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Identifying community risk factors for quota share loss

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1. Introduction

Catch share programs have been shown to be effective at addressing overcapitalization in fisheries (Arnason, 1996; Casey et al., 1995; Campbell et al., 2000; Grafton et al., 2000), but researchers are increasingly documenting some adverse impacts of the resultant consolidation and the loss of access opportunities from high entry costs (Olson, 2011; Copes and Charles, 2004; Grimm et al., 2012; Leonard and Steiner, 2017; Ropicki et al., 2018). The associated geographic redistribution of fishing privileges and access rights can have multilayered economic impacts on fishing communities from losses of employment, income diversification opportunities, tax revenue, and shoreside support businesses and infrastructure (Campbell et al., 2000; Colburn et al., 2017; Copes and Charles, 2004; Eythórsson, 1996, 2000; Holland and Kasperski, 2016; Holland et al., 2017; Kasperski and Holland, 2013). Catch share programs may also create dichotomies between the program's winners and losers in fishing communities. These imbalances include inter-generational inequities in initial distributions, as well as changing dynamics between vessel owners and crewmembers, which can affect the social bonds in the community (Carothers, 2008, 2015; Carothers et al., 2010; McCay et al., 1995; McCay, 2004;Pálsson and Helgason, 1995). Although such community impacts are receiving increasing attention, specific community attributes, which may contribute to or buffer against losses of fishing privileges, are not well documented. Such information could be used to develop more nuanced management programs that attenuate adverse effects on vulnerable fishing communities. This study identifies potential factors associated with community vulnerability to changing conditions in relation to catch share implementation for the Pacific halibut (*Hippoglossus stenolepis*) fishery, by examining community attributes associated with quota share buying and selling decisions.

The Pacific halibut fishery is unique amongst the federally managed fisheries in Alaska for its accessibility to small vessels with limited capital investment in gear. During the development of the Pacific halibut Individual Fishing Quota (IFQ) Program, the North Pacific Fishery Management Council (NPFMC), which develops management plans for North Pacific federal fisheries, wanted to preserve the small boat characteristic of the fleet and to limit the potentially adverse impacts of the program on rural and coastal Alaska communities dependent on this fishery (North Pacific Fishery Management Council/ National Marine Fisheries Service (NPFMC/NMFS), 1992). Therefore, while allocating partially restricted tradable individual fishing quota, the program also includes a number of diverse fleet and community protection measures, making it a particularly unique catch share program in the United States (Holland et al., 2015).

The basic use privilege in the Pacific halibut IFQ Program is quota shares (QS), which are translated to IFQs in the form of annual fishing pounds based on the annually calculated Total Allowable Catch (TAC). Quota shares in the program are designated by vessel class, corresponding to who can own the shares and how the resulting IFQ can be harvested. Class A shares were allocated to freezer-longline vessels with at-sea processing capacity, have no vessel length restrictions, are available for purchase by any individual or non-individual entity, and may be leased. Class B through Class D shares are designated for catcher vessels by vessel length (see Fig. 1) that have to make landings at shoreside processors, although the length restrictions have been loosened over time with IFQ designated for larger vessels allowed to be harvested on smaller vessels. The IFQ Program also restricts catcher vessel QS acquisition for new participants to individuals only and includes several measures to limit leasing of these shares. In order to limit consolidation and ensure the availability of QS on the market suitable for small operations, QS that would have resulted in less than 20,000 lbs of IFQ at the start of the program were issued as non-severable blocks. There are restrictions on the number of such blocks, and the amount of blocked and unblocked QS that a shareholder may own. Pacific halibut QS and IFQ are also specific to geographic management areas (Fig. 1). Area 2C, corresponding to Southeast Alaska, has special provisions under the IFQ Program. These provisions were intended to protect its small boat and owner-operated fleet (North Pacific Fishery Management Council/ National Marine Fisheries Service (NPFMC/NMFS), 2016a), with greater constraints than other areas on who is eligible to acquire QS, how much QS one can own, and how IFQ can be harvested (North Pacific Fishery Management Council/ National Marine Fisheries Service (NPFMC/NMFS), 2016a).

One of the anticipated mechanisms of QS loss for remote Alaska communities from the IFQ Program was a change in the production of

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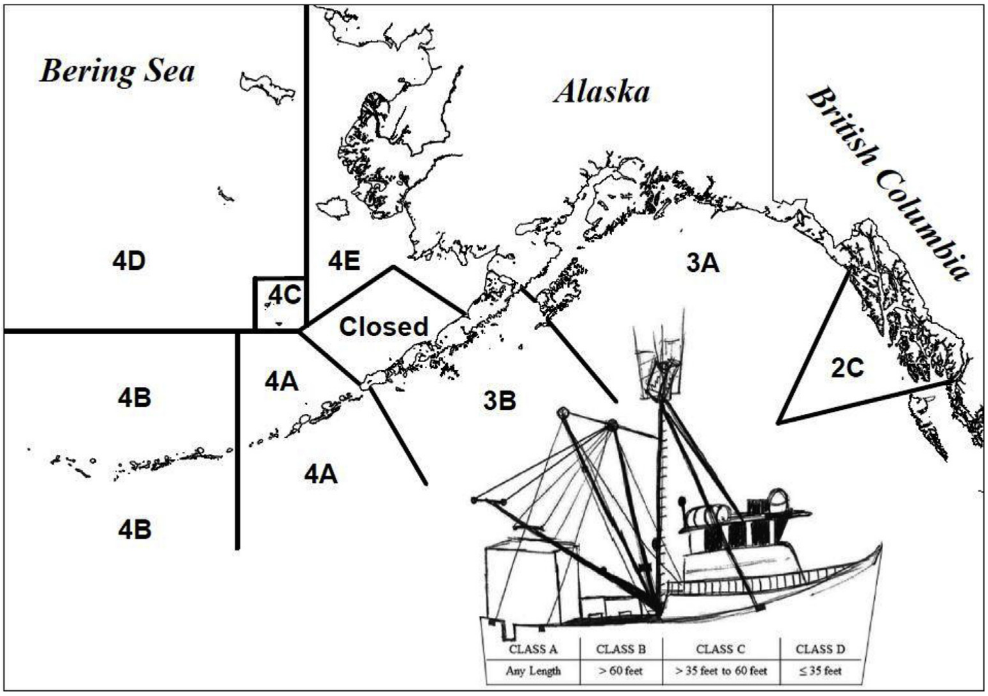

Fig. 1. Halibut IFQ regulatory areas and QS vessel class designations.

halibut to meet the demands of the fresh market, which would necessitate access to fast transportation. Prior to the IFQ Program, the majority of halibut caught off Alaska was produced for the frozen market, which could be transported by barge; the demands of the fresh market could not be met at that time due to the short open seasons and large quantities of fish landed during the derby fisheries, which limited processors to largely producing for the frozen market. The expansion of the fishing season length under the IFQ Program spread these landings over a much longer time frame and allowed processors to shift production towards the fresh market, provided they had access to appropriate transportation to then move the product, such as airports for cargo planes and/or the road system. A similar shift in halibut production occurred after the implementation of the individual vessel quota program in the British Columbia halibut fishery a few years prior to the implementation of the IFQ Program (Casey et al., 1995). Thus, some outmigration of quota from remote Alaska communities was also expected. Processors in communities without access to air or road transportation had to compete in a market that increasingly consisted of fresh halibut while those communities that did have air and road transportation were able to offer higher ex-vessel prices. Fishermen could participate in the halibut fishery pre- and post-IFQ even without a processor in their community provided they could land their fish elsewhere. However, IFQs may have made those with access to a buyer within their community more competitive because that access can facilitate short trips to deliver fresh high quality product rather than longer trips to another community to deliver and return home.

As expected, since IFQ implementation there has been a gradual increase of fresh halibut production from just under 20% of all processing before the IFQ Program to over 60% in recent years (Szymkowiak et al., 2019). The recent 20-year review of the IFQ Program also showed stable halibut landings and QS holdings for rural Alaska communities (defined as those with fewer than 2500 people), but an overall redistribution amongst these communities towards those with transportation access (Szymkowiak et al., 2019). The 20-year review, however, did not systematically examine how these community attributes affected QS migration patterns. The ensuing discussions within the NPFMC following the presentation of the 20-year review indicated interest in examining the program's impacts on communities using various specified population cutoffs, which we utilize in the analysis below (North Pacific Fishery Management Council(NPFMC), 2016b).

Previous research has explored QS migration in the halibut IFQ fishery and the associated broader social implications. Following the first few years of the IFQ Program, researchers documented the outmigration of QS from communities on the Alaska Peninsula (Commercial Fisheries Entry Commission (CFEC), 1998). Carothers, Lew, and Sepez (2010) analyzed QS market behavior during the first five years of the halibut IFQ Program by community of residence of the QS buyers and sellers. The authors found residents from small remote fishing communities[1] had a greater probability of selling their QS. Carothers (2010, 2015) examined how fisheries privatization, including the IFQ Program, have negatively impacted traditional values, culture, and fishing practices in Kodiak and the Alutiiq communities of the Kodiak archipelago. Based on a survey of halibut IFQ market participants, Carothers (2015) illustrates that older individuals, those who make less money, and indigenous fishermen are more likely to sell than buy quota. Women and those who are primarily employed in fishing are more likely to buy quota (Carothers, 2015).

Our analysis updates and extends the Carothers et al. (2010) study, which explored halibut QS transfers from 1995 to 1999. Here we focus on QS transfer decisions from 1995 to 2016 with additional community-level variables that account for the increasing necessity of transportation post-IFQ and individual level covariates representing the participant's quota shareholdings and QS attributes. We sought to answer a number of questions related to how community attributes inform QS transfer decisions in the halibut IFQ fishery including the following: 1) Are the results for examining QS transfer decisions as supported by residency in small remote fishing communities (SRFC) consistent when comparing the first five years of the program to the full 21 years of the IFQ Program?; 2) Are the results for the SRFC covariates robust to the inclusion of individual-level QS holdings variables and other

[1] Small remote fishing communities were identified as those with fewer than 1500 residents within 10 miles of the coastline, having rural status according to the U.S. Federal Subsistence Board and at least one resident who received an initial quota share allocation.

community attributes?; 3) Are the results sensitive to the definition of SRFCs?; and 4) Can we identify community-level attributes that may buffer against or contribute to QS transfer decisions that can be tracked over time?

To answer these questions, we developed an econometric model of QS buying and selling decisions for individuals that includes several community-level variables of interest while controlling for individual and QS attributes that would affect QS transfer decisions. We find that community-level attributes are important predictors of QS transfers, but the most important predictors of transfer behavior are different from the ones traditionally examined by researchers and the NPFMC, such as the presence of a halibut buyer (market) within the community; an airport with a runway length greater than 4500 ft; and whether the individual has diversified QS holdings.

1.1. Data

We examine halibut QS transfers from 1995 to 2016 utilizing halibut QS transfer and QS holdings data maintained by the National Marine Fisheries Service and sourced through the Alaska Fisheries Information Network (AKFIN). Consistent with the Carothers et al. (2010) paper, we limit our analysis to permanent transfers by individual QS holders with Alaska residency. The final dataset is comprised of 11,318 observations, with an average of 514 transfers per year over the 21-year period of our study. Because the halibut IFQ fishery includes regulations specific to areas and vessel classes, as well as TACs that are area-specific and have changed differentially over time, and ex-vessel prices and participation costs (e.g., fuel, moorage, etc.) that vary by area, we included QS-level characteristics in the models. Participants in these fisheries often hold QS in multiple areas and vessel classes due to the increasing flexibility in how the resulting IFQ can be harvested by vessels of various lengths that has evolved over time and the proximity of many communities to multiple IFQ areas. Also, the staggering of seasons prior to IFQ implementation allowed participants to build fishing history in multiple areas, and the eight month season post-IFQ provides participants with the flexibility to harvest in multiple areas. In addition to QS-level characteristics sourced through AKFIN, explanatory variables include community and QS holder attributes (see Table 1).

Community attribute data included population size, access to Alaska's road system and a certain scale of air transportation, access to the coastline, the presence of a halibut buyer, and community involvement in the halibut fisheries pre-IFQ. Community population size was included to reflect fishery managers' considerations about the effects of population. Access to Alaska's road system and to a specified scale of air transportation reflect a community's capacity to move fresh fish to markets. Coastal access facilitates fisheries participation. The presence of a halibut buyer in the community is also included since buyers could be processing for the fresh or frozen market. Community involvement in the halibut fisheries pre-IFQ Program serves as an indicator of historical participation.[2] Annual population data were compiled from the Alaska Department of Labor population estimates for places and Census designated places (CDPs).[3] Access to Alaska's road system, which links a number of communities in Southeast and Southcentral Alaska, the Interior, the Kenai Peninsula, and the North Slope to British Columbia and the lower 48 states was derived from Alaska's Department of Commerce, Community, and Economic Development's “Community Database Online” (CDO). The CDO was also the source for information about whether the community has access to the coast, including access for upriver communities, which is encompassed in our categorizations of fishing communities.[4] A proxy for the capacity to move fresh halibut via air transportation was included with a variable that captures whether a community has an airport with a runway length longer than 4500 ft. This cutoff was identified by an Aviation Policy Planner with Alaska's Department of Transportation (AK DOT) as the runway length needed for a small-to medium-sized cargo plane to move fresh halibut out of communities (R. Sewell, AK DOT, personal communication; January 3, 2018). The airport runway length was determined from AK DOT's Airport Database, provided by AK DOT, and to the extent possible is updated historically so that runway upgrades and resultant changes in the capacity to move fish are included over time in our models. While communities on the road system that participate in the halibut fishery are geographically concentrated in Southcentral and (a few) in Southeast Alaska, communities with airports greater than 4500 feet in length are distributed more widely throughout the State. Because frozen halibut production continues to be a substantial segment of the market and does not necessitate transportation access, we included a variable for the presence of a halibut fish buyer in the community based on annual Commercial Operator's Annual Report (COAR) buying data. The data denotes buyers who took fish landings in a given year. A community's pre-IFQ dependence on the halibut fishery is captured by noting whether the community had a resident with halibut QS holdings at the implementation of the program, which is included in our categorizations of fishing communities.

In addition to the residency of the QS holder, QS holder data used includes age, and whether the QS holder was an initial recipient, as well as characteristics of their holdings. We include QS holders' age, and a squared-age term since the relationship between QS selling decisions and age may not be linear. Other individual-level demographic information (like gender, race, and income) is not available. Because previous research indicated that some initial QS recipients received allocations that were not economically worthwhile to fish (Knapp, 1997), we wanted to examine how residency in small, remote communities affected QS selling decisions when controlling for an individual's QS holdings. Previous research on the halibut IFQ fishery has shown a relationship between the quantity and diversity of QS holdings and operational decisions on leasing, which could affect QS selling as well (Szymkowiak and Felthoven, 2016). We therefore included characteristics of the participant's status in the fishery (dummy for initial QS recipient), their initial QS allocations, the diversity and quantity of their QS holdings in the year of the transfer, and the type of QS being transacted including the area, vessel class, and blocked or unblocked classifications.

We applied a number of categorizations for fishing communities in Alaska to distinguish potential vulnerabilities to adverse IFQ impacts, differentially including rural, coastal, and historical participant status, as well as market variables (access to transportation and presence of a buyer). The first is a set of dummy variables for small, medium, and large remote fishing communities (RFCs) that were identified under each of these designations in Carothers et al. (2010). The small, medium, and large RFC designations were differentiated on the basis of

[2] The correlation coefficients for these covariates indicated limited concern over collinearity.

[3] According to the U.S. Census Bureau, **Census Designated Places (CDPs)** are the statistical counterparts of incorporated places, and are delineated to provide data for settled concentrations of population that are identifiable by name but are not legally incorporated under the laws of the state in which they are located. Carothers, Lew, and Sepez (2010) utilized U.S. Census population data in their analysis, which are only available on a decennial basis for places and CDPs in Alaska. The Alaska Department of Labor provides annual population estimates for all Alaska places and CDPs. We expect that averaged across all of the communities, the two population data sources do not provide substantially different estimates.

[4] The inclusion of upriver access to the coast differentiates our coastal designation from the one utilized in Carothers et al. (2010), where coastal communities were defined as those less than 10 miles from the Alaska coast using GIS software. However, the distinction does not account for any difference in the designation of communities under the SRFC and New SRFC dummies, as discussed below.

Table 1
Explanatory variables in analysis of QS selling decisions.

Variable type	Variable name	Measured as
QS holdings (diversity and quantity)	Diversified in class	Equals 1 for QS holder having QS in another vessel class other than the QS being transacted
	Diversified in area	Equals 1 for QS holder having QS in another area other than the QS being transacted
	IFQ held	Annual amount of IFQ held in the area, vessel class, and block category, in 100,000 lbs in the year of transaction
Initial status	Initial recipient	Equals 1 for QS holder being an initial QS recipient
	Initial IFQ	Amount of initially allocated IFQ in area, vessel class, and block category that is transacted in 100,000 lbs
Age	Age	Age of participant in the year of the transaction
Population size	Population size	Population of QS holder's resident community in the year of the transaction, in 100,000s
Community attributes	Road	Equals 1 for QS holder's resident community being on the road system
	Airport	Equals 1 for QS holder's resident community having an airport with a runway greater than 4500 ft in length
	Halibut buyer	Equals 1 for QS holder's resident community having a halibut buyer in the year of the transaction
Fishing community categories	Small RFC Medium RFC Large RFC All other Alaska	Dummy variables for communities that have: (a) a Federal Subsistence Board rural declaration, (b) proximity to coastline (less than 10 miles), and (c) historical participation in the Alaska halibut fishery (at least one resident received an initial quota share allocation). Dummy variables differentiated by population size of community in 1990: Small RFCs (less than 1500); Medium RFCs (1500–2500); Large RFCs (2501–7500); "All other AK" is any community in Alaska that does not otherwise fall under the Small RFC, Medium RFC, or Large RFC designations
	Community LT 1500 Community 1500to 2500 Community 2501 to7500 Community GT 7500	Dummy variables for communities differentiated strictly by population size (in 1995). LT is less than and GT is greater than
	New SRFC	Equals 1 for communities that: (a) had fewer than 1500 people in 1995, (b) are coastal (according to AK CDO), (c) had a QS holder in 1995 who was an initial recipient in the halibut IFQ Program, (d) are not on the road system, and (e) do not have an airport with a runway greater than 4500 ft in length
Quota share attributes	Area fixed effects	Equals 1 for each IFQ regulatory areas as shown in Fig. 1
	Vessel class fixed effects	Equals 1 for each vessel class as shown in Fig. 1
	Blocked QS	Equals 1 for blocked QS
Attributes of the year	Year fixed effects	Equals 1 for each year 1995–2016

population sizes in the 1990 Census of < 1500; 1500–2500; and 2501–7,500, respectively. The remaining qualifying criteria were the same for these designations: Federal Subsistence Board rural declaration, proximity to coastline (less than 10 miles), and historical fishing participation (at least one resident received an initial halibut quota share). The second set of community categorizations is a set of dummy variables where fishing communities are classified only on the basis of their populations in 1995 (using the same population cutoffs that were utilized for the small, medium, and large RFC designations). The third set of community categorizations is a dummy variable that we termed the "New small RFC (SRFC)" for ease of comparison. This set includes communities with populations of fewer than 1500 in 1995, that are coastal (according to the Alaska CDO), had a QS holder who was an initial QS recipient, are not on the road system, and do not have an airport with a runway greater than 4500 ft in length. The key difference between the original small RFC and the new SRFC categories is that the latter also takes into account whether the communities have access to transportation. The population cutoffs utilized across the models reflect the NPFMC's recent discussions about examining IFQ impacts on rural communities utilizing different population cutoffs (North Pacific Fishery Management Council(NPFMC), 2016b). The SRFC definition applied in the New SRFC model was intended to capture the multiple facets of vulnerability to the IFQ Program including remoteness and population size, while accounting for the NPFMC's objectives to limit the Program's adverse impacts on Alaska coastal communities that had historical participation in the halibut fishery.

Time effects are captured with dummy variables for each year of the dataset. The year dummies are included to capture any temporal effects of a program that is over 20 years old and has been subject to numerous amendments over time that could have affected participants' decisions to buy or sell QS, in addition to annual changes in TACs and ex-vessel prices that would have affected these decisions.

Table 2 shows the number of communities and unique buyers and sellers for each fishing community category and community attribute examined in the models. There were a total of 97 unique communities in our dataset; however, the total number of communities with and without a halibut buyer is greater because the presence of a fish buyer varies across time for communities. Our dataset includes a total of 4355 unique individuals making transfers, with 3333 unique sellers and 2691 unique buyers. The total number of buyers and sellers varies across fishing community categories and community attributes, because individuals can be both buyers and sellers and change their residency over time. The number of unique buyers is smaller than the number of

Table 2
Number of communities and unique buyers and sellers by fishing community category and community attribute.

Fishing community categories and attributes	Number of communities	Number of unique buyers	Number of unique sellers
Small RFC	47	491	712
Medium RFC	4	244	284
Large RFC	3	660	634
Other Alaska	43	1396	1734
Community LT 1500	71	564	809
Community 1500 to 2500	7	170	183
Community 2500 to 7500	13	969	1109
Community GT 7500	6	1072	1307
New SRFC	37	289	441
Non SRFC	60	2432	2911
On road system	34	893	1145
Not on road system	63	1832	2223
Has an airport with long runway	25	2092	2459
Does not have an airport with a long runway	72	673	931
Has a halibut buyer	42	2276	2677
Does not have a halibut buyer	72	507	727

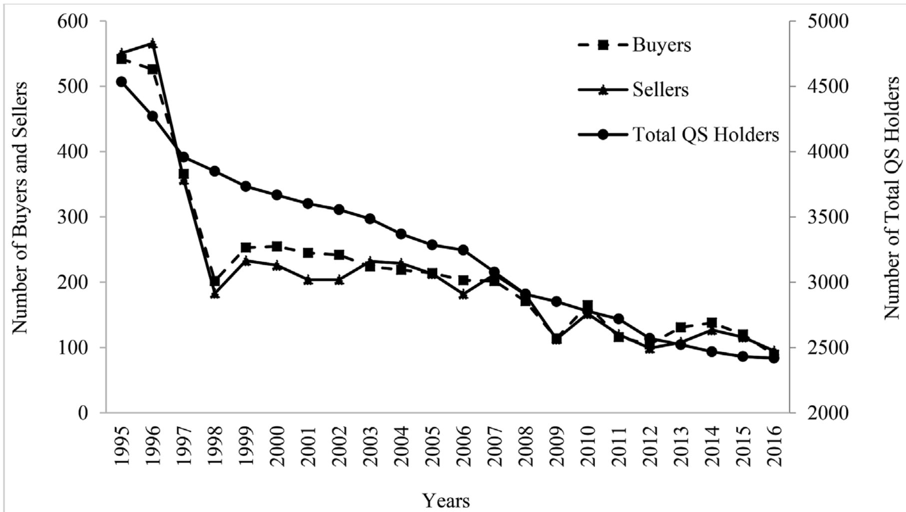

Fig. 2. Number of unique buyers and sellers by year included in our models, as well as the total number of unique QS holders overall in the halibut IFQ fishery.

unique sellers for several reasons, including overall consolidation in the halibut fishery over time as well as the potential that some buyers were not included in the models because they had disqualifying values on some of the other criteria (e.g., corporations, residency outside of Alaska).

Fig. 2 captures the overall trend of consolidation in the halibut fishery, both in terms of the number of total QS holders as well as unique buyers and sellers over time. The total QS holders in Fig. 2 include all QS holders in the fishery irrespective of residency, but Alaskans make up 75% of the QS holders in the halibut IFQ fishery over time. The figure demonstrates that the overall transaction data is fairly balanced in terms of unique buyers and sellers by year, despite the disparity in the total number of unique buyers and sellers in the data. Although the number of buyers and sellers has decreased over time, after the first several years of the IFQ Program the rate of that decrease has slowed as well.

2. Methods

We model QS transfer (buying and selling) behavior at the market transaction level—specifically, the probability of selling QS (Pr[sell])-with a discrete choice (logit) model using STATA software. The probability of an individual selling QS and the probability of an individual buying QS (Pr[buy]) are such that Pr[sell] = 1 – Pr[buy], which allows one to gain inferences about buyers and sellers from the model results.[5] Our model specifications allow us to investigate the effects of community-level characteristics on QS transfer decisions while controlling for QS holder, QS holdings, and QS attributes. We assume the probability of selling or buying QS depends on several community-level variables, including population size, the presence of fish buyers, access to road and air transportation and the coast, having a QS holder at the start of the IFQ Program, and dummy variables for different fishing community categories grouped by community population and remoteness. Individual-level variables include residency of the QS holder, age of seller, IFQ holdings, initial IFQ allocation, and whether the individual is diversified (holds QS) across multiple halibut regulatory areas or vessel classes; as well as QS attributes, and annual fixed effects (Table 1).

We developed four empirical models to test our hypotheses on the importance of community- and individual-level variables on the probability of selling QS, and to assess the robustness of the models to different specifications that include or exclude some of these variables. The first model is the baseline model, which is the same specification as used in Carothers et al. (2010) extended to 21 years of the IFQ Program. The baseline model is included as a reference point to examine the utility of additional community- and individual-level variables included in the other models (the extended baseline, population cutoffs, and new SRFC models), and to assess whether QS selling behavior in small RFCs is consistent when you compare the first five years of the program to the last 21 years. In the extended baseline model, we added community-level transportation attributes and the presence of a fish buyer as well as QS holdings, initial status, community-level, and QS attributes to test whether these RFC covariates are robust to the inclusion of individual-level QS holdings variables and other community attributes. With the population cutoffs and new SRFC models, we examined the impacts of varying designations for potentially vulnerable fishing communities. The population cutoffs model accounts strictly for population cutoffs rather than the RFC designations. By incorporating a lack of transportation access into the definition of a small RFC, the new SRFC model is used to test how sensitive these results are to the definition of small RFCs.[6]

3. Results

For all four models, likelihood ratio tests indicate that the parameters in the models are jointly statistically different from zero ($p < 0.01$) (Table 3). McFadden's R-squared statistics indicate better predictive power when going from the baseline community-level model to the models with additional community characteristics and individual and QS attributes (the extended baseline, population cutoffs, and New SRFC models). Furthermore, the log-likelihood, Akaike Information Criterion (AIC), and Bayesian Information Criterion (BIC) all indicate model improvement with these additional covariates. All of these model fit statistics are fairly similar between the extended baseline, population

[5] An individual can transfer a portion of their QS provided that QS is not designated as blocked QS. Furthermore all transfers in our data occur at the QS level of area, vessel class, and blocked/unblocked and we do not have multiple transactions by year at that level.

[6] The modeling approach treats each market transaction as independent and uses year dummies to control for temporal effects. This approach ignores possible individual-level fixed effects that could potentially be identified through a panel modeling approach. However, due to the highly unbalanced nature of the data and endogeneity of additional choices inherent therein (e.g., decision by some individuals to move communities or exit/reenter the fishery during the time period), we leave for future research the investigation of panel fixed effects and acknowledge the reduced form nature of our model.

Table 3
Predictive power and model statistics.

	Baseline model	Extended baseline model	Population cutoffs model	New SRFC model
McFadden's R^2	0.06	0.244	0.244	0.243
AIC	14,802.73	11,959.24	11,956.01	11,962.77
BIC	15,022.76	12,325.95	12,322.72	12,300.17
Log likelihood	−7371.37	−5929.62	−5928.1	−5935.38

cutoffs, and new SRFC models. Because the models are intended as a robustness check on the community-level covariates that contribute to or buffer against QS transfer decisions, we focus much of our discussion of the results on these key variables.

The estimation results for the baseline and extended baseline models including the logit coefficients and the marginal effects are presented in Table 4. We omitted categories for the area, vessel class, year, and fishing community dummies, which in both models were Area 2C, Class D QS, the year 1995, and "All Other Alaska", respectively. The marginal effects (for all four models) are the change in the probability of selling given a one-unit change in the variable, estimated at the mean of the sample for the continuous variables. For categorical or dummy variables, the marginal effect is the discrete change when the variable goes from a zero to a one.

The baseline model results are largely consistent with the findings of Carothers et al. (2010) in terms of significance and direction of coefficients, indicating that the relationship between the variables is consistent with the additional years of data.[7] The individual's age and residency in a small RFC community positively contribute to the probability of selling QS, while residency in a medium or large RFC and the population of the resident community negatively affect selling.

The statistical significance and magnitude of the fishing community dummy variables from the baseline model substantially decline or are eliminated altogether in the extended baseline model, which adds other community attributes (transportation access, halibut buyer), the participant's status in the fishery (initial recipient), their initial QS allocations, their QS holdings, and the type of QS being transacted. The effect of residency in a small RFC on the probability of selling is no longer statistically significant in the extended baseline model, while the magnitude and significance of residency in medium RFCs and large RFCs is reduced and the effect of the community's population size is eliminated. The extended baseline model results indicate that the presence of a fish buyer is highly significant and negatively contributes to selling QS, as does having an airport with a long runway.

The extended baseline model also highlights the importance of other explanatory variables in explaining QS selling behavior that were not included in the baseline model. Age continues to have a significant positive effect on the probability of selling in the extended baseline model, but the marginal effect is substantially smaller when these other factors are included. In addition, whereas the baseline model results indicate that the relationship between age and the probability of selling is linear, the extended baseline model (and the population cutoffs and new SRFC models) imply that after controlling for other community, individual, and QS attributes, the (positive) effect of age on selling increases as individuals get older. The extended baseline model results also indicate that there are differences in the probability of selling given the type of QS transacted, the individual's status in the fishery, and their QS holdings. The model indicates a positive relationship between initial QS recipient status as well as the amount and diversity of their QS holdings and the probability of selling, but a negative effect from the

[7] Results from estimating Model 1 for only 1995–1999 are very similar to those found in Carothers et al. (2010) and are available from the authors upon request.

Table 4
Baseline and extended baseline model logit coefficients and marginal effects on probability of selling QS.

Variables	Baseline model	Marginal effect on Pr (sell)	Extended baseline model	Marginal effect on Pr (sell)
Age	0.04*** (0.008)	0.01*** (0.0004)	0.006 (0.009)	0.005*** (0.046)
Age squared	0.00003 (0.00008)		0.0003*** (0.0001)	
Population size	−0.233 (0.281)	−0.101* (0.056)	0.145 (0.354)	0.014 (0.071)
Population size	0.141 (0.097)		−0.076 (0.124)	
Population size x Age	−0.005** (0.002)		−0.001 (0.003)	
SRFC	0.112* (0.063)	0.028* (0.016)	−0.023 (0.101)	−0.006 (0.025)
MRFC	−0.235*** (0.082)	−0.058*** (0.02)	−0.179* (0.099)	−0.045* (0.025)
LRFC	−0.176*** (0.051)	−0.044*** (0.013)	−0.137* (0.074)	−0.034* (0.018)
Halibut buyer			−0.203** (0.08)	−0.0506** (0.02)
Airport			−0.184** (0.081)	−0.046** (0.02)
Road			0.003 (0.077)	0.0007 (0.019)
Initial recipient			2.317*** (0.068)	0.516*** (0.012)
IFQ held			33.14*** (1.8)	2.63*** (0.128)
IFQ held x Age			−0.492*** (0.033)	
Initial IFQ			−39.43*** (3.043)	−3.444*** (0.206)
Initial IFQ x Age			0.558*** (0.055)	
Diversified in area			0.632*** (0.072)	0.155*** (0.017)
Diversified in class			0.480*** (0.057)	0.119*** (0.014)
Area 3A			−0.024 (0.059)	−0.006 (0.015)
Area 3B			−0.123 (0.085)	−0.031 (0.021)
Area 4A			0.221** (0.1)	0.055** (0.025)
Area 4B			0.055 (0.156)	0.014 (0.039)
Area 4C			−0.228 (0.25)	−0.057 (0.062)
Area 4D			−0.145 (0.267)	−0.036 (0.066)
Class A			0.496** (0.215)	0.122** (0.051)
Class B			−0.107 (0.086)	−0.027 (0.022)
Class C			−0.107** (0.055)	−0.027** (0.014)
Blocked QS			0.374*** (0.076)	0.093*** (0.018)
1996 year	0.033 (0.081)	0.008 (0.02)	0.277*** (0.095)	0.067*** (0.023)
1997 year	−0.009 (0.091)	−0.002 (0.023)	0.203* (0.108)	0.049* (0.026)
1998 year	−0.007 (0.113)	−0.002 (0.028)	0.23* (0.137)	0.056* (0.033)
1999 year	−0.098 (0.105)	−0.024 (0.026)	0.354*** (0.127)	0.086*** (0.031)
2000 year	−0.114 (0.104)	−0.0285 (0.026)	0.467*** (0.126)	0.114*** (0.0310)
2001 year	−0.255** (0.109)	−0.0633** (0.027)	0.401*** (0.133)	0.098*** (0.033)
2002 year	−0.228** (0.107)	−0.057** (0.027)	0.345*** (0.13)	0.084*** (0.032)

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Table 4 (*continued*)

Variables	Baseline model	Marginal effect on Pr (sell)	Extended baseline model	Marginal effect on Pr (sell)
2003 year	−0.012 (0.106)	−0.003 (0.027)	0.643*** (0.129)	0.158*** (0.032)
2004 year	−0.026 (0.11)	−0.006 (0.027)	0.63*** (0.132)	0.155*** (0.032)
2005 year	−0.111 (0.111)	−0.028 (0.028)	0.603*** (0.135)	0.148*** (0.033)
2006 year	−0.191* (0.115)	−0.048* (0.029)	0.564*** (0.138)	0.139*** (0.0338)
2007 year	−0.055 (0.111)	−0.014 (0.028)	0.656*** (0.133)	0.162*** (0.033)
2008 year	−0.113 (0.115)	−0.028 (0.029)	0.571*** (0.137)	0.14*** (0.034)
2009 year	−0.249* (0.142)	−0.062* (0.035)	0.567*** (0.166)	0.139*** (0.041)
2010 year	−0.33*** (0.123)	−0.082*** (0.03)	0.57*** (0.145)	0.14*** (0.036)
2011 year	−0.358*** (0.132)	−0.089*** (0.032)	0.783*** (0.155)	0.193*** (0.038)
2012 year	−0.349** (0.148)	−0.086** (0.036)	0.736*** (0.17)	0.181*** (0.042)
2013 year	−0.418*** (0.136)	−0.103*** (0.033)	0.804*** (0.155)	0.198*** (0.038)
2014 year	−0.409*** (0.131)	−0.101*** (0.032)	0.827*** (0.15)	0.204*** (0.036)
2015 year	−0.255* (0.135)	−0.063* (0.033)	1.003*** (0.154)	0.246*** (0.036)
2016 year	−0.129 (0.152)	−0.032 (0.038)	1.032*** (0.171)	0.252*** (0.04)
Constant	−1.773*** (0.183)		−2.547*** (0.26)	

Standard errors in parentheses; *** denotes statistical significance at $p < 0.01$, ** at $p < 0.05$, and * at $p < 0.1$.

amount of initially allocated IFQ. The year dummy variables change in significance and direction when additional community, individual, and QS holder attributes are added to the baseline model. In fact, the year coefficients become all positive and significant in the extended baseline model when the initial recipient and initial IFQ variables alone are added.

In the population cutoffs and new SRFC models we extended the analysis to examine whether redefining potentially vulnerable fishing communities affects the findings. In the population cutoffs model we redefined vulnerable communities strictly by population, while in the new SRFC model we delineated communities based on the inclusion of transportation access variables. The population delineations applied in the population cutoffs model are aligned with those underpinning the RFC dummy variables in the baseline and extended baseline models. Similarly to the baseline and extended baseline models, the omitted categories for the area (vessel class, year, and fishing community dummies in the population cutoffs and New SRFC models) are, respectively, Area 2C, Class D QS, and the year 1995, with an omitted fishing community category of “Community GT 7500” in the population cutoffs model and all other Alaska communities that do not qualify as new SRFC communities in the new SRFC model.

The results of the population cutoffs and new SRFC models (Table 5) showcase the importance of understanding the multiple components of vulnerability for fishing communities, beyond population. When accounting exclusively for population size in the fishing community dummy variables in the population cutoffs model (Table 5), only residents of communities with populations of 2500 to 7500 people have a statistically different (and lower) probability of selling their QS relative to residents of communities with populations greater than 7500 people. This effect is consistent with the results for the same population size dummy in the baseline and extended baseline models (large RFC). However, it should be noted that only about 5% of the observations are

Table 5
Population cutoffs and new SRFC model logit coefficients and marginal effects on probability of selling QS.

Variables	Population cutoffs model	Marginal effect on Pr (sell)	Small remote fishing communities model	Marginal effect on Pr (sell)
Age	0.005 (0.009)	0.005*** (0.001)	0.005 (0.009)	0.005*** (0.001)
Age squared	0.0003*** (0.0001)		0.0003*** (0.0001)	
Population size	−0.071 (0.375)	−0.035 (0.076)	0.249 (0.308)	0.035 (0.06)
Population size squared	−0.019 (0.127)		−0.122 (0.107)	
Population size x Age	−0.001 (0.003)		−0.001 (0.003)	
Community LT 1500	−0.068 (0.106)	−0.017 (0.026)		
Community 1500to2500	−0.162 (0.12)	−0.04 (0.03)		
Community 2500to7500	−0.219*** (0.078)	−0.055*** (0.019)		
New SRFC			0.195** (0.086)	0.049** (0.021)
Halibut buyer	−0.203** (0.08)	−0.051** (0.02)	−0.319*** (0.071)	−0.079*** (0.018)
Airport	−0.157* (0.086)	−0.039* (0.022)		
Road	0.179** (0.073)	0.045** (0.018)		
Initial recipient	2.317*** (0.067)	0.517*** (0.012)	2.317*** (0.067)	0.515*** (0.012)
IFQ held	33.1*** (1.801)	2.627*** (0.128)	32.99*** (1.795)	2.615*** (0.128)
IFQ held x Age	−0.491*** (0.033)		−0.49*** (0.033)	
Initial IFQ	−39.36*** (3.038)	−3.446*** (0.206)	−39.15*** (3.038)	−3.441*** (0.206)
Initial IFQ x Age	0.556*** (0.054)		0.552*** (0.054)	
Diversified in area	0.635*** (0.072)	0.156*** (0.017)	0.625*** (0.072)	0.153*** (0.017)
Diversified in class	0.48*** (0.057)	0.119*** (0.014)	0.486*** (0.057)	0.121*** (0.014)
Area 3A	−0.061 (0.059)	−0.015 (0.015)	−0.01 (0.054)	−0.003 (0.014)
Area 3B	−0.17** (0.084)	−0.042** (0.021)	−0.118 (0.082)	−0.03 (0.02)
Area 4A	0.191* (0.099)	0.048* (0.025)	0.244** (0.096)	0.061** (0.024)
Area 4B	−0.001 (0.155)	−0.0003 (0.039)	0.052 (0.154)	0.013 (0.038)
Area 4C	−0.25 (0.251)	−0.062 (0.061)	−0.209 (0.249)	−0.052 (0.061)
Area 4D	−0.185 (0.267)	−0.046 (0.066)	−0.134 (0.267)	−0.034 (0.066)
Class A	0.46** (0.214)	0.114** (0.052)	0.499** (0.214)	0.123** (0.051)
Class B	−0.121 (0.086)	−0.03 (0.021)	−0.129 (0.086)	−0.032 (0.021)
Class C	−0.108** (0.055)	−0.027** (0.014)	−0.117** (0.054)	−0.029** (0.014)
Blocked QS	0.37*** (0.076)	0.091*** (0.018)	0.382*** (0.076)	0.095*** (0.018)
1996 year	0.278*** (0.095)	0.067*** (0.023)	0.264*** (0.095)	0.064*** (0.023)
1997 year	0.197* (0.108)	0.047* (0.026)	0.185* (0.108)	0.045* (0.026)
1998 year	0.224 (0.137)	0.054 (0.033)	0.215 (0.137)	0.052 (0.033)
1999 year	0.351*** (0.127)	0.085*** (0.031)	0.346*** (0.127)	0.085*** (0.031)
2000 year	0.459*** (0.126)	0.112*** (0.031)	0.458*** (0.126)	0.113*** (0.031)
2001 year	0.401*** (0.133)	0.098*** (0.033)	0.389*** (0.133)	0.095*** (0.0327)

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Table 5 (*continued*)

Variables	Population cutoffs model	Marginal effect on Pr (sell)	Small remote fishing communities model	Marginal effect on Pr (sell)
2002 year	0.356***	0.086***	0.335**	0.082**
	(0.13)	(0.032)	(0.13)	(0.032)
2003 year	0.647***	0.159***	0.636***	0.157***
	(0.129)	(0.032)	(0.129)	(0.032)
2004 year	0.635***	0.156***	0.609***	0.15***
	(0.132)	(0.032)	(0.132)	(0.032)
2005 year	0.608***	0.149***	0.59***	0.146***
	(0.135)	(0.033)	(0.135)	(0.033)
2006 year	0.57***	0.140***	0.551***	0.136***
	(0.138)	(0.034)	(0.137)	(0.034)
2007 year	0.667***	0.164***	0.643***	0.159***
	(0.133)	(0.033)	(0.133)	(0.033)
2008 year	0.57***	0.14***	0.557***	0.137***
	(0.137)	(0.034)	(0.137)	(0.034)
2009 year	0.573***	0.14***	0.561***	0.138***
	(0.166)	(0.041)	(0.165)	(0.041)
2010 year	0.571***	0.14***	0.554***	0.136***
	(0.145)	(0.036)	(0.145)	(0.036)
2011 year	0.769***	0.189***	0.769***	0.19***
	(0.155)	(0.0377)	(0.154)	(0.038)
2012 year	0.735***	0.181***	0.717***	0.177***
	(0.169)	(0.042)	(0.169)	(0.041)
2013 year	0.807***	0.198***	0.795***	0.196***
	(0.155)	(0.038)	(0.155)	(0.038)
2014 year	0.837***	0.206***	0.816***	0.201***
	(0.15)	(0.036)	(0.15)	(0.036)
2015 year	0.996***	0.244***	0.975***	0.239***
	(0.154)	(0.036)	(0.154)	(0.036)
2016 year	1.039***	0.254***	1.012***	0.248***
	(0.171)	(0.04)	(0.17)	(0.04)
Constant	−2.522***		−2.638***	
	(0.266)		(0.245)	

Standard errors in parentheses; *** denotes statistical significance at $p < 0.01$, ** at $p < 0.05$, and * at $p < 0.1$.

from communities with 1500 to 2500 residents, which could be affecting the significance of the coefficient for this dummy. In the New SRFC model, the probability of selling halibut QS for residents of the new SRFCs is greater than for all other Alaskan communities.

In the population cutoffs and new SRFC models, the results for many of the other community, individual, and QS attributes are similar to those of the extended baseline model. However, when accounting for population differences exclusively, having a road becomes a significant and positive predictor of QS selling decisions. Furthermore, in the new SRFC model the road and airport are not included as covariates since they are already accounted for in the new SRFC dummy.

4. Discussion

Comparing the results across these four models demonstrates that interpretations of halibut QS selling behavior are highly sensitive to definitions of fishing communities. The decrease in the significance and magnitude of the fishing community dummy variables in the extended baseline model indicate that these dummy variables and the constant in the baseline model were actually capturing some of the variability explained by other community-level covariates. The exploration of these other covariates across the models showcases the importance of certain community attributes in explaining QS selling decisions and thus some of the drivers of QS redistributions following the implementation of the Pacific halibut IFQ Program.

The results of the extended baseline, population cutoffs, and new SRFC models provide a nuanced understanding of the components of community vulnerability to QS selling behavior, especially with respect to the “remoteness” attribute and the presence of a buyer. Airport access and the presence of a fish buyer are consistently negatively associated with QS selling behavior, and lack of airport access seems to significantly contribute to QS selling decisions even when the presence of a halibut buyer is included in the model. The presence of a fish buyer signifies not only a ready wholesale market participant for halibut, but likely other fisheries as well, which can facilitate overall fisheries participation. Furthermore, residents of communities with a fish buyer may have a comparative advantage in making multiple halibut landings, which can facilitate participation especially in a fresh market. Interestingly, the coefficient on the road variable is not consistent across the models, as it is only significant in the population cutoffs model. This may be due to the small, medium, and large RFC dummies in the extended baseline model actually capturing some of the variability that would otherwise be explained by the road variable since most of the communities that fall under this set of dummy variables are not on the road system. The positive sign on the road coefficient in the population cutoffs model may be indicative of QS holders in these communities having greater accessibility to alternative employment, which increases their opportunity costs of participating in the halibut IFQ fishery and thus increases their probability of selling their QS.

The results of the new SRFC model further highlight how relative to all other Alaska communities, the probability of selling halibut QS for residents of the smallest and remote fishing communities is greater even when controlling for other community, individual, and QS attributes. Given that there is no statistical difference in the probability of selling (relative to residents of larger communities) for residents of SRFCs in the extended baseline model and for communities with fewer than 1500 residents in the population cutoffs model, this significant result for the new SRFC dummy indicates that the difference may be narrowed down to a few communities which have access to airports with long runways and/or are on the road system.

The effect of the age and time variables on halibut QS selling behavior also changes with the addition of other individual, community, and QS covariates from the four models. It is likely that this difference in interpretation of the age variable between the baseline and the other models is due to the age variable in the baseline model capturing some of the variability explained by the age interaction terms in the other models. The change in the significance and direction of the year dummies in the extended baseline, population cutoffs, and new SRFC models suggests the year dummies may be capturing some of the effect of initial allocations and statistical noise in the baseline model. With the addition of more community and individual level variables in the extended baseline, population cutoffs, and new SRFC models, the year dummies become more refined and capture any remaining unmodeled time-related effects.

Comparisons of the results of the extended baseline, population cutoffs, and new SRFC models also demonstrate that the interpretation of the effects of the QS attributes on selling decisions are sensitive to the definitions of fishing communities and which community covariates are included in the models. Inter-area differences in the probability of selling may be driven by various interests including localized concerns over trawl fleet bycatch impacts on long-term halibut abundance or size-at-age (Summers, 2015; Messick, 2016; Deep Sea Fishermen's Union (DSFU), 2018), differences in location of landings, consolidation incentives associated with differentiated regulations and opportunity costs, inter-annual variation in TAC changes (the effects of which are averaged across the 21 years of the dataset), and other factors that are beyond the scope of this paper. Between-vessel class differences in the probability of selling could be indicative of differing incentives for QS retention based on the flexibility of how the resulting IFQ can be harvested. The positive relationship between blocked QS and the probability of selling is aligned with expectations given that QS holders have less flexibility in acquiring additional QS when they hold blocked QS.

The addition of other individual-level covariates capturing initial recipient status and allocated IFQ as well as contemporaneous holdings also significantly and consistently contribute to explaining halibut QS selling behavior. Positive coefficients on initial QS recipient status as well as the amount and diversity of their QS holdings may be explaining the differences between those who have QS to sell (especially initial QS holders) and those who are buying into the halibut IFQ fishery, as well as QS holders' decisions to consolidate holdings to minimize fishing costs. Findings of a negative relationship between initially allocated IFQ and the probability of selling is aligned with previous literature indicating that initial QS recipients who received small amounts of initially allocated QS sold out of the program because they received IFQ that was not economically worthwhile to fish (Knapp, 1997).

Across the extended baseline, population cutoffs, and new SRFC models the marginal effects indicate that—holding all other variables at their means—the probability of selling varies by community attribute (transportation access and presence of a fish buyer) by approximately 3–8% with differing directions for the impacts. The presence of a halibut buyer has the strongest effect among these variables. Diversification of QS and the type of QS being transacted (specifically whether it is blocked or Class A QS) seem to have a slightly stronger marginal effect on QS selling probability (9–16%) than the community characteristics and fishing community classifications. The QS holder's status as an initial QS recipient has the largest marginal effect on the probability of selling (52%), which may be indicative of, inter alia, simply having QS to sell, as well as consolidation responses immediately following the implementation of the IFQ Program, and QS holders aging out of the fishery, as shown by the positive and statistically significant effect of the initial IFQ and age interaction term in the extended baseline, population cutoffs, and new SRFC models.

5. Conclusions

The Pacific halibut IFQ Program is one of the most complex catch share programs implemented in the United States, with numerous provisions intended to protect small boat operators, fleet diversity, and rural Alaska communities. Some consolidation was expected by the NPFMC at the time of IFQ implementation concurrent with an anticipated shift towards fresh halibut production. These changes were predicted to result in some outmigration of fishing privileges for remote Alaska fishing communities. However, the specific factors underlying QS migration patterns given the differentiated characteristics of harvesting privileges in the IFQ Program, differences in initial QS allocations, and the variation in transportation access across Alaska have not been well understood (North Pacific Fishery Management Council/ National Marine Fisheries Service (NPFMC/NMFS), 2016a).

This study reveals that community-level attributes are important predictors of QS selling decisions even when controlling for various individual and QS-level attributes. The most important characteristics are access to an airport with a long runway and the presence of a halibut buyer, both of which facilitate access to markets, and these attributes are different from the ones previously examined by researchers and the NPFMC. The presence of a fish buyer in the community has a consistent negative effect on the probability of selling, which may be related to not only the importance of having a relatively accessible buyer (given that vessels can land their fish in other communities), but of broader fisheries diversification opportunities, and the less tangible effects of having a viable/functional fishing culture in the community. Thus the closure of a sole fish buyer in a community can have wide-ranging negative implications for not just fisheries participants but the community more broadly, especially in remote areas without alternative buyers or with few employment opportunities.

The classification of remote fishing communities is central to understanding QS transfer decisions for residents of Alaska communities, as the conclusions about the likelihood of QS sales are sensitive to this definition. These findings also respond, at least in part, to the NPFMC's recent inquiry about how different population cutoffs for defining rural communities may affect relative impacts of the IFQ Program. The results are consistent across the models indicating that relative to the largest communities in Alaska, residents of the smallest communities (those with fewer than 1500 people) have a higher probability of selling QS; whereas residents of communities with 2500 to 7500 people have a lower probability.

This study focused on individual and community level drivers because these directly reflect IFQ Program objectives to limit the program's adverse impacts on Alaska coastal and rural communities. Overall, the results indicate that fishery management would benefit from tracking a variety of community-level attributes over time in order to better understand catch share impacts and access for new participants. Currently in the North Pacific, the NPFMC's IFQ committee is discussing a variety of options to increase entry opportunities for new participants into the halibut and sablefish IFQ fisheries (North Pacific Fishery Management Council/ National Marine Fisheries Service (NPFMC), 2017a; 2017b, 2018). Given that QS selling decisions appear to be heavily influenced by attributes of residency and access to markets, management changes made to entry opportunities into the halibut and sablefish IFQ fisheries would be improved by a detailed understanding of differentiated QS purchase trends for residents of rural Alaska communities. As fisheries managers around the world continue to grapple with balancing various social and economic goals for catch share programs, understanding the specific components that influence transfers of harvesting privileges and long-term access more broadly is critical to creating policies that may help to mitigate disproportionate or negative impacts on fishery participants and communities.

This research provides useful insights into the link between halibut QS transfer behavior, community characteristics, and market access; however, limited data prevented inclusion of potentially important individual drivers of QS buying and selling decisions, such as expectations about earnings, broader entry/exit and fisheries participation decisions, opportunity costs of time, and alternative investment opportunities. Research exploring the role these individual factors have on QS transfer decisions could provide additional insights, but would likely require more theoretically-driven structural frameworks than the one used here. Future extensions of this research could also examine the sensitivity of community-level drivers to time as the halibut market stabilized and regional differences in the importance of these drivers as the capacity to move fresh fish and the number of fish buyers are both much more constrained in the Bering Sea and Aleutian Islands than in the Gulf of Alaska.

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Appendix A. Supplementary data

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