Landowner behavior can determine the success of conservation strategies for ecosystem migration under sea-level rise

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The human aspects of conservation are often overlooked but will be critical for identifying strategies for biological conservation in the face of climate change. We surveyed the behavioral intentions of coastal landowners with respect to various conservation strategies aimed at facilitating ecosystem migration for tidal marshes. We found that several popular strategies, including conservation easements and increasing awareness of ecosystem services, may not interest enough landowners to allow marsh migration at the spatial scales needed to mitigate losses from sea-level rise. We identified less common conservation strategies that have more support but that are unproven in practice and may be more expensive. Our results show that failure to incorporate human dimensions into ecosystem modeling and conservation planning could lead to the use of ineffective strategies and an overly optimistic view of the potential for ecosystem migration into human dominated areas.

tidal marsh migration | shoreline protection | coastal resilience | climate change beliefs | conservation easements

Conserving biodiversity in the face of climate change is one of humanity’s greatest challenges, but it is uncertain which strategies will be most effective in confronting this challenge (1). There is growing consensus that knowledge from the natural and social sciences must be integrated (2, 3), but progress toward integration is slow (1). While research on peoples’ responses to climate change is rapidly growing (4), it remains largely focused on beliefs, attitudes, and the general actions people support rather than on specific actions they might take to achieve biological conservation (5). In addition to the general challenge of understanding human behavior toward conservation, climate change introduces specific challenges, including the invisibility of causes, lack of direct experience with the consequences, and the distance of impacts in time and space (6, 7).

Much of the nascent literature on the human dimensions of biodiversity conservation under climate change focuses on the beliefs of scientists and protected areas managers (e.g., refs. 8–11). While this research is key to understanding conservation in protected areas, such areas constitute only 15.4% of the globe’s land area and 3.4% of ocean area (12). Additional conservation strategies are clearly needed if we are to meet global conservation goals (13). Whether such strategies involve adding to protected area networks or actions elsewhere, the behaviors of people, especially private landowners, will largely determine their success (14, 15).

Here we show how the behavioral intentions of landowners could determine the effectiveness of a leading strategy for conservation under climate change: facilitating species and ecosystems movement into new areas (16, 17). We focused on tidal marshes because they provide a disproportionate share of global ecosystem services (18) and are already experiencing ecosystem shifts in response to sea-level rise (19, 20). The success of mitigation strategies to prevent marsh losses will depend on the behavior of millions of landowners (21) who might decide to build shoreline protection that would prevent marsh migration. In our study area alone (Fig. S1) there are over 30,000 landowners in the zone projected to become tidal marsh by 2100 (22, 23).

Regulatory responses to climate change by local or national governments might provide mechanisms that encourage ecosystem migration in coastal areas. Options such as regulatory rolling easements (24) or zoning that prohibits shoreline protection are straightforward to identify, but there are major impediments to implementing these approaches. Gradual hazards, such as increased coastal flooding, typically do not receive policy attention, especially in contentious political environments or when faced with fiscal constraints (25). These impediments to regulation are unlikely to change in the near future (25, 26). Existing regulations, including wetland mitigation programs, such as regulatory in-lieu fee or conservation banking, may not apply to upland areas that are projected to become wetlands as sea levels rise, limiting their use in facilitating ecosystem migration. Decision-makers from public institutions may respond to sea-level rise more slowly than coastal communities, as the behavioral responses of individuals typically operate over temporal scales that are better aligned with rates of ecological change (27). In light of these challenges to effective regulation and the rapid rate of change in coastal systems (19, 20), better understanding the drivers of individual behavior will likely continue to be important for conservation in coastal areas.

In this paper we report results from a systematic survey of the behavioral intentions of landowners with respect to building shoreline protection or participating in conservation agreements aimed at protecting corridors for marsh migration. We then (i) quantify the effects on behavioral intentions of a set of beliefs,

Significance

Key questions remain about the role of social factors, especially the behavior of private landowners, in determining the outcome of strategies for conservation under climate change. We surveyed the behavioral intentions of coastal landowners in the northeast United States, where extreme sea-level rise threatens tidal marsh persistence unless private landowners allow landward marsh migration. Our results identify (i) conservation strategies currently being implemented that may not have enough support among target populations to mitigate losses from sea-level rise, and (ii) beliefs and attitudes that may be effective targets for outreach aimed at increasing participation in these strategies. The importance of these social factors as constraints on marsh migration highlights the need for wider integration into planning for coastal adaptation.

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attitudes, experiences, and group membership attributes that would be natural targets for intervention aimed at encouraging conservation behavior and (ii) integrate social data and ecosystem projections to quantify the effect that behavioral intentions are likely to have on the extent of the marsh migration zone that is available for protection. Finally, we discuss how our results could help inform future research on the social and ecological dimensions of marsh migration.

**Specifying Conservation Agreements**

We quantified the stated behavioral intentions of coastal landowners with respect to four conservation agreements and building shoreline protection. We chose the basic types of agreements to represent both well-established strategies and agreements that are just beginning to be implemented in coastal areas. The well-established strategies were property purchase and conservation easements. Conservation easements are one of the most commonly used land-protection strategies in the United States because they are flexible and often far cheaper than purchasing land outright (28). For example, over 130,000 easements, representing >10 million ha of protected land, have been archived by the National Conservation Easement Database (www.conservationeasement.us). The emerging strategies considered were restrictive covenants, binding agreements to forgo shoreline protection that are entered into mutually by a neighborhood, and future interest agreements, wherein ownership reverts to a conservation organization and the landowner receives the fair market value from the time of signing should a flood reduce property value by more than 50%. The general terms of the agreements were taken from an overview of coastal protection options (24) and modified to align with the tax laws, observed incentives, and ongoing conservation activities of our study area to ensure that respondents were faced with realistic scenarios (see Supplementary Information and SI Appendix for more information about agreement terms).

The conservation agreements were presented to landowners as being offered by conservation organizations, which we described in the questionnaire as nonprofit organizations that focus on land conservation (SI Appendix). Several of the major organizations working on land protection in our study area have a national or global scope, making our phrasing and choice of agreements broadly applicable to developed coastal regions where such organizations work.

**Strategies for Increasing Conservation Behavior**

We quantified the effects on behavioral intentions of a range of natural targets for intervention aimed at encouraging conservation behavior. We identified targets using evidence from across disciplines that beliefs, attitudes, and experiences can influence behaviors (discussed below). We also identified targets for intervention that were motivated by ongoing conservation activities, resulting in a broad range of strategies: strengthening beliefs in climate change and its impacts, increasing conservation effort after extreme weather, changing attitudes toward ecosystem services and wildlife species, and group membership attributes.

A prominent strategy for encouraging conservation is to strengthen people’s beliefs in climate science and the impacts of climate change through public education (29, 30). Strengthening beliefs that climate change is happening encourages conservation behaviors (30), but the effect size is often small to moderate (4, 31), and stronger effects are often related to low-stakes activities, such as recycling and planting trees (31). Much less is known about the influence of climate-change beliefs on high-stakes behaviors that have the potential to affect personal wealth and well-being.

Recent evidence suggests that climate awareness and education efforts might be most effective immediately after target populations experience extreme weather events (7, 32). Because 12% of our respondents’ homes were flooded during Hurricane Sandy (in 2012, 2 y before our survey was conducted), we quantified whether such events could influence behavioral intentions and the effectiveness of conservation strategies.

Another strategy for encouraging conservation behavior is to make the links between ecosystem functions and their benefits to humans (ecosystem services) (33) more central to research, policy, and communication. This strategy has received considerable attention over the last decade, and proponents have used powerful language to describe its potential to spur a conservation renaissance by changing people’s attitudes and behaviors (34). There has been little empirical research, however, on the attitudes of the public toward ecosystem services (35), especially compared with more traditional concepts such as nature’s inherent benefits (e.g., ref. 36). Empirical evidence is especially lacking on whether attitudes about ecosystem services have the potential to influence conservation behaviors (37).

Tidal marshes protect coastlines from damaging storm tides, which are becoming more frequent and extreme as sea levels rise (38). Raising awareness of the services provided by tidal marshes is a common strategy of ongoing education efforts in coastal areas (e.g., ref. 39). The capacity for marshes to protect coastal areas from storm tides is ideal for testing the potential for ecosystem services to influence behavior, as this phenomenon has a direct and easily communicated link to the wealth and well-being of landowners (40, 41).

Finally, we considered the potential for increased membership in environmental groups (land trusts, wildlife conservation organizations, and hunting groups) to increase conservation behavior. Environmental group membership represents one of the most common forms of political group membership (42), but little is known about how this trend affects the prevalence of conservation behavior. Environmental groups generally have a direct line to their members via mail, email, or social media. As a result, members presumably are better informed about conservation issues than the general population, and it has been shown that people with strong beliefs about climate science can be more likely to support immediate action (30). Moreover, members familiar with the missions and actions of environmental groups would be expected to have fewer concerns about being treated fairly when participating in conservation agreements (e.g., via compensation).

**Spatial Variation in Behavioral Intentions**

Despite growing recognition that spatial variation in social data is important for effective conservation planning (15), little is known about how human behavior affects the interpretation of spatial projections of species and ecosystems under climate change. The integration of social and ecological data needed to make such inferences is impeded by the different spatial scales at which data often exist; typically, social data are difficult or costly to obtain at the higher spatial resolution of ecological data. Here we overcome this impediment by (i) sampling the population based on the extent of our focal ecosystem (projections of marsh distribution in 2100) instead of political boundaries (such as townships or counties) and (ii) quantifying spatial variation in behavioral intentions across a grid used for ecological assessments (see ref. 43) and conservation planning (44), making it possible to quantify whether spatial variation in the social data exists at ecologically meaningful scales. We then overlaid our analysis of spatial variation in behavioral intentions with projections of marsh distribution to quantify how much of this zone is currently available for protection (Statistical Methods).

**Study Area**

Our study population was landowners in coastal Connecticut whose property is within the zone that is projected to be tidal marsh by 2100 (Fig. S1) (22). This zone is situated within the northeast coast of the United States, a region that will need to adapt to rates of sea-level rise that are unprecedented in modern
The effect sizes for a selection of the strongest predictors of behavioral intentions ($n = 1,002$). The column on the left shows the belief, attitude, or experience that is a predictor of the associated behavioral intention in the column on the right. Bars show the mean increase in stated intentions between a landowner who reported strongly disagree/strongly unlikely/no vs. strongly agree/strongly likely, as appropriate for the question. This increase in stated intentions is expressed as how many times more likely the respondent was to respond with “likely” or “very likely” to the question (e.g., landowners who were members of local land trusts were 1.5 times more likely than nonmembers to report that they were likely or very likely to participate in a restrictive covenant). We estimated this increase using back-transformed values of the parameter estimates from Fig. 2, calculated while holding all other variables constant at their observed sample means. Whiskers show 95% credible intervals.

![Figure 1](image-url)
Parameter estimates for variables that potentially influence behavioral intentions with respect to easements, outright purchase, restrictive covenants, future interest agreements, any agreement vs. no agreement, and the likelihood of constructing shoreline protection. Bars are 95% credible intervals, and white dots are posterior means. Credible intervals that do not overlap zero are shown in black. Positive values for parameter estimates indicate a positive relationship between the variable and the outcome.

Fig. 2. Parameter estimates for variables that potentially influence behavioral intentions with respect to easements, outright purchase, restrictive covenants, future interest agreements, any agreement vs. no agreement, and the likelihood of constructing shoreline protection. Bars are 95% credible intervals, and white dots are posterior means. Credible intervals that do not overlap zero are shown in black. Positive values for parameter estimates indicate a positive relationship between the variable and the outcome.

Discussion

We found a general pattern of weak relationships between behavioral intentions and a wide range of beliefs and attitudes that are common targets for conservation and environmental education. Variables that were strong predictors of intentions often revealed surprising relationships with immediate relevance to conservation practice. For example: (i) strengthening beliefs in climate change could have both negative and positive outcomes; (ii) while environmental group members may ultimately support conservation, for example through private donations, there is little evidence that they differ from the general population when it comes to higher-stakes decisions about their properties; and (iii) there was little evidence that emphasizing ecosystem services is likely to lead to greater participation in conservation. This last finding highlights the need for additional research on the attitudes, beliefs, and behavioral intentions of stakeholders in relation to ecosystem services to better quantify the power of this concept to meet conservation goals.

Easements, although popular with conservation practitioners, might not be as effective in the face of sea-level rise as other alternatives. More landowners preferred restrictive covenants, even though covenants do not offer a monetary incentive. One
likely explanation for this seemingly counterintuitive result is the evidence for concern among landowners that conservation organizations will act fairly when entering into binding agreements such as easements. The potential for this concern to be widely held warrants further study, as we have shown it can influence intentions with respect to several types of agreements. We also need similar information from other systems to evaluate whether the attitudes toward easements in our study are widespread. Although we anticipate that the wealth and education level of our study population will, if anything, bias attitudes in favor of high adoption rates, this assumption warrants testing. The low participation rates predicted here might be even lower in practice because intentions do not always translate into actions (50). The community engagement needed to enact agreements, however, might increase participation by providing opportunities to address landowners’ concerns. While it is unlikely that any one factor can fully explain the pattern of low intentions to participate in conservation behavior, attitudes about individual property rights may be a strong predictor. Factors that we expected to strongly covary with attitudes about property rights (political party membership and demographic characteristics), however, were not generally predictive of behavioral intentions (Fig. 2).

Addressing landowners’ concerns about the likelihood and fairness of incentives would likely be straightforward and inexpensive. The strong effects of these concerns (Fig. 2) suggest that reducing them could increase the proportion of landowners who are likely to forgo shoreline protection or participate in conservation agreements from the baselines presented here.

While the focus of our study was land protection by the private sector, coastal areas in the United States also have the option to participate in Federal “buyout” programs, which aim to bolster natural defenses in the wake of major storms by acquiring properties, typically for fair market value. In our study area, such programs have experienced very low participation rates despite being promoted by governments at local, state, and federal levels. Well under 100 properties in our study region have participated in acquisition programs by either the Federal Emergency Management Agency (https://www.fema.gov/) or the Natural Resources Conservation Service (https://www.nrcs.usda.gov/) since 2010, despite federal funding being made available in the aftermath of two major hurricanes (Irene in 2011 and Sandy in 2012). The number of properties acquired by these programs, compared with the number of eligible properties, suggests a lower participation rate than the stated intentions from our survey. If government programs are to play an important role in conserving lands threatened by sea-level rise, more research is needed to determine the underlying cause of this apparent discrepancy, which may be related to attitudes about government vs. nonprofit conservation organizations.

Our study used a stated preference survey, which can provide measures of beliefs, attitudes, and behavioral intentions across large spatial scales. Surveys that collect these measures for the populations that will determine program outcomes and efficiency are integral to formative assessments of program effectiveness (51). Obtaining the relevant measures with adequate spatial replication and representativeness is likely to be particularly important for conservation programs, which often operate over large areas.

Importantly, our results can guide future research that integrates concepts and approaches from additional areas of social science, especially those that can provide information that is beyond the scope of our methods. For example, baseline intentions to participate in conservation agreements could inform additional stated-preference research that seeks to refine agreement terms and incentives (e.g., contingent valuation) (52). Some of the patterns discovered here, in particular that restrictive covenants were preferred over conservation easements, also could be further clarified by qualitative approaches that are designed to investigate the role of social norms (e.g., ref. 53) and public deliberation (sensu ref. 54) in decision-making.

Fig. 3. Spatial variation in landowner intentions to participate in conservation agreements shown for (A) conservation easements and (B) outright purchase. Landowners who reported being very likely to participate in the given agreement are shown in red; landowners who reported being very unlikely to participate are shown in black (n = 1,002 respondents). The predicted extent of marsh migration by 2100 is shown in blue.

Projections of species and ecosystems under climate change are ubiquitous in the ecological literature, and many implicitly assume that human land-use decisions will not limit ecosystem shifts. Our results illustrate how this implicit assumption can overestimate an ecosystem’s ability to respond to climate change, highlighting the potential value of better integrating human dimensions into ecosystem modeling. Ecological models that better reflect human decisions would be especially valuable for coastal areas in the short term, where the impacts of climate change are already being directly felt (49) and half of the world’s population (55) is adapting to climate change alongside threatened species and ecosystems.

Methods
We conducted a four-wave mail survey of 3,050 landowners (Fig. S1), following the Tailored Design Method (56), between February and June 2015. We received 1,002 completed surveys (33% response rate). We used five-point Likert scales (57) to measure stated behavioral intentions with respect to the conservation agreements and constructing shoreline protection within the next 20 y. We also used five-point Likert scales (strongly unlikely to strongly likely, or very bad to very good, as appropriate) to quantify climate-change beliefs, attitudes about ecosystem services and wildlife, and concerns about incentives. We measured which agreement landowners were most likely to participate in, including the option of not participating in any agreement as a choice. Additional details about survey implementation and analyses are given in Supporting Information. The questionnaire, which contains the full terms of the conservation agreements, is given in SI Appendix. The full list of variables and associated numbers in the questionnaire are given in Table S1.

Data used in this paper are archived at Harvard Dataverse (doi:10.7910/DVN/NAKY2D). All work was conducted in accordance with IRB-approved protocol H14-086 from the University of Connecticut. Participants were informed of the purpose of the survey in a cover letter (SI Appendix) and consented by returning the questionnaire.

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