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Fishermen, markets, and population diversity

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ABSTRACT

Fishing impacts biodiversity on multiple levels, potentially resulting in unintended feedbacks to the economic performance of the fishery over time. For example, targeting observable traits within a population can impact genetic diversity and targeting valuable species can impact biodiversity at the ecosystem level. The bioeconomic literature, however, has given little attention to the effect of fishing on population diversity, even though population diversity contributes to ecosystem services and estimates of population extinction rates are three orders of magnitude higher than species extinction rates. Here we develop a stochastic bioeconomic model that links the harvest of multiple salmon populations in a single commercial fishery to the trajectory of population diversity in a salmon stock complex. We parameterize our model with biological and economic data from the Copper River Chinook salmon fishery. We show that markets can incentivize the degradation of population diversity, reducing infra-marginal fishery rents, and increasing variability in economic returns. We also show that second-best management can conserve population diversity and improve welfare. Furthermore, depending on fishermen's time preferences, this management strategy is potentially self-financing.

1. Introduction

Fishing is one type of anthropogenic selection impacting biodiversity on genetic, species, and ecosystem levels. Due to economic incentives and regulatory constraints, fishermen target specific genetic characteristics within fish populations (e.g. age at maturity), populations within species (e.g. spatial populations), and species within communities (e.g. top predators). At any of these levels, fishing can have unintended consequences for the ecological dynamics and the economic performance of the fishery over time.

The effects of fishing on genetic diversity within a fish species (reviewed in Jørgensen et al., 2007) and fishery biodiversity at the species level (e.g. Pinnegar et al., 2000; Mumby et al., 2008) are well established. However, ecologists and economists have only recently given attention to the effects of fishing on biodiversity at the population level (Luck et al., 2003). Populations are groups of individuals from a single species with a high degree of genetic exchange within the group but limited genetic exchange between groups.

Understanding the welfare implications of altering population diversity within a fishery is important for a number of reasons. First, current estimates of population extinction rates are three orders of magnitude higher than species extinction

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rates (Hughes et al., 1997). Second, population diversity (the existence and relative abundance of populations) provides valuable ecosystem services (Lomborg, 2001; Balmford et al., 2003; Luck et al., 2003). Finally, the unintended consequences of altering population diversity can have ripple effects throughout the ecosystem and therefore, maintenance of population diversity is important to consider when designing ecosystem-based management policies (Botsford et al., 1997; Pikitch et al., 2004).

To investigate the importance of population diversity, an emerging literature in ecology uses salmon as a prototype species (Hilborn et al., 2003; Schindler et al., 2010a; Moore et al., 2010; Carlson et al., 2011). Because salmon return to their natal spawning grounds to reproduce (a trait known as homing), a single river network can be comprised of hundreds of salmon populations that are reproductively isolated and evolve independently, adapting to local environmental conditions (Dittman and Quinn, 1996). One important finding in this literature is how independent population dynamics within a fishery can stabilize aggregate fishery returns across the complex through what is known as the "portfolio effect". This effect is analogous to the role of asset diversity on the stability of financial portfolios.[1] As population diversity decreases, the portfolio (stock complex) becomes less diversified and potentially leads to increased variability in ecological returns over time, depending on the nature of the correlations between the populations. For example, Schindler et al. (2010b) find that recruitment to the Bristol Bay salmon complex was significantly less variable (coefficient of variation of 55%) than the recruitment of any one population (average coefficient of variation of 77%). While the ecology literature has demonstrated the existence and potential importance of the "portfolio" effect, little attention has been given to the underlying ecological, economic, and social mechanisms that could lead to a reduction in population diversity.

In contrast, a significant focus of the fisheries economics literature is on identifying the incentives that lead to changes in marine ecosystems and the associated economic returns. The literature, generally speaking, has shown how rule-of-capture incentives lead to rent dissipation often characterized as "too many boats chasing too few fish". Recent research, however, is unraveling the rent dissipation process, revealing the multiple dimensions where it occurs, such as space, age or size, habitat, genetic diversity, etc. (see Abbott and Wilen, 2011; Smith, 2012; Reimer et al., 2014; Diekert, 2012).

Here, we identify how the rule-of-capture incentives are a potential driver of changes in population diversity and investigate whether there are feedbacks that affect the mean and variance of economic returns. At the same time, we consider how fish output markets, which can magnify the effects of ill-defined rights, can drive the within-season targeting behavior of fishermen. Specifically, we examine how seasonality in prices can create population-specific values that shift fishing effort toward higher-valued fish populations within a stock complex. The within-season shift in effort, in turn, can affect population diversity, and reduce economic returns to the fishery and, through the "portfolio" effect, reduce the stability of those returns.

The Copper River Chinook salmon fishery, in Cordova, Alaska, motivates our research questions and methodology. As with other salmon fisheries, the Copper River Chinook stock complex is comprised of multiple salmon populations (Templin et al., 2008) that have population-specific run times. Run timing is a life history trait that is genetically determined and corresponds to the time a stock migrates through the fishery on its way to its spawning grounds (Carlson and Seamons, 2008; Quinn et al., 1999; Stewart et al., 2002; Hodgson et al., 2006). Unique to the Copper River fishery, however, is that in the 1980s fishermen made investments in marketing and product quality improvements that resulted in a price premium for salmon coming from the region (Jardine et al., 2014). Additionally, the prices are highest in the beginning part of the season and subsequently fall as the season progresses (Knapp et al., 2007; Alaska Seafood, 2005). Therefore, populations migrating through the fishery early in the season are more valuable on the market.

The nature of prices for Copper River Chinook provides fishermen with incentives to target high-value early-run salmon. While the data do not exist to correlate higher prices with increased fishing effort in the early parts of the Chinook run, archival records discuss a shift in the distribution of fishing effort beginning in the 1980s just as these markets were being developed (Alaska, 2005). For example, in 1987, managers delayed the second opening of the fishery after fishermen took 20% of the total annual catch in the first opening. If left unchecked, we hypothesize that over time this selection pressure could alter population diversity with late returners making up a greater share of the Chinook stock complex. These changes in population diversity, therefore, reduce the ability of the fishermen to capture market rents from higher early-season prices, thereby reducing the returns on investments in product quality and marketing. Additionally, changes in population diversity can potentially increase the variability in economic returns to the fishery.

To examine the economics of population diversity, we couple a stochastic population dynamic model of multiple salmon populations, a model describing the seasonal effort distribution of heterogeneous fishermen, and a model describing the behavior of fishery managers. We parameterize our model with biological and economic data from the Copper River Chinook salmon fishery. With our coupled bioeconomic model, we analyze biodiversity outcomes and the mean and variance of fishery value under different market conditions including seasonal prices, where prices decline over the season due to exogenous consumer preferences, and endogenous prices that respond to fishery harvest levels. Both market scenarios are plausible depictions of the market dynamics in the Copper River fishery, which supplies some of the first wild salmon of the season when consumer demand is high (Knapp et al., 2007) and is also a branded product (Jardine et al., 2014). We examine the impacts of markets on population diversity by comparing outcomes to a baseline where prices are constant over the season.

[1] Schindler et al. (2010b) credit (Figge (2004) with establishing the term of the "portfolio" effect.