Catch- quota Balancing Regulations in the Icelandic Multi-species Demersal Fishery: Are they useful for advancing Ecosystem-based Management?

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Summary
Implementation of single-species catch limits in multi-species fisheries is problematic when individual species quotas become limiting, and can therefore preclude advancement toward the holistic approach of ecosystem-based management. By adding flexibility to regulations controlling how quotas may be used by fishermen, the constraints of single species quotas may be alleviated, potentially yielding greater short-term profits. However, this greater flexibility may be detrimental in the long term if it simultaneously allows for greater risk in stock depletion due to persistent surpassing of catch limits. This study uses a bioeconomic model to analyze how catch-quota balancing mechanisms currently implemented in Iceland affect long-term sustainability of individual species and profitability of the fishery as a whole. We focus on the mechanism that allows species transformations of quota whereby quota for one species can be transformed into quota of another species at specified rates related to relative value, so called "cod equivalents." This system reduces the likelihood or degree that the total allowable catch (TAC) of any particular species constrains catch of others but also allows catches of some species to exceed TACs which could lead to their depletion or collapse. A process for setting total allowable catches while accounting for expected species transformations are discussed.

Introduction
Including ecosystem considerations into fisheries management is not a new concept, but the recent drive toward increased value in an ecosystem approach to fisheries has opened new avenues of inquiry into the question of how exactly an ecosystem approach may be implemented (Christie *et al.* 2007). This question extends well beyond that of traditional fisheries management boundaries, as changes are needed in the scale of information and governance needed to implement a management plan on the scale of an entire ecosystem. Furthermore, inherent in many definitions of an ecosystem approach to fisheries is the idea that social and economic factors should be part of the analysis (Christie *et al.* 2007); hence the development of many models that link ecosystem dynamics with a human dimension (e.g., Atlantis (Fulton *et al.* 2011), etc.).

"Catch-quota balancing" regulations in fisheries managed with individual tradable quotas (ITQs) include a variety of measures designed to allow fishermen to match up quota with catch. These include quota trading and retroactive catch balancing, the ability to carry forward unused quota or borrow from the next year's allocation, transformation of quota from one species into another and the option to pay for or reduce profits from overages, etc. (Sanchirico *et al*. 2006). Iceland currently employs one of the most expansive sets of catch-balancing rules, which includes between-year transfers, species transformations, and some leniency in penalizing over-quota landings, alongside trade. The purpose of this study is to analyze the utility of catch-quota balancing regulations in the Icelandic multi-species demersal fishery using a bioeconomic model of the Icelandic demersal fishery.

Material and Methods
In Iceland, ITQs can be transformed from one species to any other species according to ratios of "cod equivalence," which are set according to relative market price of the previous year. However, these

transformations are subject to certain limitations. Generally speaking (as these rules can vary slightly from year to year), no more than 1.5% of the total quota holdings in cod equivalent units may be transferred into any one species, and no more than 5% of that same total may be transferred at all. An important exception is that nothing can be transformed into Atlantic cod and langoustine. Up to 15% of a species quota is transferrable to the next year and implemented such that they can be carried forward indefinitely (but not accumulate), and 5% can be used to account for accidental overfishing as a transfer from the following year. In addition, up to 5% of quota for demersal species to be landed can be auctioned, from which the vessel operator is allowed to retain 20% of the earnings. These regulations were incorporated into a deterministic multi-species, age-structured, bioeconomic model using a combination of Matlab v. 8 and AD Model Builder v. 11 software. Short-term profit maximization occurred each year by optimizing effort parameters by species, emulating independent production. This scenario addresses the idea that although species transformations were intended to alleviate fishers' inability to match catch ratios with quotas exactly, they may have unintended consequences under the assumption of independent targetability. The goal was to analyze how short-term maximizing behavior affects the long-term goals of maximizing sustainability and profitability in the fishery as a whole with vs. without these regulations in place.

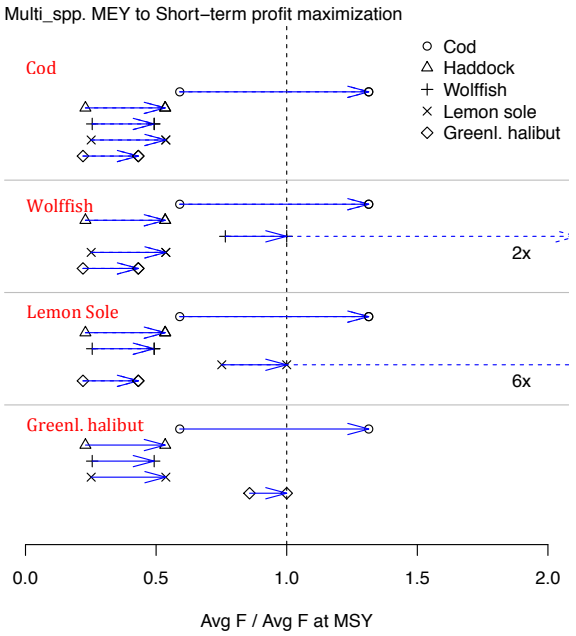

Figure 1. Solid arrows indicate fishing mortality under short-term profit maximization after 60 years with no species transformations (sp. tr.) included; dashed lines are with sp. tr. Each vertical panel is a different model run; the species labeled on the left indicates the one with the highest revenue per unit effort. Included. In the latter case, the shift from fishing mortality F that should occur under maximum economic yield to that obtained under short-term profit maximization can be quite high depending on revenue per unit effort.

Results and Discussion

The stock status at the end of 60 years of short-term profit maximization was heavily dependent on the species revenue gained per unit effort relative to other species being fished. Revenue per unit effort resulted from assumptions regarding catchability. The species with the most vulnerability in terms of long-term sustainability were those with either low abundances or low values, as a result of how species transformation exchange rates were defined. However, the overall profitability of the multi-species system changed little due to the dominance of Atlantic cod. Therefore, utility of these regulations need to be evaluated not only in terms of the overall profitability of the system, but also the socioeconomic or direct benefits associated with increased flexibility or ecosystem diversity.

We also demonstrated how TAC limits could be set with the expectation that they will be surpassed periodically using species transformation rules, and compare these with a case in which species transformations are not implemented. The utility of these rules when there is environmental fluctuation or uncertainty in the TAC-setting process were also discussed.

References

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