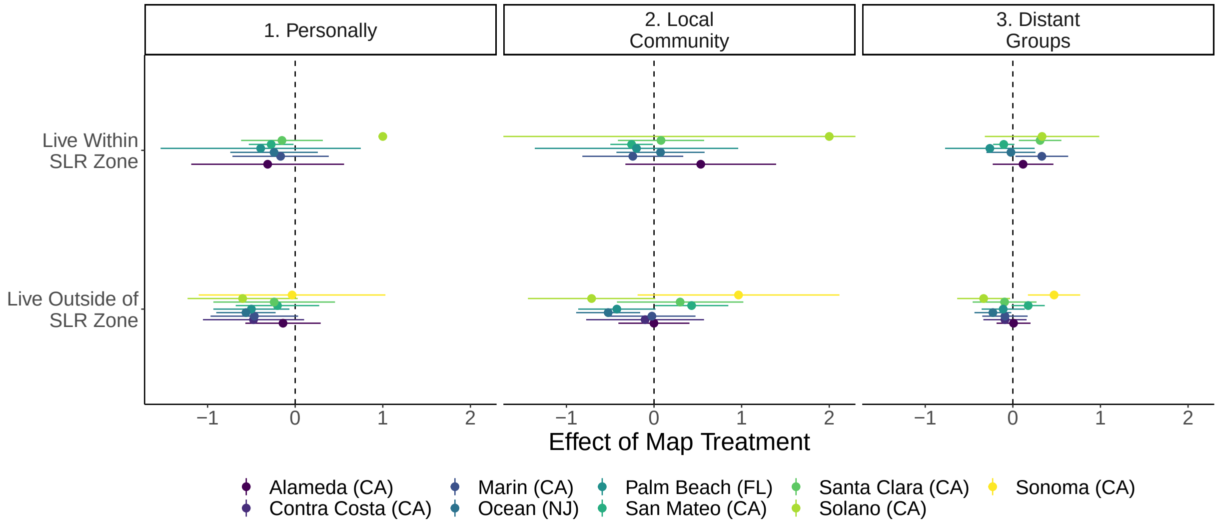

Figure A2—**Sea-level rise maps decrease personal concern for residents by sampling county.** Figure shows treatment effects of being shown an individually-tailored sea-level rise map, including an indicator for the respondent's house, on the threat that sea-level rise poses to diverse categories of people, for respondents in four sample states. Bars show 95% confidence intervals. Respondents whose addresses are projected to experience flooding under a 1 m sea-level rise scenario are labeled as "Live Within SLR Zone". Respondents whose addresses are projected to remain outside the sea-level rise zone under a 1 m sea-level rise scenario are listed as: "Live Outside of SLR Zone". Points show regression coefficient and line segments show 95% confidence intervals, computed with HC1 standard errors. Alameda County n = 113; Contra Costa County n = 48; Marin County n = 108; San Mateo County n = 317; Santa Clara County n = 91; Solano County = 37; Palm Beach County n = 116; Ocean County n = 177.

2 Robustness to Alternative Specifications

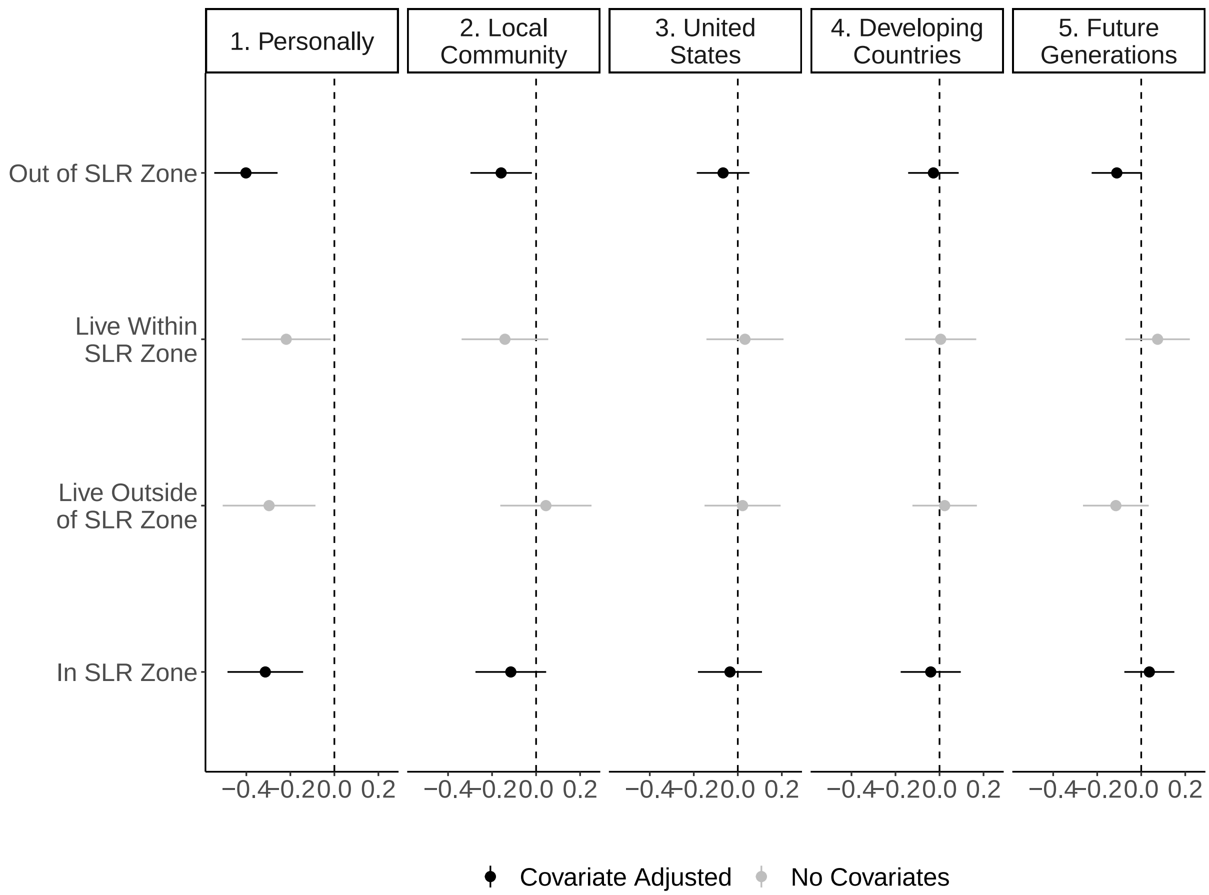

Figure A3—**Main results from text are robust to covariate adjustment/** Figure shows treatment effects of being shown an individually-tailored sea-level rise map, including an indicator for the respondent's house, on the threat that sea-level rise poses to diverse categories of people. Bars show 95% confidence intervals. Grey bars show bivariate models while black bars control for race and ethnicity, gender, education, and partisanship. All regressions contain fixed effects for location (CA, FL, NJ, VA). Concern is measured on a 4-point scale. Respondents whose addresses are projected to experience flooding under a 1 m sea-level rise scenario are labeled as "Live Within SLR Zone". Respondents whose addresses are projected to remain outside the sea-level rise zone under a 1 m sea-level rise scenario are listed as: "Live Outside of SLR Zone". n = 1,242.

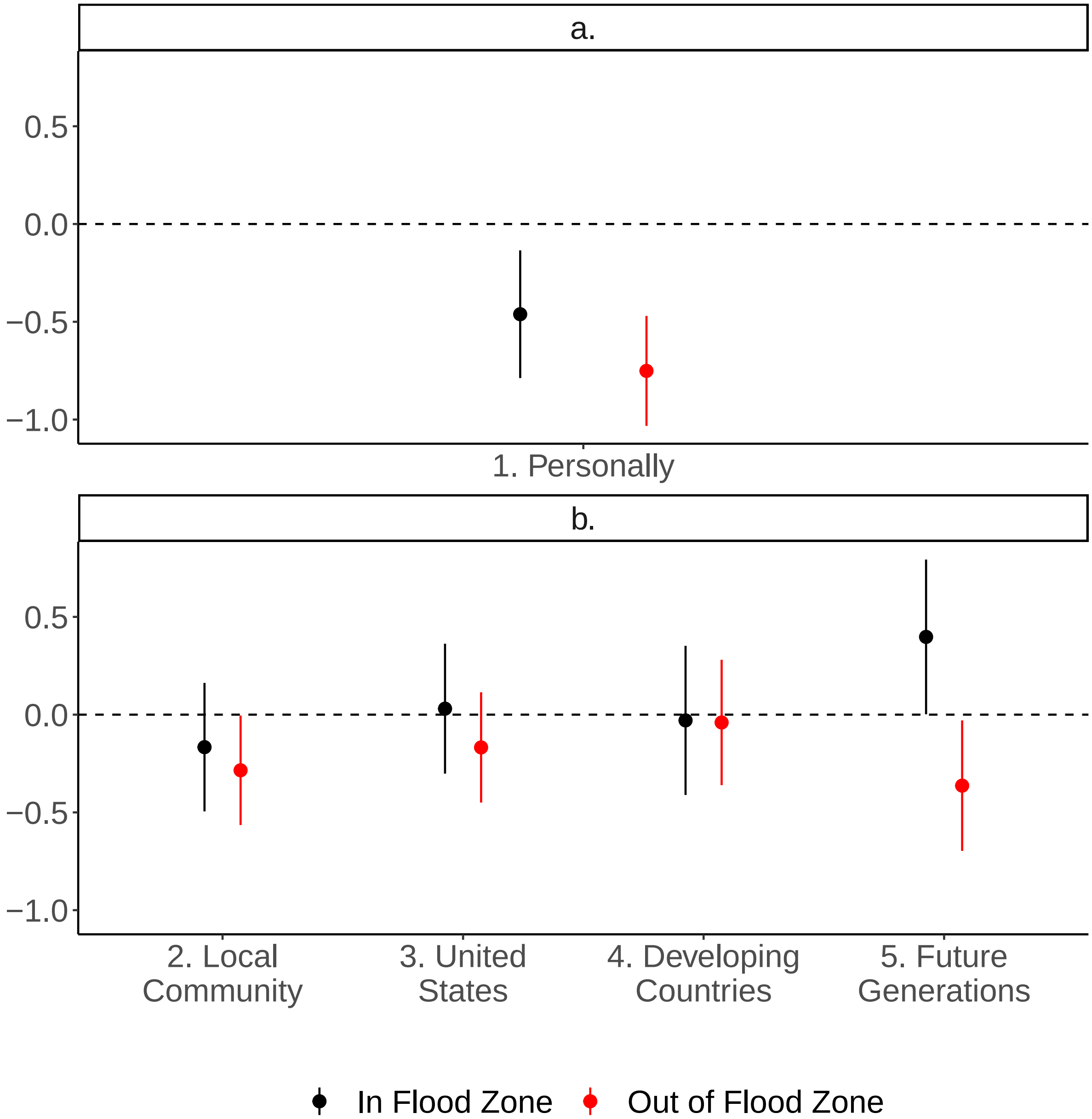

Figure A4—**Main results from text are robust to ordered logit model/** Figure shows treatment effects of being shown an individually-tailored sea-level rise map, including an indicator for the respondent's house, on the threat that sea-level rise poses to diverse categories of people. Bars show 95% confidence intervals. All regressions contain fixed effects for location (CA, FL, NJ, VA). Concern is measured on a 4-point ordinal scale. Respondents whose addresses are projected to experience flooding under a 1 m sea-level rise scenario are labeled as "Live Within SLR Zone". Respondents whose addresses are projected to remain outside the sea-level rise zone under a 1 m sea-level rise scenario are listed as: "Live Outside of SLR Zone". n = 737.

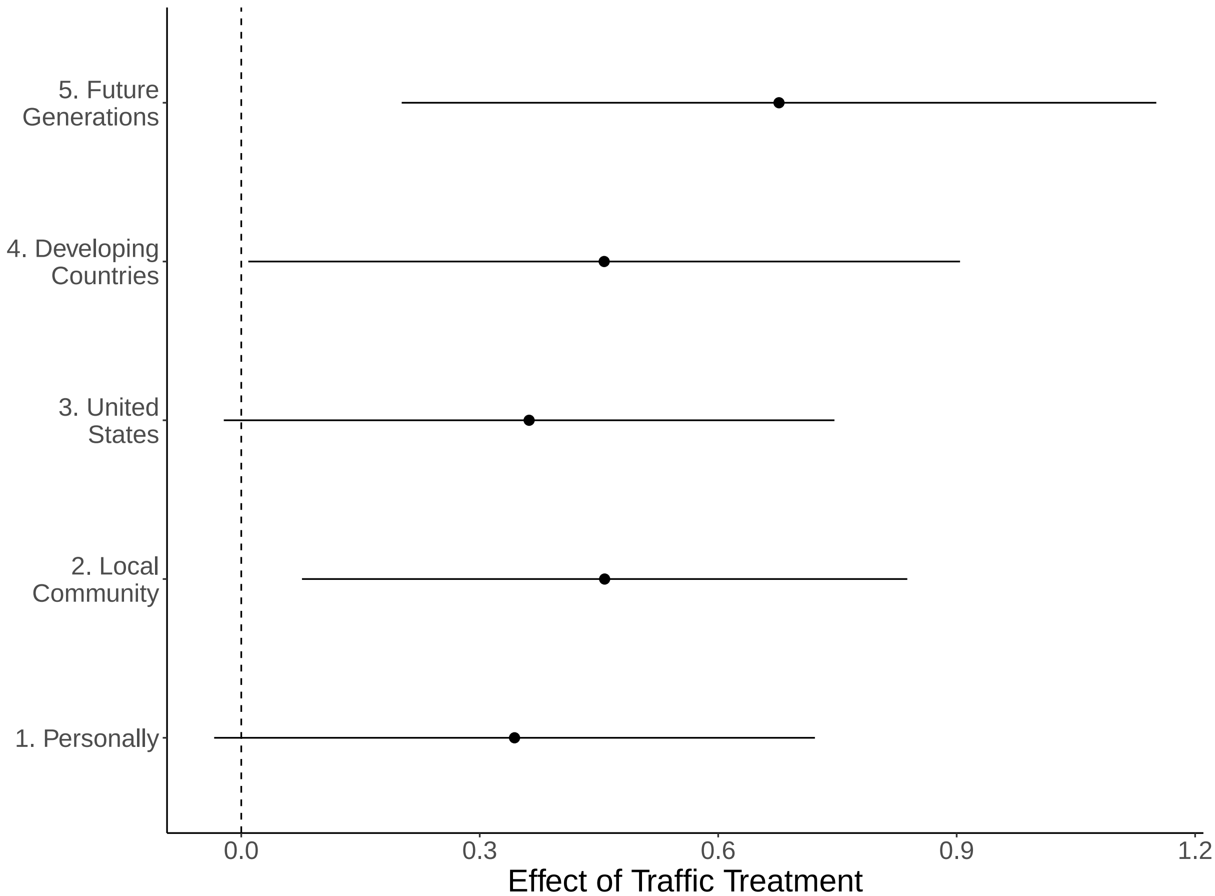

Figure A5—**Main results from text are robust to ordered logit model/** Figure shows treatment effects of projected 1 minute increase in zipcode-level traffic due to SLR for 5 separate ordered logit regressions of traffic treatment on levels of perceived harm (4-point scale). Bars show 95% confidence intervals. All regressions contain fixed effects for location (CA, FL, NJ, VA). Concern is measured on a 4-point ordinal scale. Respondents whose addresses are projected to experience flooding under a 1 m sea-level rise scenario are labeled as "Live Within SLR Zone". Respondents whose addresses are projected to remain outside the sea-level rise zone under a 1 m sea-level rise scenario are listed as: "Live Outside of SLR Zone". n = 1,243.

3 Tabular Results

	Mean Inside SLR	Mean Outside SLR	Difference	p value
1. Personally	1.71	1.49	-0.22	0.01
2. Local Community	1.95	1.92	-0.02	0.76
3. United States	2.04	2.09	0.05	0.47
4. Developing Countries	2.48	2.45	-0.03	0.63
5. Future Generations	2.53	2.55	0.01	0.84

Table A1: Two-sample t-test of difference in mean levels of concern between respondents inside and outside of Sea Level Rise zones. Tests are two-tailed. Concern variable is scaled to range between 0 and 1.

Variable	SLR	estimate	std.error	p.value
1. Personally	Live Outside of SLR Zone	-0.30	0.11	0.01
1. Personally	Live Within SLR Zone	-0.22	0.10	0.03
2. Local Community	Live Outside of SLR Zone	0.04	0.11	0.67
2. Local Community	Live Within SLR Zone	-0.14	0.10	0.16
3. United States	Live Outside of SLR Zone	0.02	0.09	0.81
3. United States	Live Within SLR Zone	0.03	0.09	0.72
4. Developing Countries	Live Outside of SLR Zone	0.02	0.07	0.75
4. Developing Countries	Live Within SLR Zone	0.01	0.08	0.95
5. Future Generations	Live Outside of SLR Zone	-0.12	0.08	0.13
5. Future Generations	Live Within SLR Zone	0.07	0.07	0.32

Table A2: Tabular results of map experiment. P-value provides results from two-sample t-test of difference in means.Tests are two-tailed.

Variable	SLR	estimate	std.error	p.value
1. Personally	Traffic Treatment	0.22	0.07	0.00
2. Local Community	Traffic Treatment	0.29	0.07	0.00
3. United States	Traffic Treatment	0.20	0.06	0.00
4. Developing Countries	Traffic Treatment	0.21	0.05	0.00
5. Future Generations	Traffic Treatment	0.20	0.05	0.00

Table A3: Tabular results of traffic experiment. P-value provides results from two-sample t-test of difference in means.Tests are two-tailed.

4 Map Results for California Sample only

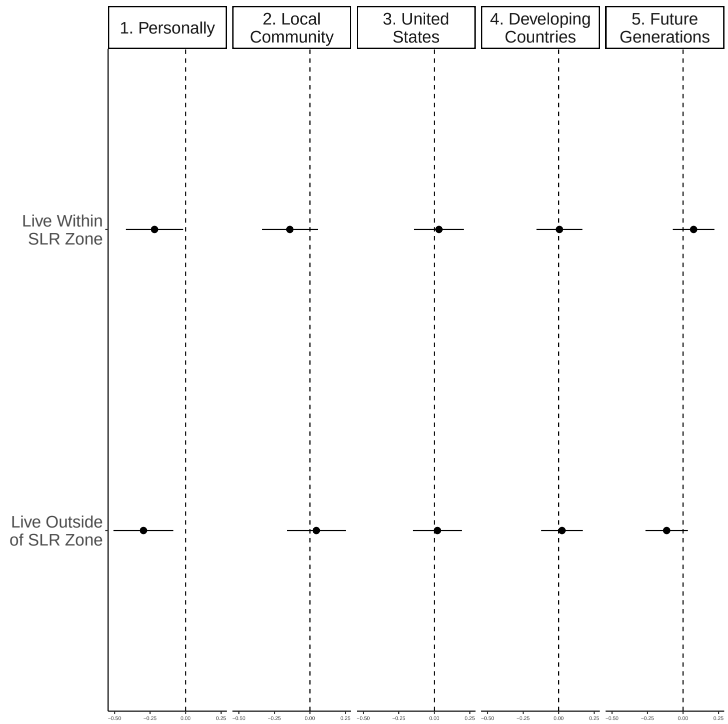

Figure A6—**Sea-level rise maps decrease personal concern for residents of CA only** Figure shows treatment effects of being shown an individually-tailored sea-level rise map, including an indicator for the respondent's house, on the threat that sea-level rise poses to diverse categories of people, for respondents in four sample states. Bars show 95% confidence intervals. Respondents whose addresses are projected to experience flooding under a 1 m sea-level rise scenario are labeled as "Live Within SLR Zone". Respondents whose addresses are projected to remain outside the sea-level rise zone under a 1 m sea-level rise scenario are listed as: "Live Outside of SLR Zone". n = 737.

5 Willingness to Pay Results

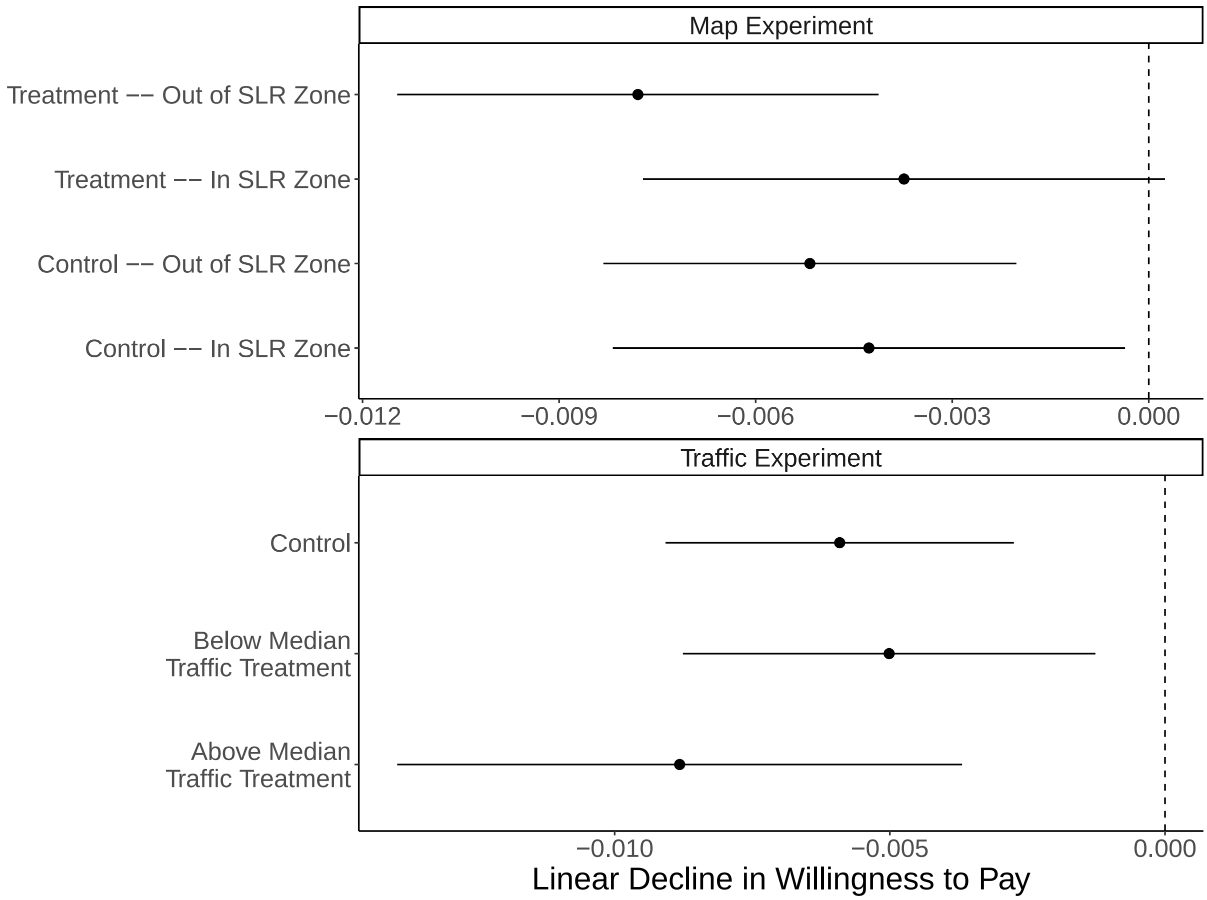

Figure A7—**Linear Decline in Support for Policies Does Not Vary by Treatment Conditions** Figure shows slopes on willingness to pay for climate policies under different treatment conditions in map (CA, FL, NJ, VA) and traffic (CA only) experiments. Slopes are calculated by regressing policy support on randomly varied price of policy. Bars show 95% confidence intervals. Regressions include fixed effect for policy outcome. Respondents whose addresses are projected experience flooding under a 1 m sea-level rise scenario are labeled as "Live Within SLR Zone". Respondents whose addresses are projected to remain outside the sea-level rise zone under a 1 m sea-level rise scenario are listed as: "Live Outside of SLR Zone." Treatment respondents are shown a map; control respondents are not. For traffic experiment, control respondents are not shown traffic vignette; treatment respondents are shown vignette and are here split into respondents whose treatment was below and above the median traffic increase time of 15 minutes. Map experiment n = 1,243. Traffic experiment n = 737.

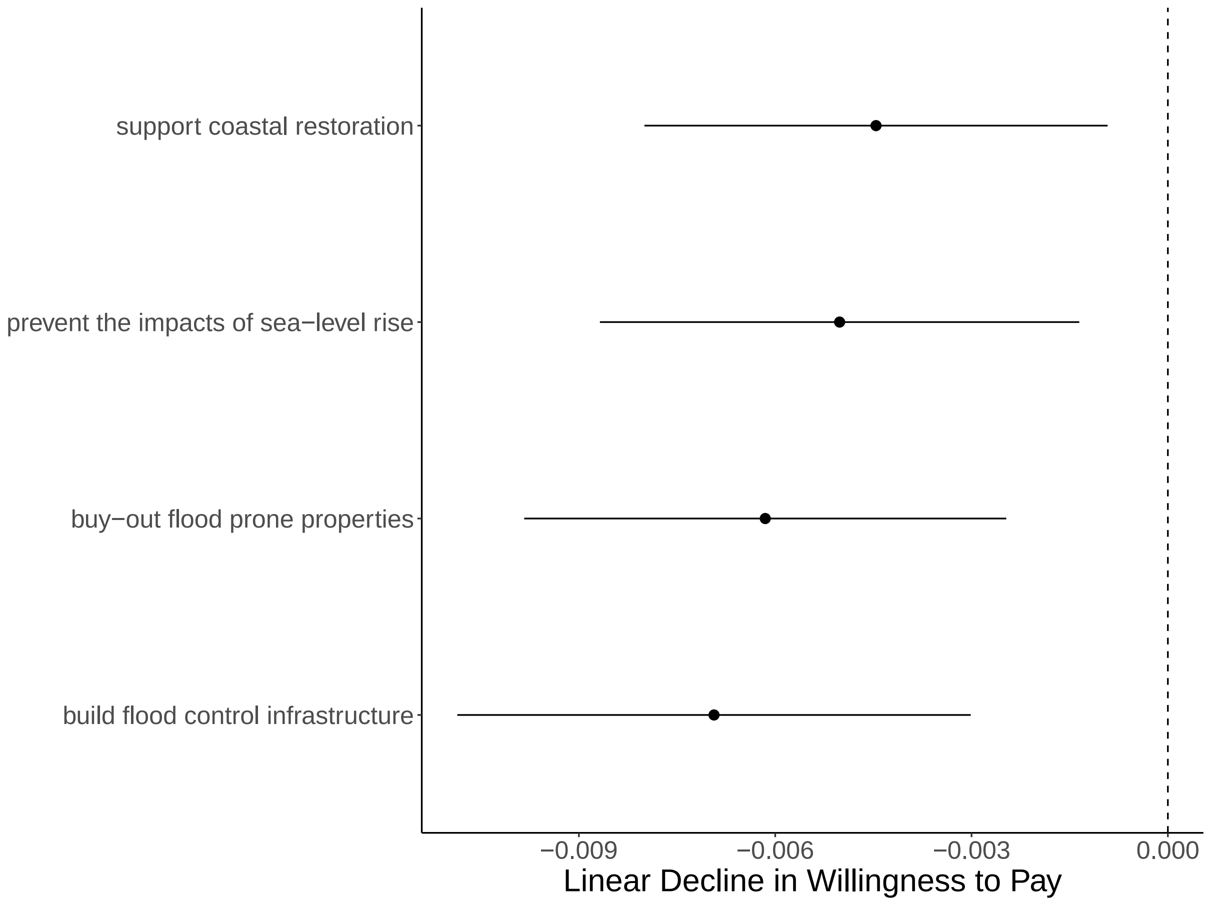

Figure A8—**Linear Decline in Support Does Not Vary by Policy** Figure shows slopes on willingness to pay for four climate policies. Sample is pooled across all four study sites. Slopes are calculated by regressing policy support on randomly varied price of policy. Bars show 95% confidence intervals. n = 1,243.

6 Results by Party

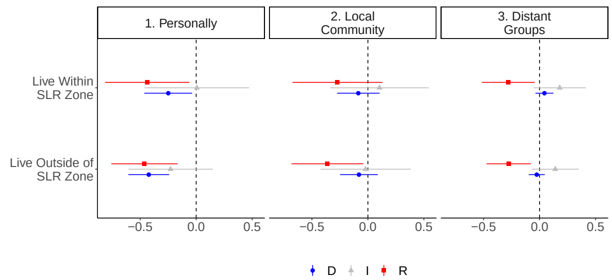

Figure A9—**Sea-level rise maps decrease personal concern for Democrats and Republicans equally; only Republicans decrease concern for local community and distant groups.** Figure shows treatment effects of being shown an individually-tailored sea-level rise map, including an indicator for the respondent's house, on the threat that sea-level rise poses to diverse categories of people, for self-identified Democrats and Republicans (including leaners), and pure Independents. Bars show 95% confidence intervals. All regressions contain fixed effects for location (CA, FL, NJ, VA). Policy support is measured on a 7-point scale. Respondents whose addresses are projected to experience flooding under a 1 m sea-level rise scenario are labeled as "Live Within SLR Zone". Respondents whose addresses are projected to remain outside the sea-level rise zone under a 1 m sea-level rise scenario are listed as: "Live Outside of SLR Zone". The United States, developing countries, and future generations are collapsed into "Distant Groups." Democrats n = 667; Republicans n = 238; Independents n = 192.

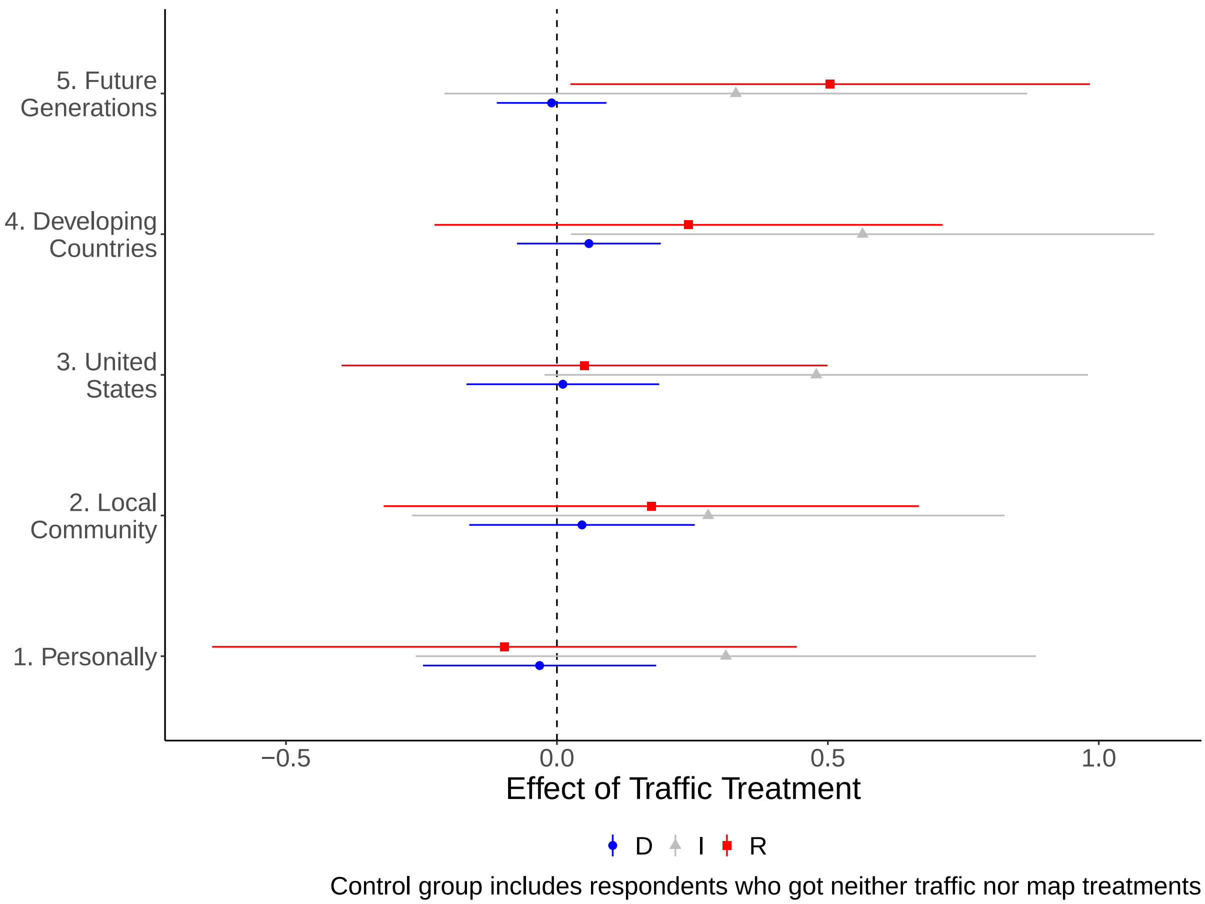

Figure A10—**Independents increase perceived concern when shown traffic information; partisans do not**. Figure shows treatment effects of projected 1 minute increase in zipcode-level traffic due to SLR for 5 separate regressions of traffic treatment on levels of perceived harm (4-point scale). Points show regression coefficient and line segments show 95% confidence intervals, computed with robust standard errors. Regressions control for whether respondents received map treatment. Sample includes only California respondents. Democrats n = 335; Republicans n = 120; Independents n = 90.

7 Results by Acceptance of Anthropogenic Climate Change

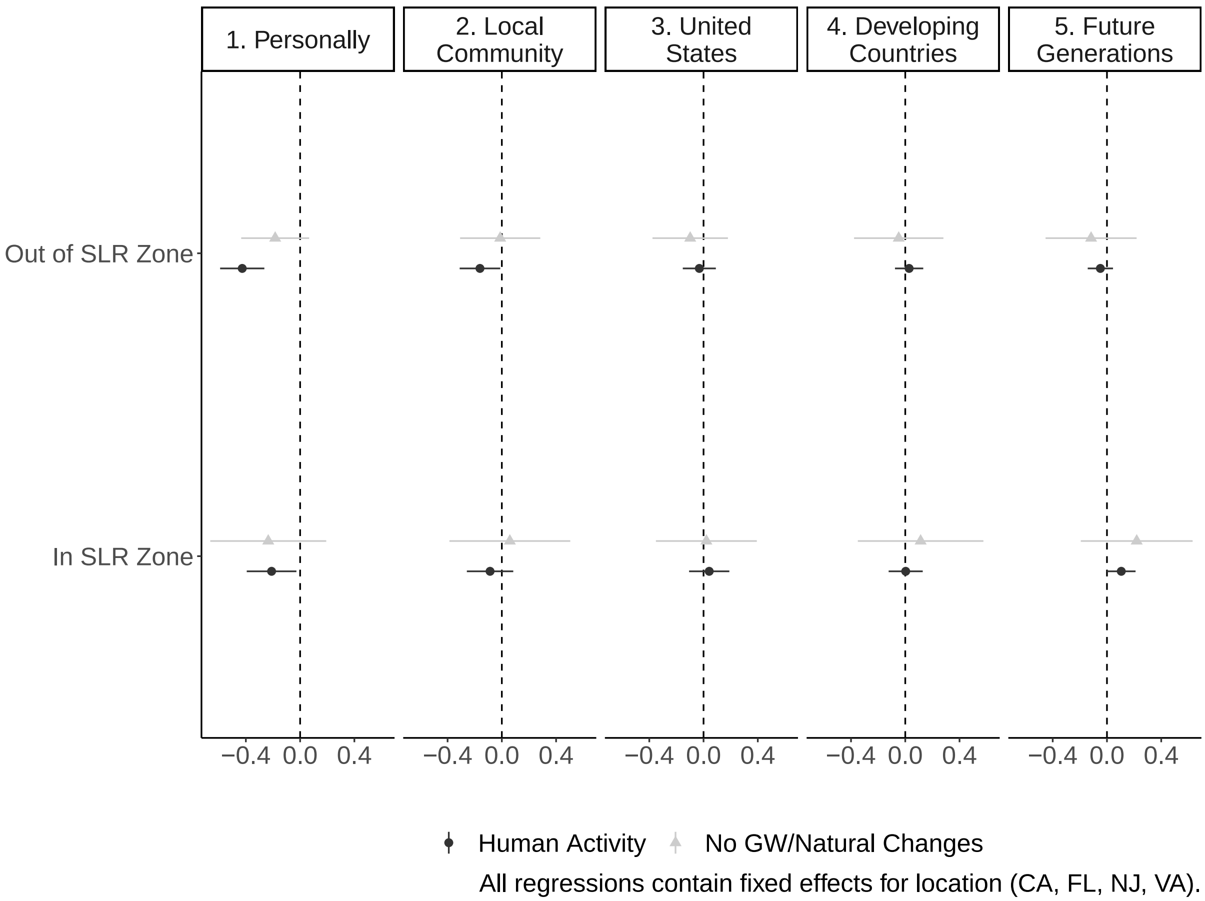

Figure A11—**Sea-level rise maps decrease personal concern more for those who do not believe in human activity causing global warming** Figure shows treatment effects of being shown an individually-tailored sea-level rise map, including an indicator for the respondent's house, on the threat that sea-level rise poses to diverse categories of people, for respondents who believe in human-caused climate change, and those who either do not believe the planet is warming or that it is not human-caused. Bars show 95% confidence intervals. Respondents whose addresses are projected to experience flooding under a 1 m sea-level rise scenario are labeled as "Live Within SLR Zone". Respondents whose addresses are projected to remain outside the sea-level rise zone under a 1 m sea-level rise scenario are listed as: "Live Outside of SLR Zone". Human Activity n = 925; No GW n = 317.

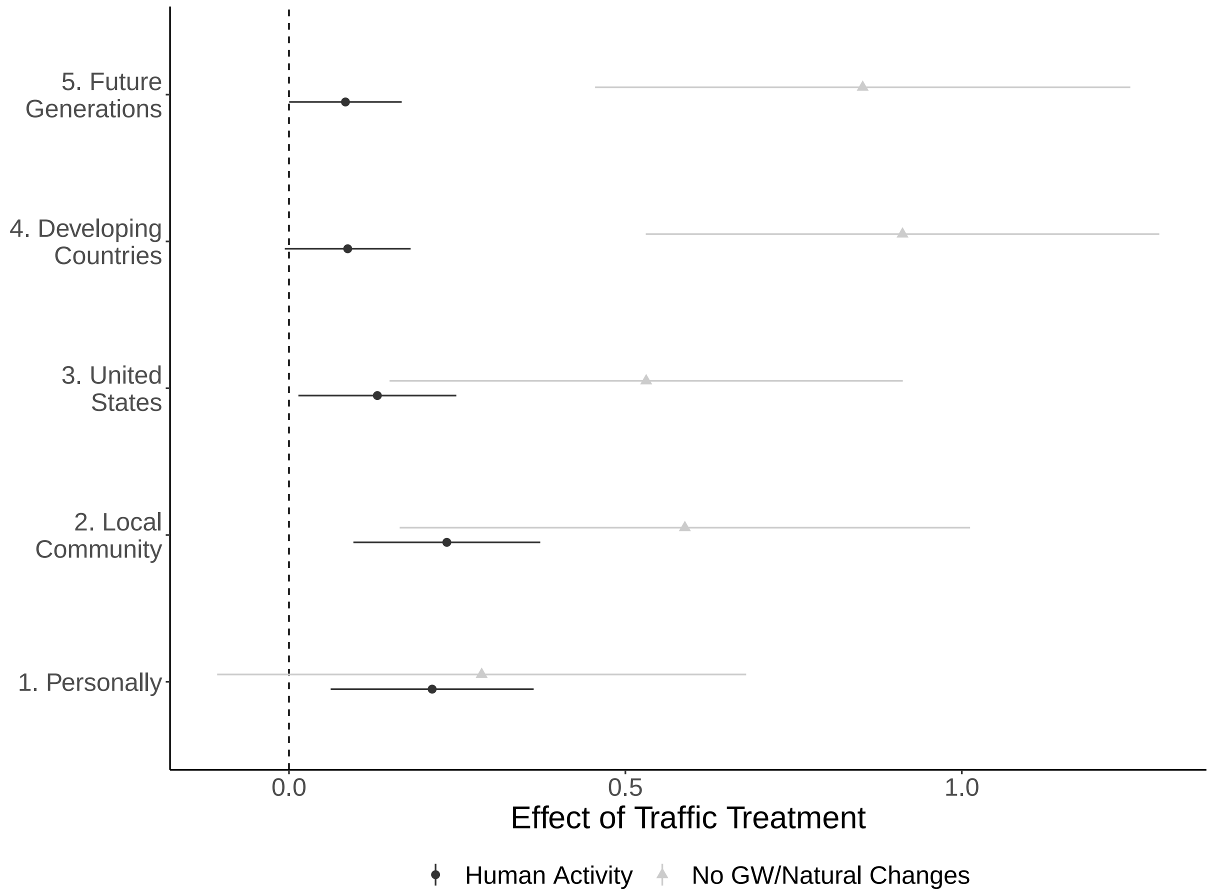

Figure A12—**Both global warming believers and non-believers increase perceived concern when shown traffic information; non-believers increase their concern significantly more** Figure shows treatment effects of projected 1 minute increase in zipcode-level traffic due to SLR for 5 separate regressions of traffic treatment on levels of perceived harm (4-point scale). Points show regression coefficient and line segments show 95% confidence intervals, computed with robust standard errors. Regressions control for whether respondents received map treatment. Sample includes only California respondents. Human Activity n = 614; No GW n = 123.

8 Experimental Results by Home Ownership

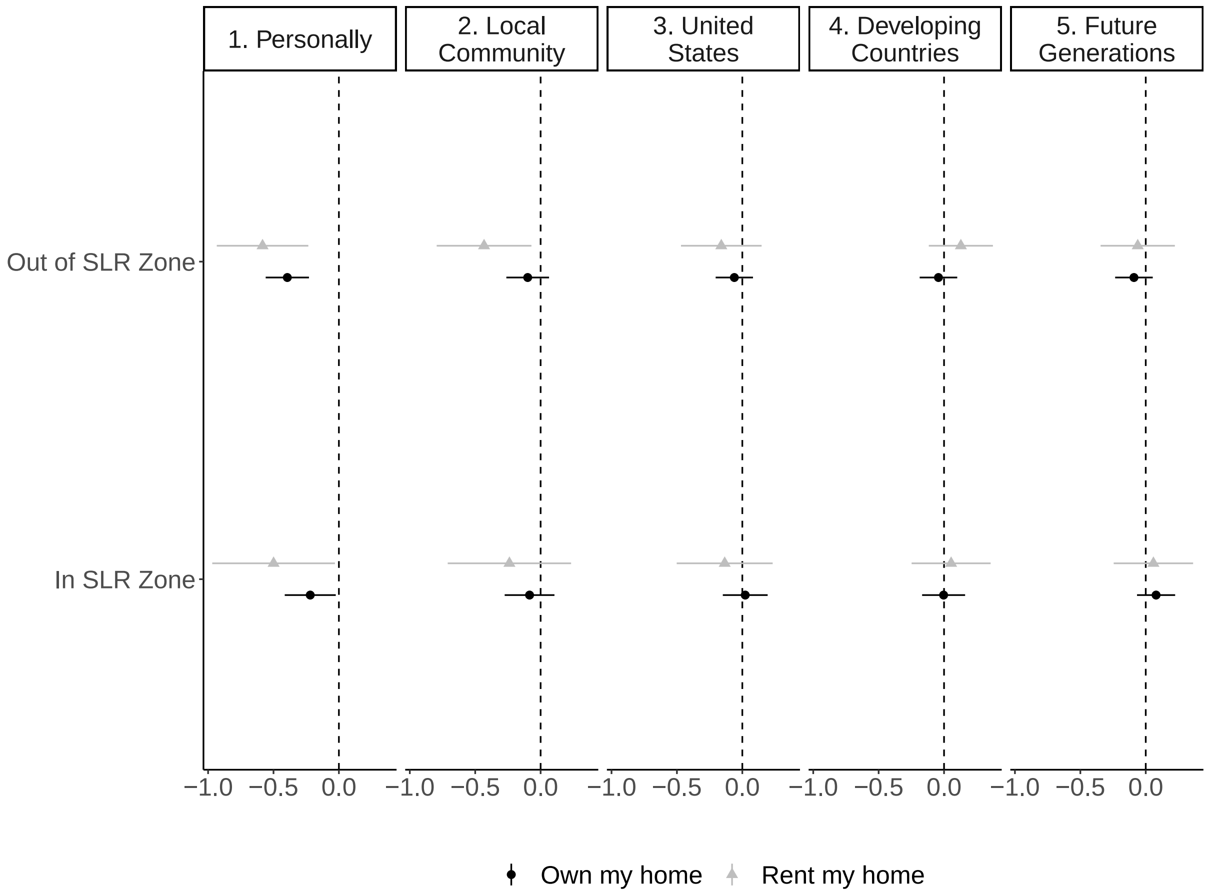

Figure A13—**Sea-level rise maps decrease personal concern for homeowners and renters equally; only renters decrease their sense of harm to local community** Figure shows treatment effects of being shown an individually-tailored sea-level rise map, including an indicator for the respondent's house, on the threat that sea-level rise poses to diverse categories of people, for self-identified homeowners and renters. Bars show 95% confidence intervals. Results pool CA, NJ, FL, and VA respondents. Respondents whose addresses are projected to experience flooding under a 1 m sea-level rise scenario are labeled as "Live Within SLR Zone". Respondents whose addresses are projected to remain outside the sea-level rise zone under a 1 m sea-level rise scenario are listed as: "Live Outside of SLR Zone". Own n = 970; Rent n = 191.

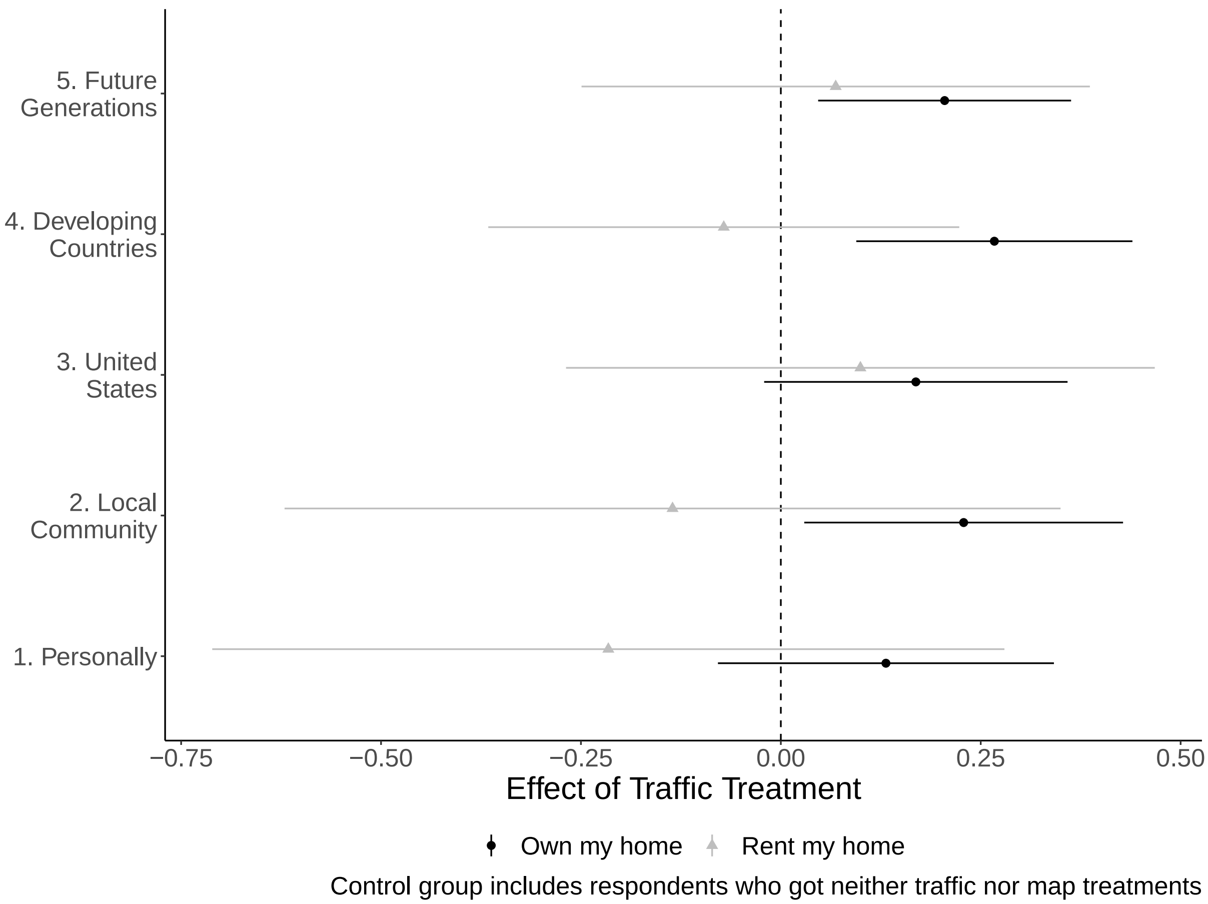

Figure A14—**Homeowners increase perceived concern when shown traffic information; renters do not** Figure shows treatment effects of projected 1 minute increase in zipcode-level traffic due to SLR for 5 separate regressions of traffic treatment on levels of perceived harm (4-point scale). Points show regression coefficient and line segments show 95% confidence intervals, computed with robust standard errors. Regressions control for whether respondents received map treatment. Sample includes only California respondents. Own n = 290; Rent n = 98.

537 # 9 Experimental Results by FEMA Flood Zone

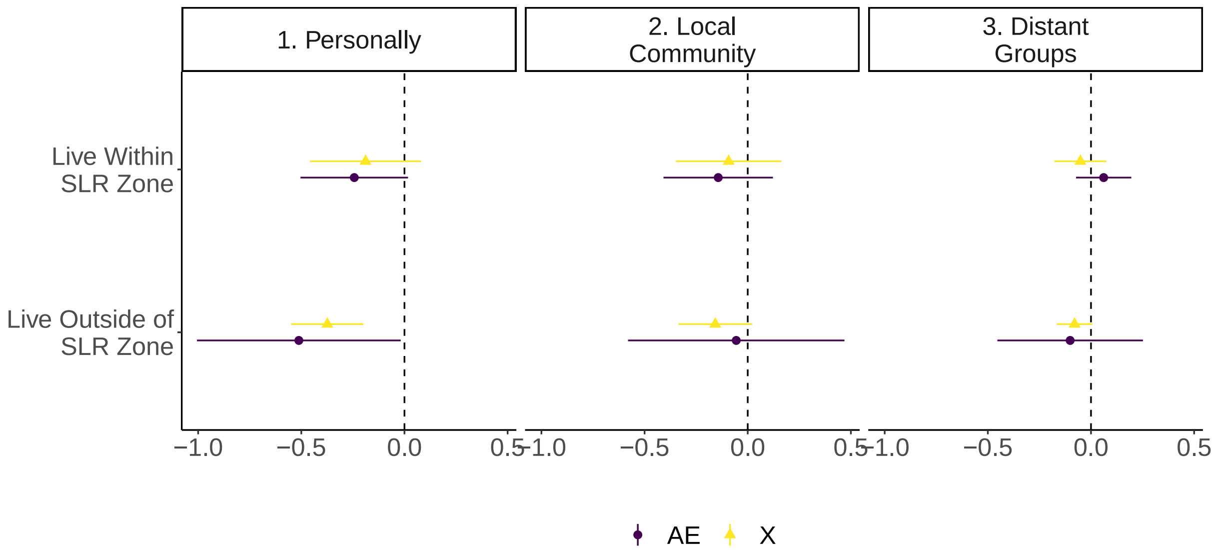

Figure A15—**Sea-level rise maps decrease personal concern for residents of high-risk and moderate risk flood zones** Figure shows treatment effects of being shown an individually-tailored sea-level rise map, including an indicator for the respondent's house, on the threat that sea-level rise poses to residents of homes in AE (high risk) and X (moderate risk) flood zones. Figure pools respondents from CA, FL, NJ and VA and includes state fixed effects. Bars show 95% confidence intervals. Respondents whose addresses are projected to experience flooding under a 1 m sea-level rise scenario are labeled as "Live Within SLR Zone". Respondents whose addresses are projected to remain outside the sea-level rise zone under a 1 m sea-level rise scenario are listed as: "Live Outside of SLR Zone." Points show regression coefficient and line segments show 95% confidence intervals, computed with HC1 standard errors. AE n = 272; X n = 744.

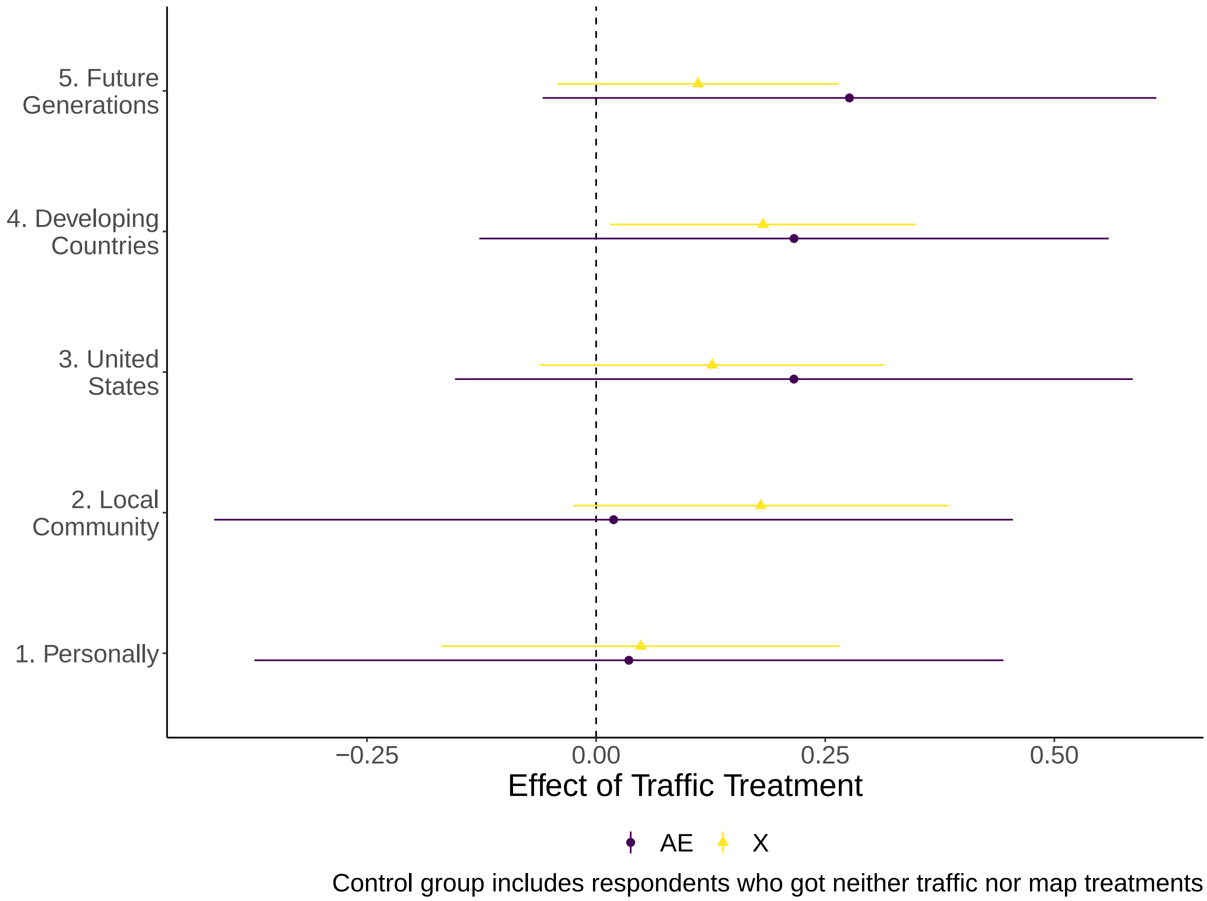

Figure A16—**Homeowners increase perceived concern when shown traffic information; renters do not** Figure shows treatment effects of projected 1 minute increase in zipcode-level traffic due to SLR for 5 separate regressions of traffic treatment on levels of perceived harm (4-point scale) to residents of homes in AE (high risk) and X (moderate risk) flood zones. Points show regression coefficient and line segments show 95% confidence intervals, computed with HC1 standard errors. Regressions control for whether respondents received map treatment. Sample includes only California respondents. AE n = 77; X n = 305.

10 Sample Recruitment Information

Figure A17—Cover of invitation mailer (a "snappack" with perforated edges).

11 Sample Balance Table

Table A4: **Respondents on Either Side of Sea Level Rise Boundary Similar on Observed Characteristics; Whites, College Graduates, Homeowners Overrepresented in Sample Relative to Population**: First three columns of table show mean values of demographic and political characteristics of respondents within 250m of sea level rise boundary. p value calculated from a t-test of difference in means. Right 3 columns show mean values of demographic characteristics of survey respondents relative to census tracts in sampling frame. Census data come from 2015-2019 ACS estimates; respondent data is self-reported. p value calculated from a t-test of difference in means.

	In SLR	Out SLR	p value	Sample	Mean	p.value
Gender: Male	0.53	0.62	0.16	0.56	0.5	0
Race: Asian	0.14	0.25	0.01	0.19	0.18	0.4
Race: Black	0.04	0.03	0.62	0.04	0.11	0
Race/: Hispanic	0.06	0.04	0.54	0.06	0.21	0
Race: White	0.78	0.67	0.04	0.71	0.45	0
Edu: college	0.37	0.34	0.65	0.33	0.25	0
Edu: postgrad	0.36	0.43	0.23	0.4	0.18	0
Edu: some HS	0.02	0.03	0.27	0.04	0.17	0
Edu: some college	0.17	0.12	0.19	0.16	0.26	0
Homeowner	0.9	0.83	0.07	0.84	0.54	0
Party ID	2.52	2.34	0.31			
Ideology	3.75	3.55	0.26			

INVITATION TO PARTICIPATE

Public Opinion Research Survey

September 5, 2019
To: Current resident
[redacted]

Dear resident,

We are **inviting you to participate in an online research survey** to help understand what residents in coastal Virginia think about future risks. You are receiving this letter because your address was randomly selected from addresses in your neighborhood. This survey is not a political poll or part of any political campaign. There are no questions about the 2020 election on this survey. Instead, we want to know what you think about some issues important to Virginia.

We expect this survey will take between 8 and 12 minutes. Responses are voluntary and will be kept confidential.

As s a small token of our appreciation, we will send you a **$5 digital gift card for completing the survey, redeemable at over 100 online vendors like Amazon or iTunes.**

If you have any questions about this project, you can email [redacted] the research project director, at [redacted]

To answer the survey or to learn more, use your smartphone or computer to visit:

https://ucsurvey.com/VL321

By taking a few minutes to share your thoughts and you will help us understand what people who live in Virginia think. The survey is available now. We would appreciate if you would respond by October 15.

We hope you enjoy completing the questionnaire and look forward to receiving your responses.

Many thanks,

[redacted]

Figure A18—Sample invitation letter, when unfolded.

12 Spatial Distribution of Response Rates

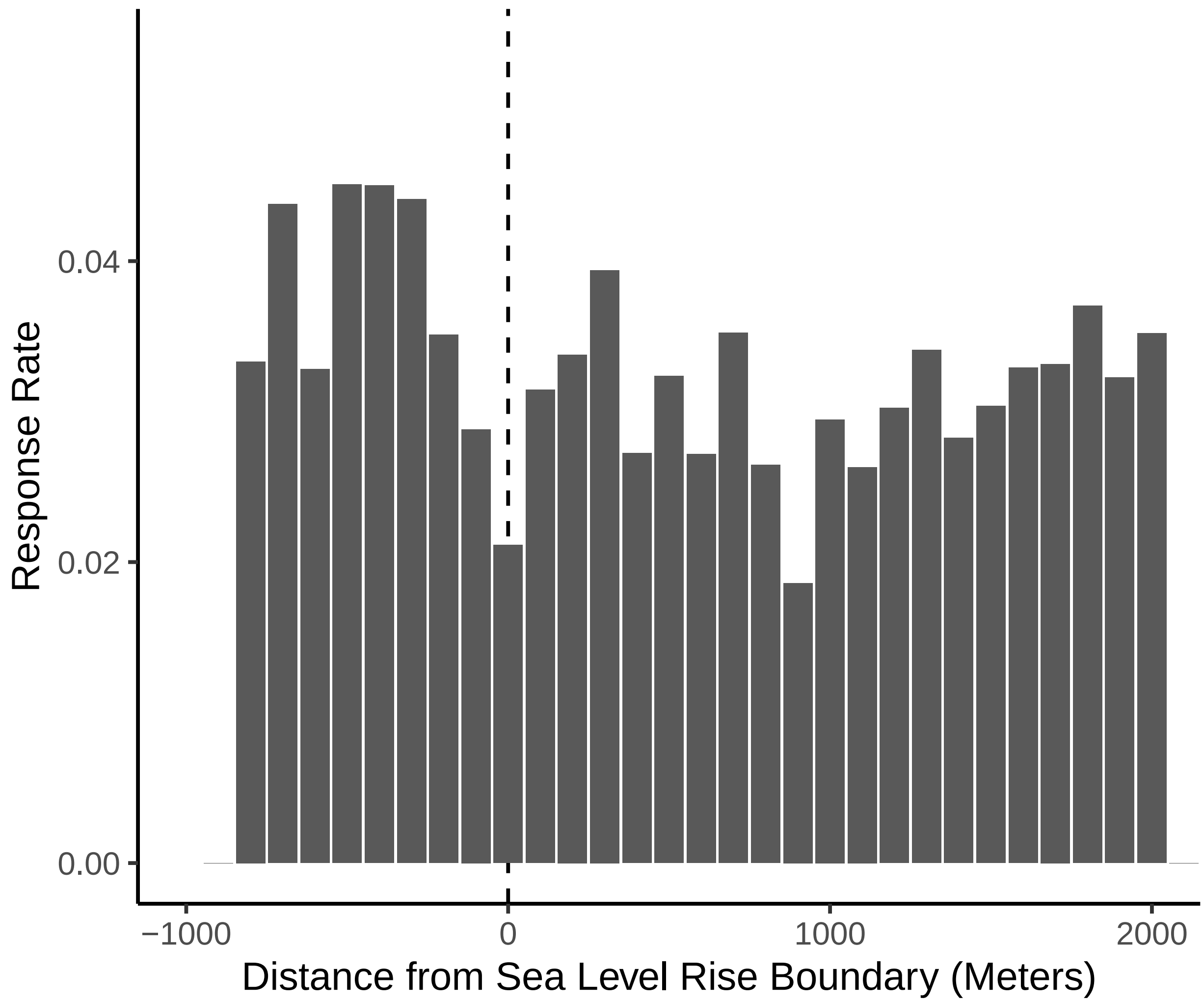

Figure A19—**Survey Response Rates Around Sea-Level Rise Boundary**. 100m binned response rates shown around sea-level rise line. X-axis is truncated at 2000m above the sea-level rise boundary. Average response rates inside and outside sea-level rise boundary are 2.6% and 3.1%, respectively.

13 Spatial distribution of traffic models

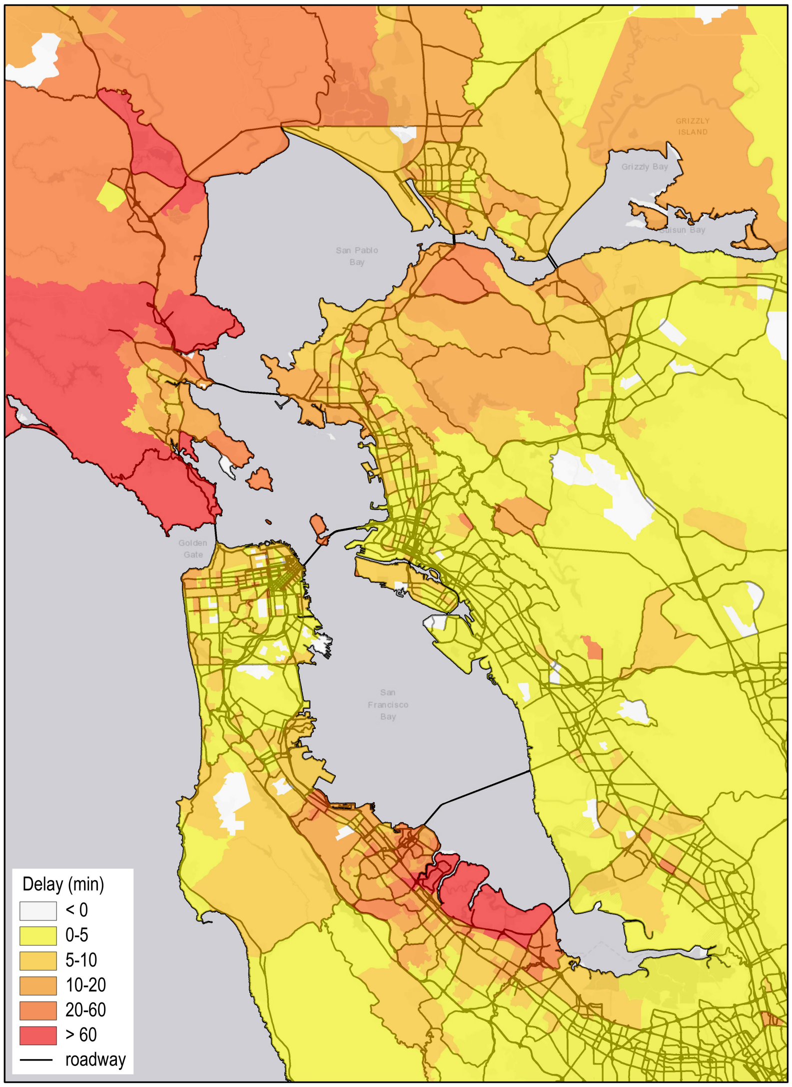

Figure A20—**Projected traffic increases in Bay Area census tracts, used for traffic experiment treatment**. Figure shows census tract-level projected average traffic delays in minutes due to flooding from a 1 m sea-level rise scenario in 2100, calculated using the MATSim model. Respondents were treated with their census tract's average.