Fleet connectivity across West Coast fisheries: quantifying the effect of a management intervention on revenue diversity in an interconnected socioeconomic environment

Emma Fuller, Jameal Samhouri, James Watson, Joshua Stoll

# Abstract

# Introduction

Ecosystem-based management (EBM) has become the approach du jour of ocean and coastal conservation and stewardship, appearing prominently in an array of highly visible policy documents *(Pew 2003, USCOP 2004, and EO 13547 2010, Australia’s Ocean Policy (DEWR 1998), Canada’s Ocean Act (GC 1996), the European Marine Strategy Framework (EC 2008), and the Convention on Biological Diversity’s Ecosystem Approach (CBD 2000)*. The shift towards EBM is motivated by a combination of real and perceived concerns, including conflict between ocean users (Crowder and Norse 2008), poor coordination across governing bodies (Norse 2010), failure to adequately sustain living marine resources through single-species management (Jackson 2001, Worm et al 2006), and increasing recognition of the complex, non-linear, and coupled human-natural interactions within marine systems (Wilson…). However, despite the increasing emphasis on EBM, the transition from EBM in theory and policy to practice has been slow (Pitcher et al. 2008). This slowness, in part, underscores the technical and scientific challenges that underlie EBM and the uneven, sometimes contradictory, and difficult task of understandings of the social-ecological structure of marine ecosystems (Evans and Klinger 2008).

In the last decade, numerous efforts have been waged to better define (e.g., Slocombe 1998, EPAP 1999, Pikitch et al. 2004, McLeod et al. 2005) and forward EBM (e.g., Curtin and Prellezo 2010, SPC 2010, Heenan et al. 2013, Pomeroy et al. 2013). This progress is often cast as a sharp departure from traditional, single-species management regimes (Chapin et al. 2009), though Link (2002:19) has challenged the “apparent duality” between existing fisheries management and proposed EBM strategies, arguing that there is a “gradient of approaches” along the continuum of management decisions that exist. Aswani et al. (2011:1) offer a similar view, arguing that EBM “is best thought of as an expansion of customary management and integrated coastal management, rather than a paradigm shift.”

Much of the research in this burgeoning domain of science has sought to illuminate the connectivity within and between the biotic and abiotic components of these systems, using sophisticated modeling approaches such as OSMOSE, Ecopath/Ecosim, and Atlantis. For example, the latter is used in the integrated ecosystem assessment (IEA) framework proposed by Levin et al (2009) and adopted by the National Marine Fisheries Service to guide management decisions. Atlantis, like others, can be used to model simple trophic interactions and more highly complex ecological structures (Flower et al. 2013). These efforts represent progress along Link’s conceptual gradient, but focus almost exclusively on the ecological components of these systems, without consideration of the social or economic influences that interact across time and space. Understanding these human interactions therefore represent an important frontier to EBM science.

In this paper we aim to contribute to this gap by presenting an approach for measuring human connectivity of fisheries at individual and community level and use it to evaluate how a change in management affects anthropogenic connectivity in US west coast commercial fisheries. We employed a novel clustering algorithm to determine commercial fishing strategies along the US west coast. We found that the algorithm correctly identified spatial and temporal patterns of known single – and multispecies fisheries, and used the classification method to (i) determine vessel-level participation in individual fisheries and emergent diversification of their participation across fisheries, and (ii) describe networks of fisheries participation for entire communities (ports). We found that the majority of vessels examined were generalists, which participated in more than one commercial fishery in our time-period. In addition, interconnectedness of fisheries participation varied strongly across ports. Using these individual and community-level measures of fisheries diversification, we evaluated how the introduction of a new management structure influenced vessel-level participation in the affected fishery, along with diversity measures for vessels and ports as a function of their participation in the affected fishery.

We hypothesized that catch shares would affect fishing strategies in one of two ways: causing vessels to either drop out of the fishery or, for those that remained in the fishery, allowing them to diversify by participating more heavily in other fisheries. For port communities, we tested whether changes at the vessel level were reflected at the port-level. We found that the implementation of catch shares caused a minority (6%) of vessels to leave commercial fishing altogether, while 66% of vessels continued to participate in the affected fishery and diversified by participating in additional fisheries, only 13% of vessels continued to participate in the affected fishery with fishing participation unchanged. A third group consisted of vessels that exited catch shares but continued to fish commercially (28%). These vessels showed a mixed response, with increased and decreased fishing diversity observed. We also found that these changes at the vessel-level qualitatively matched the patterns of participation among fisheries at a community level. This work helps to formalize and quantify social ecological linkages across scales.

**Methods**

**Description of Data Sources**

We used landings tickets that record all commercial landings on the US west coast between 2009-2013 from the Pacific Fisheries Information Network (PacFIN) database ([www.psmfc.org](http://www.psmfc.org/)). While rich, this dataset lacked information on outside employment and/or any commercial fishing landings outside of the US west coast EEZ. To account for this, we restricted our analyses to vessels with an average of at least $5,000 in annual revenue and removed vessels that landed commercial catch in Alaska. We did not analyze landings from 2011, a management transition year in which catch shares were established. We also removed landings from vessels which participated in the California Halibut trawl fishery due to concerns about inconsistencies in landing tickets. This left 2,413 vessels that were responsible for approximately 93% of the total revenue and biomass commercially landed during this period.

**Defining Realized Fisheries**

We defined realized fisheries as a gear-type that targeted a coherent species assemblage (van Putten et al. 2011). The Pacific Fisheries Management Council (PFMC) has developed a set of sector based definitions similar to this approach for the federally managed groundfish landings (www.pcouncil.org), but no equivalent exists for non-groundfish fisheries (The Northwest Fisheries Science Center 2015). In order to treat the landings dataset uniformly, we applied a métier-like analysis to this landing data (Deporte et al. 2012).

A métier analysis constructs these realized fisheries by clustering species composition of landings. We used the Hellinger distance *D* (P. Legendre and Legendre 2012) to calculate the similarity in revenue profiles between trips and generated a pairwise distance matrix. The Hellinger distance between the species composition of two fishing trips *A* and *C* is defined as

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|  | (1) |

with

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|  | (1a) |

where *ai* is the revenue derived from species *i* on trip *A*, *ci* is the revenue derived from species *i* on trip *C, a+* (*c+*) is the total revenue from trip *A* (*C*) across all species, where there are *S* total species. With this metric, trips *A* and *C* become increasingly similar (and the Hellinger distance declines) as the proportion of revenue attributable to each of the *S* species becomes increasingly matched.

We transformed the distance matrix into a similarity matrix by subtracting the distance metric’s upper limit () from each pairwise distance and used these similarities to generate a weighted, undirected network where nodes were fishing trips and edge weights were pairwise similarity. We used the infoMap community detection algorithm (Rosvall and Bergstrom 2008) and identified groups of trips with similar target assemblages. Because our dataset contained 340,466 unique trips, it was computationally impossible for us to construct a single matrix containing all pairwise similarities. To facilitate data analysis we used one year of landings (2010) that we split by gear which resulted in manageable matrix sizes (between 1,700 and 31,000 rows/columns). Pairwise distances among trips and community detection were used within each gear partition which grouped trips into target assemblage categories. To make the final assignment of realized fishery, we linked the species-composition clusters to gear used for the trip. To classify the 2009, 2012 and 2013 trips to realized fisheries, we assigned each unclassified trip to the same realized fishery as the 2010 trip to which it was closest in multi-dimensional space.

A drawback of this classification method, and part of the reason for its need, is that there exists no independent classification of US west coast fisheries to which we could compare. To address this drawback, we tested the reliability of our classification approach by evaluating if it recovered known spatial and temporal structure for well-described US west coast fisheries and fishery sectors. Specifically, because we did not bound our clusters spatially, temporally, or by vessel characteristics, we were able to compare our realized fisheries to existing sector definitions of groundfish, and groundfish impacting fisheries provided by the Northwest Fisheries Science Center Observer Program (The Northwest Fisheries Science Center 2015).

**Calculating changes in vessel and community level fishing diversity**

To estimate revenue diversity for each vessel, we calculated the effective Shannon index *H* of revenue diversity (Lou Jost 2006). *H* for vessel *j* is calculated as

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where *F* is the number of realized fisheries and *pi* is the proportion of revenue derived from realized fishery *i*. We define specialist vessels are those that land a single realizing fishery (*H* = 1) and generalist vessels are vessels that land in more than one fishery (*H* > 1).

To represent connectivity among fisheries at the port level we built directed, weighted networks. Nodes represented a realized fishery, and the strength of the connections between nodes represented the number of vessels that landed both. More formally, we built a network *Gi* for each port *i* in which an edge *AB* was the number of vessels participating in fisheries *A* and *B* divided by the total number of vessels that participated in fishery *A*. Similarly, edge *BA* is the number of vessels participating in both fisheries divided by the total number of vessels that participated in fishery *B* (Fig. 1)*.*

To measure port-level revenue diversity we developed a network metric that increases with the number of fisheries present and the evenness of participation. Common network topology measures such as shortest path and centrality metrics capture the evenness of connectivity across the network but don’t reflect the difference between a port with many or few nodes (fisheries). To address these concerns we developed an index of average fishery connectance *C* for port *j* defined as the sum of edge weights *w* present in network *Gj* divided by the number of nodes *V* in *Gj*.

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|  | (3) |

Because edge weights are constrained to be between 0-1, this value can be interpreted as the average number of fisheries to which a fishery is fully connected (i.e. all vessels participate in both fisheries) at port *j*.

**Analysis of changes in revenue diversity and port connectance due to catch shares**

We determined whether a change to catch shares management in the limited entry groundfish trawl sector was associated with a change in revenue diversity or a change in port connectance. At the vessel level we calculated change in revenue diversity as

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We defined a change in connectance at the port level as

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|  | (5) |

Thus a value of zero for Δ*H* or Δ*C* indicated there was no change in revenue diversity or port connectance, respectively, between the two periods, and a positive value indicated the vessel or port increased the evenness and/or the number of fisheries from which it received revenue.

In the analysis of changes in vessel level revenue diversity, we assigned vessels to one of three categories *Mi*. First, we defined vessels unaffected by catch shares as the *general fleet*, which included only those vessels for which we observed no commercial landings in the catch-shares affected fishery in 2009-2010 or 2012-2013 (*M1, n* = 1,878). Second, we defined *catch share participants* as those vessels that fished in the limited entry trawl fishery prior to 2011 and continued to fish by using catch share quota to land fish after 2011 (*M2, n* = 71). Third, we defined *limited entry exits* as those vessels that fished in the limited entry trawl fishery prior to 2011, but exited the fishery with the implementation of catch shares (*M3, n =* 35, Fig. 2).

If catch shares allowed vessels to be more flexible in their fisheries participation, we would expect that catch share participants would, on average, demonstrate increased revenue diversity after the implementation of catch shares. To this end we fit the following regression,

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The ability to change diversity between two periods is related to the starting period diversity. For example, if a vessel is a specialist (i.e. *H* = 1), then it is impossible for that vessel to drop in diversity and any random variation will bias *ΔH* upwards. Similarly, if a vessel was maximally diversified, then the vessel could either remain the same or with random variation drop in diversity. Thus, we also evaluated a model in which the pre-catch share revenue diversity of each vessel was a covariate as

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To determine whether a change to catch shares management in the limited entry groundfish trawl sector was associated with a change in fishery connectance at the port level, we used a simple linear regression to compare the change in connectance between ports that were and were not affected by catch shares. Paralleling our vessel-level analysis, a port was considered a *general port* if there was no record of vessels landing groundfish with trawl gear prior to 2011 and no quota used to land commercial catches after 2011 (*P1, n* = 48). Ports were *catch share ports* if there were landings of groundfish trawl prior to 2011 and either continued to land quota after 2011 (*P2, n* = 16) or *limited entry port exits* if the ports no longer had groundfish trawl landings after 2011 (*P3, n* = 10). Thus our port level analysis paralleled the vessel-level model with

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In both the vessel and port level analyses, we compared alternative models using the information theoretic approach that allows direct comparison of the models’ goodness of fit using model likelihoods (Burnham and Anderson 2002). The Akaike Information Criterion (AIC) was used to find the most parsimonious model which balanced both the goodness of fit (as measured by likelihood) and model complexity (as measured by the number of parameters). Here the lower the AIC, the better the model (Burnham and Anderson 2002). We calculated 95% confidence intervals on the model parameters by bootstrapping to determine whether the confidence intervals overlapped with zero. To do so, we randomly selected data with replacement from our vessel and port datasets until we had a dataset the same size as our original and then refit the models. This procedure was repeated 10,000 times and the resulting distribution give the 95% confidence intervals for each parameter.

**Results**

**Definitions of realized fisheries**

Our clustering algorithm identified 109 realized fisheries. Realized fisheries often consisted of a single species but could also comprise assemblages of species (Fig. S1a). Whether their catch consisted of a single species or multiple species, the realized fisheries were characterized by distinct patterns of temporal and spatial structure (Fig. S2a, b). These patterns suggested strong agreement between our realized fisheries and NWFSC Observer sector designations, as did comparisons of vessel sizes and catch composition (single- vs. multi-species, Table 1).

The realized fisheries also varied by several orders of magnitude in effort (number of trips) and revenue (Fig. S1b), with a small number of fisheries accounting for the majority of effort and revenue. For example, only 10 of the 102 fisheries were responsible for 90% of ex-vessel revenue and landings (pounds) in the time period we examined (Table 1). These fisheries included sectors which have been well-studied but not quantitatively described prior to now (e.g., dungeness crab pots (Botsford & Wickham 1978), spiny lobster pots (Kay et al. 2012), or red urchin diving (Smith & Wilen 2003) (Table 1).

**Changes in vessel and community level fishing diversity**

The existence of 109 realized fisheries on the US west coast opens up a variety of opportunities for diversification of fishing practices by individual vessels. We found that between 2009-2010, 66% of commercial vessels on the west coast participated in more than one realized fishery (Fig. 3a) although the degree to which vessels diversified varied. Breaking these patterns down regionally using PFMC management regions, generalists outnumbered specialists (Fig. 3b). The distribution of diversity varied among the generalists, from vessels that were highly specialized but had a few landings in additional fisheries to those that fished in many fisheries evenly (Fig. 3c). Notably, the majority of diversified vessels revenue was dominated by revenue from a single fishery (71%), with very small percentages coming from alternatives. However almost a quarter (24%) of diversified vessels were participating in at least two fisheries equally, with some vessels (4%) participating evenly in more than three fisheries (Fig. 3c).

The preceding analysis focused on fishing strategies employed by individual vessels, without consideration of how those strategies came together to create characteristic fisheries participation networks for specific ports. We found differences in the number and interconnectedness of fisheries across ports (Fig. 3a). Ports had anywhere between 0-7 fisheries connected. This variation is exemplified by participation networks in Santa Barbara, CA and Neah Bay, WA (Fig 3ab). Santa Barbara was characterized by a much more complex participation network, with more than double the average fishery connectance of Neah Bay. The ports had a spectrum of vessels landing at them and we found that there was a positive, but not a strong, relationship between vessel and port level diversity (Fig S3).

**Analysis of changes in revenue diversity and port connectance due to catch shares**

We find that at the vessel level the model that best explained changes in revenue diversity following catch shares implementation included a term for pre-catch shares diversity (*H*pre) and catch shares category (*Mi*) (Table S1). Vessels with higher participation diversity prior to catch shares were more likely to show a reduction in diversity following catch shares (Fig 4a). Between the period before (2009-2010) and after (2012-2013) catch shares, vessels in the general fleet showed a modest, but significant, 2.6% increase in fisheries diversification (*Hpre* =1.52 to *Hpost* =1.57, p < 2e-16). However, we found that catch share participants demonstrated a four-fold higher (12%) increase in diversification as compared to vessels in the general fleet (*Hpre* =1.77 to *Hpost* =1.98, p = 5.22e-05) while limited entry exit vessels declined in diversity by 21% (*Hpre* = 2.0633 to *Hpost* = 1.62953, p = 0.0207). We also found the limited entry exits and catch share participants were 16% more diverse than vessels in the general fleet prior to 2011 (two sided t-test, 1.76 to 1.52, p = 0.00279).

At the port level, the model that best explained changes in port connectance following catch shares implementation included only a term for port level connectance values prior to catch shares. Ports with higher connectance values prior to catch shares were more likely to show a reduction in connectance following catch shares, however examining a port level model which includes the equivalent catch share categories as the vessel level model, we find qualitatively similar results, despite lack of significance (Fig. 4b).

Post-hoc we examined how catch share participant and limited entry exit vessels changed their fisheries participation after catch shares. We define a *fishing portfolio* as the group of fisheries a vessel combines within a time period (in this case two, two year periods 2009-2010 and 2012-2013). We found that over 80% of the limited entry exit vessels did not stop fishing commercially and that approximately 75% of these vessels added new fisheries (Fig. 5).

**Discussion**

We find that more than 60% of fishermen are generalists, effectively connecting the multiple fisheries in which they participate. This finding runs counter to conventional ways of thinking about fisheries systems. Historically theoretical models of fishing have defined fleets as homogenous groups of specialist vessels focusing a set of species with a particular gear and ignoring the other fisheries in which the vessels may participate (Schaefer 1954; Mangel 1982). Following these formulations, most empirical analyses have also taken a similar approach (van Putten et al. 2012). Even EBM, with a focus on systems-level analyses and species interactions, treats fleets as unconnected (Field 2004). This gap is problematic as fisher behavior is central as it will mediate how changes in management translate into changes in the marine environment(Fulton et al. 2010).

Ecologically, there is a large literature demonstrating the importance of accounting for apparent competition, where the competition between two species is obscured by the predation by a common predator. Failing to account for apparent competition has resulted in being unable to predict the impact of extinction in a food web (refs). Similarly, failing to account for the anthropogenic connectivity among fisheries may result in changes in one fishery unexpectedly affecting the participation in a fishery targeting a species which is ecologically unconnected. Dungeness crab and albacore tuna fisheries on the west coast provide an appealing, but untested example. There are myriad examples of the importance of properly characterizing ecological connectivity both for better understanding of species responses to perturbations and management change. Indeed ecosystem based management is largely a response to the lack of connectivity provided in traditional single-species fisheries management. Similarly, recent work on bushmeat and artisanal fishing has highlighted the importance of recognizing the connections between these activities in order to provide adequate alternatives to relive pressure on scarce wildlife (Brashares et al. 2004).

As management agencies have shifted from single species to system-level management goals these holistic management goals are accompanied by policy language explicitly valuing human wellbeing alongside ecological integrity (J. L. Anderson et al. 2015). EBM modeling approaches and empirical studies focusing on species interactions have gone a long way to help understand and conceptualize marine ecosystems ecological connectivity, however understanding the human scale is still a challenge. In EBM models, humans are represented as fishing fleets (Field 2004). Fleets are not unlike predators with a set of prey selectivities, and these fleets may grow in size, or change effort levels depending on revenue. Changes in human wellbeing then, can only be modeled as changes in fleet revenue. Yet here we demonstrate that a single vessel on the US west coast is likely to participate in multiple fleets. The social implications of this generalism have been most directly related to reduced exposure to financial risk (Kasperski and Holland 2013; Sethi et al. 2012). Previous work has demonstrated that vessels with increased participation diversity have less variable revenues, and that changes in management have been associated with reduced participation diversity in these fisheries (Kasperski and Holland 2013). Thus measuring participation diversity across vessels before and after a management change helps to understand how changes in system characteristics affect one facet of human well being.

We document the generalism present among US west coast fishing fleets, but also that the implementation of catch shares has increased revenue diversity at the vessel level for vessels that continued to participate in the fishery. If previously documented relationships between vessel participation diversity and revenue variability hold, catch shares thus has reduced these vessels’ exposure to risk. It’s important to note, however, that not all groundfish trawl boats made the transition into the catch shares regime. Most analyses of the impacts of catch shares have focused on the vessels that continue fishing, assuming that vessels that exit also exit commercial fishing. This work demonstrates that the majority of vessels continued fishing, albeit in other fisheries. Closely examining what happens to these trawlers that exited groundfish fisheries, and whether these patterns in of connectivity can predict new entries is an important next step for this work.

Most people talk about impacts of just vessels in fishery rather than all vessels and/or community. By conducting analyses at a certain scale, we lack the full picture. We find that the effect is the same, but attenuated, at the community level, but too little work has been done for us to know if that result is general. This is worth further study empirically and theoretically, since many management groups are mandated to consider community and vessel level changes (refs). We know a lot more about vessels and a lot less about how to meet legal commitments at community level.

The goal of this work is largely exploratory, to develop ways of quantitatively measuring changes in human connectivity as a result of a management intervention. And it should be cautioned that our time series is short, and fishing fleets will continue to adjust to the management changes. We also recognize that there are many possibly appropriate scales at which to conceptualize a “fishing community” and that these communities are affected by much more than just fisheries. Similarly we also recognize that fishermen frequently have employment outside of the fishing industry, vessels constitute more than one person. To more fully include the social aspects of these SESs all these issues need additional attention.

In this work we show how measuring and mapping human connectivity of marine systems can help develop human components of EBM models that better reflect the human scale. Due to human connectivity among fisheries, changes in one fishery revenue may affect human well being, even if no impact is felt in the focal fleet. Our work here provides a method of determining ecologically realized fisheries, and mapping a vessel’s participation across them. An important next step would be to develop fishing portfolios, or characteristic combinations of fisheries that vessels participate in annually, in order to better map changes in marine species abundance and range to changes in fishing livelihoods.

**References**:

Anderson, James L, Christopher M Anderson, Jingjie Chu, Jennifer Meredith, Frank Asche, Gil Sylvia, Martin D Smith, et al. 2015. “The Fishery Performance Indicators: a Management Tool for Triple Bottom Line Outcomes.” Edited by George Tserpes. *PloS One* 10 (5): e0122809–20. doi:10.1371/journal.pone.0122809.

Brashares, Justin S, Peter Arcese, Moses K Sam, Peter B Coppolillo, A R E Sinclair, and Andrew Balmford. 2004. “Bushmeat Hunting, Wildlife Declines, and Fish Supply in West Africa.” *Science (New York, N.Y.)* 306 (5699). American Association for the Advancement of Science: 1180–83. doi:10.1126/science.1102425.

Burnham, Kenneth P, and David R Anderson. 2002. *Model Selection and Multimodel Inference: a Practical Information-Theoretic Approach*. Edited by Springer Science & Business Media.

Deporte, N, C Ulrich, S Mahevas, S Demaneche, and F Bastardie. 2012. “Regional Metier Definition: a Comparative Investigation of Statistical Methods Using a Workflow Applied to International Otter Trawl Fisheries in the North Sea.” *ICES Journal of Marine Science* 69 (2): 331–42. doi:10.1093/icesjms/fsr197.

Field, John C. 2004. “Application of Ecosystem-Based Fishery Management Approaches in the Northern California Current .” Edited by Robert C Francis.

Fulton, Elizabeth A, Anthony D M Smith, David C Smith, and Ingrid E van Putten. 2010. “Human Behaviour: the Key Source of Uncertainty in Fisheries Management.” *Fish and Fisheries* 12 (1): 2–17. doi:10.1111/j.1467-2979.2010.00371.x.

Kasperski, S, and D S Holland. 2013. “Income Diversification and Risk for Fishermen.” *Proceedings of the National Academy of Sciences*. doi:10.1073/pnas.1212278110/-/DCSupplemental.

Legendre, P, and L Legendre. 2012. *Numerical Ecology*. Elsevier.

Lou Jost. 2006. “Entropy and Diversity.” *Oikos* 113 (2): 363–75.

Mangel, Marc. 1982. “Search Effort and Catch Rates in Fisheries.” *European Journal of Operational Research* 11 (4): 361–66.

Rosvall, Martin, and Carl T Bergstrom. 2008. “Maps of Random Walks on Complex Networks Reveal Community Structure.” *Proceedings of the National Academy of Sciences* 105 (4). National Acad Sciences: 1118–23. doi:10.1073/pnas.0706851105.

Schaefer, Milner B. 1954. “Some Aspects of the Dynamics of Populations Important to the Management of the Commercial Marine Fisheries.” *Inter-American Tropical Tuna Commission* 1 (2): 27–56.

Sethi, Suresh Andrew, Michael Dalton, Ray Hilborn, and Marie-Joelle Rochet. 2012. “Quantitative Risk Measures Applied to Alaskan Commercial Fisheries.” *Canadian Journal of Fisheries and Aquatic Sciences* 69 (3): 487–98. doi:10.1139/f2011-170.

The Northwest Fisheries Science Center. 2015. “Data Analysis and Products.” *Fisheries Observation Science*. Seattle, WA. Accessed December 8. http://www.nwfsc.noaa.gov/research/divisions/fram/observation/data\_products/bottom\_trawl.cfm#description.

van Putten, Ingrid E, Soile Kulmala, Olivier Thébaud, Natalie Dowling, Katell G Hamon, Trevor Hutton, and Sean Pascoe. 2012. “Theories and Behavioural Drivers Underlying Fleet Dynamics Models.” *Fish and Fisheries* 13 (2): 216–35. doi:10.1111/j.1467-2979.2011.00430.x.