

1 TITLE

2 The Persistence of Subsistence: Wild Food Harvests in Rural Alaska, 1983-2013¹

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7 The Persistence of Subsistence in Alaska

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ABSTRACT

Many Alaskans depend on family-centered harvests of wild fish, wildlife, and plants in what could be considered a home production model. State and federal laws provide priorities for these “subsistence uses,” a divisive political issue in Alaska. We explore Alaska’s subsistence economies using community-level demographic, economic, and subsistence harvest estimates from more than 18,000 household surveys administered during 354 projects in 179 Alaska communities. Neither mean subsistence harvests nor mean incomes are significantly associated with time alone. But harvests are associated with time in multiple regression models that explain more than 60% of the variation in mean subsistence harvests per person at the community level. Propensity score matching finds that roads have significant, strong, and negative effects on subsistence harvests, but no significant effects on incomes. Results suggest that – given sustainably managed renewable resources and appropriate levels of exclusion – subsistence economies can co-exist with market economies.

KEYWORDS

Alaska; home production model; subsistence; hunting; fishing; development impacts; roads; Alaska National Interest Lands Conservation Act; ANILCA, Alaska Native Claims Settlement Act; ANCSA

I. INTRODUCTION

Many Alaskans depend on family-centered harvests of fish, wildlife, and wild plants for food, fuel, clothing, shelter, and art, in what could be considered a home production model (Becker 1965; Gronau 1986; Kerkvliet and Nebesky 1997). Although subsistence harvests account for barely 1% of Alaska’s total production of wild fish and meat, subsistence contributes about 295 pounds per person annually to the diets of rural Alaskans (Fall 2016). In some remote, majority indigenous communities, harvests are much higher. Alaskans value subsistence so highly that both state and federal laws provide priorities for subsistence over other consumptive uses such as commercial fishing. In this article, we explore the persistence of subsistence in Alaska. We incorporate Goldsmith’s (2007) analysis of the remote rural Alaska economy. We replicate and extend several subsistence productivity models, adding time, a factor with policy implications that is missing from previous models (Wolfe and Walker 1987, Wolfe *et al.* 2011).

Since the Russians came looking for sea otters in the 1740s, subsistence users in Alaska have faced competition for wild resources, often with devastating consequences.² Cognizant of that history and concerned about growing demands for limited supplies of renewable wild resources, the Alaska Legislature and the U.S. Congress adopted several laws and ratified treaties with other nations to preserve subsistence opportunities in Alaska, while providing for other uses.³ The laws and treaties provide for subsistence in different ways, affecting different species, areas, and groups of Alaskans. Each excludes some potential users, and provides a mechanism for allocation. The exclusions have been challenged repeatedly in court and most allocations are

² “When we deal in an historical sense with Alaska’s economic or historical evolution, we are generally discussing exploitation rather than development” (Rogers 1982:7).

³ Fall (2016) summarizes state and federal laws, regulatory structures, and court decisions affecting subsistence management in Alaska since statehood in 1959.

subject to regular administration review, fostering competition and conflict within and between user groups.⁴ McGee (2010), a former Alaska assistant attorney general, calls subsistence hunting and fishing “one of the most divisive and intractable political issues in Alaska.” Yet Alaskans continue to harvest wild foods in abundance, at least when they are allowed to do so (and sometimes when they are not).⁵

At the heart of the matter are rational users seeking preferential allocations or protesting exclusionary management. In the simplest view, indigenous Alaskans, who predominate in rural areas, see it as a battle for cultural survival, while non-indigenous Alaskans, who predominate in urban areas and outnumber indigenous Alaskans four to one, see it as a battle for equal rights (Morehouse and Holleman 1994, White 1994, Thornton 1998).

In a survey of North American inland fisheries, Cooke and Murchie (2015) note that “some of the most well-documented aboriginal harvests are in Alaska.” Yet, as Goldsmith (2007) notes,

⁴ Alaskans argue about subsistence allocations on the basis of Native rights (Alaska Federation of Natives 2012), states’ rights (Alaska Outdoor Council 2015), water rights (Alaska v. Babbitt 1995(Katie John I)), equal access (White 1994), food security (Thériault et al. 2005, Inuit Circumpolar Conference 2015), and even freedom of religion (Frank v. State 1979). Indigenous Alaskans plead their case to the International Whaling Commission and the United Nations (Huntington 1989). In response to citizen lawsuits, the Alaska Supreme Court upended state subsistence management (McDowell v. State of Alaska 1989) and the Ninth Circuit Court affirmed federal subsistence management in waters claimed by the state (John v. United States 2013). See John v. United States (Katie John III, 720 F.3d 1213) for an extensive summary of the 1980 Alaska National Interest Lands Conservation Act (ANILCA), the rural priority, state and federal efforts to protect subsistence uses, and subsequent Alaska subsistence legal cases in both state and federal courts. When the U.S. Supreme Court heard oral arguments in an Alaska moose hunting case in January 2016 (Sturgeon v. Masica), all three members of Alaska’s congressional delegation attended.

⁵ In June, 1961, to protest a prohibition on spring harvests of migratory birds, 138 *Iñuit* hunters presented themselves to a game warden, each with an illegally taken duck in hand (Chance 1990:146-147, Huntington 1992, Burwell 2004). The event became known as the Barrow “Duck-In.” A similar act of civil disobedience occurred in 2012, when *Yup’ik* fishers set nets in the Kuskokwim River to protest closures of Chinook salmon subsistence fisheries (Weymouth 2014, Medred 2013a).

reliable economic data about remote rural Alaska and subsistence economies are hard to come by. To that end, we synthesize and analyze a unique dataset: community-level demographic, economic, and subsistence harvest estimates aggregated from more than 18,000 household surveys administered during 354 projects in 179 Alaska communities from 1983 through 2013. We find that neither mean per person subsistence harvests nor mean per person incomes are significantly associated with time alone. Harvests are associated with time in multiple regression models that include other factors, such as regional location, access, and income, and which explain more than 60% of the variation in mean subsistence harvests per person at the community level. The most significant factors are (1) economic region and (2) road access to urban centers. We find that roads have a significant and strong effect on subsistence harvests, but no significant effect on incomes. These are interesting findings, given that some have argued that subsistence is “failing” (Deman 1982), that rural Alaska communities are in an inevitable, irreversible decline (Morehouse 1989), and that a “lack of transportation infrastructure” challenges community viability in Alaska (Alaska Arctic Policy Commission 2015).

The article is organized as follows. Section II reviews the context. Section III summarizes the data and methods. Section IV explores demographic and economic trends. Section V identifies factors associated with subsistence harvest levels and personal incomes. Section VI replicates, evaluates, and extends several models of subsistence productivity. Section VII considers the effects of road access. Section VIII discusses and Section IX concludes.

II. CONTEXT

Alaska is the largest of the United States (1.48 million km²) but 48th in population (735,601 people in 2014),⁶ giving it by far the lowest population density of any state, only 0.5 persons per km². Alaska also is – in the words of the state demographer – “a state of immigrants” (Williams 2004). Sixty-two percent of its residents were born in another state. Yet Alaska has the longest history of human habitation of any state (Sandberg, Hunsinger, and Whitney 2013), and is unique among the United States in having indigenous majorities in two thirds of the state, census areas⁷ mostly inaccessible by road (Figure 1). These factors contribute both to the persistence of subsistence and to conflicts over subsistence.

Waring and Smythe (1988) estimate the indigenous population in Alaska at contact about 1740 to have been about 74,000 (Figure 2A). By 1880, when the first formal census was conducted, the indigenous population had been reduced by conflict and disease to about 35,000, and did not reach pre-contact levels again until the 1980s. By 2010, the indigenous population in Alaska had increased to 138,312 (Norris, Vines, and Hoeffel 2012), still less than twice the estimated population at contact.

Not only is Alaska’s population sparse, it is concentrated in just three urban boroughs – Anchorage, Fairbanks, and Juneau – where 59% of Alaska’s population lived in 2014 (Alaska Department of Labor and Workforce Development 2015). Since 1980, populations in Alaska’s three metropolitan statistical areas have doubled (from 246,230 to 496,578) primarily as a result

⁶ Table 1. Annual Estimates of the Resident Population for the United States, Regions, States, and Puerto Rico: April 1, 2010 to July 1, 2014. U.S. Census Bureau. Retrieved December 26, 2014.

⁷ In this article, the term “census area” includes 19 boroughs and 10 US Census Bureau-defined census areas. Boroughs are the equivalent of counties in other U.S. states; some Alaska boroughs and rural census areas are as large as a typical state.

of migration from other states or from rural Alaska census areas, while populations in rural Alaska have grown much more slowly (Figure 2B). In 2010, 19% of Alaska's population reported as Alaska Native or American Indian, either alone or in combination with other races (U.S. Census Bureau 2012). In 2014, an estimated 53,767 Alaska Natives (38% of all Alaska Natives) lived in the Anchorage, Fairbanks, or Juneau census areas (U.S. Census Bureau 2016).⁸

In short, the population of remote rural Alaska remains much as it has been for centuries, sparse and predominantly indigenous. The density of the remote rural population in 2014 was only 0.06 persons per km², scarcely more than the population density estimated at contact (0.05 persons per km²). Remote rural indigenous communities usually are situated within current indigenous residents' ancestral territories. An extreme example is Point Hope (Figure 1), whose residents believe, with considerable justification, that they live in the oldest continuously occupied site in North America (Jensen 2014).

A. Subsistence and the Alaska Economy

Goldsmith (2007) defined three economic regions for Alaska: urban, other rural, and remote rural (Figure 3). The "urban" region includes the Anchorage, Matanuska-Susitna, Kenai Peninsula, Fairbanks, and Juneau boroughs. The "other rural" region includes boroughs and census areas outside urban areas but along the road system, served by a marine ferry system in southeast Alaska, or dominated by commercial fishing or military activities. The "remote rural" region includes the remaining boroughs and census areas west and north of the road-connected parts of Alaska.

⁸ For more on migration patterns, motivations, and consequences in Alaska, see Hamilton and Seyfrit 1994; Martin, Killorin, and Colt 2008; Huskey 2009; Howe 2009; and Williams 2010.

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Economic conditions in Alaska’s urban region are similar to smaller metropolitan areas of the U.S. This is not true of remote rural Alaska, where the cost of living can be twice that of urban Alaska (McDowell Group 2009), yet incomes are 35% less.⁹ Housing stocks in remote rural Alaska often are substandard (Howell, Keiffer, and Berger 1997). Some communities lack residential water or sewer services, which is associated with higher levels of respiratory infection in young children (Gessner 2008). Very few remote rural communities are accessible by road. Scheduled air taxi services fly passengers from small communities to regional hubs, where passengers connect with airline flights to Anchorage. Local travel in remote rural Alaska is primarily by boat in summer and snowmobile in winter.

In most communities in remote rural Alaska, subsistence was *the* economy well into the 20th century, so much so that VanStone (1960) could observe that “the basic pattern of subsistence activities at Point Hope today remains much the same as in the pre-contact period.” DeMan (1982) told a conference on rural economic development in Fairbanks in 1978 that “subsistence has been and continues to be the largest single employer in the state.” Yet, as Goldsmith (2007) notes, “the subsistence and informal sectors are nowhere captured by the indicators which are designed only to measure activity in the cash economy.”

Nor does the term “subsistence” capture the role of wild foods in Alaska’s many cultures. “Understandings of subsistence as a meager economic existence, or as a static relic of the past, are the antithesis of the Alaska Native (and, generally, the anthropological) view and have no basis in law or in practice” (Wheeler and Thornton 2005). A subsistence diet in Alaska typically

⁹ For 2012, the estimated mean income per person in the remote rural economic region was \$22,202, compared with \$29,287 in the other rural economic region, and \$34,080 in the urban economic region. Regional estimates were calculated from American Community Survey community estimates, all values in 2012\$ (U.S. Census Bureau 2016).

includes wild foods like salmon, halibut, king crab, moose, caribou, and blueberries (Figure 4), while the harvesting, processing, and distribution of subsistence foods occurs in a dense network of social relations (Lee 2002; Magdanz, Utermohle, and Wolfe 2002; BurnSilver *et al.* 2016).

The discovery of oil at Prudhoe Bay in 1968 was a watershed event, leading directly to the Alaska Native Claims Settlement Act (1971), and subsequently to the Alaska National Interest Lands Conservation Act (1980). Yet oil and gas development “produces only modest direct economic benefit for most residents” of remote rural Alaska (Goldsmith 2007). This is a long-standing historical pattern. In a study of timber development in southeast Alaska in the 1950s, Rogers (1982) found that “Native people tended to move away from the centers in which employment opportunities developed.” Mining and petroleum development, Rogers argues, were “superimposed on rural Alaska, [but] did not interact very much with rural Alaska.” The general impact of a century of mining in Alaska, “was to create the beginnings of urban Alaska and that was all” Rogers (1982).

Small-scale commercial fishing is an exception. Commercial fishing generates much less income overall than mineral development, but individuals’ incomes from commercial fishing can be substantial and that income is spread more widely among the rural population (Goldsmith 2007). Yet, where fishing rights have been privatized in Alaska, rights tend to migrate away from rural communities (Carothers 2008, Carothers, Lew, and Sepez 2010, Knapp 2011). And commercial fishermen can be buffeted by global market forces, as happened in Bristol Bay in the 1990s (Hébert 2015).

The largest single source of wage income in remote rural Alaska is the federal government, through employment in health care, transportation, housing, and defense services in what Knapp and Huskey (1988) call “the transfer economy.” Wages paid to local workers in remote rural

Alaska are subject to very low economic multipliers, as they pay for imported fuels, foods, and services (Goldsmith 2007).

In the latter half of the 20th century, economic and political developments resulted in higher standards of living throughout the state, though not to the same degree among Alaska Natives as among other Alaskans and other Americans (Martin and Hill 2009). The conventional view (Murphy and Steward 1956, Burkhalter and Murphy 1989), summarized by Langdon (1991), was that subsistence economies “are transitory and will not be able to reproduce themselves” once exposed to market influences. Morehouse (1989) concludes that “instead of being in transition to a self-sustaining economy and society, village Alaska appears to be collapsing.” Medred (2013b) argues that “no one wants to face the reality that subsistence itself is dying beneath a population boom and the changing views of an evolving society.”

Many scholars do not support the conventional view. Kruse (1991) found that the percentage of North Slope households obtaining more than half of their food from subsistence increased with increased labor force participation and increased income. For seven rural regions of Alaska, Wolfe and Ellanna (1983) describe a “mixed economy” characterized by “a domestic mode of production, a seasonal round of economic activity, networks of distribution and exchange, traditional systems of land use and occupancy, and systems of beliefs and ideologies.” For two communities on Alaska’s North Slope, “elements of mixed economies observed three decades ago – simultaneous household engagement in subsistence, markets, and traditional social relations – have proven remarkably persistent” (BurnSilver *et al.* 2016).

Langdon (1991) notes that indigenous Alaskans are unusual but not unique; other groups in the world have been “able to develop cultural patterns in which foraging persisted as the primary mechanism even after extensive contact with the world capitalist economic system.” In a study

of two Western Alaska Yup'ik Eskimo communities, Langdon (1991) found “little evidence that cash had a significant, unambiguous effect on subsistence activities in these communities.” He attributes the persistence of subsistence in two western Alaska study communities to “a constellation of specific factors,” including low human population densities, harvestable surpluses of wild resources, limited external demands for resources, artisanal fishing opportunities for cash generation, traditional land tenure systems, and no significant appropriation of local production by the state and federal governments (Langdon 1991). Langdon concludes that his two study communities had “attained a special balance in the modern world, but their ability to sustain and reproduce that balance is open to question on many fronts. ”

From a nutrition perspective, wild foods are healthy foods (Nobmann 1997). “Native foods continue to play an important role in their diet and contribute to the high consumption of protein, iron, and Omega 3 fatty acids” (Johnson *et al.* 2009). But indigenous people in the Arctic have not avoided the “nutrition transition – the switch from traditional to modern diets – observed globally among low-income populations (Popkin 1998, Kuhnlein *et al.* 2004, Egeland 2011 Egeland *et al.* 2011). Low intakes of vegetables and fruits (expensive or unavailable in rural Alaska) and high intakes of fats and sugars are associated with high food insecurity and low diet quality (Ballew *et al.* 2004, Bersamin *et al.* 2006, Huet, Rosol, and Egeland 2012).

While indigenous Alaskans always have depended on wild foods, many non-indigenous Alaskans arrived with or later adopted wild food diets, and value opportunities to hunt, fish, and gather wild foods. In 2014, the Alaska Department of Fish and Game estimated that Alaskans harvested 50 million pounds of wild foods annually for personal and family consumption, conservatively valued at \$200-\$400 million using hamburger prices (Fall 2014). Limited instances of customary trade suggest that much higher valuations would be appropriate, given the

216 prices paid for traditional foods like smoked salmon strips and wild berries.¹⁰ Fall (2016)
217 estimated that rural Alaskans harvest 37 million pounds of wild food annually, or 295 pounds per
218 person, providing 189% of the protein requirements of the rural population. Rural Alaskans
219 harvested, on average, 50% more wild meat and fish than the mean 195 pounds of domestic
220 meat, poultry, and fish consumed by residents of the United States (U.S. Department of
221 Agriculture 2003). Subsistence harvests in Alaska are deemed so important that an Alaska Food
222 Policy Council study concludes that “subsistence foods are a key piece of Alaska’s food system”
223 and makes “fostering subsistence hunting and related skills” its highest priority (Meter and
224 Goldenberg 2014).

225 B. Allocation of Fish and Wildlife

226 In Alaska, fish and wildlife are common-pool resources subject to multiple uses – subsistence,
227 personal use, sport, and commercial – by residents of Alaska and by others. The vast majority of
228 harvests (98.2% by weight) are commercially caught fish (Figure 5). The Alaska Department of
229 Fish and Game estimates that subsistence harvests account for about 1.1% of Alaska’s total
230 harvests (Fall 2014).¹¹

¹⁰ Non-commercial, low-volume sales of subsistence-caught goods between private individuals are permitted in law (termed “customary trade”), but are limited by regulation (Magdanz *et al.* 2007, Moncrieff 2007). Commercial sales of subsistence-caught and sport-caught fish and wildlife are prohibited in Alaska. Customary trade in Alaska is not analogous to the bush meat trade generating conservation concerns in South America, Africa, and Asia (Robinson, Redford, and Bennett 1999, Fa, Peres, and Meeuwig 2002, Yasuoka 2006, Brugiere and Magassouba 2009).

¹¹ Following Fall (2016): “Subsistence includes fish and wildlife harvests by Alaska’s rural residents, estimated through household surveys; fish taken under subsistence regulations by urban residents; and wildlife taken by urban residents in hunts specifically classified as subsistence hunts. Personal use includes fish taken in personal use fisheries and wildlife taken

Fish and wildlife are managed within a bewildering array of jurisdictions and authorities. Depending on target species, use, harvest location, and users' ethnicity, the State of Alaska, the United States government, or one of several indigenous co-management bodies are responsible for management. By design, most management bodies consist of appointed or locally selected citizens, far more likely to be resource users than resource professionals. Also by design, management usually is a contested public process in which different user groups lobby management bodies for allocations favorable to their group.¹² Allocations are not inconsequential. The ex-vessel value of Alaska's commercial fisheries exceeded \$1.8 billion in 2013 (National Marine Fisheries Service 2014). A University of Alaska study estimated the total economic significance of sport fishing in Alaska in 1993 to be "9,236 jobs, \$209 million in payroll, and \$637 million in sales" (Haley *et al.* 1999). Such high values create incentives to influence allocations.

Were allocations left completely to the market, species with high value and high demand like salmon, halibut, crab, moose, caribou, and bear likely would be allocated primarily to commercial interests, secondarily to sport interests, and entirely away from personal and subsistence uses, an outcome the Alaska public likely would find unacceptable. In fact, that is exactly what happened with Alaska salmon under disinterested federal management in the first

under general hunting regulations by urban residents. Personal use fisheries involve fishing with efficient gear (gill nets or dip nets) in non-subsistence areas or fishing for stocks that are not customarily or traditionally used. Sport harvests include wildlife harvested by nonresidents, fish harvested by nonresidents of the state as permitted by sport fishing regulations, and fish harvested by urban Alaskans (generally with rod and reel gear) under those same regulations. Harvests in commercial fisheries are intended for sale in markets."

¹² Even the locations of regulatory meetings are contested, on the theory that allocation decisions may be influenced by public testimony from local users. "The latest Cook Inlet salmon war is brewing not over allocation but location – the setting for an Alaska Board of Fisheries meeting scheduled for February 2017" (Hollander 2015).

half of the 20th century (Arnold 2009). Regaining control of salmon management was one of the major motivations for Alaska statehood (Naske and Slotnick 1994). In similar fashion, the entire allocation of Alaska halibut went to commercial and sport fisheries until 2003, when subsistence uses finally were recognized and granted allocations (Fall *et al.* 2004). Western Alaska subsistence fishers protested the bycatch of Chinook salmon in the massive commercial pollock fishery in the Bering Sea, prompting the North Pacific Fishery Management Council to adopt a “controversial” program in 2011 to reduce bycatch (Ianelli and Stram 2015).

Within these allocation battles, subsistence has been a special case. At the insistence of the state, the 1971 Alaska Native Claims Settlement Act (ANCSA) extinguished aboriginal hunting and fishing rights (Caulfield 1992, Norris 2002, Thornton 2001).¹³ The congressional conference committee expected “both the Secretary and the State to take any action necessary to protect the subsistence needs of the Natives” which, Kancewick and Smith (1990) argue, did not happen. In 1980, Congress adopted the Alaska National Interest Lands Conservation Act (ANILCA), setting aside 157 million acres of federal public lands in Alaska for new parks, refuges, and other conservation areas. In addition, believing that subsistence economies in Alaska were “threatened by the increasing population of Alaska... [and] by increased accessibility of remote areas containing subsistence resources,” Congress allowed residents of rural Alaska communities with customary and traditional histories to continue to hunt and fish in the new conservation areas, and created a subsistence priority for rural Alaskans on all federal public lands. Finally, Congress

¹³ See Dombrowski (2007) for a discussion of ANCSA’s aboriginal rights extinguishment and its impact on subsistence in southeast Alaska: “Subsistence use and consumption, more than any other local practice, has come to be seen by village residents as iconic with Nativism in the region. Anything that imperils or even affects subsistence is seen as something that directly affects not just Native people, but their ability to live and reproduce their Nateness.” Kancewick and Smith (1990) and Kimmel (2014) argue for a Native subsistence priority.

withheld the state's authority to manage subsistence on federal public lands unless the state adopted a similar rural priority for subsistence, which the Alaska Legislature did in 1978 (AS§16.05.258).

Given the ethnic distribution of the state's population, a rural priority is much more beneficial to Alaska Natives than to non-natives. While many indigenous Alaskans see ANILCA's rural subsistence priority as a compromise (Alaska Federation of Natives 2012), some Alaskans see it as discrimination, a futile attempt to preserve failing indigenous economies at the expense of urban hunters and fishers (Caulfield 1992, Medred 2013b).

At least since 1972, when the Marine Mammal Protection Act exempted coastal Alaska Natives from a general prohibition on taking, exclusion has been an integral part of subsistence management in Alaska. This is not surprising. When demand is high and subtractability exists, allocation inevitably involves some form of exclusion (Schlager and Ostrom 1992). Under ANILCA, Alaska residents who did not live in rural areas of the state are excluded from subsistence hunts and fisheries.¹⁴ Under the state subsistence law, subsistence activities are excluded from more populous areas of the state.

Roads – or rather the absence of roads – are another form of exclusion. The lack of roads in remote rural Alaska excludes urban hunters and fishers unwilling or unable to pay the high cost of access by air. Hunting and fishing pressures from urban residents along Alaska's limited road system could be intense (Schandelmeier 2014, Edge 2015). As a case example, hunting pressure from urban Alaskans on the rural but road-accessible Nelchina Caribou Herd resulted in maximally restrictive hunting regulations for local residents (Fall and Simeone 2010). More

¹⁴ See Wolfe and Fischer (2003) for a discussion of methods for "rural / non-rural" determinations for the purposes of federal subsistence management in Alaska.

generally, roads create *de facto* allocations of resources by altering spatial patterns of human activities (Panitch 1975; Boer 1990; Adam and Stuart-Smith 2000; Trombulak and Frissell 2000; Beazley *et al.* 2004; Brinkman *et al.* 2007).

While lawsuits and politics have fractured subsistence management in Alaska into conflicted state and federal systems, the laws and treaties mentioned above remain in effect in 2016. Alaskans are heavily invested – culturally, financially, nutritionally, and emotionally – in harvesting wild renewable resources for personal and family consumption. Management of Alaska’s subsistence economies is of considerable public policy interest.

C. Rationale and Research Questions

So under what conditions is subsistence sustainable? Generally speaking, this is not a difficult question. Subsistence is sustainable when local fish stocks and wildlife populations are sufficient to support local human populations, conditions that exist in most of remote rural Alaska today. Subsistence is not sustainable in densely populated urban areas, unless urban populations are free to roam into rural areas (which is the nut of the legal conflict between the state and the federal government over ANILCA’s rural priority). But what of the gray areas in between: a small indigenous community in the shadow of Anchorage, or a cluster of homesteaders halfway between Anchorage and Fairbanks, or a burgeoning regional center in a remote borough? Are subsistence boundaries between urban and rural Alaska necessary and, if so, where?

To address such questions, Robert Wolfe and his colleagues proposed several models of subsistence productivity in Alaska, combining estimates from comprehensive household

subsidence surveys in rural areas with harvest reports and permits from urban areas.¹⁵ In 1987, Wolfe *et al.* found that harvests levels tended to be higher in communities away from urban centers, not connected to Alaska's road system, with higher proportions of Alaska Natives, and with lower personal incomes. Road access alone was highly influential: "Harvests of communities along the road network or marine highway system are 69% less than harvests by communities off the road network." In 2003, Wolfe *et al.* found that a weighted 30-mile- radius population density alone was strongly associated with wild food harvests.¹⁶ They suggested that two simple factors – weighted population densities and wild food harvests – could be used to categorize communities into rural or non-rural groups.

In 2011, Wolfe *et al.* published a model similar to the 1987 model, in which mean income per person, percentage Alaska Native, road status, and urban proximity were significantly related to mean harvest per person. That effort predicted future salmon harvests, where future harvests were a function of 10 factors, but which assumed that harvests per person did not change over time. Yet Wolfe and Scott (2010) found that weaker salmon runs and associated regulatory restrictions did contribute to declining salmon harvests in the Yukon drainage, where "weak salmon runs undermined the viability of mixed, subsistence-cash economies and village

¹⁵ In his 1987 and 2011 models, Wolfe used hunting and fishing data collected by ADF&G through harvest reports, permits, and mail-out surveys to estimate harvests in urban areas. Many urban residents do not hunt and fish. To compensate for incomes missing from the survey data, Wolfe and Walker used 1982 estimates of community incomes per tax return from the Alaska Department of Labor.¹⁵ They also used ethnicity data from the 1980 U.S. census. They included only one observation for each community, thus they could not estimate trends.

¹⁶ Wolfe and Fischer's goal in 2003 was to explore methodologies for identifying rural and non-rural populations, so they did not publish regression statistics of harvests on population density. Our regression of their published data found that weighted population density alone explained 67% of the variation in mean harvests per person ($t = -19.91$, $p < 0.001$ *adj. r*² - 0.6709).

populations.” Using a population-based method¹⁷ to estimate non-commercial harvests for all Alaskans, Fall found that rural Alaska residents’ total harvests decreased by 17% between 1990 and 2012, while urban Alaska residents total harvests increased by 27%. “This increase illustrates the harvest potential of the growing population of urban Alaska, even while the per capita harvest remains relatively low” (Fall 2016).

Consistently, Wolfe, Fall, and their colleagues find that rural and urban Alaskans are fundamentally different in their reliance on subsistence production. But they have not modeled production for rural populations in isolation from urban populations, and they did not model production over time. Model statistics are substantially influenced by the inclusion of urban areas; this may obscure factors significant in rural areas. And the temporal dimension of subsistence in rural Alaska is subject to much debate. With 31 years of data it seems appropriate to include a time factor, regardless of its statistical significance. A statistically insignificant time factor would be a significant policy result.

In this analysis, we limit our sample to small- and medium-sized communities, most located in areas that could be expected to sustain local subsistence economies. We explore change over time for that population of communities as a whole and – through panel analyses – for individual communities. Unlike previous efforts, our models use population, harvest, and income estimates from a single source, collected with a standard survey instrument, from the same samples of households, at the same times. We ask: Have human populations, subsistence harvests, and personal incomes in rural Alaska changed over the last three decades? What factors are

¹⁷ For three points in time – 1990, 2000, and 2012 – Fall calculated total harvests for each borough or census area by applying the most recent per capita harvest estimates from surveyed communities to the total population of each borough or census area for each major category of wild foods (salmon, other fish, land mammals, marine mammals, etc.). For more on his methods, including equations, see Fall (2016:51-55).

associated with different subsistence harvest levels in rural Alaska? Can analytical models of subsistence be improved? What effect does road access have on subsistence harvests and personal income?

III. DATA AND METHODS

Data for this study were collected by the Alaska Department of Fish and Game, Division of Subsistence, during 18,029 household surveys in 354 community-based survey projects from 1983 to 2013 (Fall 1990, Wheeler *et al.* 2005, Fall 2016). Results from individual projects are available in agency reports and an on-line database, the “Community Subsistence Information System” (CSIS 2014). Each observation consists of summary data for one community in one year (a “project”). During the study period, 179 communities were surveyed, and 98 of those communities were surveyed more than once (mean=3 times, range 2 to 9), creating both a cross-sectional dataset and an unbalanced community panel. Kivalina is a typical panel community (Figure 6).

For these analyses, the sample of communities was limited to communities whose estimated populations fell between 50 and 10,000 people during at least one survey administration in the study period, 1983-2013 (Table 1). Although communities that never included 50 people were occasionally surveyed, such small places tend to be remote extended family camps or homesteads strung along rural roads with no clear community identity and do not function economically like larger communities (Wolfe *et al.* 2003). Places larger than 10,000 – there were only 6 in Alaska – also are not included, simply because there are no available comparable subsistence harvest data. In 2014, Alaska included 381 communities identified as “census designated places,” of which 307 communities (80% of all communities) were in the eligible size

range and 179 communities (58% of eligible communities) had been surveyed by the division at least once. Reflecting the distribution of community sizes in Alaska, the study communities are small, 161 of the 179 communities were less than 1,000 in population when surveyed.

Annual samples of communities were small and purposive, based on geographic, regulatory, development, disaster, or funding considerations¹⁸. From 2000 to 2009, because of funding considerations, annual samples were sometimes as small as a single community, and communities on Alaska's road system were under-represented. Thus, for any given year, sampled communities are rarely representative of the population of small Alaska communities.

Over the 35-year life of the ADF&G program, however, the sample of communities became increasingly complete and representative. Communities near the median size (189 people) are somewhat over-represented; otherwise distribution of community sizes is similar for sampled communities and for all eligible communities (Figure 7A). Trends in community sizes are almost identical for sampled and all eligible communities (Figure 7B). Sampled communities are located throughout the rural regions of the state, both on and off the road system and include some small communities in the urban region (Figure 8). In smaller communities (<100 households), sampling designs typically call for a census. In larger communities, simple random and stratified random sampling designs are used. Households are surveyed regardless of

¹⁸ Before the Exxon Valdez Oil Spill (EVOS) in 1989, the Division of Subsistence had conducted comprehensive surveys in 18 rural communities impacted by the spill. After the spill, the U.S. Minerals Management Service funded the Division "to investigate the long term social and cultural consequences of the development of Alaska's outer continental shelf" (Fall and Utermohle 1995:I-1). This effort added 24 comprehensive surveys to the Division's community data set. To evaluate the potential influence of oversampling EVOS communities, we estimated our final models for three groups: EVOS communities, non-EVOS communities, and all communities. Coefficient signs were the same and magnitudes were similar. We elected to keep EVOS communities in the data set.

ethnicity, participation in subsistence activities, or employment status. The only eligibility requirement is a minimum residency in the community (typically 3 months).

Surveys are conducted with heads of households, who are asked to report on activities of all household members during the previous 12 months. Occasionally respondents are unable or reluctant to provide all household members' harvests or incomes. Missing harvest and income data are imputed using mean replacement by species (for harvests) and by job class and job duration (for earned income). Community estimates are calculated based upon the application of weighted means (Cochran 1977), while 95% confidence intervals for harvests on a species-by-species basis and for each community as a whole are calculated using sample standard deviations and finite population correction factors appropriate to the sampling design.

Figure 9A illustrates an aspect of the sampled communities not apparent from summary statistics, ethnically bifurcated communities. Communities with ethnically balanced populations (40% to 60% indigenous) are rare. In the remote rural economic region, most communities have pronounced indigenous majorities (Figure 9B). Majority indigenous and majority non-indigenous communities occur in similar proportions in the remainder of Alaska (urban and other rural economic regions).

Table 2 summarizes the study sample. As suggested by differences between mean and median values, community populations, harvests and incomes are not normally distributed. They are approximately log normal, and are transformed to log normal functional forms for regressions.

In remote rural census areas, larger communities usually are "regional centers," with daily jet service from Anchorage, hospitals that serve a larger area, school district offices, regional Native corporation offices, and (usually) well-stocked grocery stores. Examples include Barrow in the

North Slope Borough, Nome in the Nome Census Area, and Bethel in the Bethel Census Area. In 2014, these three census areas included 72 communities and a total population of 36,480 people (excluding the industrial enclave at Prudhoe Bay) (Alaska Department of Labor and Workforce Development 2015). Forty one percent of that population lived in the regional centers of Barrow, Nome, or Bethel (mean population 4,810), leaving 61% in the 69 smaller communities (mean population 305). Elsewhere in Alaska, populations are not so skewed. With road access to urban Alaska, larger communities in other rural areas are less likely to have major airports, hospitals, or bureaucracies. Population densities vary substantially across Alaska. Following methods outlined in Wolfe and Fischer (2003), we calculated a weighted population density for each community using the Vincenty Ellipsoid function in the geosphere package in R (R Core Team 2013, Hijmans 2014).

In most analyses in this article, the dependent variable is the estimated mean subsistence harvest per person for a given study community in a given year. The mean harvest per person is the sum of all wild fish, wildlife, and plant harvests reported by all surveyed households divided by the sum of all people living in the surveyed households. Because harvest data are collected for resource management purposes, harvests include all fish and wildlife harvested by a household for personal or family use.¹⁹ In the 1980s, harvests of fish for dog teams in a few communities resulted in high harvest outliers, but harvests for dogs declined over time. Harvests are typically reported as numbers (for example, “3 caribou”) or volumes (“2 gallons of herring”). Actual harvest weights usually are unknown. Counts and volumes are converted to edible pounds using

¹⁹ Harvests include fish retained from commercial harvests for personal use, as well as fish taken with rod and reel, defined as “sport gear” in some areas and “subsistence gear” in other areas. Regulatory definitions of “subsistence gear” changed over time. Also, areas identified as rural (in federal regulation) and as non-subsistence (in state regulation) changed over time.

standard, regionally adjusted conversion factors. Conversion factors introduce some uncertainty into estimates of harvested weights not reflected in confidence intervals.

Earned incomes are collected for each individual job held by each person in each household, and unearned incomes (such as public assistance) are collected for each household. Incomes are adjusted to 2012 US dollars based on the consumer price index for Anchorage. The highest household incomes tend to occur in rural communities with vibrant commercial fishing or petroleum sectors, such as Kodiak, a major commercial fishing port, and Valdez, the southern terminus of the Alaska oil pipeline. While incomes in Alaska can seem high, they reflect the high cost of living in Alaska (McDowell Group 2009). Cost-of-living data are incomplete for rural Alaska communities, so incomes here are not adjusted for the cost of living.²⁰

A “road” dummy variable indicates the presence or absence of a road connecting a study community to Alaska’s highway system. A few communities off the road system, notably Nome and Kodiak, have local roads leading to a few nearby communities. These local roads are less than 100 miles long, and none connect to Alaska’s highways. Communities with local roads are categorized as “not road connected.” Some communities along Alaska’s southern coast are served by a state marine ferry system; a “ferry” dummy variable indicates ferry service in a study community. Ferry routes include coastal communities on Alaska’s road system, making it possible to take a car or truck from Alaska’s urban centers to ferry-connected communities.

²⁰ Food and energy costs in small, remote Alaska communities can be double and triple the costs in Anchorage. But small rural communities, which are the focus of this data set, are under-represented in cost-of-living surveys. When such communities are sampled in the University of Alaska’s “Cost of Food at Home” program, estimated costs range from 1.5 to 4 times Anchorage costs. A study sponsored by the State of Alaska “to identify differences in the cost of living that could affect pay equity among state employees” found remote rural costs to be 1.39 to 1.61 times Anchorage costs (McDowell Group 2009). The focus was on communities with state employees, which are biased larger.

Other variables potentially are associated with subsistence harvests: the cost of living, the price of fuel oil, local resource abundance, distance from urban center, ecological region, cultural group, and others. Data for some of these factors are not available for all of the community-year combinations in the sample, but regional dummies can capture some of their effects. Wolfe and Walker used Division of Subsistence regional definitions, which are not easily replicated by others. Census areas are more easily replicated, but Alaska has 19 boroughs and 10 census areas, an unwieldy number for regression. Goldsmith's (2007) aggregation of boroughs and census areas into three economic regions resolved these problems. Following Goldsmith's lead, we add three dummy variables indicating a community's location in one of the economic regions. While economic regions correlate with some factors in our models,²¹ they also capture unobserved factors (explaining an additional 10% of harvest variation).

Ordinary least squares regressions are used to test for associations among variables. The most common dependent variable – mean harvest per person – is a bounded estimate rather than a measured value. The 95% confidence intervals of estimated harvests per person (expressed as percentages) are used as analytic weights in robust regressions, giving more weight to more accurate estimates. Because samples of communities in a single year are unlikely to be representative, cases also were categorized into five-year and ten-year periods for analyses using pooled-cross-sectional methods. Ninety-nine communities were surveyed more than once, so unbalanced panel models also are employed to estimate mean harvests per person. Data were prepared in SPSS (2008) and R (2013), and analyzed in Stata (2009).

²¹ The remote rural region is associated with road access ($r = -0.411$), ferry access ($r = -0.417$), and percent indigenous ($r = 0.307$). The other rural region is associated with road access ($r = 0.320$) and ferry access ($r = 0.521$). Population density is strongly associated with community population ($r = 0.839$) and with ferry access ($r = 0.258$). Ferry access is associated with community population ($r = -0.275$). No other pairwise correlations exceed 0.250.

IV. DEMOGRAPHIC AND ECONOMIC TRENDS

We begin by exploring trends in community populations, harvests, and incomes.

A. Community Populations

Estimates of population in the 179 communities in the study sample ranged from 34 to 8,535 people (mean=612, median=189). Observations from the median, smallest, and largest communities illustrate the nature and diversity of the sample.

The community closest to median size was Kaktovik, a coastal *Iñupiaq* Eskimo community in northeast Alaska (Figure 8) represented in the sample by three surveys (1985, 1986, and 1992). Estimated community populations were 188, 194, and 193 people, respectively. Over the seven years between the first and last observation, subsistence harvests increased from 328 to 433 to 886 pounds per person, respectively. Differences in annual harvest estimates reflected success in the bowhead hunt (which accounted for 0, 225, and 560 pounds per person, respectively). Personal incomes in Kaktovik increased from \$15,224 to \$24,480 to \$29,194 per person (in 2012 US\$). Only 111 miles east of Prudhoe Bay, Kaktovik enjoyed increased employment opportunities, directly from industry and through public services supported by oil field taxes.

The community with the smallest estimated population, Levelock, included only 34 people in 2005. Levelock was a coastal *Yup'ik* Eskimo community in southwest Alaska (Figure 8) represented in the sample by three surveys (1988, 1992, and 2005). During that time, estimated populations declined (109, 111, and 34, respectively). Estimated harvests also declined (1,253, 884, and 528 pounds per person), while estimated incomes increased (\$11,811, \$12,787,

\$19,117). Such a dramatic change was atypical for a rural Alaska community, but not unique. Levelock depended on the historically lucrative Bristol Bay sockeye salmon fishery. Salmon prices collapsed in the mid-1990s, leading to a series of disaster declarations from 1997 to 2001 (Herrman *et al.* 2004; Krieg, Holen, and Koster 2009).

The community with the largest population in the sample was Sitka, a multi-cultural community in southeast Alaska (Figure 8) with a substantial *Tlingit* Indian population, surveyed in 1987 and 1996. Over nine years, Sitka's estimated population increased (8,061 to 8,535), as did its estimated subsistence harvest (145 to 205 pounds per person). Estimated income per person in 1987 was \$27,046; income data for 1996 were missing.

For all communities in the sample, regressing log normal estimated community populations on year found no significant association with time ($t = -.47, p = .637$) (Figure 6B). Regressing log normal population on year for pooled 10-year periods and for community panels also found no significant association. Regressing ethnicity (percent indigenous in population) on year found no significant associations ($t = 1.29, p = .198$). In a pooled 10-year cross section, communities surveyed in the third decade (2000-2009) were significantly more indigenous than communities in the base decade (1980-1989) ($t = 3.03, p = .003$). However, this likely reflects an over-sampling of remote rural communities in that third decade.

B. Subsistence Harvests

Over the 31 years and 354 surveys, the 179 surveyed communities harvested an estimated total of 51.5 million edible pounds of wild food, an average of 145,608 pounds per study community per year (median=58,710 pounds, range 5,856 to 2.2 million pounds) (Table 2).

Although a general perception in Alaska was that subsistence harvests were declining over time, several robust regressions of estimated total community harvests and mean harvests per person found almost no significant associations between log harvests and time. Table 3 summarizes the regressions; the four graphs in Figure 10 correspond to the four models in Table 3. The community panel graph (Figure 9D) illustrates the variety of community harvest trends, stable, declining, and increasing.

The only significant association was in the third decade of the pooled cross section (Table 3, Model C). With 1983-89 as the base period, logged harvests were associated with time in the first decade of the 2000s, significant at the 5% level. In that decade, mean harvests per person were expected to increase by 25% over the base decade. But communities on the road system were under-represented in the early 2000s (only 7 of the 46 communities surveyed were on the road system). As we shall see below, road access has a significant negative effect on harvests. The statistical significant change seen here is most likely a sampling artifact. In any event, longitudinal models explained less than 2% of the variation in subsistence harvests (maximum $adj. r^2=.014$).

C. Personal Incomes

Income questions were not asked on every survey, so income estimates were available for only 279 of the 354 projects. On average, the total income for a study community was \$15.5 million (median=\$3.2 million, range \$343,163 to \$218 million). The mean community income per household was \$58,823 (median =\$54,988, range \$9,336 to \$170,213).

Four income models are summarized in Table 4; Figure 11 corresponds. Regressing income over individual years found no significant association between total income for the community

and time ($t=-1.52$, $p=.130$). Significant associations were found in two models for mean income per person over time. Mean income per person was expected to decline 1.2% annually in a cross-sectional model (Table 4, Model B). A pooled cross sectional model (Table 4, Model C) suggested that these declines occurred later in the study period; real incomes in the decade from 2000 through 2009 were expected to be 19% lower than in the 1980s, the base decade ($t=-1.90$, $p=.059$), and to be 21% lower in the most recent decade ($t=-2.88$, $p=.004$).

Individual communities, as is evident in Figure 11D, experienced many different income trajectories, perhaps to be expected in a state where the three major sources of income – petroleum, mining, and fisheries – historically have been boom and bust. While the community panel suggested declining real incomes, the association was not significant. Longitudinal models explained less than 3% of the variation in incomes (maximum *adj. r*²=.029).

V. FACTORS ASSOCIATED WITH HARVEST AND INCOME

We turn now to associations between harvests, incomes, and other factors. We begin with demographic factors.

A. Demographic Factors

Throughout the study area, substantial differences existed between smaller and larger communities (Table 5). On the one hand, people in smaller communities harvest 114% more subsistence food (in edible pounds) than people in larger communities, a mean per person subsistence harvest of 373 pounds compared with 175 pounds. On the other hand, people in larger communities have 63% more personal income than people in smaller communities, a per person

mean income of \$27,674 compared with \$16,991. These contrasts in harvests and incomes suggest that community population influences Alaska's small community economies, specifically, that harvests decrease and incomes increase with increases in community population. We explore this idea empirically.

Four community population models are summarized in Table 6; Figure 12 corresponds. Expected total subsistence harvest for a community increases by 0.8% for each 1% increase in community population. Community size alone explains 72% of the variation in total harvests. Expected total personal income for a community also increases, at a slightly higher rate, 1.1% for each 1% increase in community population. Both associations are strong and positive, as expected (Table 6A, 6C; Figure 12A, 12B).

The difference in rates hints that associations with community population differ for individuals. This is evident in Table 6B, 6D and Figure 12C, 12D. Expected mean harvests per person decline by 0.2% for each 1% increase in community population ($t = -6.60, p < .001$). Expected mean incomes per person increase by 0.1% for each 1% increase in community populations ($t = 3.67, p < .001$). We note that the rate of decline in harvest per person, though small, is almost twice the rate of increase in income per person. Population density ($t = -10.18, p < .001, adj. r^2 = .283$) explains twice as much variation in mean harvests as population alone ($adj. r^2 = .129$). Population density is significant ($t = 4.32, p < .001$) but not nearly as influential on incomes; it explains only 7% of the variation (while population explains 5% of the variation).

The bifurcated nature of community ethnicity, previously noted in Figure 9, was evident in Figures 12E and 12F. Most majority indigenous communities have fewer than 1,000 residents, while majority non-indigenous communities have a uniform natural log distribution (Figure 12E). The indigenous proportion of a community was expected to decrease by 1 percentage point

for each 9% increase in population ($t=-5.86, p<.001$). Mean subsistence harvests per person, however, were expected to increase by 1% with each 1 percentage point increase in the proportion of indigenous people in the population ($t=12.73, p<.001$) (Figure 13B). Ethnicity alone explained almost 35% of the variation in mean harvest per person ($adj. r^2=.347$).

B. Income Factors

We now explore associations between harvests and incomes without regard for community size. For 269 projects with valid observations, community mean harvests per household decrease by 2.5% for each 10% increase in community mean income per household (Figure 13A). Controlling for household size, the influence of income on harvests is almost twice as strong. Community mean harvests per person decrease by 4.3% for each 10% increase in community mean income per person ($t=-3.95, p<.001$) (Figure 13B).

At the household level in a particular community, however, these associations do not hold. Figure 14C presents household level data from an example community (others are similar). Unlike observations in previous figures, the observations in Figure 13C are individual household reports of harvest and income. In Figure 13D, each household's report is divided by the number of people in that household to give the mean harvest and income per person for that household. Note that about a quarter of the households in this community, across the full range of incomes, reported no subsistence harvests. This also is typical, as certain households – elders, teachers, disabled, or otherwise dysfunctional – do not harvest their own subsistence foods. They rely on redistributions from other households or do without.

Even with zero-harvesting households included, there is a strong positive association between household harvests and incomes ($t=3.94, p<.001$), with harvests increasing by 14% for

each 10% increase in income (Figure 13C). This association disappears completely when harvests and income are controlled for household size (Figure 13D). On a per person basis, harvests have no association with income ($t=.05$, $p<.963$).

C. Regional Factors

In this section, we explore harvests and incomes in Alaska's three economic regions. First, we note that community populations show no trend in any of the regions over time. Figure 14 summarizes trends in harvests and income over time by region, and also explores the influence of community populations by region.

Mean subsistence harvests per person are highest in the remote rural region and lowest in the urban region (Figure 14A). In the urban region ($n=34$ observations) and other rural region ($n=169$ observations), mean harvests per person were not associated with time. In the remote rural region ($n=138$ observations), harvests per person were expected to decrease by 1.4% for each additional year; the association was significant at the 1% level ($t=-2.76$, $p=.007$). The model explained 7% of the variation in per person harvests ($adj. r^2=.068$).

Mean incomes (in 2012 US\$) across regions are more similar than harvests (Figure 14B). Expected incomes increased in the urban region, and decreased in the other economic regions, but none of the regional income trends were significant. For the population of communities as a whole, real incomes were expected to decline by 0.9% each year ($t=-3.03$, $p=.003$), but time explained less than 3% of the variation ($adj. r^2=.024$).

Community populations were influential for harvests across regions. For all regions, a 10% increase in community population is associated with a 1.8% decrease in expected mean harvest per person ($t=-6.28$, $p<.001$) (Figure 14C). The influence of community populations is strongest

in the urban region, a 2.2% decrease, while a 1.6% decrease is expected in other rural areas. Community population is not significantly associated with mean harvests per person in the remote rural region ($t=-.98$, $p=.327$). Population alone explains 26% of the variation in mean harvests in the urban region ($adj. r^2=.258$), and 17% of the variation in the other rural region ($adj. r^2=.166$).

For all regions, mean incomes per person are expected to increase about 1% for each 10% increase in community population ($t=3.67$ $p<.001$). Population explains about 5% of the variation in income (Figure 14D). In very small communities, with about 75 people, incomes are expected to be about \$14,000 per person annually regardless of economic region. As community size increases, income expectations diverge by region. In the remote rural region, a 10% increase in community population is associated with a 0.6% decrease in mean income per person, but the association is not significant ($t=-1.04$, $p=.298$). In the other rural region, expected mean incomes increase 1.7% with a 10% increase in population ($t=6.900$ $p<.001$), and population explains 20% of the variation in income ($adj. r^2=.201$). The income-population association is not significant in the urban region ($t=.450$ $p=.656$).

D. Access Factors

Access is a defining feature of community life in Alaska.²² State highways and marine ferries provide passenger service to 72 of the 179 study communities (40%); the remainder are accessible only by air. Roads and ferries facilitate the movement of people, goods, and services

²² In this context, “access” refers to passenger service. Some coastal and some inland communities are served by barges carrying fuel and cargo from Anchorage or southern ports like Seattle, but are not on the road or ferry systems. These communities are categorized as “no road or ferry access.”

between urban hubs and rural communities, potentially reducing the cost of living. Tourist traffic on roads and ferries potentially increases opportunities for local residents to sell goods and services to tourists. Roads and ferries facilitate access to rural hunting, fishing, and gathering areas, potentially increasing competition. For all these reasons, we expect incomes to increase and harvests to decrease with increases in access.

Table 7 summarizes harvest and income models for four modes of access; Figure 15 corresponds. Mean harvests per person in communities accessible by roads are expected to be 59% lower ($t=-10.83$ $p<.001$) than mean harvests in communities off the road and ferry system. Harvests in communities served by ferries are expected to be 36% less, and harvests in the four communities on the road system and served by a ferry are expected to be 75% less. These differences are evident in Figure 15A. In the communities accessible by air only, the median community harvest is 367 pounds per person, compared with 164 pounds per person in road-connected communities. Communities connected only by ferry have relatively high median harvests, 250 pounds, compared with communities accessible by road and ferry. Ferry accessible communities tend to be commercial fishing centers, which may explain their higher harvests. Commercial fishermen may retain some of their catch for families and crew members; these retentions are included in their households' subsistence harvest estimates. Access explains 37% of the variation observed in mean subsistence harvests ($adj. r^2=.372$).

Access is similarly influential on mean incomes, but in the opposite direction (Figure 15B). For communities on the road system, mean incomes per person are expected to be 32% higher than in communities accessible only by air ($t=3.78$, $p<.001$). For communities served by ferries, mean incomes are expected to be 46% higher, and for communities on the road system and served by ferries, 121% higher. Recall that estimated incomes in these data are not adjusted for

local costs of living. Communities off the road system typically have higher costs of living (as much as 250% of Anchorage's cost of living), increasing the gap in purchasing power between remote and accessible communities. In the communities accessible by air only, the median income is \$13,785 per person per year, compared with \$19,904 in road-connected communities, and \$35,344 in communities connected by both road and ferry. Access explains 13% of the variation in mean incomes (*adj. r*²=.132).

Regressing harvest and income over time and access finds no significant associations with time, except for mean incomes in the four communities accessible by both roads and ferries (*t*=10.76, *p*<.001) based on only seven observations from four communities.

Figure 16 illustrates the interactions of road access and economic region. We divided communities into two groups, those connected to the highway system ("on-road") and others ("off-road").²³ Harvests and real incomes are similarly distributed in off-road and on-road groups, but harvests are higher and incomes are lower in the off-road group (Figure 16A, Figure 16B). Regardless of road status, harvests increase from the urban to the other rural to the remote rural region (Figure 16C). Regardless of economic region, harvests decrease from off-road to on-road communities. The difference is especially strong between the urban and other rural regions on one hand, where median harvests are 241 pounds and 259 pounds per person, respectively, and the remote rural region on the other hand, where the median harvest is 413 pounds per person. The difference between 15 on-road communities and 20 off-road communities is especially large in the urban region, where median harvests off the road system are almost three

²³ We use road as dummy variable instead of access categories, because community groups would be too small with access categories. No study communities in the urban region are served by ferry, and no study communities in the urban region and remote rural region are served by both road and ferry. Of the 179 study communities, 49 are road accessible (including 4 served by ferries), and 130 are not road accessible (including 23 served by ferries).

times greater than median harvests on the road system (241 pounds compared to 87 pounds per person). The difference is less, but still substantial in the other rural region (259 to 165 pounds), and in the remote rural region (413 to 236 pounds).

The interaction of road and region is less straightforward for income (Figure 16D). In communities on the road system, median incomes decline from the urban region to the other rural region to the remote rural region (\$24,391 to \$20,557 to \$16,467), the inverse of harvests but not nearly as pronounced. In communities off the road system, the highest median incomes (\$18,613) are found in the other rural region, not the urban region. The other rural region includes major commercial fishing ports along the Pacific Ocean and Bering Sea coasts (Petersburg, Cordova, Kodiak, Unalaska, Dillingham, and others) as well as Valdez, the southern terminus of the Alaska Oil Pipeline. Median incomes in off-road communities are similar for the urban region and remote rural region (\$14,092 to \$13,149), but the high cost of living in remote rural communities erodes their purchasing power.

VI. MODELING SUBSISTENCE HARVESTS

We turn now to full models of subsistence productivity, beginning with the original statistics reported in Wolfe and Walker's 1987 model (Table 8, Model A). As we have done, Wolfe and Walker first explored influential individual factors, then constructed a multiple regression model, regressing log harvest per person on ethnicity (which they called "settlement entry"), income, and five regional dummy variables. Table 8, Model B replicates the 1987 model with our data from 1983 to 2013. None of the coefficients' signs change; five of the seven original factors remain highly significant. Income is more significant than in 1987, although less influential than three of the regional dummy variables. In the 1987 model, "a community's resource harvests

were expected to decrease by 2.2 pounds per capita for every percent increase in non-Native population,” about 1%. In the replication, a 1% change in ethnicity was expected to result in a 0.02% change in harvests. With the removal of urban observations and the addition of multiple rural observations, the explanatory power of the model falls from 78% to 42% (*adj. r*²=.420).

In 2011, Wolfe and a new group of colleagues updated their data with harvest estimates for 149 communities and proposed a revised model. They replaced mean income per tax return with mean income per person, replaced six regional dummy variables with a single urban dummy, and added a road dummy. Their model explained 81% of the variation in harvests (*r*² = .809). With the removal of urban observations and the addition of multiple rural observations, the explanatory power of the model falls from 81% to 42% (*adj. r*²=.424) (Table 8, Model C).

Table 9 summarizes three alternate models: (A) a simple cross section, (B) a pooled cross section, and (C) a community panel. The three models include the same independent factors (except decades replace years in the pooled cross section), and each model explains at least 60% of the variation in mean harvests per person. Across the three models, the signs of the coefficients are the same and the magnitudes are similar.

All three models show significant negative associations with time. Mean harvests per person are expected to decline by 1.5% for each additional year in the cross sectional model, and 0.6% per year in the community panel model. Mean harvests in the third and fourth decades of the study period are expected to decline by 27% and 31% over the base decade (1983-1989). Road access is strongly associated with lower harvests in all three models; harvests in communities accessible by road are expected to be 31% lower (Model B) to 47% lower (Model C) than in communities not accessible by road. Ferry access is significant only in the community panel (Model C), where it is associated with a 27% decline in expected harvests. Communities

accessible by both road and ferry – of which there are only four in the sample – have expected harvests 67% percent less than other communities.

Economic region is very influential, significant at the 0.1% level in every model for every region. Communities in the other rural region have expected harvests 68% (Model A) to 78% (Model C) higher than communities in the urban region. Communities in the remote rural region have expected harvests 136% (Model C), 196% (Model A), and 221% (Model B) higher than communities in the urban region.

Mean income per person is significantly associated with mean harvests, though the influence is not strong. For each 1% increase in income, mean harvests are expected to decrease 0.2% in all three models. Ethnicity, which was a very influential factor of Wolfe and Walker's 1987 model, is not significant in the alternative model, most likely because ethnicity influences are being captured by the economic region and access dummies. If regional and access factors are removed from the alternate cross-sectional model, ethnicity becomes both influential and significant ($\beta = .051$, $t = 3.73$, $p < .001$).

VII. ROAD EFFECTS

With increases in access, harvests are expected to decline and incomes are expected to increase. We have no natural experiments (surveys before and after communities were connected to the road system). However, plausible explanatory mechanisms exist, similar differences exist at all levels of harvests (Figure 17A) and incomes (Figure 17B), and correlations are large and significant. The case for access effects on community mean harvests and incomes cannot simply be discarded (Hilborn 2016).

In the absence of experimental data, propensity score matching (PSM) provides a method to estimate a treatment effect (Rosenbaum and Rubin 1983; Becker and Ichino 2002).²⁴ Using PSM, we match cases on a vector of observed conditions known to be influential on harvests and income. Then we evaluate the effects of a treatment – in this case, access to Alaska’s road system – on the matched cases. For harvests, the observed conditions include economic region, community population, percent indigenous, and mean real income. For income, we replace the income condition with a harvest condition. We use four PSM methods: nearest neighbor, radius matching, kernel matching, and stratification matching. Table 10 summarizes the results.

All four PSM methods find that road access has significant and substantial negative effects on subsistence harvests at the 0.1% level. Estimates of roads’ effect range from a reduction of 31% $\pm$ 9% (nearest neighbor) to 39% $\pm$ 7% (radius matching). In contrast, estimates of roads’ effect on income are not significant in any of the four matching methods.

To further explore the implications of road access, we select a subsample of small, communities in one economic region, controlling for three influential factors: regional location, community size, and ethnicity. The other rural economic region, with 139 observations in 35 on-road and 28 off-road communities, is well suited to the exercise.²⁵ Of the 63 communities with fewer than 1,000 residents and known ethnicities, 28 had indigenous majorities, and 35 had non-indigenous majorities. Although we have no observations before roads were built, we assume that the 28 indigenous communities in the other rural region were similarly situated before roads were built and have been subject to similar influences since then, except for road construction. If

²⁴ We thank Chris Wright for suggesting propensity score matching.

²⁵ The other rural region is the only economic region with a sufficient number of communities in both road categories. The urban economic region has only 5 off-road communities; the remote rural region has only 3 on-road communities.

that assumption is true, then differences in harvests and incomes between the off-road and on-road groups today, if any, are likely to be a result of differences in road access. We also compare indigenous majority communities with non-indigenous majority communities. Table 11 and Figure 17 summarize observations for the subsamples.

Indigenous majority communities were much more likely to be off-road (20 of 28 communities). On-road indigenous communities were about 8% smaller, on average, than off-road indigenous communities. Mean harvests per person in indigenous communities were 23% lower on-road than off-road, and mean incomes were 7% lower on-road than off-road. For people living in majority indigenous communities, living in an on-road community is expected to result in fewer available resources in both the subsistence and market sectors, compared with living in an off-road community.

Non-indigenous majority communities were more likely to be on-road (23 of 35 communities). On-road non-indigenous communities were on average about 82% larger than off-road non-indigenous communities. Mean harvests per person in non-indigenous communities were 20% lower on-road than off-road, and mean incomes were 26% higher on-road than off-road. Thus, for people living in majority non-indigenous on-road communities, lower harvests were at least partly compensated for by higher incomes, on average. These effects are evident in Figure 17, where road effects on harvests are negative for both types of communities (Figure 17A), while road effects on incomes are positive for non-indigenous majority communities and negative for indigenous majority communities (Figure 17B).

Table 11 and Figure 17 suggest that road access has different effects on small communities, depending on their ethnicity. Off the road system, small indigenous majority communities have a modest advantage over small non-indigenous communities in subsistence (306 pounds compared

with 280 pounds, +8%), and a very slight disadvantage in the market (\$17,964 compared with \$18,238, or -2%). Harvests per person are negatively associated with incomes per person for both indigenous communities ($t=-2.61$, $p=0.012$) and non-indigenous communities ($t=-3.29$, $p=0.005$). On the road system, differences in harvests and incomes are magnified. Small indigenous majority communities on the road system still have a substantial advantage in subsistence harvests (236 pounds compared with 167 pounds, +29%), but an even more substantial disadvantage in market pursuits (average \$16,631 compared with \$22,974, -38%). On the road, associations between harvest and income are no longer significant for either community group ($t=1.60$, $p=0.132$; $t=-1.13$, $p=0.271$). Being on-the road system seems to exacerbate harvest and income inequalities between small indigenous and non-indigenous communities in the other rural economic region.

VIII. DISCUSSION

This article explored demographic and economic trends in a large sample of small- and medium-sized Alaska communities, identified factors associated with subsistence harvest levels and personal incomes, modeled subsistence harvest levels, and considered road effects on harvests and incomes. For the sample of communities as a whole, we found almost no significant changes over time in community populations (Figure 7), or in total and per capita harvests and income (Table 3, Figure 10, Table 4, Figure 11), but significant regional trends do exist. In the remote rural region, we found a significant decline over time in community mean harvests (Figure 14), but no significant change in real incomes. In all regions, subsistence harvests remain more than sufficient to provide, on average, an adult's protein needs.

The evidence suggests that subsistence in Alaska is persistent, stable, sustainable, and valuable. While conservation and allocation challenges do exist – Chinook salmon in the Yukon and Kuskokwim river drainages and caribou in the Western Arctic Herd are current examples – stable human population and harvest levels suggest that rural subsistence activities in general do not threaten local fish stocks or wildlife populations, nor do they threaten existing allocations to commercial fishing, recreational fishing, or recreational hunting. The same cannot be said of urban activities, as Fall (2016) pointed out; increases in demand for non-commercial harvests are coming from urban populations, not rural.

Goldsmith's economic regions add at least 10% to the explained variation in harvests, more than the individual factors of population density (people per 100 mi²) and ethnicity (percent indigenous). That should not be interpreted to mean density and ethnicity are not important. Density alone explains 67% of the variation in harvests if the entire population of Alaska is included (Wolfe and Fischer 2003). This makes sense. Density is a clear concept directly related to human-land relationships; human populations in excess of local carrying capacities cannot be supported without importing foods. A better interpretation is that the economic region dummies capture density and ethnicity, as well as additional unobserved factors such as natural resource productivity and the cost of living. Figure 1, Figure 3, and Figure 9B, for example, illustrate the correlation between economic region and ethnicity.

Although our data set includes no natural experiments – a road built after a comprehensive survey – propensity score matching found that roads have a significant and strong negative effect on subsistence harvests, likely a result of exclusion. Roads expose local residents to competition from urban hunters, while the absence of roads excludes most urban hunters. ANILCA's rural subsistence priority on federal public lands also excludes urban hunters from hunting under

830 subsistence regulations in rural areas (urban hunters usually can hunt under non-subsistence
831 regulations, which may be more restrictive).

832 In contrast with the road effect on harvests, propensity score matching found no significant
833 road effect on incomes. For indigenous-majority communities, expected losses to subsistence
834 harvests are greater than expected gains to income. In the other rural economic region,
835 unexpectedly, road access for indigenous majority communities is associated with lower mean
836 personal incomes. This may be a result of non-indigenous settlers outcompeting indigenous
837 residents for local jobs and in entrepreneurial endeavors. The results suggest that extending
838 Alaska's road system into remote rural Alaska might reduce well-being in indigenous-majority
839 communities.

840 The exclusionary effects of roads and laws remind us of Elinor Ostrom's (2010) design
841 principles for sustainable common-pool resource management, in particular her first principle,
842 enforceable boundaries.²⁶ The end of the road system functions as a *de facto* boundary between

²⁶ Ostrom's eight design principles are: (1) clearly defined boundaries, (2) appropriation & provisioning congruence, (3) collective choice arrangements, (4) monitoring, (5) graduated sanctions, (6) conflict-resolution mechanisms, (7) minimal recognition of rights to organize, and (8) nested enterprises (for larger common-pool resource systems). Title VIII of the Alaska National Interest Lands Act incorporates these principles through the administrative regulations recommended by the Regional Advisory Councils and the federal management bureaucracy. The State of Alaska system is similar, but lacks enforceable boundaries, and lacks appropriation and provisioning congruence.

State boundaries exist, but any resident of Alaska is eligible to participate in any state-managed subsistence fishery or hunt. In some cases, the Alaska Board of Game adopted regulations to make entry into subsistence hunts less appealing or more difficult – trophy destruction, locally available registration permits, or community hunts, for example – but creative hunters find circumventions. In the classic case, two sitting members of the Alaska Board of Game and the director of ADF&G's Division of Wildlife Conservation circumvented a trophy destruction requirement that the board had adopted to limit demand in a Nome area subsistence muskox hunt (Coyne 2012a). An Alaska State Troopers' investigation was not "able to establish that the conditions of the permit were violated" (Coyne 2012b, Medred 2012). Another example comes from a self-described punk rocker from Wasilla who formed "The Bike Collective" so as to be

843 urban Alaska and remote communities. The ANILCA provision limiting subsistence
844 opportunities to local rural residents of areas with customary and traditional uses creates an
845 enforceable *de jure* boundary, but not a closed class of users (users can move into and out of rural
846 communities). These boundaries resemble pre-contact indigenous land tenure systems described
847 by Burch (1972, 1998, 2005, 2006) and Ray (1967) for northwest Alaska, which limited access
848 to traditional territories occupied by allied families and societies. Like rural priorities, territorial
849 boundaries could be relaxed at certain times or places, as happened during the *Sisualik* summer
850 trade fair near the modern location of Kotzebue (Nelson 1899). As in state Tier II hunts and with
851 ANILCA's section 804, traditional boundaries could be constricted in times of shortage.

852 While the rural subsistence priority is controversial, exclusionary approaches to natural
853 resource management are common in Alaska today. Alaska amended its constitution in 1972 to
854 allow for limited entry fishing permits, excluding fishermen with insufficient commercial fishing
855 histories. Individual fishing quotas for halibut, adopted by the federal government in 1995, are
856 similar. Mining claims, oil leases, and timber sales are also exclusionary approaches to common-
857 pool natural resource management. At one time, big game guides in Alaska established exclusive
858 guide areas which, with the full administrative support of the state, guides bought and sold as if
859 the areas were private property. That system, like the state's rural subsistence priority, was found

able to legally participate in a community subsistence hunt in the Copper Basin (Young 2015).
The federal rural priority does not have such issues.

The state's subsistence hunts and fisheries are managed by a two statewide boards, who also
manage commercial and recreational uses. Commercial users – either commercial fishermen or
guides -- are highly incentivized to become members of these boards (although most identify as
subsistence users themselves). Recreational hunters and fishers are also highly motivated; their
interest groups lobby governors to appoint their candidates. Thus, in the state system,
commercial users are provisioned by their own appropriations. Recreational users (to a lesser
extent) are also so provisioned. Subsistence users are not. Subsistence appropriations are
determined by primarily by users who are in competition with subsistence uses; this is not
appropriation and provisioning congruence.

to be unconstitutional by the Alaska Supreme Court (*Owsich v State* 1988), so the state legislature developed a new guide-use-area system, still based on exclusionary principles but without the transferrable property rights.

Paradoxically, while subsistence harvests in rural areas are more than sufficient to provide for protein needs, high levels of food insecurity and poor diet quality have been reported among rural Northern indigenous populations. Diet quality is measured in part by applying Euro-American diet standards, measuring consumption of grains, vegetables, and fruits (Bersamin *et al.* 2006), by which standards virtually any traditional northern diet would have been judged “poor.” Nonetheless, detrimental effects of increased consumption of fats and sugars are evident (Bersamin *et al.* 2008). The high harvest-poor diet paradox warrants further attention.

IX. CONCLUSION

From the smallest village to the largest city, many Alaskans enthusiastically embrace a mixed subsistence-market economy. They engage in both home production and market pursuits. From an economic perspective – to say nothing of tradition and nutrition – self-reliance on local foods is a rational choice, particularly in remote areas where costs are high and incomes low.

When the U.S. Congress adopted the Alaska National Interest Lands Conservation Act in 1980, it identified four threats to subsistence: (1) Alaska’s increasing population, (2) sudden declines of some wildlife species, (3) increasing road access to remote areas, and (4) unprincipled harvests of fish and wildlife.²⁷ The doubling of Alaska’s urban population, recent

²⁷ Alaskans bristle when Congress alleges that Alaskans are “unprincipled.” A review of efforts to rebuild over-fished global stocks observes: “The inherent uncertainty in fisheries, however, requires that agencies act before it comes to that stage; this is especially true in light of

declines of some salmon stocks and caribou populations (which historically have been cyclical), and the substantial negative effect of roads on subsistence harvests (as shown in this analysis) provide a basis for at least some of Congress' concerns. Growing urban populations and generally much higher harvests in remote rural communities also provide support for Congress' decision to limit subsistence opportunities to local rural residents of communities or areas with customary and traditional uses.²⁸

These concerns have not abated. The Alaska Legislature recently adopted an Alaska Arctic Policy, which states: "Alaska lacks some of the basic infrastructure needed for emergency and environmental response capacity, search and rescue, telecommunications, ports, roads and railways... The lack of infrastructure and the speed at which global development in the Arctic is occurring should be a call to action – to build and to create" (Alaska Arctic Policy Commission 2015:3).

Given the substantial and traditional dependence of Northern peoples on subsistence foods, the social relations built around subsistence (Burch 1975, Collings, Wenzel, and Condon 1998, Bodenhorn 2000, Magdanz, Utermohle, and Wolfe 2002), the clear commitment Northern peoples have to maintaining their subsistence livelihoods (Kruse *et al.* 2008, Poppel and Kruse 2009), and economic efficiencies inherent in depending on local sustainable, renewable

accelerating global change. We found that only Alaska and New Zealand seemed to have acted with such foresight, whereas other regions experienced systemic overexploitation." (Worm *et al.* 2009)

²⁸ ANILCA limited subsistence opportunities to local rural residents living in communities or areas with histories of customary and traditional uses. Importantly, "local rural resident" is not a closed class. Under federal rules, any urban Alaska resident could move from Anchorage to Ambler, for example, and become a federally eligible local rural resident, but few choose to do so. Under state rules, any Alaska resident can legally hunt or fish for subsistence in any area open to subsistence harvesting. Thus the federal system excludes urban from subsistence hunts and fisheries; the state system does not.

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896 resources for sustenance, maintaining subsistence economies in Alaska has become a social goal
897 embodied in state and federal law (Norris 2002). The Alaska experience with subsistence
898 management suggests that, given responsibly managed wild resources and appropriate levels of
899 exclusion, traditional, cooperative subsistence economies can co-exist with market economies.
900

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TABLE 1

ALASKA COMMUNITIES AND THE SURVEY SAMPLE

Community Size	Surveyed		Not Surveyed		All ^a	
	N	(Row %)	N	(Row %)	N	(Col %)
More than 10,000 people	0	(0%)	6	(100%)	6	(2%)
SAMPLE: 50 to 10,000 people^b	179	(58%)	128	(42%)	307	(80%)
Less than 50 people	37	(53%)	33	(47%)	70	(18%)
Total	216	(56%)	167	(44%)	383	(100%)

^a The total is the number of census designated places (CDPs) identified by the Census Bureau as having populations in 2014, not including "balance of census area" CDPs. The number of populated CDPs varies over time.

^b A community was considered eligible if it had more than 50 people in any one survey. The sample contains a few observations where a community had less than 50 people in one survey, but 50 or more in another survey.

TABLE 2

SUMMARY STATISTICS

	Mean	SD	Median	Min	Max	Obs.
PROJECTS^a						
<i>N of eligible projects</i>	-	-	-	-	-	354
SAMPLES						
<i>Communities</i>						
<i>N eligible</i>	-	-	-	-	-	179
<i>N panel eligible</i>	-	-	-	-	-	98
<i>Households</i>						
<i>N surveyed in all projects</i>	-	-	-	-	-	
<i>N in community</i>	198	410	61	12	3,053	354
<i>N surveyed in community</i>	51	43	40	10	466	354
<i>% surveyed in community</i>	61%	26%	68%	2%	100%	354
VARIABLES						
<i>Demographics</i>						
<i>N of people in community</i>	612	1,213	189	34	8,535	354
<i>% indigenous in community</i>	63%	36%	81%	0%	100%	318
<i>Population density^b</i>	0.514	0.338	0.398	0.111	2.327	354
<i>Subsistence harvest</i>						
<i>Total lbs for community</i>	145,608	226,837	58,710	5,856	2.2 M	354
<i>Mean lbs per household</i>	1,222	1,037	898	112	6,098	354
<i>Mean lbs per person</i>	350	253	276	48	2,157	354
<i>Personal income</i>						
<i>Total US\$ for community</i>	15.5 M	38.0 M	3.2 M	343,163	218.0 M	279
<i>Mean US\$ per household</i>	58,823	25,892	54,988	9,336	170,213	279
<i>Mean US\$ per person</i>	18,292	8,819	16,684	2,626	49,040	279
<i>Economic region</i>						
=1 if in urban economic region						35
=1 if in other rural economic region						172
=1 if in remote rural economic region						147
<i>Access</i>						
=1 if not accessible by road or ferry						193
=1 if accessible by road						77
=1 if accessible by ferry						75
=1 if accessible by both road and ferry						9

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^a A "project" is a series of household surveys conducted in a single community in a single year. Each observation in the sample is an aggregation of household reports from one survey project, expanded for unsurveyed households. Projects conducted in a census designated place with a population between 50 and 10,000 people during at least one survey project are "eligible." An eligible community surveyed more than once is "panel eligible." Income and ethnicity questions were not asked on all surveys.

^b Density is measured in persons per 100 mi², weighted by distance from a study community.

SOURCE: Alaska Department of Fish and Game, Division of Subsistence.

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TABLE 3

ESTIMATED HARVESTS OVER TIME

	Ln(total harvest)	Ln(mean harvest per person)		
	(A)	(B)	(C)	(D)
	Cross section	Cross section	Pooled cross section	Community panel
Year	-.014 (1.95)	.002 (0.55)		-.003 (1.06)
1983-1989 (base)				
=1 if 1990-1999			-.027 (0.24)	
=1 if 2000-2009			.236 * (2.07)	
=1 if 2010-2013			-.075 (0.65)	
constant	11.400 (83.20)	5.574 *** (65.04)	5.584 *** (70.09)	5.679 *** (71.55)
N of observations	341	341	341	273
r ²	.013	.001	.023	
r ² within				.006
r ² between				.005
adj. r ²	-.010	-.002	.014	.003
AIC	1084.8	697.4	693.8	
BIC	1092.5	705.0	709.2	

Robust OLS. Analytic weight=95% CI of harvest.

Absolute value of t statistics in parentheses.

* Significant at 5%, ** Significant at 1%, *** Significant at 0.1%

TABLE 4

ESTIMATED PERSONAL INCOMES OVER TIME

	Ln(total income)	Ln(mean income per person)			
	(A)	(B)	(C)	(D)	
	Cross section	Cross section	Pooled cross section	Community panel	
Year	-.012 (1.52)	-.009 ** (3.03)		-.004 (1.01)	
1983-1989 (base)					
=1 if 1990-1999			.013 (0.19)		
=1 if 2000-2009			-.209 (1.90)		
=1 if 2010-2013			-.229 ** (2.88)		
constant	15.740 (95.78)	9.822 *** (179.63)	9.749 *** (198.22)	9.787 *** (144.86)	
N of observations	279	279	279	206	
r ²	.006	.027	.040		
r ² within				.000	
r ² between				.048	
adj. r ²	.003	.024	.029	.008	
AIC	977.4	412.2	412.7		
BIC	984.7	419.5	427.2		

Robust OLS. Absolute value of t statistics in parentheses.

* Significant at 5%, ** Significant at 1%, *** Significant at 0.1%

TABLE 5

ESTIMATED HARVESTS AND INCOMES BY COMMUNITY SIZE CATEGORY

	Mean	Median	Obs.
SMALL COMMUNITIES, < 1,000 people (N=161)			
<i>Subsistence harvest (estimated edible pounds)</i>			
Total for community	90,275	47,041	312
Mean per household	1,313	997	312
Mean per person	373	305	312
<i>Personal income (estimated 2012 US\$)</i>			
Total for community	4.3 M	2.7 M	245
Mean per household	55,196	52,497	245
Mean per person	16,991	15,224	245
LARGE COMMUNITIES, 1,000 or more people (N=18)			
<i>Subsistence harvest (estimated edible pounds)</i>			
Total for community	556,653	440,498	42
Mean per household	542	452	42
Mean per person	175	164	42
<i>Personal income (estimated 2012 US\$)</i>			
Total for community	96.7 M	74.3 M	34
Mean per household	84,958	85,198	34
Mean per person	27,674	26,881	34

SOURCE: Alaska Department of Fish and Game, Division of Subsistence

TABLE 6**ESTIMATED HARVESTS AND INCOMES OVER COMMUNITY POPULATION**

	Ln(harvest)				Ln(income)			
	(A)		(B)		(C)		(D)	
	Est. total		Est. total		Est. total		Est. total	
	for		Mean per		for		Mean per	
	community		person		community		person	
Ln(community population)	.805	***	-.194	***	1.100	***	.100	***
	(27.41)		(6.60)		(40.43)		(3.67)	
constant	6.670	***	6.660	***	9.139	***	9.139	***
							(60.39	
	(40.25)		(40.23)		(60.39)		)	
N of observations	329		329		279		279	
r ²	.723		.131		.872		.053	
adj. r ²	.722		.129		.872		.050	
AIC	606.8		606.0		404.6		404.6	
BIC	614.4		613.6		411.9		411.9	

Robust OLS. Model (A) & Model (B) - analytic weight=95% CI of harvest.

Absolute value of t statistics in parentheses.

* Significant at 5%, ** Significant at 1%, *** Significant at 0.1%

TABLE 7

ESTIMATED HARVESTS AND INCOMES OVER ACCESS CATEGORY

	Ln(harvest)		Ln(income)	
	(A)		(B)	
	Mean per person		Mean per person	
No road or ferry access (base)				
=1 if road access	-.884 *** (10.83)		.275 *** (3.78)	
=1 if ferry access	-.438 *** (5.61)		.378 *** (5.02)	
=1 if road & ferry access	-1.379 *** (8.93)		.791 *** (6.75)	
constant	5.972 *** (119.55)		9.535 *** (249.13)	
N of observations	341		279	
r ²	.378		.141	
adj. r ²	.372		.132	
AIC	540.0		381.5	
BIC	554.3		396.1	

Robust OLS. Model (A) - analytic weight=95% CI of harvest.

Absolute value of t statistics in parentheses.

* Significant at 5%, ** Significant at 1%, *** Significant at 0.1%

TABLE 8

PRIOR SUBSISTENCE PRODUCTION MODELS, REPLICATED

	Ln(mean harvest per person)		
	(A)	(B)	(C)
	Wolfe <i>et al.</i> (1987)	Wolfe <i>et al.</i> (1987) Replication	Wolfe <i>et al.</i> (2011) Replication
Ln(percent indigenous)	.254 *** (.368)	.021 (1.94)	.023 * (2.12)
Ln(mean income per tax return)	-.131 * (2.05)		
Ln(mean income per household)		-.419 *** (5.80)	
Ln(mean income per person)			-.342 *** (5.61)
=1 if on road			-.540 *** (7.10)
=1 if urban-urban periphery			-.539 *** (4.28)
Urban-urban Periphery (base)			
=1 if Yukon Koyukon	.499 *** (9.22)	.126 (1.14)	
=1 if Northwest Arctic	.315 *** (6.17)	.992 *** (8.96)	
=1 if Southwest Alaska	.297 *** (5.61)	.737 *** (8.78)	
=1 if Western Alaska	.362 *** (6.36)	.613 *** (5.18)	
=1 if Kodiak	.109 * (2.08)	.296 ** (2.80)	

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constant		9.747 ***	9.000 ***
	(2.69)	(12.36)	(15.16)
N of observations	98	265	265
r ²	.780	.436	.433
adj. r ²		.420	.424
AIC		371.7	367.1
BIC		400.3	385.0

Model A statistics from Wolfe and Walker (1987) Table 6.

Replications use OLS on current data.

Absolute value of t statistics in parentheses.

* Significant at 5%, ** Significant at 1%, *** Significant at 0.1%

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TABLE 9

ALTERNATE SUBSISTENCE PRODUCTION MODELS

	Ln(mean harvest per person, edible lbs)					
	(A)		(B)		(C)	
	Cross Section		Pooled Cross Section		Community Panel	
Year	-.015	***			-.006	*
	(4.50)				(2.26)	
1983-1989 (base)						
=1 if 1990-1999			.095			
			(1.33)			
=1 if 2000-2009			-.320	***		
			(3.52)			
=1 if 2010-2013			-.367	***		
			(4.19)			
No road or ferry access (base)						
=1 if road access	-.445	***	-.371	***	-.626	***
	(4.59)		(3.87)		(7.15)	
=1 if ferry access	-.189		-.140		-.305	**
	(1.66)		(1.23)		(3.20)	
=1 if road & ferry access	-1.119	***	-1.076	***	-1.053	***
	(7.13)		(7.25)		(11.96)	
Urban economic region (base)						
=1 if other rural	.520	***	.524	***	.575	***
	(5.18)		(5.25)		(4.53)	
=1 if remote rural	1.085	***	1.167	***	.857	***
	(10.11)		(10.54)		(7.49)	
Ln(mean income per person, 2012\$)	-.218	***	-.248	***	-.216	***
	(3.82)		(4.84)		(3.46)	

The Persistence of Subsistence in Alaska

Ln(percent indigenous)	.011	.011	.022
	(1.12)	(1.04)	(1.90)
constant	7.376 ***	7.462 ***	7.305 ***
	(13.07)	(14.88)	(11.73)
N of observations	260	260	196
r ²	.626	.646	.600
r ² within			.040
r ² between			.650
adj. r ²	.614	.632	
AIC	288.3	277.8	
BIC	320.3	317.0	

Robust OLS. Analytic weight=95% CI of harvest. Absolute value of t statistics in parentheses.

* Significant at 5%, ** Significant at 1%, *** Significant at 0.1%

1276

TABLE 10

ESTIMATED EFFECTS OF ROAD ACCESS ON HARVESTS AND INCOME

			Average effect of treatment on the treated (ATT)		Standard Error	<i>t</i>
	<i>n</i> treat.	<i>n</i> control				
Ln(mean harvest per person)						
Nearest neighbor	68	125	-.376	***	± .083	4.521
Radius matching	68	125	-.493	***	± .068	7.283
Kernel matching	68	125	-.417	***	± .065	6.442
Stratification matching	67	126	-.388	***	± .064	6.093
Ln(mean income per person)						
Nearest neighbor	68	30	-.050		± .114	.438
Radius matching	60	111	.047		± .090	.527
Kernel matching	68	111	-.057		± .086	.663
Stratification matching	53	126	-.133		± .085	1.567

Average effect of treatment is calculated by propensity score matching, where "the propensity score is the conditional probability of assignment to a particular treatment given a vector of observed conditions" (Rosenbaum and Rubin 1983). See text. Bootstrapped standard errors.

* Significant at 5%, ** Significant at 1%, *** Significant at 0.1%

TABLE 11

POPULATIONS, HARVESTS, AND INCOMES, BY ETHNICITY AND ROAD STATUS

	mean	sd	median	obs.
Majority indigenous communities (n=28)				
Estimated community population				
Off Road (n=20)	227	211	130	65
On Road (n=8)	208	133	191	21
Mean harvest per person (edible lbs)				
Off Road (n=20)	306	109	300	65
On Road (n=8)	236	109	221	21
Mean income per person (2012 US\$)				
Off Road (n=20)	17,964	7,992	16,764	65
On Road (n=8)	16,631	9,355	12,923	21
Majority non-indigenous communities (n=35)				
Estimated community population				
Off Road (n=12)	171	158	102	20
On Road (n=23)	312	239	210	33
Mean harvest per person (edible lbs)				
Off Road (n=12)	280	92	256	20
On Road (n=23)	167	69	150	33
Mean income per person (2012 US\$)				
Off Road (n=12)	18,238	5,902	17,870	20
On Road (n=23)	22,974	8,102	22,378	33

NOTE: Limited to 63 communities with < 1,000 people in the "other rural" economic region.

FIGURE LEGENDS

Figure 1. Alaska Natives (19% of all Alaska residents) are in the majority in sparsely populated western and northern census areas (69% of the state's total area). Eighty percent of the state's population lives in five urban census areas (with 9% of the state's area) that include Anchorage, Fairbanks, and Juneau.

Figure 2. (A) Since contact, most of Alaska's population growth resulted from immigration. Structural breaks in immigration coincide with the gold rush (~1900) and World War II (1941-45). Indigenous populations did not surpass pre-contact estimates until the 1980s. (B) Since statehood, Alaska's population growth occurred primarily in urban areas. See Figure 3 for boundaries of economic regions.

Figure 3. Goldsmith (2007) identified three economic regions in Alaska, aggregating census areas based on accessibility and economic characteristics. Although ethnicity was not a stated factor in determining regional boundaries, Goldsmith's economic regions mirror the distribution of Alaska's indigenous population (Figure 1).

Figure 4. Members of the Semaken family process Chinook salmon at their fish camp on the Yukon River. The dictionary definition of subsistence as “a bare or minimum level of existence” does not capture the importance of wild foods in Alaska.

Figure 5. Most fish and wildlife harvests in Alaska are allocated to commercial fishing. Subsistence accounts for about 1.1% of the total annual harvest, by weight.

Figure 6. The Division of Subsistence conducted three comprehensive subsistence survey projects in the remote northwest Alaska community of Kivalina during the study period: 1983, 1992, and 2007. In smaller communities like Kivalina, with 85 households and 374 people in

1305 2010, research designs usually call for a census rather than a probability sample. See Figure 8 for
1306 Kivalina's location.

1307 **Figure 7.** (A) Communities with 100 to 300 people are over-represented in the sample compared
1308 with all Alaska communities (solid line). (B) Population trends for the sampled communities and
1309 all eligible communities are almost exactly the same.

1310 **Figure 8.** Study communities (n=179) and other communities (n=142) in Alaska. A paved
1311 highway system connects southcentral and interior communities. A gravel industrial road
1312 connects Prudhoe Bay to the highway system. The Alaska Marine Highway (a ferry system, not
1313 shown) connects some southern Alaska communities.

1314 **Figure 9.** (A) The sampled communities in Alaska are ethnically bifurcated, either
1315 predominantly indigenous or predominantly non-indigenous. (B) Almost all sampled
1316 communities in the remote rural region have indigenous majority populations.

1317 **Figure 10.** From 1983 to 2013, no significant change is evident in (A) total harvests by
1318 community, (B) mean harvest per person, (C) mean harvest per person in a pooled decadal cross
1319 section, except in the third decade, or (D) mean harvest in a 98-community panel. See also Table
1320 3.

1321 **Figure 11.** From 1983 to 2013, real incomes trend lower, although not all income and time
1322 associations are significant. (A) Total incomes for a community decline by 1.2% annually, but
1323 the association is not significant. Associations are significant for (B) mean income per person,
1324 and (C) mean income in a pooled cross section. (D) Mean income is not associated with time in a
1325 94-community panel. See also Table 4.

1326 **Figure 12.** (A) Total harvests and (B) incomes increase with community size. (C) Mean harvests
1327 per person decrease and (D) incomes per person increase with increases in community size. (E)

1328 Percent indigenous decreases with increases in community size. (F) Mean harvest per person
1329 increases with increases in percent indigenous.

1330 **Figure 13.** (A) In 269 study communities, mean household harvests decreased with increases in
1331 mean household incomes. (B) A similar, stronger association was observed between mean
1332 harvests and mean incomes per person. (C) In a single study community with 84 surveyed
1333 households, however, the association was reversed. Higher household incomes were associated
1334 with higher household harvests. (D) In the same community, controlling for household size
1335 eliminated the association between harvests and incomes.

1336 **Figure 14.** (A) In all regions, mean harvests decrease over time, but decrease is significant only
1337 in the remote rural region. (B) Mean incomes decrease over time in the urban and remote rural
1338 regions, but increase significantly in the other rural region. (C) In all three economic regions,
1339 mean harvests per person decrease with increases in community populations. (D) Mean income
1340 expectations diverge with increases in community populations. (Community harvest and income
1341 observations appear in previous graphs. To simplify presentation, they are not shown here.)

1342 **Figure 15.** Increases in access are associated with (A) lower mean harvests per person and (B)
1343 higher mean incomes per person. Table 7 corresponds.

1344 **Figure 16.** (A) Mean harvests per person are similarly distributed in off-road and on-road
1345 communities, but substantially higher off-road. (B) Mean incomes per person also are similarly
1346 distributed, but lower off-road. (C) Estimated harvests increase stepwise from urban to other
1347 rural to remote rural regions in both two road categories, and decrease from off-road to on-road
1348 within each region category. (D) Region and road are not as strongly associated with incomes.
1349 Mean incomes decrease stepwise from urban to remote rural on the road system, but that pattern
1350 is not evident in off-road communities.

1351 **Figure 17.** (A) In the "other rural" economic region, road access is associated with lower mean
1352 harvests per person in both types of communities (non-indigenous majority and indigenous
1353 majority). (B) In the same region, road access is associated with higher mean real incomes per
1354 person in non-indigenous communities, and lower mean real incomes in indigenous
1355 communities.

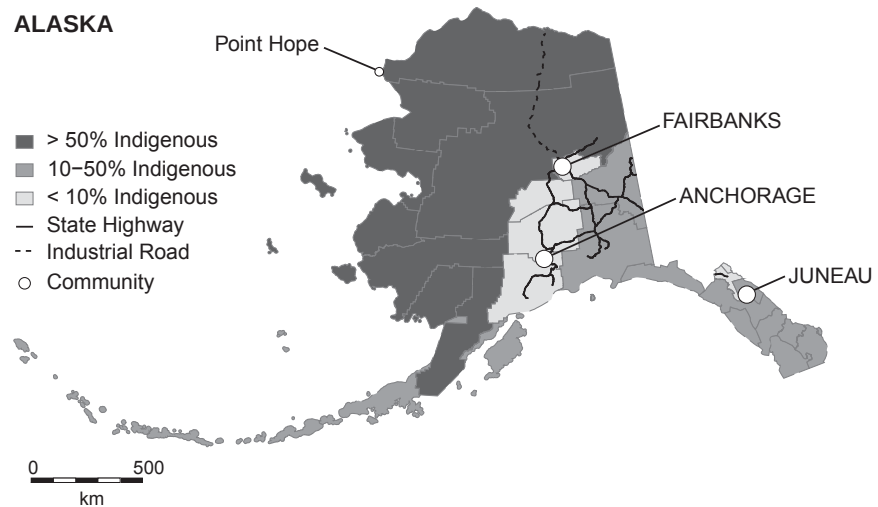
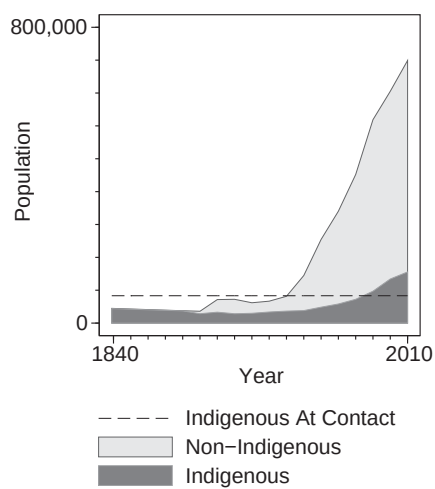
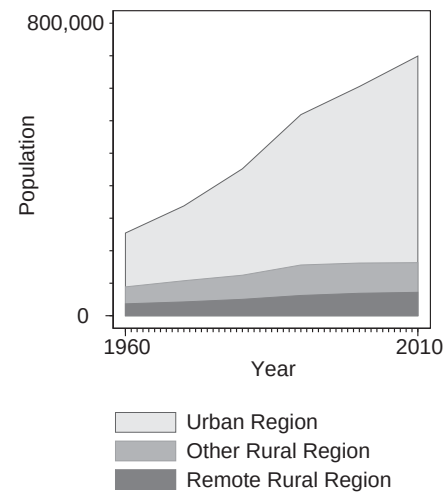


Figure 1.

A. Population by Origin, 1840–2010



B. Population by Region, 1960–2010



NOTE: Regional definitions from Goldsmith (2007)

Figure 2.

ALASKA

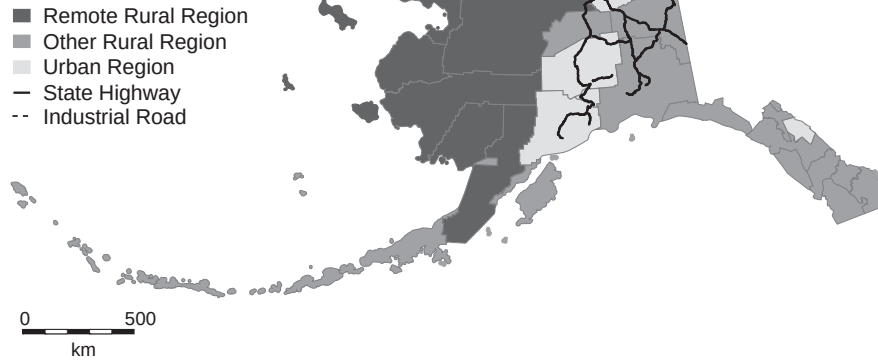


Figure 3.



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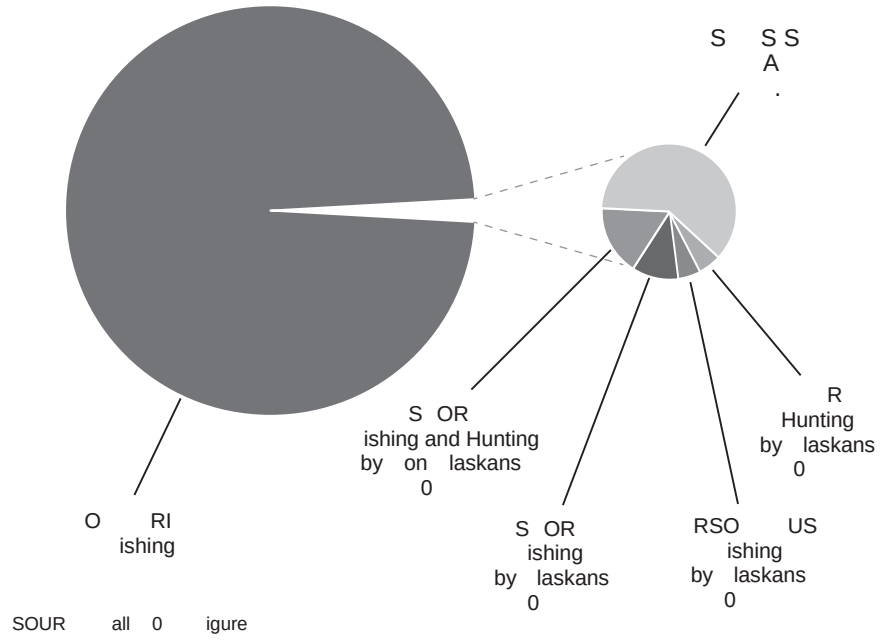
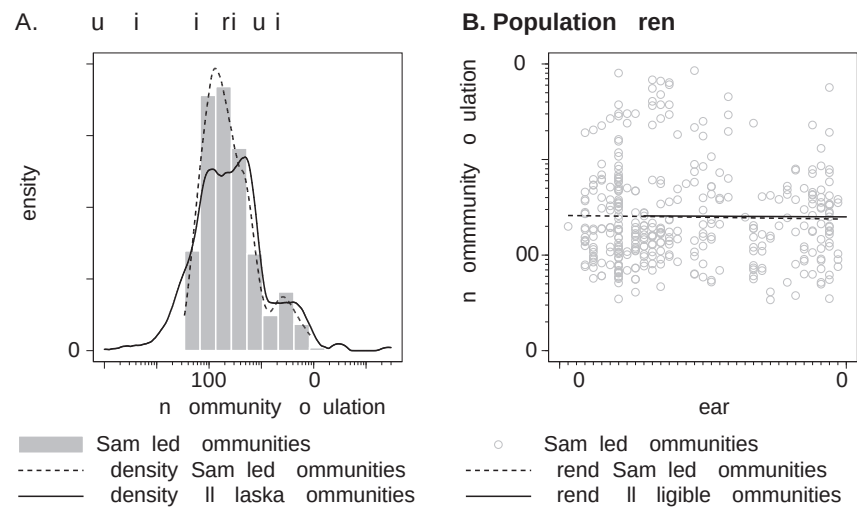


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NOTE: Eligible communities are communities ith 0 to 10,000 people.

Figure .

ALASKA

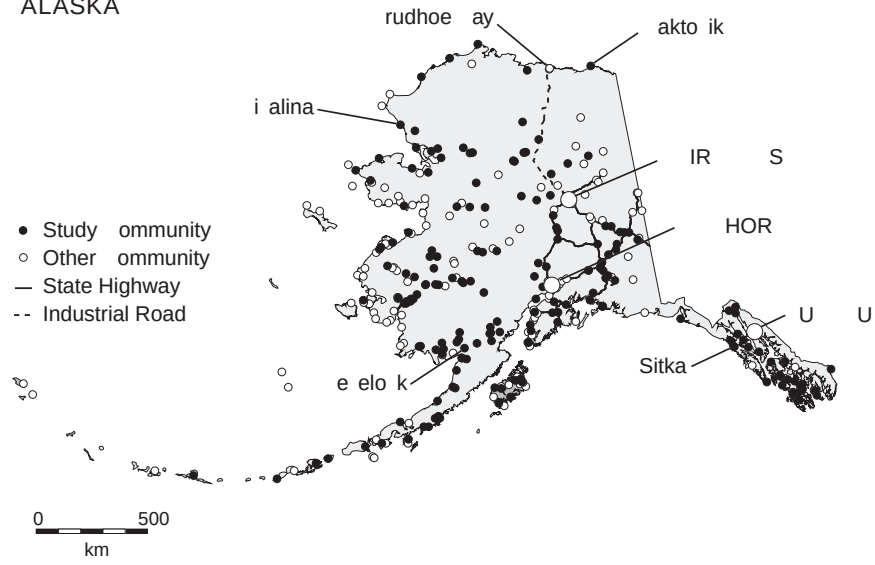


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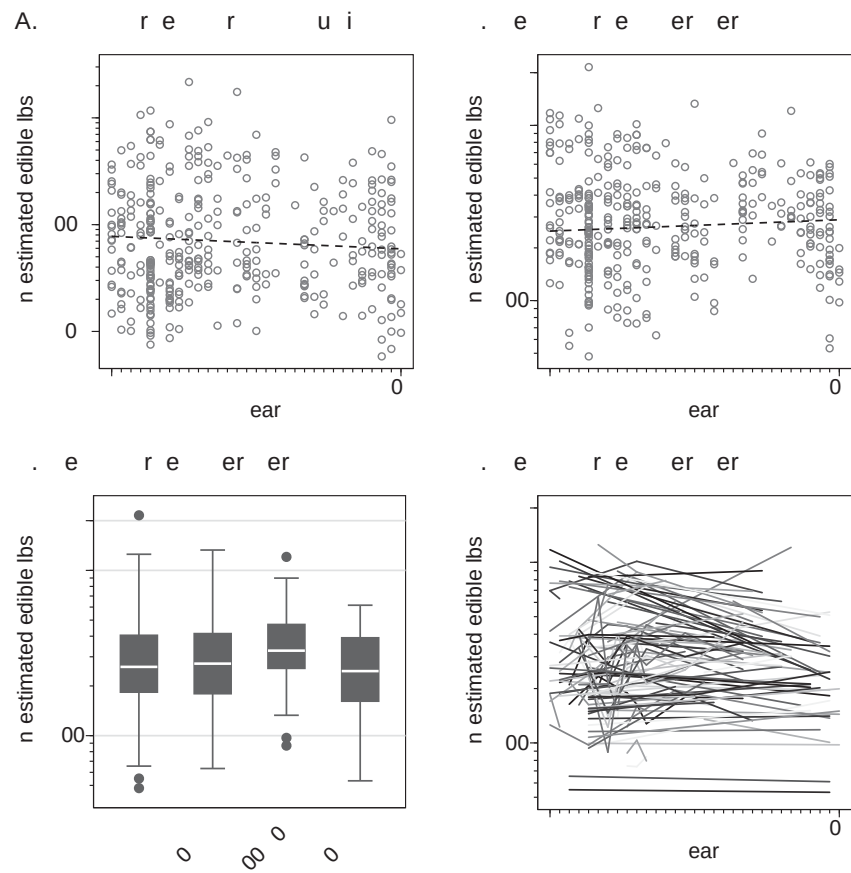


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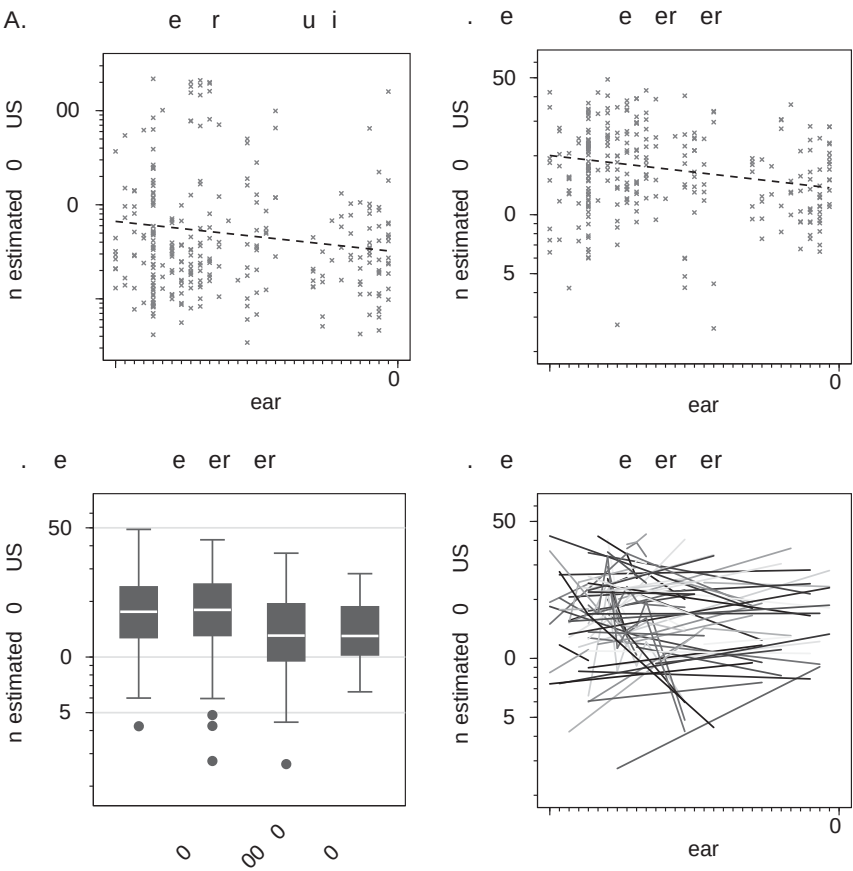


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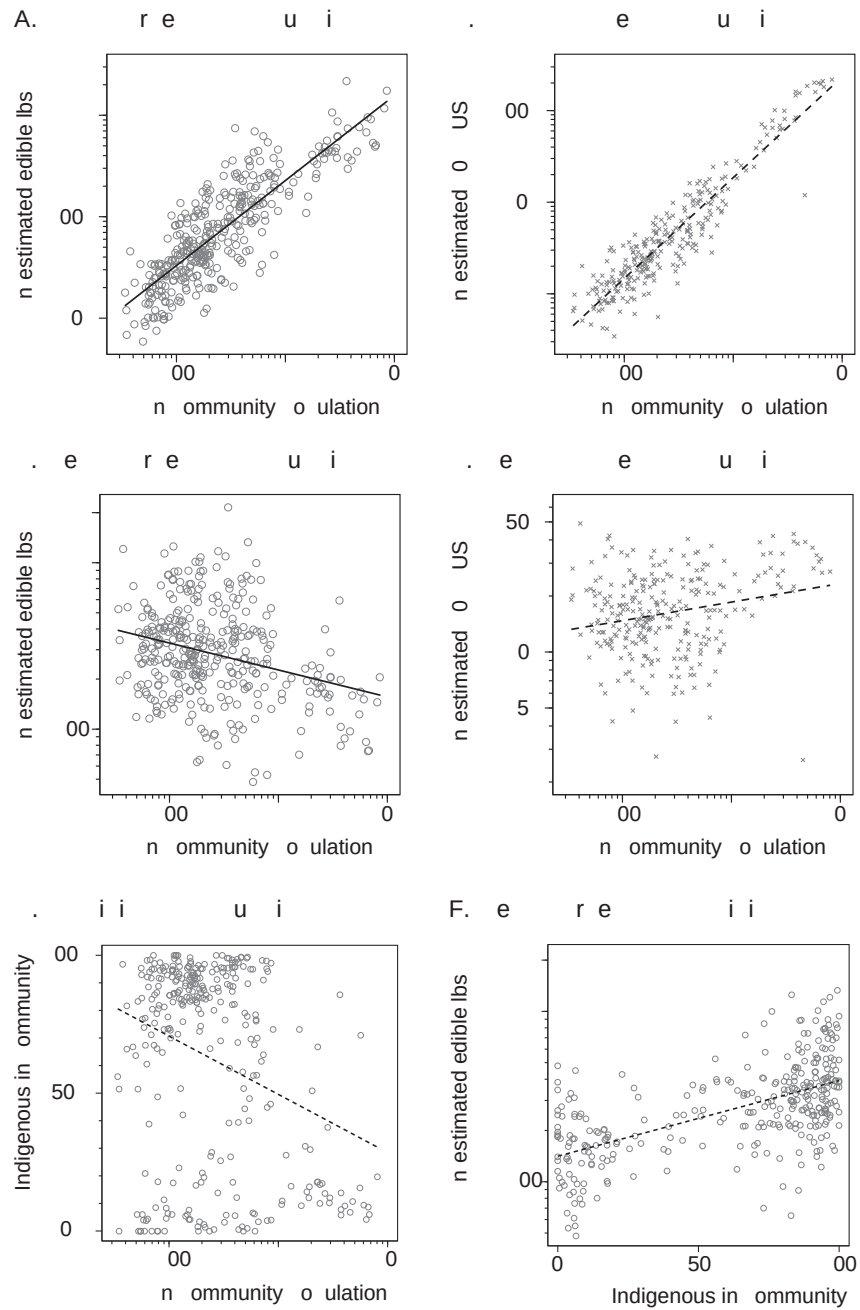
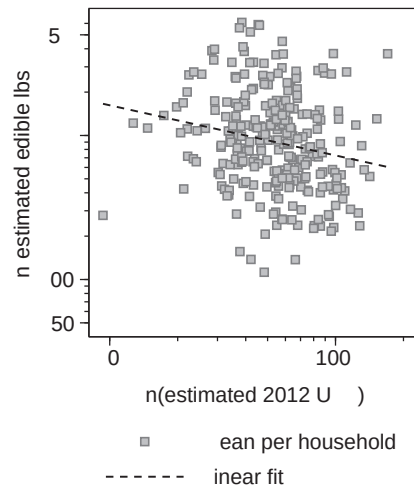
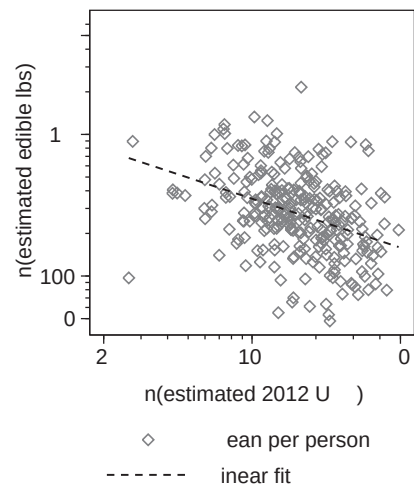


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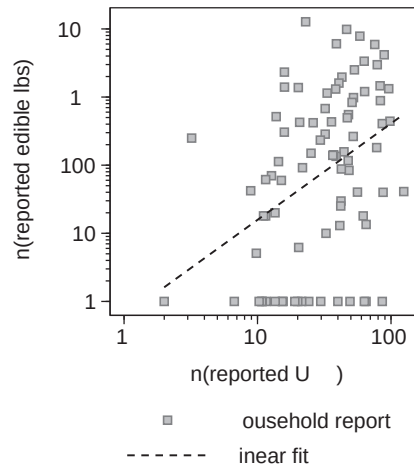
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B. 269 o unity ti ate



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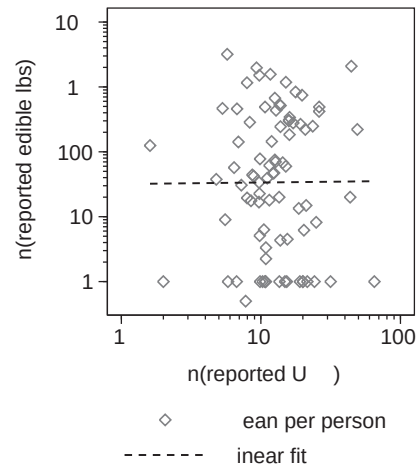


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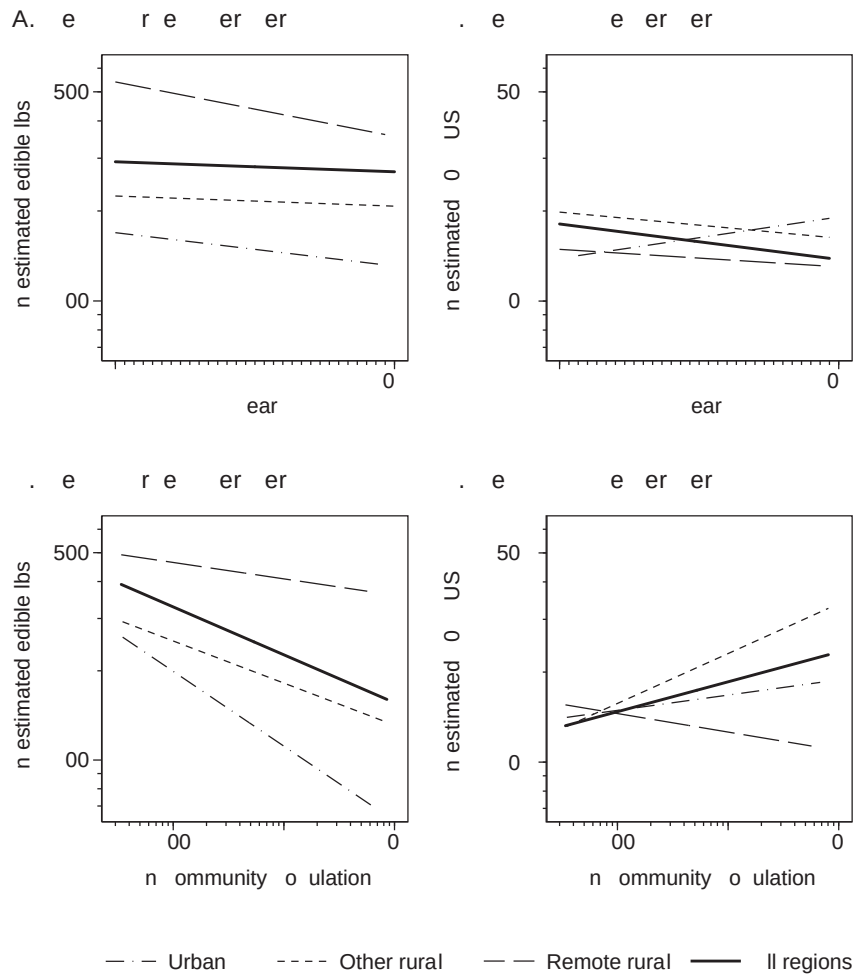
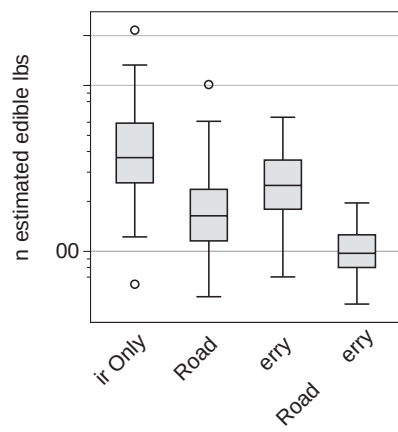


Figure 1.

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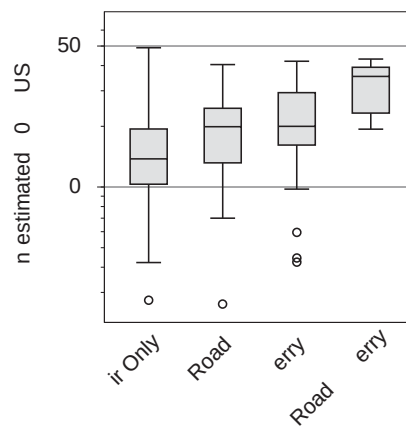


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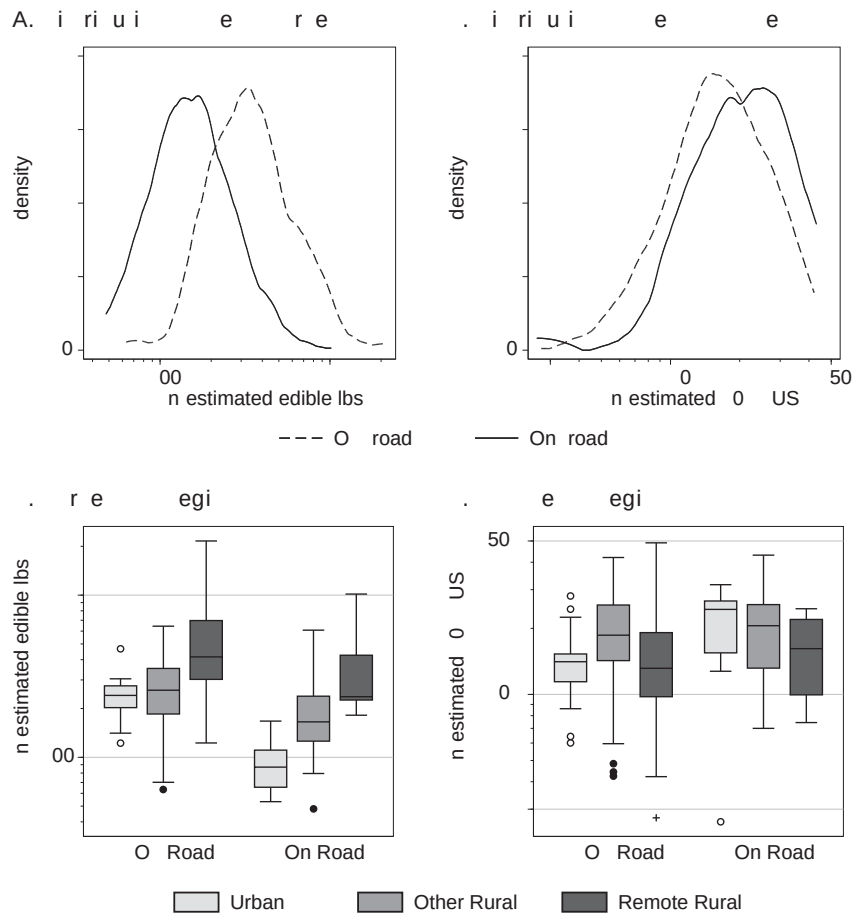


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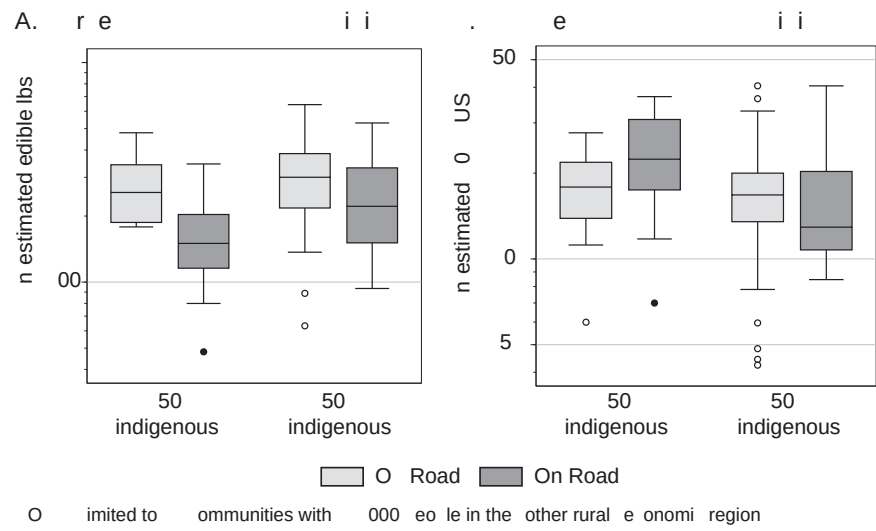


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