Adaptive governance and institutional strategies for climate-induced community relocations in Alaska

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This article presents governance and institutional strategies for climate-induced community relocations. In Alaska, repeated extreme weather events coupled with climate change-induced coastal erosion impact the habitability of entire communities. Community residents and government agencies concur that relocation is the only adaptation strategy that can protect lives and infrastructure. Community relocation stretches the financial and institutional capacity of existing governance institutions. Based on a comparative analysis of three Alaskan communities, Kivalina, Newtok, and Shishmaref, which have chosen to relocate, we examine the institutional constraints to relocation in the United States. We identify policy changes and components of a toolkit that can facilitate community-based adaptation when environmental events threaten people's lives and protection in place is not possible. Policy changes include amendment of the Stafford Act to include gradual geophysical processes, such as erosion, in the statutory definition of disaster and the creation of an adaptive governance framework to allow communities a continuum of responses from protection in place to community relocation. Key components of the toolkit are local leadership and integration of social and ecological well-being into adaptation planning.

climate change | coastal retreat | climigration

Human displacement could be a severe humanitarian consequence of climate change (1). Natural disasters have increased substantially over the past century, with ~370 natural disasters (more than one per day) displacing 38 million people in 2010 (2, 3). Floods caused 182 of these disasters, affecting 180 million people and killing 8,100 (2).

Approximately 10% of the world's population resides in coastal communities that are 10 m or less above current sea level (4, 5). The complex interplay of repeated extreme weather events and on-going biophysical processes, such as erosion and climate-induced sea-level rise, may permanently displace the inhabitants of many coastal communities, particularly in low-lying island nations (6), subsiding river deltas (7), and zones of active coastal erosion (8, 9).

Disaster relief and hazard mitigation are the traditional humanitarian responses to extreme environmental events and are primarily aimed at rebuilding and repairing infrastructure in place and protecting them from future hazards (10). However, this approach may be futile when climate change-induced biophysical changes repeatedly alter ecosystems, damage or destroy public infrastructure, and endanger human lives (11), in which case community relocation involving permanent population displacement may be the only viable adaptation. Climigration is a specific type of permanent population displacement that occurs when community relocation is required to protect residents from climate-induced biophysical changes that alter ecosystems, damage or destroy public infrastructure, and repeatedly endanger human lives (11). In this context, community relocation includes the reconstruction of livelihoods as well as the rebuilding of housing and public infrastructure in a location, away from vulnerable risk-prone coastal and riverine areas. Such relocation provides an opportunity for planned retreat from untenable situations.

In the United States there is currently no institutional framework or agency with the authority to relocate the entire public and private infrastructure of a community and rebuild livelihoods in a new location to protect them from climate change-induced hazards (10). Determining appropriate adaptive responses requires a sophisticated on-going assessment of a community's social, political, and economic susceptibility to harm caused by climate change and its capacity to adapt through protection in place, managed retreat of some structures, or community-wide relocation. There is currently no legislation authorizing funding for such assessments.

Climate change already impacts the habitability of many Alaskan communities. The US Government Accountability Office found that flooding and erosion affect 184 of 213 of Alaska Native villages (12), with 31 of these imminently threatened, and 12 communities planning to relocate (10). [Throughout this article the term "village" refers to an Alaska Native community: (*i*) deemed eligible as a Native village under the Alaska Native Claims Settlement Act; and (*ii*) which has a corresponding Alaska Native entity that is recognized and eligible to receive services from the Department of the Interior's Bureau of Indian Affairs (10). The term "community" is used more broadly to describe Alaska Native villages as well as other population aggregations defined by geographic proximity.] Despite state and federal expenditure of millions of dollars, erosion control and flood protection have not been able to protect some communities. The inability of technology to protect people who reside in vulnerable risk-prone coastal and riverine communities could affect millions of people globally. The 2012 devastation caused by Hurricane Sandy exemplifies these risks. The state governments of New York and New Jersey are now evaluating whether rebuilding coastal communities is possible and whether erosion and flood control infrastructure can protect these communities in the future (13).

This article describes the Alaskan experience with these issues. For several Alaska Native communities protection in place is not possible, and communities and government agencies agree that relocation is the only adaptation strategy that can protect them from accelerating climate-change impacts. We first discuss the suitability of the current postdisaster and hazard-mitigation statutory framework to address climigration in the United States. We then examine the institutional challenges faced by Alaskan communities seeking to relocate in response to climate change. We conclude by describing an adaptive-governance strategy that can provide a continuum of responses from protection in place to community relocation and would allow more effective and less costly adaptation to climate change. Finally, we suggest some policy changes to implement this strategy.

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Results

Policy Analysis: Postdisaster and Hazard Mitigation Statutory Framework. Significant statutory limitations prevent the government from responding effectively to the gradual biophysical changes that force communities to relocate in Alaska. The Federal Emergency Management Agency (FEMA), whose activities are defined by the 1988 Stafford Disaster Relief and Emergency Assistance Act, is the federal agency responsible for hazard mitigation and disaster relief in the United States (10, 14). The act requires a presidential disaster declaration to access federal funding for postdisaster recovery, as well as most hazard-mitigation activities (14). Under the Stafford Act, the President is authorized to declare a disaster for natural catastrophes, such as hurricanes and tornados. Drought is the only gradual biophysical process listed in the statute as a potential catalyst for a presidential disaster declaration (14). Erosion, which is one of the significant hazards faced by Alaskan coastal communities, is not included in the list of major disasters in the Stafford Act (14). Federal resources for postdisaster recovery are primarily intended to help rebuild individual homes in their current location (10, 14).

The Disaster Mitigation Act of 2000 modified the Stafford Act by establishing a federal program for predisaster mitigation. Five FEMA grant programs comprise the predisaster-mitigation federal response, none of which provide for community-wide relocation (10). One of the federal hazard-mitigation grant programs, the Hazard Mitigation Grant Program, provides funds to develop a Hazard Mitigation Plan for areas that have been declared a federal disaster (10). Mitigation planning requires a comprehensive risk assessment that helps a community identify and prioritize mitigation activities to prevent or reduce losses from identified hazards (15). Although the regulations require that approved mitigation plans be reviewed at least every 5 y, the integration of this information into risk analyses to inform mitigation activities is costly (15). Funding for mitigation activities is allocated nationally on a competitive basis based on cost-benefit ratios (10). Voluntary property acquisition is one of the tools of the Hazard Mitigation Grant Program to permanently remove structures from floodplains after a disaster has occurred. Homes are individually purchased and demolished or relocated to another location outside the floodplain (16). FEMA recommends that communities not develop relocation sites to which community members can move because of the complexity and expense of the process (16). The program requires that the land in the floodplain be designated as open space for recreational or agricultural purposes in perpetuity after the structures are removed [44 CFR 206.434(d)].

Alaskan communities have difficulty competing for hazard mitigation funds, including the property acquisition program, because of their remote location and low population, which equates to high costs and low benefits (10). In addition, erosion is the primary cause for relocation, and erosion is not included in the list of environmental events, as defined by law, that can initiate a presidential disaster declaration (17). Disaster-relief and hazard-mitigation measures are important when protection in place is possible, but are insufficient to respond to the climate-induced biophysical changes occurring in Alaskan communities.

To respond to this gap, the Alaska State Legislature created the Alaska Climate Change Impact Mitigation Program (ACCIMP) in 2009 to supplement the federal Hazard Mitigation Grant Program (3 AAC 195.040). The ACCIMP provides funds for hazard impact assessments to evaluate climate change-related impacts, including gradual biophysical change, such as erosion. The remaining funds are allocated for the planning needs and adaptation strategies to reduce vulnerability to the hazards identified in these assessments. Relocation planning activities can be funded.

Funding from the ACCIMP is limited to two community categories. Noncompetitive funding is allocated to six communities designated by name that are currently threatened by climate-induced biophysical change. The remaining funds are administered through a competitive grant process to communities based on an evaluation of four factors: (*i*) risk to life or safety during storm or flood events; (*ii*) loss of critical infrastructure; (*iii*) threats to public health; and (*iv*) loss of 10% or more of residential dwellings. The ACCIMP is a government-bridging program that provides a mechanism for communities to assess climate risks and create adaptation strategies, including relocation. However, this regulation does not mandate or authorize any state agency to provide relocation technical assistance, even if relocation is determined to be the most feasible adaptation option to protect lives and property. As a consequence, although ACCIMP allows relocation planning, no institutional relocation governance framework exists to implement community relocation in Alaska.

Community Relocation Efforts in Alaska. Community relocation in Alaska is already a recognized need. In the past, arctic sea ice protected indigenous coastal communities along the Bering and Chukchi Sea from coastal erosion and flooding by creating a barrier to storm-related waves and surges. Regional warming has thawed coastal permafrost because of warmer air and water temperatures (9, 18) and has reduced summer sea ice cover by 39–43% since 1979 (19), leading to a longer fetch and taller waves (20). Together, these changes have increased rates of coastal erosion, especially during severe autumn storms, which (because of the longer ice-free season) are now more likely to occur during ice-free conditions (8, 9).

In this section, we describe the relocation process of the three communities identified in the 2003 US Government Accountability Office report as most critical to relocate. The governments of Kivalina, Shishmaref, and Newtok (Fig. S1) concluded decades ago that community relocation was the only solution to protect their respective communities from life-threatening biophysical change. Each community has undertaken a three-pronged relocation process that involved: (*i*) identification of a new village site, (*ii*) resident voter approval of the relocation site, and (*iii*) documentation to substantiate the need to relocate and the suitability of the relocation site for the community (21–24). Each community commissioned several social-ecological assessments and relocation evaluations. Despite the similarity of the steps taken by each community to relocate, only Newtok has begun the relocation process. A comparison of the three case studies demonstrates a common suite of challenges faced by Alaskan communities seeking to relocate and some of the factors that have either contributed to or constrained progress toward relocation.

The ancestors of the current residents of Kivalina, Shishmaref, and Newtok moved seasonally among coastal and inland hunting and fishing camps (24–27). This migratory lifestyle changed during the late 19th and early 20th centuries primarily because the US Department of the Interior's Bureau of Education began to develop a formal educational system for the Alaska Native community (25, 28). The construction of schools along the western coast of Alaska and the requirement that Alaska Native children attend school caused the Alaska Native population to consolidate and settle (25, 28). Barge accessibility to transport construction materials determined the location of the schools (25, 26). The building of permanent schools and housing and of sewage, water, and electricity infrastructure led to a change from seasonal migration to establishment of permanent communities at the school sites selected by the federal government (24). This change reduced the flexibility of each community and created a new set of dependencies on government to respond effectively to environmental changes.

Kivalina. The Village of Kivalina is an Inupiaq Eskimo federally recognized indigenous tribe located on the tip of a thin, 6-mile-long barrier reef island in the Chukchi Sea, 128 km above the Arctic Circle (22) (Fig. S2). Storm surges and flooding threaten

the community as a result of diminished arctic sea ice and the delay in freezing of the ocean. Between 2002 and 2007, six extreme weather events threatened Kivalina. The state and federal government issued three disaster declarations (23). The most recent extreme event was a hurricane-strength storm in November 2011 (29). Between 2006 and 2009, government agencies spent $15.5 million on erosion-control projects that have failed to protect the community (23, 30).

Erosion caused by storm surges impacts infrastructure that is essential for the viability of the community in its current location until such time as relocation can occur. These infrastructures include the only means of access to the community (the summer barge landing and the community airstrip), the community's sole water source, and the stability of the community's solid waste storage containment area (22, 23, 27).

In 1998 and 2000, the community voted to relocate and chose two different relocation sites, which the US Army Corps of Engineers (USACE) later determined after each vote were unsuitable because of thawing permafrost (23). In January 2012, Kivalina residents voted to construct a new school 7 miles from their current location. Funding for the new school comes from a lawsuit settlement agreement involving funding inequities that harmed rural Alaskan schools (31). Kivalina's efforts to raise additional relocation funds from a climate-change lawsuit against oil, coal, and gas companies have been unsuccessful. The Kivalina Evacuation and School Site Access Road Committee is coordinating the work to determine the viability of constructing a road between the current community location and the school site. The road will provide an evacuation route during extreme weather, and the school may serve as pioneer infrastructure for community relocation. Funding for the road construction may come from the Alaska Department of Transportation and Public Facilities (DOT) and USACE, but the timing of road construction is unclear. The additional steps required to relocate all of Kivalina's residents, infrastructure, and housing to this location have also not been identified.

Shishmaref. Shishmaref is an Inupiat Eskimo village on Sarichef Island on the northwest coast of Alaska. Between 1973 and 2009, state, federal, and tribal governments invested about $16 million in shoreline protection to address the accelerating rates of erosion (32–34). Despite this investment, storms repeatedly damaged or destroyed public infrastructure and many homes (Fig. S3). In 2001, the Native Village of Shishmaref created the Shishmaref Erosion and Relocation Coalition to work with multiple federal agencies and their contractors to identify a new, safe, and culturally appropriate community location (32, 33).

In 2002, residents voted to relocate the community, and two federal government agencies began studying the relocation issue—the USACE, mandated to provide engineering services to reduce risks from disasters, including flood control, and the US Department of Agriculture Natural Resources Conservation Services (NRCS), mandated to help reduce soil erosion and damages caused by floods and other natural disasters (10). Although neither agency had guidelines or a mandate to analyze suitability of a relocation site, both agencies conducted a series of studies regarding alternative relocation sites for Shishmaref.

In 2004 the Shishmaref Erosion and Relocation Coalition, which later dissolved as an organization, chose Tin Creek as the community's preferred relocation site. Between 2004 and 2008 the NRCS, USACE, and Alaska DOT conducted approximately six separate studies to evaluate Tin Creek's suitability as a relocation site (33). The DOT determined that the site was unsuitable because of the presence of ice-rich permafrost that could thaw as a result of climate warming and create future problems for community habitability (33). In June 2009, the City of Shishmaref received a grant through the ACCIMP to conduct a Shishmaref Site Selection Feasibility Study. As a consequence, the most recent relocation site analysis, conducted in 2010, recommended a relocation site 10 miles from the community, which may meet the community's need to be close to their traditional subsistence grounds and also meet government geophysical requirements (33). After geophysical tests are conducted to determine the site's suitability, the community will vote again to determine if this site also meets their needs (33). In 2011, the community created the Shishmaref Relocation Work Group to move the relocation effort forward. As in Kivalina, government agencies and the majority of community residents agree that relocation is the only adaptation strategy that will ensure the long-term resilience of the community, but the steps necessary to implement relocation, if the proposed site is approved, are unclear.

Newtok. Newtok, a Yup'ik Eskimo village, is located along the Ninglick River near the Bering Sea in western Alaska (35, 36). A combination of increased temperatures, thawing permafrost, and wave action has accelerated the erosion, causing the Ninglick River to move closer to the village (35) (Fig. S4). The State of Alaska spent about $1.5 million to control the erosion between 1983 and 1989 (26). Despite these efforts, erosion is projected to reach the school, the largest structure in the community, by about 2017 (35) (Fig. S5).

Six extreme weather events between 1989 and 2006 exacerbated these gradual biophysical changes. Five of these events precipitated FEMA disaster declarations (37). FEMA declared three disasters between October 2004 and May 2006 alone (37). These three storms accelerated the erosion and repeatedly "flooded the village water supply, caused raw sewage to be spread throughout the community, displaced residents from homes, destroyed subsistence food storage, and shut down essential utilities" (35). Public infrastructure that was significantly damaged or destroyed included the village landfill, barge ramp, sewage-treatment facility, and fuel storage facilities (26). The barge landing, which allows for most delivery of supplies and heating fuel, no longer exists, creating a fuel crisis. Salt water is affecting the potable water (26).

Newtok inhabitants voted three times, most recently in August 2003, to relocate to Nelson Island, 9 miles from Newtok (35). Newtok obtained title to their preferred relocation site, which they named Mertarvik, through a land-exchange agreement negotiated with the US Fish and Wildlife Service in 2003 (35). No infrastructure existed at the relocation site. In 2006, Newtok community residents built three houses at Mertarvik, with funding received by the Newtok Traditional Council. In 2009, construction of pioneer infrastructure, including a multipurpose evacuation center and barge landing, began at the relocation site through the work of the Newtok Planning Group.

Newtok Planning Group. The Newtok Planning Group is an informal boundary organization that emerged in May 2006 from an ad hoc series of meetings, when state and federal agencies realized that Newtok was serious about its relocation because it had chosen its relocation site, acquired legal title, assured geophysical stability, and constructed three homes (10, 17). No similar planning group was implemented to respond to the relocation efforts of Kivalina and Shishmaref.

The Newtok Planning Group is unique in Alaska in its multidisciplinary and multijurisdictional structure. The group consists of about 25 state, federal, and tribal governmental and nongovernmental agencies that all voluntarily collaborate to facilitate Newtok's relocation. The Alaska Department of Commerce, Community, and Economic Development (DCCED) is the lead coordinating Alaska state agency for the Newtok Planning Group, but no federal agency has authority to coordinate federal efforts for Newtok's relocation (10, 17). From the Newtok Planning Group's inception, the Newtok Traditional Council has led the relocation effort, ensuring that local needs and goals guide the process.

As is typical of boundary organizations, no state or federal statutes or regulations govern or guide the work of the Newtok Planning Group (34). Agency representatives had to educate

each other about the laws, funding options, and limitations of each agency to identify and coordinate funding, including sharing equipment costs and coordinating its use (34, 38). State funding to build public infrastructure, such as schools and air landing strips, is extremely competitive. With no population permanently residing at the relocation site, Newtok has not yet been unable to secure funds to build this critical infrastructure (26).

Initial planning efforts focused on the design and construction of pioneer infrastructure consisting of an emergency evacuation center/community center, barge landing, and an access road that connects these two structures. Seven different federal, state and tribal entities are involved with the construction and funding of these facilities, but no agency is authorized with overall supervision of the project, which has caused delays (17). Construction of the evacuation center was not yet complete as of 2012.

Meeting the requirements of the National Environmental Protection Act, which requires environmental impact assessments of federally funded construction projects, has been a significant impediment to progress (17). The National Environmental Protection Act requires designation of a federal lead agency, but the Stafford Act and other legislation provide no federal agency with authority to take a lead role in community relocation (10). These statutory impediments to Newtok's relocation will affect all Alaskan communities seeking to relocate.

In summary, although Newtok has worked for approximately a generation (19 y) to relocate, with substantial supporting efforts from numerous government agencies, statutory and institutional barriers have caused significant delays of the relocation process. In addition, there are no mechanisms in place to ensure that the extensive intergovernmental learning and collaboration that has occurred in designing Newtok's relocation will assist with the relocation of Kivalina, Shishmaref, or other Alaskan communities.

Discussion

Governance Limitations to Community Relocation in Alaska. In Alaska, the lack of an overarching institutional relocation framework has caused the relocation of Kivalina, Shishmaref, and Newtok to proceed in an ad hoc manner. Each community took a somewhat different approach to their relocation planning process. Newtok began a relocation planning process with the Alaska DCCED, whereas Kivalina and Shishmaref worked primarily with federal agencies, including the USACE. Kivalina attempted to use legal challenges to fund initial infrastructure, whereas Newtok engaged a complex group of agencies, some of which were able to access funds not specifically designated for relocation. Communities also differed in local governance structure. Newtok has only one governing body (the Newtok Traditional Council); Shishmaref formed a working group comprised of elders and tribal and city government representatives; and Kivalina worked through its two local governing bodies, the city government, which is a political subdivision of the State of Alaska, and the tribal council, which has a government-to-government relationship with the federal government of the United States (10).

The relocation site chosen by each community played an instrumental role in the willingness of state and federal government agencies to assist with relocation. The Immediate Action Workgroup recognized that, government needs to: "[c]reate a process/recipe to identify suitable relocation sites to ensure an efficient and successful outcome. Kivalina's experience is a reflection of the downsides of not having an effective process in place" (39). This process has not yet been established. Newtok chose a relocation site that was not subject to permafrost thaw and had a good water source. Both Kivalina and Shishmaref initially chose culturally appropriate relocation sites that were later opposed by federal and state government entities because of concerns with thawing permafrost. Kivalina eventually found a relocation site that meets government criteria for site suitability and is slowly moving toward relocation. The consulting firm hired by the City of Shishmaref recommended evaluation of a relocation site not previously considered by Shishmaref and suggested that additional geotechnical studies be performed to ensure the site's suitability for relocation. The absence of clear guidelines and criteria for site selection or funding for geotechnical evaluation delayed relocation efforts in Kivalina and Shishmaref, causing distrust and frustration with state and federal government authorities (24, 39).

Finally, consensus by the three communities and state and federal agencies that relocation was essential created barriers to repairing and maintaining storm-damaged infrastructure in the current locations. The statutory restrictions of the National Flood Insurance Program prevent government agencies from using funds to repair seriously deteriorated infrastructure because of their location in flood-prone areas unless the structures can be protected (30, 34, 37). For example, the design of a solid waste master plan in Newtok, Shishmaref, and Kivalina has been deferred because of each community's decision to relocate and the government's reluctance to build new infrastructure in an existing floodplain (10, 26, 27). As a result, "honey buckets," 5-gal buckets with plastic bag liners, are used in most homes instead of plumbing and sewage disposal (24, 26, 27). A 2006 public health assessment found that sanitation conditions in Newtok were "grossly inadequate for public health protection" (26). Between 1994 and 2004, 29% of Newtok's children were hospitalized with lower respiratory tract infections (17). Destruction of Newtok's barge landing by storms raised the cost of essential supplies and infrastructure repair. In summary, the communities have been unable to relocate, but it is unsafe and unhealthy to remain where they are.

Strategies for Adapting Governance to Address Climate Change. Climate-induced population displacement requires a governance framework that can dynamically respond to communities faced with accelerating biophysical changes caused by increased temperatures. Adaptive governance, in this context, means that institutions need a range of options, including postdisaster recovery, protection in place (seawall/shoreline protection), hazard mitigation, and relocation, to respond to the humanitarian needs of communities.

Here we summarize a set of general strategy elements that emerge from relocation efforts by Alaskan communities and from other climate-change adaptation efforts (Table S1). None of these strategy elements is essential or by itself guarantees success, but together they provide a toolkit for potentially successful adaptation to climate change. The toolkit is designed to create a multidisciplinary and multilevel assessment of climate-related risks that fosters leadership and integrates an iterative learning process to develop adaptation strategies (40, 41).

Identify current climate-related risks and vulnerabilities and project their future changes. Key components of governance of climate change adaptation are the capacity to monitor local social-ecological processes and implement a dynamic and locally informed institutional response (15, 42).

Kivalina, Shishmaref, and Newtok each documented the occurrence and damage from severe winter storms and accelerating rates of erosion that increasingly threatened lives and property. These assessments were confirmed by multiple agency reports. Global and Alaskan regional climate models project that severe winter storms will increasingly occur during ice-free conditions and that their erosional impact will be amplified by continued loss of protective sea ice (8, 9). The integration of local assessments with regional and national assessments can foster multilevel collaboration and well-structured dialogue among scientists, community leaders, and government representatives to develop adaptation strategies that minimize the societal risks of these climate changes (42, 43). For example, in our case studies, the communities participated in identifying climate-related risks

by gathering data and making decisions about appropriate institutional responses to the hazard.

Adapt to current climate extremes through known adaptations and adapt to novel impacts by exploring outside-the-box adaptation strategies. Through funding for disaster relief, federal and state agencies spent about $32 million on erosion control projects intended to reduce erosion and risks to life and property, and projected in 2004 that Shishmaref alone would require an additional $90 million for infrastructure upgrades and erosion protection measures within 15 y (44). Alternatively, these funds could be used for relocation, which residents and agencies responsible for erosion and flood control concurred was the only viable adaptation option. However, as described above, there is no funding or governance mechanism to implement this adaptation. Without an institutional framework to identify the steps a community must take to begin a relocation process, communities will be caught in a maze of conflicting agency regulations, and relocation will proceed in an uncoordinated and ad hoc manner (26, 30, 34). Policy changes, which include the creation of an adaptive governance framework that can dynamically respond from protection in place to community relocation, are required for substantive progress toward relocation.

Integrate ecological integrity and societal well-being. Newtok's selection of a relocation site met the needs of both biophysical integrity (no high-ice-content permafrost and not highly susceptible to long-term coastal erosion or sea-level rise) and cultural integrity (continued opportunities for community cohesion and subsistence hunting activities). By including biophysical, cultural, and socioeconomic criteria in relocation planning, the relocation plan received widespread support from both community residents and government agencies seeking to assist with community relocation. Agency opposition to the relocation sites proposed by Kivalina and Shishmaref on the grounds of permafrost instability was a key impediment to relocation progress by those communities.

Integrate climate-change adaptation with other societal goals. Although community relocation is the most urgent challenge facing our three Alaskan communities, restrictions on repairing or upgrading current infrastructure create other hardships, such as high heating costs because of poor insulation, public health risks from inadequate sewage treatment, undependable fuel supply because of degraded barge-landing facilities, and high-maintenance, expensive, and inadequate water treatment, as observed in all three of our study communities. Community relocation provides an opportunity to address these multiple societal issues to foster long-term sustainability in the process of relocating communities. Mainstreaming of climate-change policies with other agency mandates increases the likelihood of efficient implementation (45, 46) and of accounting for the interactions between climate-induced impacts and other stressors (43).

Bridge among formal organizations to facilitate communication, collaboration, and learning. The Newtok Planning Group is an informal bridging organization that has worked intensively for 7 y to develop a relocation strategy despite the lack of any official relocation mandate for participation in the group. The collaboration that occurred created innovative solutions that were less likely to have emerged through formal channels. It remains to be seen whether the social capital thus created will contribute to relocation efforts of other villages. In general, bridging organizations and informal networks create new spaces where learning can occur and which are less constrained by the formal mandates of participating groups (47, 48). Bridging organizations may be particularly important in devising novel adaptation options or governance structures to improve the fit with the new conditions resulting from climatic and other global changes, for example the seasonally ice-free conditions in a warming Arctic Ocean (49).

Seek interdisciplinary, multisector engagement that fosters local leadership and engages local governing institutions in identifying potential solutions. The breadth of stakeholder engagement by tribes, state and federal agencies, and nongovernment organizations in the Newtok Planning Group contributed to its success by reducing the likelihood of each agency and stakeholder group pursuing a separate and partially incompatible agenda (silos). Power-sharing and joint decision-making allowed learning to occur and created trust among participating groups spanning tribal, state, and federal entities (15). Leadership of the Newtok Planning Group by the Newtok Traditional Council ensured that solutions were place-based, local in scale, and understood and accepted by community residents. State and federal agencies along with nonprofit organizations, which have access to resources, geotechnical equipment to assess relocation sites, and expertise to build infrastructure, provided technical assistance to facilitate the community relocation. The Newtok Planning Group's collaborative governance structure, which recognized the need to address housing, transportation, and utilities as essential components of an integrated relocation strategy, has been essential in moving Newtok's relocation effort forward. Similarly, comprehensive multisector planning has been critical for complex adaptation planning at city, state, and national levels and is an important strategy to reduce and manage risk to climate extremes and disasters (41, 45).

Policy Implications. Our analysis suggests that climigration, as an effective adaptation strategy to climate change, requires a combination of local leadership to identify climate threats and potential solutions, elimination of higher-scale (e.g., state and national) institutional barriers that prevent effective local adaptation, and governance of climate-change adaptation that fosters innovation and efficient communication across these scales. Specifically, in Alaska, adaptation requires institutions to respond dynamically to accelerating climate-change impacts and prepare for a continuum of potential responses that include postdisaster recovery, protection in place (e.g., seawall and shoreline protection), hazard mitigation, and relocation. We therefore recommend the following:

- Amendment of federal policies such as the Stafford Act to include gradual and recurring climate-induced biophysical processes, such as erosion, would allow the President to declare such circumstances a disaster and release federal funds for predisaster hazard mitigation (42 U.S.C. § 5122) and planning as a response to climate change.
- Change in federal and state statutes to specifically permit federal disaster relief funding to be used and federal agencies to participate in building new infrastructure and relocating an entire community to a relocation site when durable adaptation is impossible in the current location.
- Creation of a relocation institutional framework to authorize government agencies to provide relocation technical assistance and funding, outline specific steps communities must take to begin a relocation planning process, (including the identification of site suitability criteria), and remove statutory barriers that impede relocation.

These amendments would allow Alaska Native villages and other communities threatened by climate-induced ecological changes to shift seamlessly from a disaster recovery to community relocation. The creation of this framework would avoid repeated humanitarian crises when communities are faced with chronic extreme weather events that accelerate biophysical change.

Conclusion

Climate-induced biophysical change threatens the lives, livelihoods, homes, health, and basic subsistence of many human populations. Governments and insurance companies may not be able to sustain the cost of rebuilding infrastructure repeatedly damaged or destroyed by these changes. Relocation may be the best adaptation response if the community's current location is

uninhabitable, or relocation reduces vulnerability to future climate-induced ecological threats. We have outlined an adaptive governance framework that can respond to rapid directional environmental change involving extreme weather events to foster resilience in the face of these changes. Testing this framework for community relocation in Alaska provides an opportunity to learn and adaptively design institutional frameworks for a broader range of climate-change impacts in the United States and globally.

Methods

To understand the community relocations occurring in Alaska, we conducted a case study of the relocation process in Kivalina, Shishmaref, and Newtok. Data-gathering tools used to collect evidence included surveys, interviews, participatory observation, and the study of organizational documents of the Newtok Planning Group, the Shishmaref Erosion and Relocation Coalition, and the Alaska Sub-Cabinet on Climate Change Immediate Action Workgroup. Archival document review included review of erosion assessments conducted by the USACE, results of the Newtok Housing Survey, community relocation lay-out documents, and geotechnical documents for each community, community relocation reports, and federal government relocation, erosion, and climate-change reports.

R.B. and F.S.C. participated in ~45 and 10 meetings, respectively, occurring on three different governance levels since 2007. These included meetings conducted by the Newtok Planning Group and the Immediate Action Workgroup and the Adaptation Advisory Group created by the Subcabinet on Climate Change.

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Supporting Information

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SI Text

The villages of Kivalina, Shishmaref, and Newtok, Alaska (Fig. S1) recognized decades ago that community relocation was the only solution to protect their respective communities from life-threatening biophysical change. These supporting materials provide details about each community's efforts to relocate.

Kivalina (Fig. S2) has been working on its village's relocation since 1953 and has held five elections related to relocation (1). About 360 people currently live in Kivalina (2). In 2006, 6 y after the 2000 relocation vote, the US Army Corps of Engineers (USACE) funded a master relocation plan. The study had two goals: to assist Kivalina residents in choosing a relocation site and to create a relocation planning process (2). The study evaluated six relocation sites, reviewed the previous 10 studies documenting the social and ecological impacts of erosion and flooding and evaluating Kivalina's relocation plan, and found that the community's relocation site Kiniktuuraq, chosen in 2000, was "vulnerable to erosion and must be armored using armor rock and riprap" (2).

In September 2006, federal government leaders arrived in Kivalina to celebrate the finalization of a multimillion dollar seawall. Before the commencement of celebrations, a storm damaged 160 feet of a 1,800-foot seawall and caused the officials to cancel the celebration (3). One year later, in September 2007, a storm once again threatened the community; its residents feared that the seawall would not provide adequate protection and therefore evacuated their community in search of safety (4, 5). After the 2007 evacuation, the USACE approved construction of a large rock revetment project with a design life of only 15–20 y (6).

Shishmaref (Fig. S3) is located on Sarichef Island, a barrier island which separates the Chukchi Sea from a saltwater lagoon. Sishmaref residents first decided to relocate in 1973 when a storm eroded 30 feet of shoreline (7). Twenty-five years later, in October 1997, an autumn storm caused severe erosion and required 14 homes and the National Guard Armory to be relocated within the current village site (2). The following year, the Alaska Department of Transportation conducted an erosion assessment and estimated the imminent loss of 22 homes from the accelerating erosion (7). This storm and the subsequent erosion assessment precipitated an earnest effort to relocate the community.

Federal government agencies have studied the erosion and relocation issue since 1996, but the actual relocation of the community has not yet started (7). In 2003, the US Department of Agriculture Natural Resources Conservation Services facilitated a community-led planning effort and evaluated eleven potential relocation sites (8). In 2004, the Shishmaref Erosion and Control Coalition facilitated a community-wide vote, which resulted in choosing Tin Creek as the preferred relocation site (8). Because of disagreement about the long-term habitability of the relocation site as a result of thawing permafrost, the community has still not relocated.

Newtok is located within the Yukon-Kuskokwim Delta, one of the largest river deltas in the world, and surrounded by marshy tundra and lakes (9) (Fig. S4). The Ninglick River borders Newtok to the south; to the east is the Newtok River (10). Newtok is a Yup'ik Eskimo village with 321 residents and about 60 houses. Erosion is causing the Ninglick River to move closer to the village of Newtok. The community has monitored erosion rates of the Ninglick River since 1983 (Fig. S5). In 1950, more than 1 mile separated the Ninglick River from the homes of community members (9). In 1994, the Newtok Traditional Council started a relocation planning process and analyzed relocation to six potential sites. Ten years later, in 2004, the Newtok Traditional Council commissioned a report to provide background documentation to government agencies and officials to justify the efforts of the village to relocate and to support requests for government assistance in this process (11). Newtok inhabitants voted three times, in September 1996, May 2001, and August 2003, to relocate to Nelson Island, 9 miles from Newtok.

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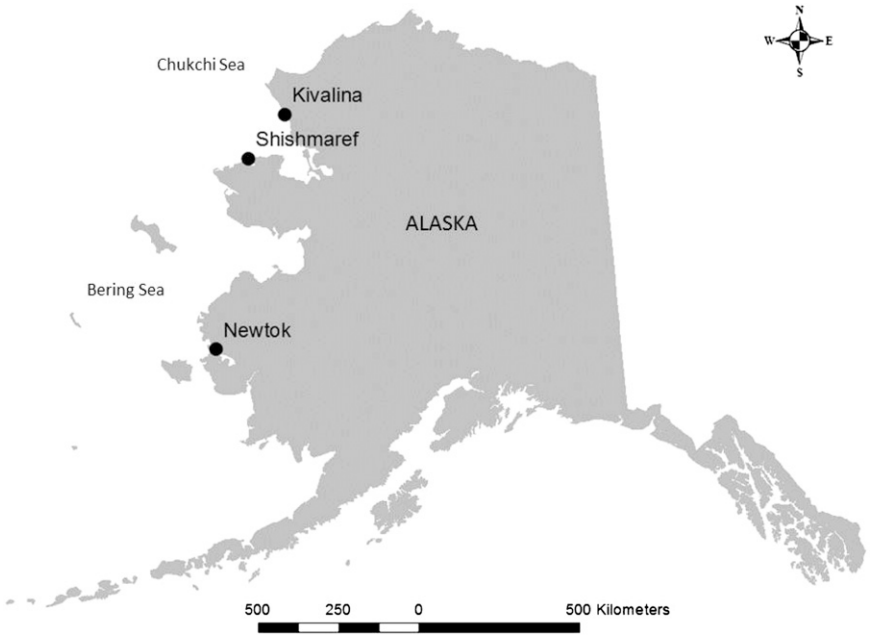

Fig. S1. Map showing locations of Kivalina, Shishmaref, and Newtok.

Fig. S2. Kivalina. Image courtesy of Robin Bronen.

Fig. S3. Shishmaref. Image courtesy of Tony Weyiouanna.

Fig. S4. Coastal erosion in Newtok. Image courtesy of Robin Bronen.

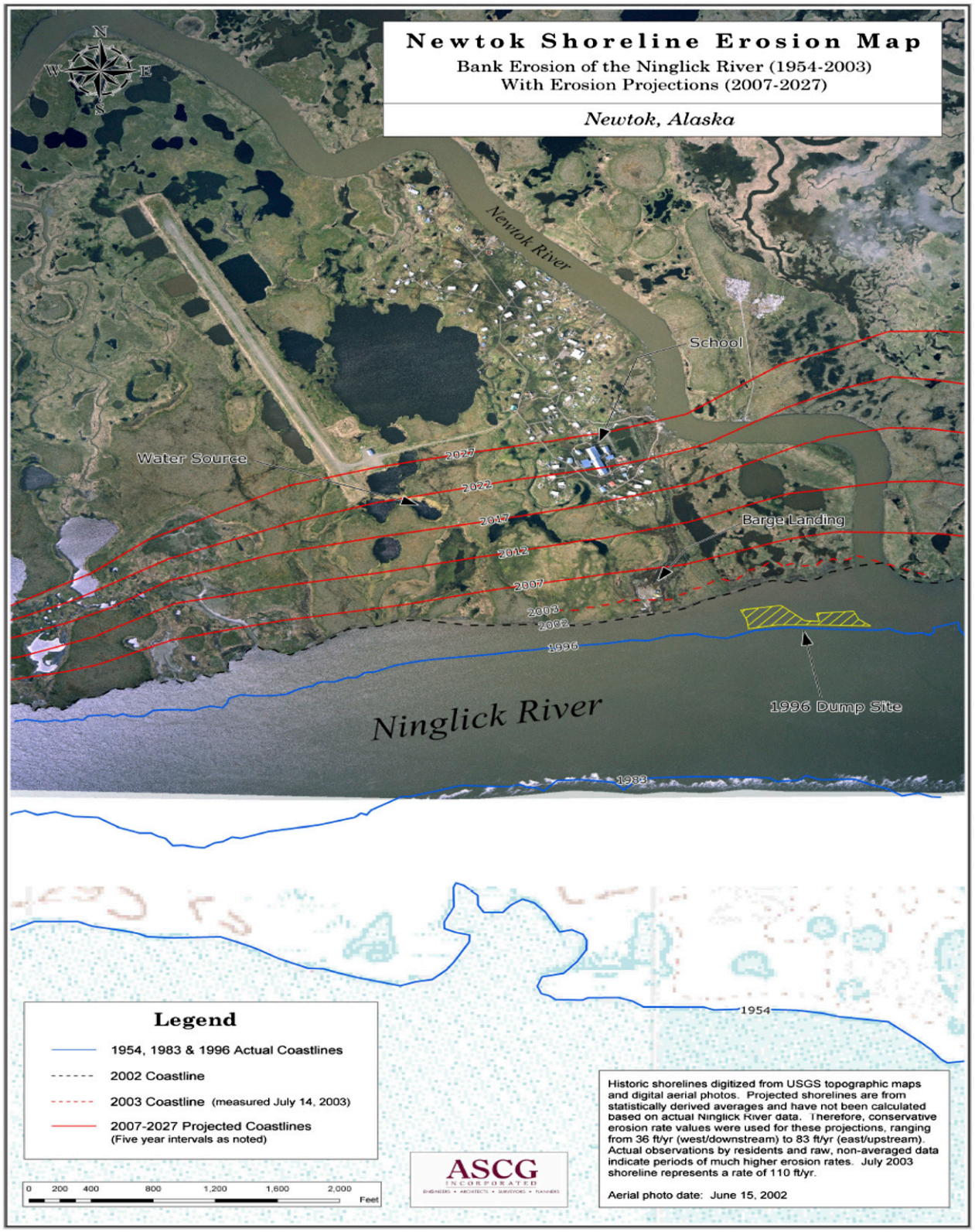

Fig. S5. Aerial photograph of Newtok, with historical and projected coastline.

Table S1. Strategies that foster adaptive governance to climate change

Adaptation strategy elements	Alaskan community relocation examples	Literature examples
Identify current climate-related risks and vulnerabilities and project their future changes.	Document and project increasing frequency and damage from severe autumn storms.	Hurricanes (1), sea level rise (2), agricultural disruption from drought (3).
Adapt to those current climate extremes that are projected to become more pronounced.	Armor coastline to prevent damage from coastal storms.	Coping with heat waves (4), extreme storm tides (5), extreme drought (3).
Identify limits to current adaptation options and explore viable alternatives.	Relocate community when community-threatening flooding and erosion cannot be prevented.	Adaptive retreat from vulnerable coasts (1, 2), agricultural relocation (3).
Integrate ecological integrity and societal well-being.	Select relocation sites that lack high-ice-content permafrost and are culturally appropriate.	Integration of environmental and societal goals (5).
Integrate climate-change adaptation with other societal goals.	Integrate community relocation with sustainable design of the relocated community.	Mainstreaming of climate-change policies with other agency goals (3).
Bridge among organizations to facilitate communication, collaboration, and learning.	Foster engagement among interested parties outside of formal governance structures (Newtok Planning Group).	Shifting resource development and sovereignty issues in an ice-free Arctic Ocean (6).
Seek interdisciplinary, multisector engagement that fosters local leadership and engages local governing institutions in identifying potential solutions.	Community resident voter approval of relocation site. Village tribal council leads relocation with government agencies providing technical assistance (Newtok Planning Group).	Global leadership for climate mitigation; regional leadership for coastal zone development; local leadership for site-specific responses (7).

None of these strategies is essential or by itself guarantees success, but each contributes to the potential success of strategies for adapting to climate change. Adapted from Natural Resources Conservation Services (8).

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