APPENDIX HD-1. FISHERY INCOME DIVERSIFICATION AND RISK FOR FISHERMEN AND FISHING COMMUNITIES OF THE US WEST COAST AND ALASKA – UPDATED TO 2012

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INTRODUCTION AND METHODOLOGY

Catches and prices from many fisheries exhibit high interannual variability, leading to variability in the income derived by fishery participants. The economic risk posed by this variability might be mitigated in some cases if individuals participate in several different fisheries, particularly if revenues from those fisheries are uncorrelated or vary asynchronously. High annual variation in income is a common problem among natural resource-dependent individuals and communities, and there has been extensive study of risk-coping mechanisms for farmers (Alderman and Paxson, 1992; Paxson, 1992; Townsend, 1994). Crop diversification is a common means of reducing risk in agriculture, taking advantage of asynchronous variation in yields and prices to minimize idiosyncratic risk (Heady, 1952; Johnson, 1967). Another common strategy in agriculture, particularly in semi-arid regions with high fine-scale variation in rainfall, is to farm a number of geographically separated plots to ensure some will be in areas with sufficient rainfall (Rosenzweig and Binswanger, 1993). A number of authors have argued that common property provides an important means risk reduction that may be undermined by privatization (Bromley and Chavas, 1989; Nugent and Sanchez, 1998; Thompson and Wilson, 1994). This literature relates primarily to grazing lands held in common to protect against the potential spatial variation in rainfall that would impact small private holdings but smooth risk for herders utilizing a much larger area held in common. However, similar strategies and principles from this literature apply to fishermen. While formal fishing insurance programs do not exist, fishermen's fishing strategies provide a means to reduce risk, in particular by diversifying their fishing activity across a variety of fisheries or areas (Minnegal and Dwyer 2008; van Oostenbrugge et al. 2002). There is also a growing literature suggesting that fishermen should adopt portfolio approaches to their species composition to achieve the lowest variance in income for any level of expected return (Baldursson and Magnusson, 1997, Hilborn et al. 2001, Kasperski and Holland 2013, Perusso et al. 2005, Sethi 2010, Sethi et al. 2012, Smith and McKelvey 1986).

Following Kasperski and Holland (2013), we measure diversification of West Coast and Alaskan entities' gross revenues across species groups and regions each year. We consider two types of entities for this analysis: individual fishing vessels and individual fishing ports. For both types of entity, we utilize the Herfindahl-Hirschman Index (HHI), defined as:

$$H = \sum_{i=1}^{S_j} \sum_{j=1}^{4} p_{ij}^2, \tag{1}$$

where p_{ij} represents percent (ranging from 0 to 100) of an entity's total gross revenues derived from species group i in region j. We define p_{ij} to be the percent of an entity's total annual gross revenue from one of 40 different species groupings in one of four regions – the Bering Sea/Aleutian Islands, Gulf of Alaska, Alaskan in-state waters, and the WC (Table HD1-1). Not every species group is caught in each region, so there are a total of 84 region-specific species groupings. HHI theoretically ranges from zero, when revenues are spread amongst an infinite number of fisheries, to 10,000 for an entity that derives all revenue from a single fishery. Thus, the less-diversified an entity's revenue sources are, the higher the HHI. We evaluate how diversification has changed over time for various fleet groups and ports. To explore how diversification of fishery income affects year-to-year variation and thus financial risk, we estimate the statistical relationship between HHI and the coefficient of variation (CV) of gross revenues for each entity across years.

Table HD1-1: Species groups used for diversification indices.

West Coast	Alaska
Pacific Whiting	Pacific Cod
Dover Sole, Thornyheads, Sablefish	Flatfish
Rockfish and Flatfish	Rockfish
Skate, Dogfish, Sharks	Atka Mackerel
Pacific Halibut	Pollock
California Halibut, Croaker	Other Groundfish
Pink Shrimp	Sablefish
Other Prawns and Shrimp	Pacific Halibut
Crab	Herring
Salmon	Chinook Salmon
Tuna	Sockeye Salmon
Herring	Coho Salmon
Coastal Pelagics	Pink Salmon
Echinoderms	Chum Salmon
Other Shellfish	Other Salmon
Squid	Red King Crab
Other Species	Other King Crab
	Opilio Crab
	Other Snow Crab (Bairdi)
	Other Crab
	Scallops
	Other Shellfish
	Other Species

RESULTS

We work with a large dataset that includes annual landings and revenues between 1981 and 2012 by species, port and vessel from all commercial fisheries in the US EEZ off the West Coast and Alaska. We present analysis based on 28,151 vessels with average fishing revenues over $5000 (adjusted to 2005 values) and at least two years of documented landings. The port level analysis includes 166 ports with average fishing revenues over $100,000 (adjusted to 2005 values) and includes 79 ports along the West Coast and 87 ports in Alaska. The large dataset enables us to identify trends in diversification and relationships between diversification and variation in revenues, despite the relationship being very noisy. We also consider a number of subsets of the larger fleet categorized by average revenues, length and whether they had landings in West Coast states (i.e., excluding vessels with revenue only from Alaska).

Average fishery revenue diversification of West Coast and Alaskan fishing vessels is variable but shows distinct trends over time (Figure HD1-1). The HHI for most vessel groups, though erratic, has generally been increasing over time meaning that diversification of fishery income has been declining. The current fleet of vessels on the US West Coast and in Alaska (those that fished in 2012) is less diverse than at nearly any point in the past 30 years, except that they are slightly more diverse than they were in 2011. For smaller vessels diversification has generally been declining (i.e., HHI has been increasing) since 1981. For larger vessels, diversification increased through the early 1990s but has mostly declined since. The causes of the decline in diversification are not completely clear and probably vary by fleet sector. One likely factor that correlates with the observed trend is the successive implementation and tightening of limited access programs and, later, individual quota programs. By the mid-1990s, entry into new fisheries was no longer possible for most vessels since nearly all fisheries had moratoriums on entry, and many were beginning to reduce fleets through attrition, vessel buybacks or catch share programs. These programs limit fishermen's ability to move into new fisheries and often push out less-active participants from a fishery. This is often necessary to limit catch and improve economic viability of the remaining participants, but it can also result in decreased diversification. Vessels that were in the fishery since 1981 have maintained a higher level of diversification than the overall fleet, while vessels that entered later tend to be less diversified, possibly due to limited access programs in many fisheries. We also looked specifically at diversification trends for vessels with at least $5000 in revenues from landings in WA, OR or CA in 2012. Overall, trends for vessels fishing the West Coast are similar to those for the larger fleet of vessels fishing the West Coast and/or Alaska.

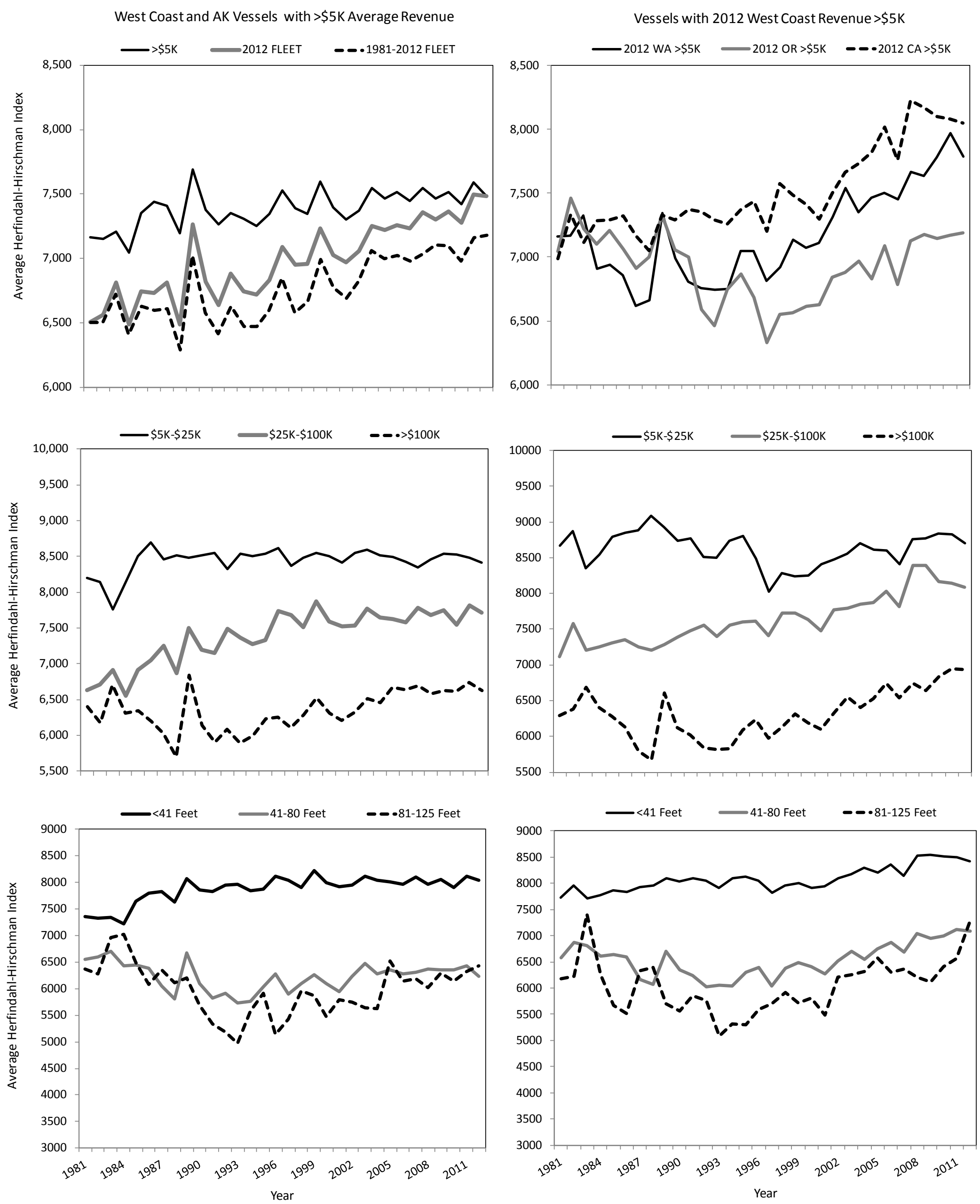

Figure HD1-1: Trends in average diversification for US West Coast and Alaskan fishing vessels (left panels) and the 2012 West Coast Fleet (right panel) filtered by all vessels with over $5,000 in average revenues (top panel), by average gross revenues classes (middle panel) and by vessel length classes (bottom panel).

While we can see some clear trends in diversification for various classes of vessels over time, there is wide variation in the degree of diversification across vessels within each class (Figure HD1-2). Higher-earning and large vessels tended to be more diversified on average than smaller vessels and those with lower earnings. The current (2012) West Coast fleet appears to be slightly less diversified on average than the larger fleet, which includes all vessels from the West Coast and Alaska, and both current and former participants.

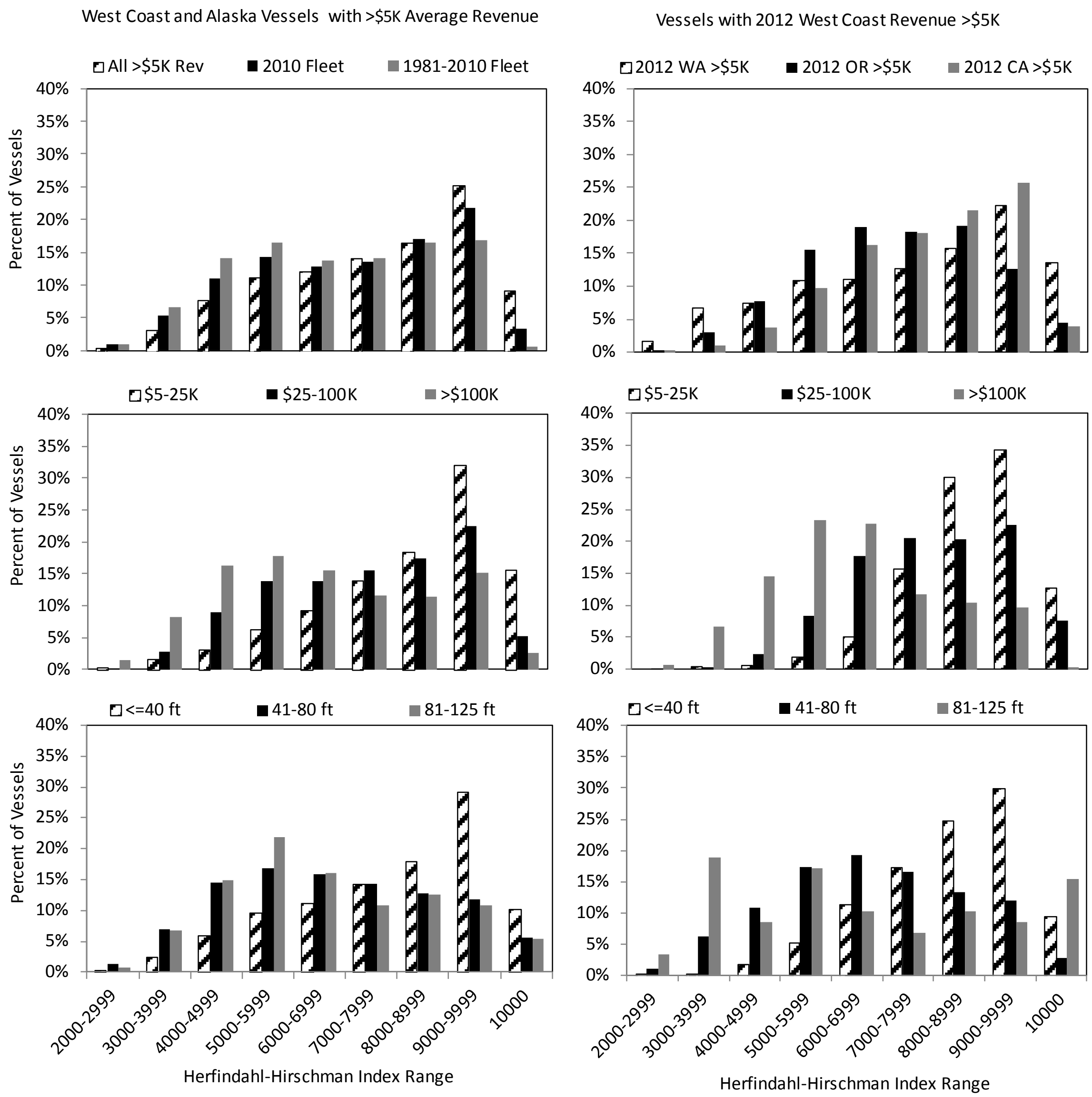

Figure HD1-2: Histograms showing percentage of vessels by ranges of Herfindahl-Hirschman index scores for US West Coast and Alaskan fishing vessels (left panels) and the 2012 West Coast Fleet (right panel) filtered by all vessels with over $5,000 in average revenues (top panel), by average gross revenues classes (middle panel) and by vessel length classes (bottom panel).

If vessels are able to diversify into multiple fisheries whose revenues vary independently or asynchronously, they should experience a reduction in volatility of revenues and thus financial risk. This is confirmed for all of our fleet groupings by estimating quadratic regressions of the CV of gross fishery revenue as a function of HHI and HHI2. Our analysis indicates a dome-shaped relationship between variability of individuals' incomes and income diversification, which implies that a small amount of diversification actually increases risk for some fleet categories, but moderate amounts of diversification can substantially reduce the variability of income that individuals receive from fishing. The decrease in CV with increased diversification varies substantially across vessel categories (Table HD1-2, Figure HD1-3), but for nearly all vessel categories there is a substantial decrease in CV when moving from a low level of diversification (e.g., a 90-10 split in revenues between two fisheries) to a high level of diversification (e.g., a 50-25-25 split between three fisheries). Annual revenues for fishing vessels in our sample have an average CV of 0.78. To illustrate how the decrease in CV associated with diversification affects the range of annual income a vessel might expect, we calculated the 50th percentile range of gross revenues for four hypothetical diversification schemes based on the functional relationship between HHI and CV for all vessels with mean annual revenues greater than $5,000. The 50th percentile range of expected revenues contracts from a range of $72,000 to $239,000, when all revenue comes from one fishery, to a range of $105,000 to $206,000 with a 50-25-25 split of revenues across three fisheries.

Table HD1-2: Predicted coefficient of variation (CV) of gross fishery revenue for Herfindahl-Hirschman index scores associated with alternative diversification schemes for groupings of WC and AK fishing vessels

	Predicted CV Herfindahl Index						
Vessel Category	Single Fishery	90-10 Split	50-50 Split	50-25-25 Split	%Drop Single Fishery to 50-25-25	Sample Size	Mean Revenue ($1000)
All >$5K Rev	0.80	0.85	0.66	0.48	23%	28,151	$ 155
2012 Fleet >$5K	0.68	0.75	0.60	0.45	33%	8,522	$ 272
1981-2012 Fleet >$5K	0.67	0.72	0.60	0.49	27%	2,577	$ 224
$5K-$25K Rev	0.86	0.94	0.75	0.55	36%	12,431	$ 12
$25K-$100K Rev	0.69	0.81	0.64	0.44	37%	10,329	$ 56
>$100K Rev	0.59	0.68	0.60	0.49	17%	5,391	$ 534
<40Feet	0.80	0.87	0.68	0.49	38%	21,848	$ 49
40-80 Feet	0.78	0.78	0.61	0.48	38%	5,269	$ 201
80-125 Feet	0.79	0.77	0.48	0.44	45%	612	$ 993
2012 WA >$5K	0.68	0.72	0.58	0.44	35%	917	$ 280
2012 OR >$5K	0.72	0.76	0.52	0.31	57%	808	$ 194
2012 CA >$5K	0.74	0.76	0.53	0.34	54%	1,359	$ 201
2012 WC $5-25K	0.79	0.90	0.50	0.14	82%	798	$ 16
2012 WC $25-100K	0.63	0.77	0.51	0.23	63%	1,048	$ 59
2012 WC >$100K	0.55	0.61	0.53	0.44	19%	898	$ 380
2012 WC <40 Feet	0.69	0.80	0.49	0.19	72%	1,618	$ 90
2012 WC 41-80 Feet	0.77	0.72	0.54	0.43	44%	1,065	$ 283
2012 WC 81 -125 Feet	0.64	0.66	0.52	0.39	38%	58	$ 1,177

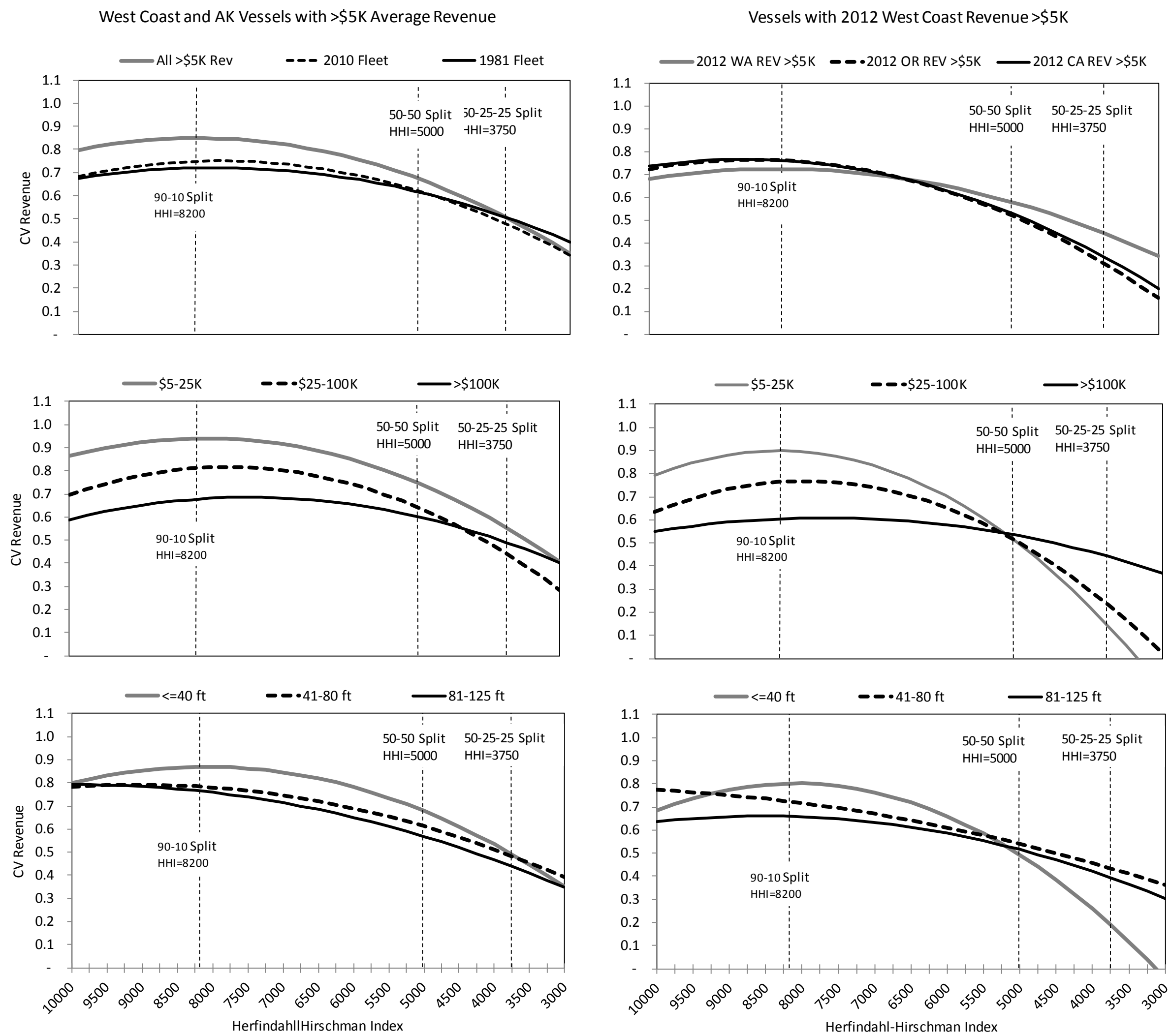

Figure HD1-3: Fitted relationships between the coefficient of variation (CV) of gross revenues for US West Coast and Alaskan fishing vessels (left panels) and the 2012 West Coast Fleet (right panel) filtered by all vessels with over $5,000 in average revenues (top panel), by average gross revenues classes (middle panel) and by vessel length classes (bottom panel).

Individual fishing ports experience a high degree of variation in diversification as well as landed revenue (Figures HD1-4 and HD1-5). Diversification of landed revenue for some ports has clearly decreased as evidenced by an increasing HHI. Examples include Seattle and most, though not all, of the ports in Southern Oregon and California. A few ports have become more diversified, including Bellingham Bay in Washington and Westport, Washington, which became less diversified through the mid-1990s but has since reversed that trend. Diversification scores at the port level are generally much lower than for individuals because port-level scores reflect landings of many different fishermen who individually may be less diversified but in aggregate land a variety of species. Diversification scores are highly variable for some ports, particularly those in Southern Oregon and Northern California that depend heavily on the Dungeness crab fishery. Crab revenue, and consequently overall landed value, in those ports over the last decade has varied dramatically year to year, which in turn drives variability in diversification (Figure HD1-5). When crab revenues are very high they dominate landed value for the port and drive up the HHI (i.e. lower diversification). HHI for Southern California ports has increased substantially in recent years as landed value from these ports has become increasingly dominated by squid.

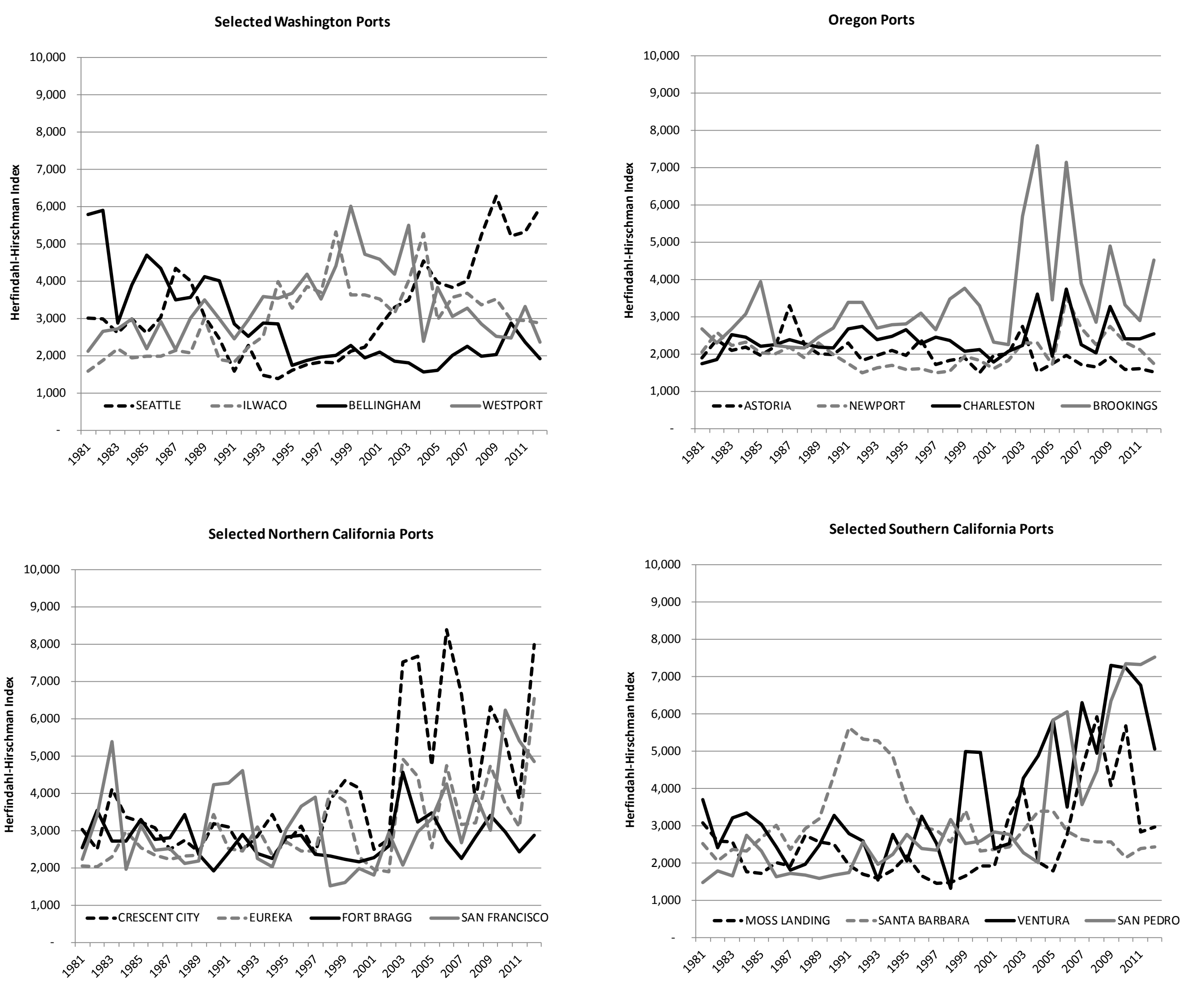

Figure HD1-4: Trends in diversification for selected primary West Coast ports in Washington, Oregon, and California.

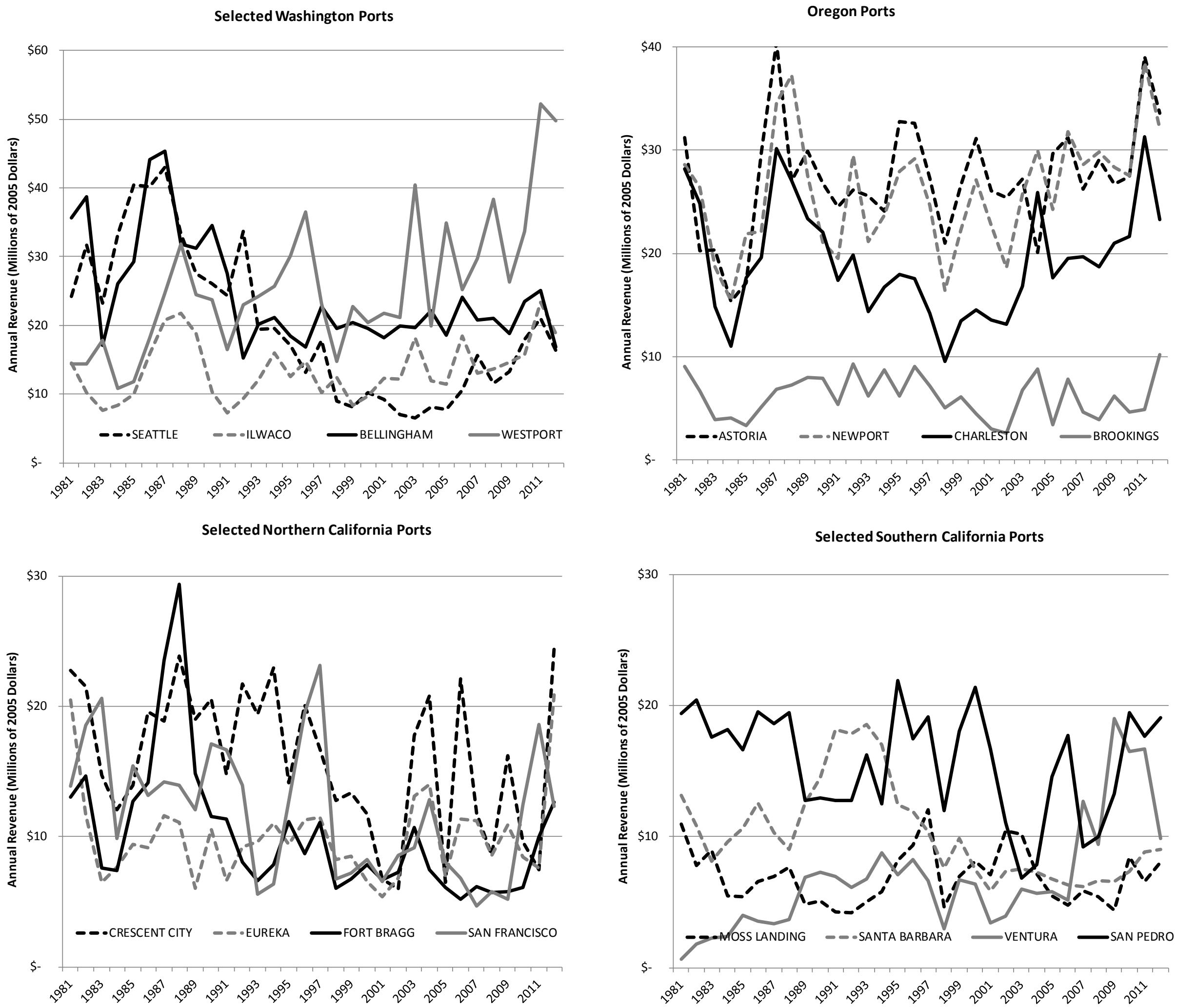

Figure HD1-5: Total landed value in 2005 dollars for selected primary West Coast ports in Washington, Oregon, and California.

As is true with individual vessels, the variability of landed value at the port level is correlated with HHI. The fitted relationship between the CV of annual landed value and HHI is domed-shape as it is for individual vessels, thus the predicted CV declines at an increasing rate as the diversification of the port increases (HHI declines) (Figure HD1-6). However, relative to the to the fitted relationship for vessels, the relationship between CV of annual landed revenues and HHI for ports has substantially more curvature and requires a much higher level of diversification to begin experiencing a decline in the CV of annual landed revenues (e.g., an HHI of 3,750, as with a 50-25-25 split).

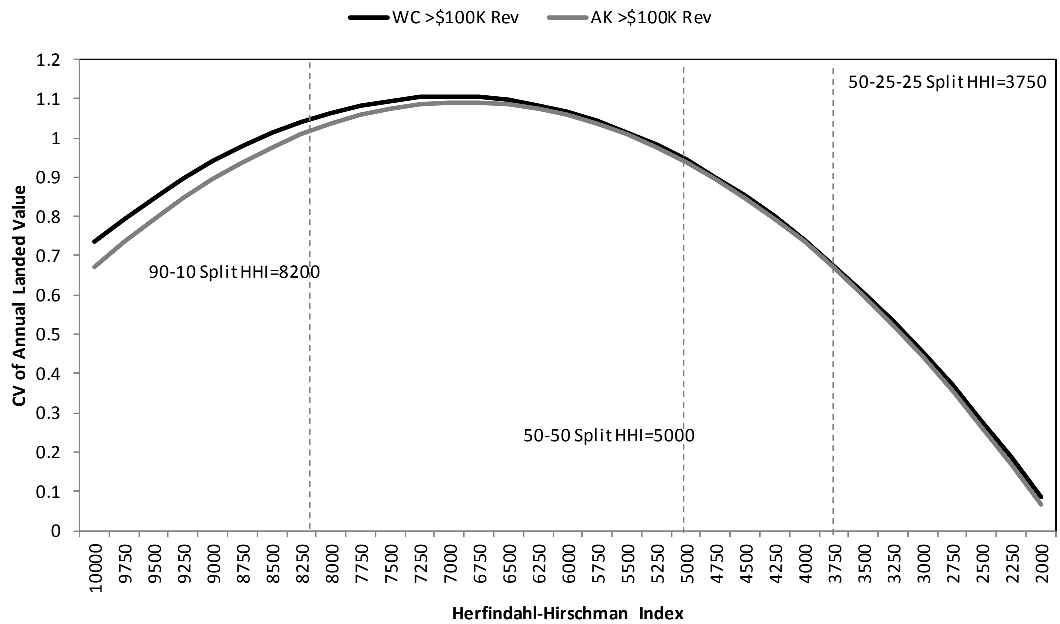

Figure HD1-6: Fitted relationships between the coefficient of variation (CV) of gross revenues for US West Coast and Alaskan fishing ports.

DISCUSSION

Diversification across multiple fisheries can reduce variation in catches and the associated financial risk. It can also increase the minimum annual revenue relative to average revenue, which should reduce the risk of a business failure (Kasperski and Holland, 2013). The ability of fishermen to diversify may be limited (or facilitated) by management approaches and regulatory actions. This should be a consideration when evaluating management actions, though in some cases management actions that reduce diversification are needed to remove excess capacity and promote efficiency.

There are a number of factors that may limit the feasibility or desirability of greater diversification. In many cases different fisheries require different gear that must be purchased and there are often costs of acquiring licenses and, increasingly, quota. It may also be the case that a vessel that can participate in several fisheries may be less efficient than more specialized vessels creating a trade-off between risk reduction through diversification and fishing efficiency. Exploration of this potential tradeoff would be an important extension of our research. Owners of multiple vessels can diversify by having individual vessels to specialize in different fisheries. Some fishermen may diversify their income with non-fishing sources. This seems particularly likely for vessels with low levels of revenue. We were unable to explore the degree or effects of this type of diversification due to a lack of data on non-fishing income. We hope to collect data on non-fishery income in future to explore this issue.

It is not clear that ports could or should increase diversification to reduce variation in landed value, but it does appear that high levels of diversification can reduce variation in landed value. High variation in overall landed value for several ports is associated with dependence on fisheries that have high variation in revenues. This variation could be socially disruptive, but this may be somewhat unavoidable if those ports want to continue to attract the landings from valuable fisheries like crab that have highly volatile annual landings. It should also be noted that the variation in landed value at ports is not necessarily closely correlated with variation in fishing income of fishermen living in those communities since those fishermen may be landing catch in other ports. The link between diversification of individual fishermen and ports and socio-economic wellbeing of communities is one that deserves further research.

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