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Novel catch projection model for a commercial groundfish catch shares fishery

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ABSTRACT

Fishery catch projection models play a central role in fishery management, yet are underrepresented in the literature. A wide range of statistical approaches are employed for the task, including multiple regression models, autoregressive methods, different classes of generalized linear models, mixed model approaches and many others. However, the applicability of these statistical approaches can be limited in specific cases of complex fisheries. We developed a new catch projection model for quota-based fisheries on the West Coast of the U.S. to forecast annual catch and landings for a variety of groundfish species in the Northeast Pacific Ocean. The model projects total and landed catch of each species by individual vessel and for the entire fishing fleet, using a combination of weighted mean vessel attainment rates and historical catch rates, and generates uncertainty intervals. It demonstrated an ability to produce highly accurate predictions at both fleet ($R^2 = 0.9847$) and vessel levels ($R^2 = 0.8447$). The model framework contains much built-in versatility, is generalizable enough to serve a variety of quota based applications, and the approach can be tailored to other fisheries around the world. With the proliferation of quota based management of commercial fisheries, tools such as this one are increasingly useful for sustainable management of fishery resources.

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1. Introduction

Effective fishery management is essential for ensuring long-term sustainability of marine resources. Fishery catch projection models play a central role in management activities, yet they are underrepresented in the literature. Fishery managers and policy makers rely on such models to project future catch levels under different management, fishery, economic or ecological conditions. Within the fishery management system for groundfish on the West Coast of the United States, catch projections are used for two main purposes. The first is to facilitate establishment of annual harvest specifications for the groundfish fishery, including Annual Catch Limits (ACLs), catch allocations for each fishing fleet (fleet allocation), and others. The second is for within-season (inseason) management, to maintain annual catch of fisheries stocks within established limits. In this study we address the former purpose, to analytically support the establishment of annual harvest specifications, as part of a thorough, transparent, and inclusive management process.

On the West Coast of the U.S., the commercial groundfish bottom trawl fishery recently underwent a dramatic change in how it is managed, a process that was called "trawl rationalization". The trawl fishery, which was previously managed using cumulative bimonthly landing limits, was switched to an Individual Fishing Quota (IFQ) system in 2011. Under the IFQ system, annual catch quotas for the fishery for each fisheries stock are divided among fishing vessels participating in the fishery (fleet) according to predetermined shares, and (unlike the previous system) the quotas account for total catch, which includes both landed (brought to port) and discarded catch (discarded at sea).

Thirty categories of groundfish stocks and stock complexes, designated by species and area, are currently managed on the U.S. West Coast using quotas under the new system. It allows several methods of trading and transfer of individual quota among participants, both

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for the current year and longer term. The quota can be caught at any time throughout the entire calendar year, which promotes safety by enabling fishers to schedule their work around bad weather, and it allows them to participate in other fisheries, without sacrificing catch in the IFQ fishery.

Limited provisions are made for “carrying over” surplus, uncaught fish from one year to the next, as well as unintentional deficit (exceeding one’s annual quota). Additional gears can be used including longline and pot gear, which were not allowed under the previous management system. Typically, with IFQ implementation, fishers’ safety increases, waste as discard rates drop, revenue and annual catch limits increase, fleet overcapacity and latent capacity are removed, and moderate fleet consolidation occurs (Branch et al., 2006; Grimm et al., 2012; Essington, 2010; Melnychuk et al., 2012; Melnychuk et al., 2014; Essington et al., 2012; Worm et al., 2009). Indications of many similar changes have been seen following implementation of the West Coast Groundfish IFQ Fishery as well (Matson, 2014; Steiner et al., 2016), and several overfished West Coast groundfish stocks have rebuilt to healthy and sustainable levels of biomass and exploitation rates during this time.

Also, under the previous management system (cumulative bimonthly landing limits), discard rates fluctuated dramatically for many species within and among years. More restrictive landing limits routinely resulted in increased discards, and this had a substantial influence on total annual catch of the fishery and its uncertainty. Therefore, the fishery was routinely and intensively managed inseason to keep catch within annual targets. Inseason management actions for this fishery have been rare in the five years since IFQ was implemented, and have consisted of a few liberalizations of closed areas, and one temporary gear/area restriction.

Given the newly found inseason stability of fishery performance under IFQ, inseason catch projection modeling is no longer necessary, yet projections to inform annual catch allocations levels for future seasons are still needed, under the Magnuson-Stevens Act, and the National Environmental Policy Act. These laws compel managers to, in addition to other environmental and economic considerations, examine expected impacts of harvest specifications, across a range of alternatives through conservation oriented and economic analyses of total catch, landings, and fisheries revenue. A range of statistical approaches are available for this task, including multiple regression models, autoregressive methods such as integrated moving average models, different classes of generalized linear models or mixed models, and others. However, few models exist in the literature for quota-based fisheries, and those available tend to focus on economics and quota trading, rather than direct prediction of catch levels for sustainability goals (Little et al., 2009; Souliíea and Thíebaudb, 2006; Clark, 1980). The modeling goals and conditions of this fishery required a new approach, as the short time series, quota structure and behavior of the fishery were not conducive to existing statistical methods alone.

The goal of this study was to address this need and develop a new fisheries model to generate annual projections of total catch and landed catch of groundfish species managed with fishery quotas, at both the vessel and fleet levels, with accompanying estimates of uncertainty. The catch projections of this new model have already been utilized in the groundfish management decision making process, establishing annual harvest specifications on the West Coast of the U.S. (PFMC, 2016). In an era where the effectiveness of quota fisheries is being demonstrated around the globe (Copes, 1986; Grimm et al., 2012; Squires et al., 2008; Costello et al., 2008; Essington, 2010; Melnychuk et al., 2012), more management entities are utilizing them, and versatile model frameworks like the one we propose are increasingly relevant for sustainable fisheries management.

2. Methods

The model is intended to forecast total catch and landings for thirty groundfish species categories in the Northeast Pacific Ocean managed under the IFQ system (listed in Table 1). Groundfish in the Northeast Pacific Ocean is a large group of species that with a few exceptions, live on or near the bottom of the ocean. Within the West Coast Groundfish IFQ Fishery, species categories are defined either individually by species, or grouped into complexes by features

Table 1
Predicted catch, actual catch, and allocation (fleet quota) in pounds for species categories managed under the IFQ Program on the U.S. West Coast.

Species category	Latin name	Predicted catch	Actual catch	Allocation
Arrowtooth flounder	*Atheresthes stomias*	3,757,415	3,824,627	7,643,603
Bocaccio rockfish South of 40°10′ N.	*Sebastes paucispinus*	19,750	19,745	174,165
Canary rockfish	*Sebastes pinniger*	23,168	23,258	90,610
Chilipepper rockfish South of 40°10′ N.	*Sebastes goodei*	706,076	688,447	2,352,883
Cowcod South of 40°10′ N.	*Sebastes levis*	382	436	2,205
Darkblotched rockfish	*Sebastes crameri*	212,793	215,612	613,789
Dover sole	*Microstomus pacificus*	16,158,009	14,319,135	49,018,682
English sole	*Pleuronectes vetulus*	404,053	523,521	11,598,189
Lingcod	*Ophiodon elongatus*	617,294	568,517	3,592,323
Longspine thornyheads North of 40°10′ N.	*Sebastolobus altivelis*	2,124,035	1,981,102	3,993,453
Minor shelf rockfish North of 40°10′ N.	*Sebastes* spp.	71,883	75,078	1,119,948
Minor shelf rockfish South of 40°10′ N.	*Sebastes* spp.	32,324	21,403	178,574
Minor slope rockfish North of 40°10′ N.	*Sebastes* spp.	368,324	405,976	1,740,285
Minor slope rockfish South of 40°10′ N.	*Sebastes* spp.	224,263	218,445	834,736
Other flatfish	*Pleuronectiformes*	1,589,834	1,852,420	9,245,746
Pacific cod	*Gadus macrocephalus*	391,350	365,985	2,483,309
Pacific halibut (IBQ) North of 40°10′ N.	*Hippoglossus stenolepis*	70,614	60,606	236,660
Pacific ocean perch North of 40°10′ N.	*Sebastes alutus*	91,343	89,311	247,535
Pacific whiting (or hake)	*Merluccius productus*	189,077,539	217,627,250	263,309,103
Petrale sole	*Eopsetta jordani*	4,697,994	5,100,488	5,242,593
Sablefish North of 36° N.	*Anoplopoma fimbria*	4,075,369	4,154,279	4,382,790
Sablefish South of 36° N.	*Anoplopoma fimbria*	272,181	454,542	1,439,839
Shortspine thornyheads North of 34°27′ N.	*Sebastolobus alascanus*	1,577,342	1,506,158	3,025,822
Shortspine thornyheads South of 40°10′ N.	*Sebastolobus alascanus*	7,589	6,040	110,231
Splitnose rockfish South of 40°10′ N.	*Sebastes diploproa*	136,341	148,024	3,472,501
Starry flounder	*Platichthys stellatus*	16,452	32,472	1,665,592
Widow rockfish	*Sebastes entomelas*	912,738	1,441,833	2,191,020
Yelloweye rockfish	*Sebastes ruberrimus*	114	123	2,205
Yellowtail rockfish North of 40°10′ N.	*Sebastes flavidus*	1,932,315	2,565,281	6,479,055