Ecosystem based fisheries management (EBFM) focuses on interactions, both between species and species and the biophysical environment. Because of the focus on interactions, EBFM is often described as managing an ecosystem as a whole, rather than individual species. This approach recognizes that other species, abiotic conditions, and human harvest are all drivers of system dynamics and seeks to manage them holistically. As such, much work on EBFM has been to build food webs, and to account for how abiotic conditions may drive species interactions from the bottom up.

The push for EBFM also comes at a time when the importance of considering the role people have in food webs is growing: increasingly, natural-resource management and conservation efforts are framing approaches in terms of ecosystem services and characterizing ecosystems more broadly as social-ecological systems (millenium ecosystem assessement). EBFM dovetails with these trends and advises managers that human impacts should be included both to better represent the ecological impacts fisheries have and to capture livelihoods and human well-being derived from harvest (ref, IEA?).

These efforts to model both social and ecological dynamics represent progress but tend to have higher resolution for the ecological components of these systems and lower resolution for the social or economic interactions. In particular, these fleets are largely modeled as independent populations of vessels with no exchange among fisheries. Yet just as predators can couple disparate food chains (refs -serengeti), there is evidence that that vessels strategically enter and exit fisheries depending on markets, regulations and ecological conditions (jonas, holland kasperski, sethi) and that multiple fleets target the same species (Colemen et al. 2004). This lack of realism is problematic important both because uncertainty in how fishermen respond to changes is a major source of uncertainty in fisheries science (Fulton et al. 2011) and because mapping the flows of ecosystem services and incorporating “human dimensions” is often an explicit goal of management (ref, IEA?). Quantifying and understanding the human connectivity in marine systems, i.e. how vessels link fisheries together by contemporaneous participation, therefore represent an important frontier to EBFM science

In this paper we contribute to this knowledge gap by presenting an approach for measuring the connectivity of fisheries at both the vessel and community levels and use it to evaluate how a change in management related to changes in these linkages across the entire commercial fishing sector on the west coast of the United States (US). Towards this objective, we developed a novel classification method to identify distinct fishing practices used by fishers along the US west-coast and constructed a comprehensive database of commercial fisheries participation. Specifically, the classification method was used to: (i) calculate vessel-level participation in individual fisheries, (ii) determine emergent diversification of a vessel’s participation across fisheries, and (iii) describe networks of fisheries participation for entire communities (ports). We found that the majority of vessels examined were generalists, defined as those participating in more than one commercial fishery between 2009 and 2013. In addition, the interconnectedness of fisheries participation varied strongly across ports. Using these individual and community-level measures of fisheries diversification, we evaluated how the introduction of the Pacific Trawl Rationalization (catch share) program in the federal groundfish fishery in 2011 influenced vessel-level participation in the fishery, along with the diversification of vessels and ports as a function of their participation in the fishery.

Discussion stuff?

This dynamic participation is relevant for both modeling changes in ecology and for predictions of how human well being might change. For example, vessels shifting effort from tightly regulated fisheries to those with more open access is surprising if the starting point is a food web with no connections among fishing fleets, but a commonly observed phenomenon. Similarly, if the sole ecosystem service that commercial vessels receive is revenue from a single fishery, it is impossible to capture the fact that participation diversity (fishing in more than one fishery) is a common feature of many industrial fisheries and can buffer against revenue volatility. Indeed previous work in the continental US, Alaska and Sweden have documented the diversity of fisheries in which vessels participate

While much of the literature on fleet dynamics focuses on single fleets (van Putten et al. 2011), a few studies focus on the composition and entry-exit dynamics of fishing fleets.

Studies that have documented fisheries connectivity highlight the impact that the environment, markets and management can have. Jonas et al. show how Swedish commercial fishermen have grown increasingly specialized as management became more restrictive, \_\_\_ et al. document how Maine fishermen have increasingly become dependent on a single species, American lobster, due to interactions among markets and ecological conditions. Similarly Sethi looks at patterns of diversity across Alaska, finding both geography and \_\_ to be related to diversity. This empirical work is important to provide intuition on how fisheries connectivity should be included in EBFM models. We add to this body of literature by examining how fisheries connectivity is influenced in response to a change in management and present an approach by which fisheries connectivity can be examined at a scale comparable to that of food webs.

EBFM focuses on interactions, both between species and species and the biophysical environment. Because of the focus on interactions, EBFM is often described as managing an ecosystem as a whole, rather than individual species. The push for EBFM also comes at a time when the importance of considering the role people have in food webs is growing: increasingly natural resource management and conservation efforts are framing approaches in terms of ecosystem services and characterizing ecosystems more broadly as social-ecological systems (millenium ecosystem assessement). EBFM dovetails with these trends and advises managers that human impacts should be included both to better represent the ecological impacts fisheries have and to capture livelihoods and human well-being derived from harvest.

In response to these [calls], much work has been devoted to modeling and measuring whole marine ecosystems. Biophysical models have been developed to model trophic interactions (refs) and to link these food web dynamics to physical oceanography (ref). Most of these models also allow human fishing pressure to be included (refs) which helps clarify the ecological impact harvest has across food webs, and allows to managers to simulate how fisheries revenues might change due to future perturbations.

These efforts represent progress but tend to have higher resolution for the ecological components of these systems and lower resolution for the social or economic interactions. In particular these fleets are largely modeled as independent populations of vessels with no exchange amongst fisheries. Just as predators can couple disparate food chains (refs -serengeti), there is evidence that vessels often participate in multiple fisheries (jonas) and that multiple fleets target the same species (colemen et al. 2004). Indeed previous work on the US west coast has documented the ability of human connectivity of marine systems (fisheries participation diversity) to hedge against revenue variability at a vessel level (kasperski & holland).

The lack of realism in these models is partly for mathematical tractability (plausible maybe? refs?), but also likely due to lack of data from which to build models. In many artisanal and subsistence fishery systems data is lacking altogether (artisinal fisheries ref), but even in relatively data-rich industrial fisheries the legacy of single-species fisheries management is reflected in the way that fleets are modeled and data is collected and analyzed (Anderson et al.). Fisheries are typically examined on a fishery by fishery basis, making it difficult to request and examine data across multiple jurisdictions (ref infographics from Tod little's group).

The lack of data is likely widespread, as there are relatively few examples of system-level analyses of wildlife consumption, be in terrestrial or marine. However the empirical cases that exist highlight the important insights these types of studies can provide, often by identifying drivers unobservable from the social or ecological studies alone (Brashares et al., Lade et al. pnas, Liu complexity science). Human connectivity has been shown to be a component of human well-being (kasperski & holland), but how such connectivity changes in response to changes in ecological, market or management conditions remains unknown.

In this paper we contribute to this knowledge gap by presenting an approach to take advantage of existing management data to measure the human connectivity of fisheries at both the vessel and community levels and use it to evaluate how a change in management related to changes in these linkages across the entire commercial fishing sector on the west coast of the United States (US). Towards this objective, we developed a novel classification method to identify distinct fishing practices used by fishers along the US west-coast. Specifically, the classification method was used to: (i) calculate vessel-level participation in individual fisheries, (ii) determine emergent diversification of a vessel’s participation across fisheries, and (iii) describe networks of fisheries participation for entire communities (ports). We found that the majority of vessels examined were generalists, defined as those participating in more than one commercial fishery between 2009 and 2013. In addition, the interconnectedness of fisheries participation varied strongly across ports. Using these individual and community-level measures of fisheries diversification, we evaluated how the introduction of the Pacific Trawl Rationalization (catch share) program in the federal groundfish fishery in 2011 influenced vessel-level participation in the fishery, along with the diversification of vessels and ports as a function of their participation in the fishery.