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Community-empowered adaptation for self-reliance

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This paper describes the integration of social–ecological science with traditional knowledge to address global-change challenges faced by indigenous communities in rural Alaska. The Community Partnership for Self-Reliance is a novel boundary organization that uses community visions for self-reliance, based on local and traditional knowledge, to link bottom-up with top-down adaptation planning. We suggest that similar boundary strategies can improve the communication of adaptation needs and opportunities across scales, empowering local communities to select adaptation choices that fit their own goals. This would facilitate regional experimentation and diffusion of innovative solutions to address rapid and heterogeneous environmental and socioeconomic change.

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Introduction and approach

Given the accelerating pace of global environmental and social change [1], identification of a vision and process for adaptation (defined here as action that enhances long-term wellbeing and sustainability) is critical if households, communities, and nations are to thrive [2,3]. Government adaptation programs often focus on specific stresses (e.g., climate change or renewable energy) in isolation, sometimes leading to unintended consequences [4]. In contrast, real-world problems are inherently transdisciplinary, that is, they require insights not only from natural and social scientists but also from practitioners seeking solutions and from communities that are affected by problems and attempted solutions.

A fundamental limitation of top-down planning is that external planners provide intended solutions that may not be closely informed by community visions for the future. This creates an inevitable tension between top-down government planning, which focuses on cost-effective provision of a few broadly applicable solutions, and local empowerment to identify locally appropriate adaptation goals and pathways [2,5]. This dilemma suggests a need for community-empowered adaptation planning and more effective integration of bottom-up and top-down planning, monitoring, and assessment to link government expertise and resources with local knowledge of adaptation history and opportunities [6,7].

In 2011 the Community Partnership for Self-Reliance (CPS) was initiated in response to Native leader Larry Merculieff's challenge to foster university research that addressed the priorities of Alaska Native communities rather than only those of individual researchers. CPS began as a collaboration of the Alaska Native Science Commission (ANSC; a tribal NGO), the University of Alaska Fairbanks (UAF), and selected rural Alaska communities. Over two years, a working group, chaired by Merculieff and composed of 13 Alaska Native leaders, 5 UAF faculty, and 3 graduate students, co-designed CPS to link community visions for self-reliance with technical expertise through *inreach* from communities to the university and agencies. We define inreach as the process by which communities tap technical expertise to address community-defined barriers to their long-term self-reliance. Native leaders in the working group identified eleven rural communities that were highly innovative and lacked local economic opportunities or road access to jobs. These communities were invited to apply to participate in CPS. Four communities applied and were accepted into CPS. The goal of the program is to foster bottom-up adaptation planning in rural Alaska that prioritizes local sustainability visions, assesses the feasibility of adaptation options, and formulates a strategy for transformative adaptive changes, that is, changes that empower communities to address their own long-term sustainability goals.

We identified twenty UAF research groups willing to provide their expertise, if requested by communities.

Most of these groups had no experience working with communities but felt that their research was, or could be, community-relevant. Their expertise included energy, housing, water systems, rural development, business, indigenous languages, education, ecology, agriculture, wildlife and fisheries, resource management, health, climate science, and climate policy.

The CPS team engaging with each community consisted of two ANSC leaders, one UAF graduate student (a different student for each community), and one-to-three UAF faculty members. The self-reliance priorities identified by each community in their applications to CPS were revised during three CPS visits to each community over a 6-month period. At the initial CPS meeting with a community's tribal council and in community-wide meetings, ANSC leaders explained the goals of CPS. They presented a scenario of continued increases in the cost of fuel and other commercial goods and a decline in services provided by funding-constrained government agencies, which together would require greater community self-reliance to solve their own problems. ANSC made available a written survey by which each community could assess its cultural strengths. During the first 1–2 CPS visits to each community, tribal leaders articulated and prioritized one-to-three sustainability issues that they believed most strongly constrained the self-reliance of their community. Based on discussions of UAF expertise relevant to these issues, tribal-council leaders chose the issues on which they wished to collaborate with UAF researchers. See Supplementary Information for detailed methods and community descriptions.

Findings

Community characteristics and adaptation challenges

The four communities that participated in CPS (Igiugig, Koyukuk, Newtok, and Nikolai) were representative of Alaska rural communities with respect to their lack of connection to the road system and electricity grid, their predominantly indigenous population (72–99%), high unemployment (50–58%), substantial poverty (29–55% of the population below the US poverty line; 6-fold higher than in Anchorage [Alaska's largest city]), and extensive nutritional and cultural dependence on subsistence hunting and fishing (Table 1). Compared to Anchorage, average costs in these villages were 1.9 times higher for fuel and 2.4 times higher for electricity and commercial goods, whereas median household income, with the exception of Newtok, was about 30% of that in Anchorage.

Table 1

General characteristics of CPS communities.

Parameter[a]	Igiugig	Koyukuk	Newtok	Nikolai
Latitude, longitude	60°N, 156°W	65°N, 158°W	61°N, 165°W	63°N, 154°W
Complexity of local government[b]	Tr, VC	Tr, Ci, VC	Tr, VC	Tr, Ci, VC
Population[a]	52	95	377	94
AK Native (% non-white)	72%	99%	96%	92%
Ethnic majority	Yup'ik	Athabascan	Yup'ik	Athabascan
Flight minutes to urban center[c]	A, 80	F, 150	A, 240	A, 90
Water source[d]	R, W	W	L	W
Sewage syst. (% of occupied homes)	88%	0%	0%	100%
# students in school (% of pop.)[a]	19 (37%)	15 (16%)	155 (41%)	11 (12%)
School language program? (Y/N)	Y	Y	Y	N
Culture camp? (Y/N)	Y	Y	Y	Y
Housing units occupied (% of total)	84%	78%	97%	77%
People per occupied house	4.0	2.4	5.3	2.7
Unemployment[a] (% of workers not in labor force)	50%	53%	58%	53%
% of jobs in public sector	67%	56%	28%	53%
Median household income[a]	$14 423	$19 583	$43 056	$15 000
% households below US poverty line[a]	42%	55%	29%	55%
Electricity cost[a] ($/kwh)				
Actual cost	$.81	$.95	$.80	$.90
Subsidized cost to residents	$.28	$.55	$.24	$.25
Heating fuel cost[a] ($/gal)	$7.79	$6.50	$6.75	$8.00
Subsist harvest (lb per household)[e]	1716	NA	NA	2902
Subsistence use (% of households)	100%	100%	100%	100%
2100 warming (Dec, Jan)[f]	9.4 °C	9.4 °C	8.9 °C	7.8 °C

[a] Alaska Community database, 2011 and 2012 information from communities.
[b] Tr: tribal council, Ci: city government, VC: Village corporation.
[c] Anchorage (A); Fairbanks (F).
[d] Water source: R: River; L: lake; W: Wells.
[e] NA (no data available).
[f] Projected increase in 2100 relative to 1960–2000 (http://www.snap.uaf.edu/).

Table 2

Prioritized issues identified by tribal councils in discussions with CPS. *Italics* indicate issues substantially addressed by communities prior to CPS engagement. Bold indicates issues finally selected by tribal council as top priorities for CPS efforts.

Igiugig	Koyukuk	Newtok	Nikolai
Cultural integrity	Cultural integrity	Cultural integrity	***Cultural integrity***
Energy security	***Flood protection***	***Village relocation***	**Access to salmon**
Clean water	***Energy security***	**Energy security**	School closure
Strengthen language	***Hunting/fishing rights***	*Job training*	*Energy security*
Food security	*Elder care*	Leadership training	Build tribal hall
Education	Emergency shelter	Development corporation	Strengthen language
	Strengthen language		Grant-writing skills
	Forestry inventory		

The communities differed in several respects. The two Yup'ik Eskimo communities were on or near the coast, and the two Athabascan Indian communities were on interior rivers. Population sizes ranged from 52 to 377. Newtok, the largest community, had a large student (K-12) population, whereas other communities were closer to the 10-student threshold below which the state closes public schools. The small student population in these three communities reflected a small village population (often constrained by housing shortage) and/or a small proportion of village youth attending school. The high cost of living, weak cash economy, and dwindling student numbers suggest high vulnerability to socioeconomic changes.

Many of the challenges faced by rural Alaska communities reflect processes beyond their control. These include climate-warming effects on permafrost stability, sea ice, coastal erosion, wildfire, and fish and game populations [8,9]; high energy-costs shaped by global market prices, isolation from the Alaska energy grid, and high transportation costs [10]; regulations that define community access to state and federal funds [11•]; and a state-defined school curriculum that reflects national education standards rather than local traditional values [12].

Agency-sponsored programs have reduced some of these constraints, including subsidized cost of electricity, insulation of private homes, and cost of mail (including food shipments); competitive grants for developing alternative energy (e.g., solar panels, wind turbines, or harvest of firewood for elders); fish and wildlife management that sometimes gives preference to rural subsistence users over other resource-user groups; and erosion-control projects to protect some communities. These programs illustrate the value of top-down agency programs that address widespread community needs.

Problem-definition and prioritization phase

CPS interacted with communities in three overlapping phases: problem definition/prioritization, feasibility/implementation, and diffusion of adaptations.

In the first of three visits to each community, community members stated that the CPS scenario of increased need for self-reliance was consistent with their observations and expectations for the future. There was broad agreement, especially among elders, that previous generations had a tradition of self-reliance, that self-reliance would be important in addressing a continuation of recent trends, and that they could provide examples of ways this might be done. Leaders in each community initially emphasized about six issues that constrained self-reliance and touched on many more. During informal discussions in the first and second visits to each village, CPS team members learned more about why each of the highlighted issues was important to the community and described UAF expertise that might address some of these issues. Based on these discussions, the tribal council of each community chose 2–3 projects where it felt that UAF could assist in meeting their goals (Table 2).

Each tribal council placed highest priority on maintaining and strengthening their cultural integrity. Igiugig leaders reported that the CPS cultural survey had highlighted for them language loss as a new area of concern, and they added a Yup'ik immersion component to their pre-school education program. Nikolai began seeking funding from the nearby Denali National Park for a culture camp to bring together elders and youth. Thus the CPS process provided an opportunity for communities to prioritize actions that linked adaptation discussions back to community goals.

Each community highlighted high costs of energy and constraints to accessing subsistence resources as critical threats to their self-reliance and sustainability. Each community also raised at least one issue that differed from issues faced by the other three communities, was critical to community self-reliance, and was not adequately addressed by any government program. This included funding for village relocation in Newtok, acceptance of Koyukuk's strategy of adapting to flooding by protecting infrastructure in place, secure rights to clean water in Igiugig, and rights to fish for salmon in Nikolai (Table 2).

Native leaders from ANSC and community leaders and elders were the key CPS participants during the problem-definition phase. The reputation of ANSC leaders as community advocates lent legitimacy to the CPS scenario of empowerment through self-reliance rather than dependence on government programs to build a sustainable future. ANSC involvement facilitated the development of trust between community leaders and the visiting team. Community leaders and elders were local sources of essential information about past and current adaptation efforts and needs. The community-appointed contact and graduate-student liaison constituted the main information conduit between community leaders and CPS. This built trust, perhaps because of perceived power symmetry.

Feasibility and implementation phase

During or after the second CPS visit to each community, discussions focused on 2–3 issues that were high community priorities and might benefit from extant technical expertise at UAF (Table 2). The topics where collaboration was requested most frequently were energy security (all four communities), renewable-resource issues (access to salmon or clean water; three communities), and flooding and erosion (two communities). Each of the communities had already made substantial progress in addressing most of these issues prior to CPS engagement, so their questions and needs were relatively well-informed and focused. CPS invited technical experts from UAF or agencies to participate in dialogue with communities about feasibility and implementation on the condition that final decisions be guided by community-defined adaptation goals. Where possible, technical experts joined CPS visits to communities to learn first-hand about critical adaptation challenges and opportunities in the communities and to minimize any perceived power imbalance between community members and external experts. The pathway by which community priorities led to specific implementation actions (or failed to) differed among the four CPS communities.

Igiugig had experimented with several forms of renewable energy (wind, solar, woody biomass, and in-river hydrokinetic power; Table 3) but wanted input on how to assess the costs, benefits, and dependability of each of these and how to design a control system that would reduce expenditures for diesel power generation. These questions matched well with the research interests of UAF's Alaska Center for Energy and Power (ACEP), which was researching control technologies for mixed wind-diesel power systems. Once the community issues and the compatible UAF research expertise were identified, ACEP researchers joined the CPS team in visits to Igiugig and subsequently became the primary UAF contact with the community. ACEP now advises the Igiugig tribal council on renewable energy technology, the

Table 3

Catalogue of adaptation actions taken by CPS partner communities in rural Alaska.

Adaptation action	Adaptation goal	Community
Energy security		
Insulation of homes	Reduce energy consumption	Igiugig, Koyukuk
Smart meters	Monitor household electricity consumption; encourage energy conservation	Nikolai
Power cost equalization	Subsidize high rural electricity costs	All communities
Wood boilers	Alternative energy for public buildings	Igiugig, Koyukuk
Firewood for elders	Reduce fuel oil consumption by elders; wages for local residents	Koyukuk, Nikolai
Wind power	Renewable energy source	Igiugig
Solar power	Renewable energy source	Igiugig, Koyukuk
Hydrokinetic power	Renewable energy source	Igiugig
Energy control system	Integrate renewable and diesel energy	Igiugig
Energy-efficient housing design	Reduce energy consumption	Igiugig, Newtok
Renewable resources		
Clarify water rights	Sustain rights to pure water	Igiugig
Clarify subsistence rights	Access to affordable and culturally appropriate food	Koyukuk, Nikolai
Greenhouse	Access for affordable nutritious food	Igiugig
Gardens	Access for affordable nutritious food	Igiugig, Nikolai
Flood and erosion protection		
Armor shoreline	Prevent erosion	No community
Community relocation planning	Safety from storms and erosion	Newtok
Phased relocation	Strategic approach to relocation	Newtok
Document flood history	Assess future flood risk	Newtok, Koyukuk
Erosion monitoring	Assess erosion risks	Newtok
Elevate infrastructure	Protect infrastructure in place	Koyukuk
Cultural integrity		
Language teaching	Maintain or rejuvenate language	Newtok, Koyukuk, Igiugig
Subsistence harvest	Harvest culturally appropriate food	All communities
Culture camp	Convey cultural traditions to youth	Igiugig, Koyukuk, Nikolai

Igiugig tribal council provides ACEP with community- and household-level data on energy use (the most complete community-level dataset on energy use available from rural Alaska), and the Igiugig tribal president sits on the ACEP advisory board to advise on renewable energy needs and capacities throughout rural Alaska.

The Newtok Traditional Council was most concerned by the urgent need to relocate their community, which is threatened by coastal erosion and storm surges that are aggravated by sea-ice decline. They had already engaged with a consortium of 25 state and federal agencies and NGOs on the relocation process for two years and therefore had access to a broad range of technical expertise. They needed funding for implementation (which CPS could not provide) and clarification of the legal and institutional constraints that prevented agencies from providing the needed funding. Therefore UAF's effort focused on identifying legal and institutional constraints and strategies [11•] (issues that justified inclusion of community relocations in the U.S. Congress Bicameral Task Force Implementation Plan of Obama's Climate Action Plan).

The Koyukuk tribal council was most concerned about their inability to attract state and federal grants for infrastructure because of their vulnerability to spring ice-dam floods [13,14]. They had already chosen a strategy of building above the historical flood-line (rather than community relocation) but needed better documentation of Koyukuk's flood history to demonstrate the adequacy of their flood-avoidance strategy. UAF assembled that flood history, providing a pathway by which Koyukuk could influence agency planning and funding.

The second CPS visit to Nikolai coincided with the first time that state regulators closed the Kuskokwim River to subsistence fishing for Chinook salmon, a primary winter food for Nikolai residents. CPS extended the range of contacts between Nikolai leaders and the regulatory agency. Agency and community leaders were then able to negotiate an arrangement that met the salmon conservation goals of the agency, provided some access to fish for Nikolai residents, and established a more explicit communication pathway to resolve future subsistence conflicts.

After three visits to each community, leaders from the four communities shared with one another the adaptation actions they had taken and their lessons learned at a workshop in Fairbanks. They also met with researchers and agency representatives specialized in each community's target issues to discuss implementation steps. The greatest benefit noted by one leader was that: 'It has helped us to step back and verbalize and summarize steps we can take towards self-reliance.' During the feasibility-implementation phase, CPS partners communicated through multiple pathways. Communication between the community contact and graduate-student liaison maintained the continuity and momentum of interactions, as in the problem-definition phase, but technical communication between village experts (e.g., powerhouse operator) and UAF experts (e.g., energy researchers) and between community leaders and UAF researchers was more frequent. See Supplementary Information for details.

Adaptation-diffusion phase

Prior to its interaction with CPS, each community had already initiated important steps in adapting to their perceived critical challenges to self-reliance. In some cases, innovation emerged within the community. Newtok, for example, negotiated a land-exchange with the U.S. Fish and Wildlife Service for a relocation site in 2003, nearly a decade before their collaboration with the consortium of agencies and NGOs or with CPS. Similarly, Igiugig built a greenhouse to grow vegetables to reduce food insecurity, and Koyukuk and Newtok had school programs that taught indigenous language and culture (Table 3).

In other cases, ideas came through social networks with other communities. Igiugig, for example, initiated renewable energy projects after learning about similar projects from a neighboring community with strong kinship ties. Similarly, two additional communities asked to join CPS after learning about the partnership from Nikolai tribal leaders, and three regional tribal organizations expressed interest in participating in CPS after learning about CPS from communities they serve, suggesting that bottom-up adaptation planning can be contagious and foster the regional spread of adaptation solutions.

In still other cases, innovations came from agencies or workshops with funding for specific adaptation actions, such as community subsidies for electricity up to a defined threshold to motivate reduced energy use, funding for firewood collection for elders (both in Nikolai), and addition of solar panels to the community laundry/shower facility in Koyukuk.

Adaptation actions mediated explicitly by CPS occurred primarily in cases where there was no apparent funding from agencies or NGOs (e.g., control technologies for integrating renewable energy with diesel power systems; subsistence arrangements that met both agency and community needs). The bridging role of CPS thus fostered social capital by facilitating access to new information and resources at other scales.

Discussion

Research approach

Our research drew on theory and practice of natural sciences (e.g., ecology and fisheries management),

engineering (e.g., theory and design of integrated power systems), social sciences (e.g., adaptation and community development), and traditional knowledge (e.g., indigenous stories and experience with self-reliance). This integration occurred via action research that addressed community concerns through collaborative transdisciplinary learning [15,16]. Similar collaborations are increasingly common in addressing complex real-world problems of a rapidly changing and unpredictable world [17••,18•,19]. We suggest that barriers to integration across disciplines and between theory and practice come more from disciplinary individuals and agencies that choose *not* to engage in, encourage, or financially support this type of action-oriented research rather than from any inherent intellectual incompatibility among disciplines or approaches. Transdisciplinarity may therefore be as much a social and political barrier as an intellectual problem within academic and funding organizations and can be an intellectual and practical opportunity for those who persevere.

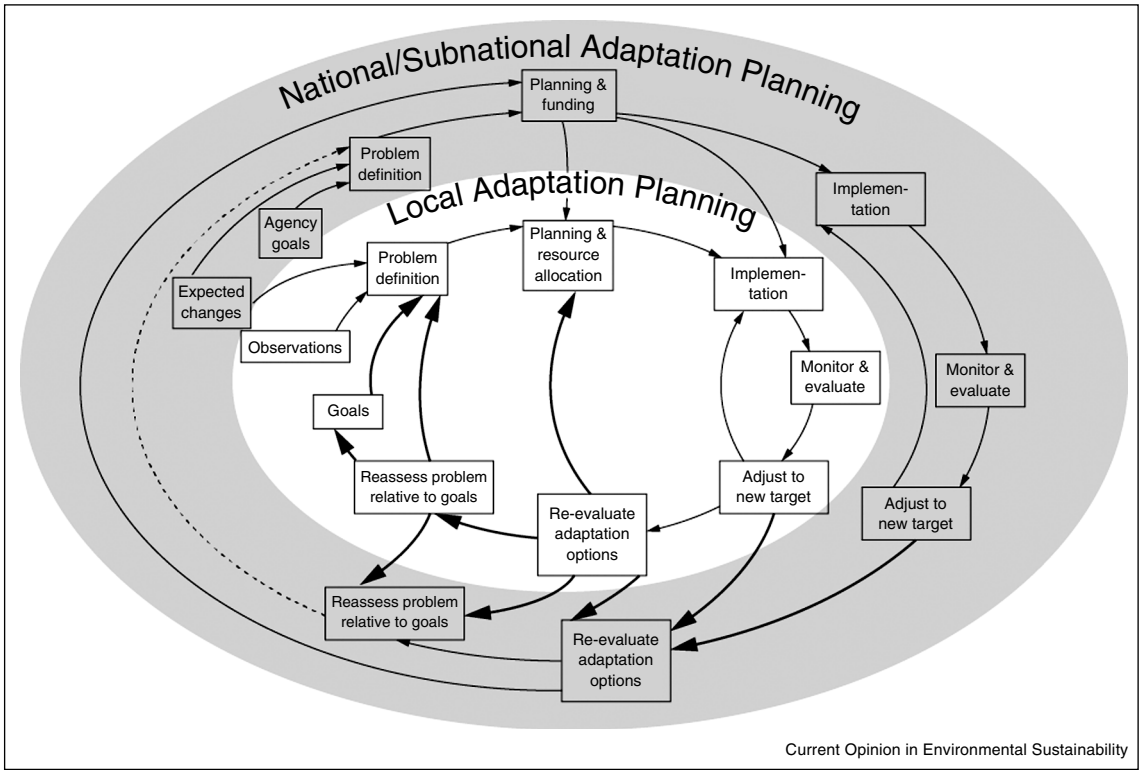
The biggest barriers to our efforts to foster community-led design and implementation of adaptations for self-reliance were the lack of facilitating institutions, funding, social relationships, and trust among potential participants. We therefore created a boundary organization (CPS) that linked communities with the university and other organizations. We focused most of our initial effort in linking together existing social relationships and building trust and asked our indigenous partners to take the lead in co-designing and implementing the process. For example, indigenous leaders who were skeptical of the motivations of university researchers led the initial two-year design phase of CPS, formulated the scenario of future conditions that CPS presented to each community, and led the selection of communities to be invited to participate. During visits to communities, tribal council members specified their goals, the structure of their interactions with visiting researchers, and the adaptation issues and actions to be pursued. This process built trust within the initial working group and with community leaders but constrained researcher influence over the overall study design. At the Fairbanks workshop, community leaders commented that our commitment to community leadership and empowerment was important to their engagement.

Linking bottom-up and top-down adaptation planning

Transboundary organizations (i.e., boundary organizations, bridging organizations, and intermediaries) [20] generally operate outside formal organizational structures across sectors and scales [21]. They can therefore facilitate communication along non-traditional pathways [22]. CPS provided five boundary functions that broadened the range of adaptation choices available to communities [23].

1. Like most boundary organizations involved in community development, CPS initially focused on providing information about opportunities, costs, and benefits of alternative adaptation options [5,24••]. For example, CPS provided access to technical advice that enabled communities to choose among multiple approaches to reducing fossil-fuel use.
2. CPS also provided a venue to frame adaptation discussions in the context of long-term community visions for self-reliance (thick arrows within the white oval of Figure 1). The resulting discussions of long-term adaptation needs (or in the case of Nikolai a short-term crisis related to long-term adaptation needs) led three of the four communities to prioritize different projects for CPS collaboration than they had originally specified in their CPS applications, in each case to align their actions with their primary goal of cultural integrity (Table 2). Reflective feedback loops that link adaptation decisions back to community leadership, choice, and empowerment reduce the likelihood of maladaptive choices based on short-term objectives [25,26] that might otherwise be adopted and institutionalized [27].
3. CPS served as a 'matchmaker' that enabled communities to convey their adaptation priorities to nationally/subnationally focused research groups and agencies (the outward-directed arrows in Figure 1). For example, in the Fairbanks workshop community leaders shared their lessons learned with other community leaders and with academic researchers and agency personnel. In some cases new learning pathways emerged, as ACEP became involved in evaluating Igiugig's alternative energy options, Igiugig's tribal president joined ACEP's advisory committee, and Nikolai's tribal council members communicated directly with ADF&G (Alaska Department of Fish and Game) managers making decisions about fish closures in the Nikolai region. Boundary-spanning organizations frequently play a critical role in strengthening bottom-up linkages [5,24••] that increase the range of adaptation options available to local communities. This facilitates communication of local adaptation needs to researchers and policy makers and identifies gaps in the adaptive landscape that may require fundamental institutional change or novel adaptive strategies.
4. Scaling up of adaptation requires diffusion of novelty not only from early adapters to researchers, agencies, and NGOs (point 3 above) but also from one community to another, as occurred in the Fairbanks workshop. CPS is experimenting with a web-based knowledge-sharing hub that identifies sources of information about common adaptation challenges (e.g., energy costs, climate change) and an adaptation catalogue that presents narratives about tested adaptive responses and knowledgeable adapters (summarized in Table 3). This web-based approach shares adaptation solutions among communities and with researchers and agencies, as advocated by virtually all (98%) reviews of climate-change assessments in

Figure 1



Observed adaptation-planning network at the national/subnational scale and at the community/local scale in rural Alaska. The dashed arrow is structurally plausible but was not observed during our brief study. Thick arrows indicate pathways strengthened by the CPS partnership.

Alaska, but it has never been implemented [28]. It complements existing outreach efforts by agencies and UAF extension programs and provides a potentially transformative process for scaling individual community-led experiments to regional adaptation.

5. Collaborative learning through action research provides students and other researchers the opportunity to better understand community needs and alternative research methodologies and ways of knowing. Differences among communities in choices that address a given problem can generate heterogeneity in outcomes, augmenting the range of options that other communities can consider. This fosters regional resilience to uncertain future changes. Comparisons among these outcomes and subsequent choices allow social learning to occur.

Adaptation strategies that reflect the vision of community leadership may not always lead to favorable outcomes. Community factions may differ in their vision (e.g., relative importance of economic development and cultural integrity), be strongly aligned with vested interests, be misinformed about factors controlling community adaptation options, or lack the power for effective implementation [5,29]. Transparent communication with and within the community (e.g., community-wide meetings) increased the likelihood that a broad spectrum of community views would be discussed.

We suggest that both top-down and bottom-up planning are essential for adaptation and that boundary organizations like CPS can play a key role in communicating between these approaches [30]. Top-down planning may efficiently deliver adaptation strategies (e.g., solar panels) that have widespread applicability, are relatively insensitive to local context, and can be readily funded and implemented within current institutional structures. In contrast, bottom-up planning is critical where local context or sector interactions strongly influence adaptation outcomes, especially for potentially transformative solutions that challenge current institutional structures. Most adaptation solutions are intermediate between these extremes and would benefit from improved dialogue between top-down and bottom-up planning processes by both *outreach* from top-down adaptation programs and *inreach* by locally informed adaptation efforts. Analogously, indigenous and local knowledge informs adaptation opportunities through both *outreach* from indigenous groups to climate-change assessments and *inreach* from researchers to learn from indigenous communities. Power, knowledge, and wisdom can be shared through dialogue that integrates inreach and outreach in both directions.

Growing interest in joining CPS expressed by local communities, regional tribal organizations, and university research groups conflicts with the assertion that bottom-up planning cannot contribute significantly to meeting the urgent need to adapt to today's rapid rates of global change [31]. At a larger scale, the Green Belt Movement empowered rural women to plant 51 million trees to reverse land degradation, restore watersheds, and meet Kenya's water needs in the face of climate change [32]. We suggest that bottom-up planning linked to the long-term visions and goals of communities can facilitate the diffusion of innovation and invigorate a more integrated and ethical approach to community adaptation. Identifying and testing alternative strategies for diffusion of innovation is a core objective for future CPS activities.

Elements that contributed to project success included, firstly, partnership with Alaska Native leaders who were trusted by communities; secondly, relationship-building to establish trust between CPS and partner communities; thirdly, culturally appropriate interactions with communities; fourthly, boundary organization outside the formal interactions between agencies and communities; and fifthly, commitment by Alaska-knowledgeable researchers to address community goals. Researchers benefit professionally from this relationship by firstly, identifying novel research questions through engagement in new methodologies and epistemologies, secondly, crystalizing potential societal benefits of their research, and thirdly, exploring ways to design studies that contribute across local-to-national scales [33•].

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.cosust.2015.12.008.

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- • of special interest
- •• of outstanding interest

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