

## THIN WHOLESALE MARKETS AND DIRECT MARKETING IN RENEWABLE RESOURCE EXPLOITATION

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### ABSTRACT

The ex-vessel supply chain for fisheries has been recognized as an important determinant of value generation. In recent years, as the retail demand for fresh seafood products has increased, many independent fishermen have bypassed thin, monopsonized, or otherwise inferior wholesale markets by engaging in implicit or explicit fixed-output contracts with consumers (e.g., restaurants, supermarkets, individuals). We investigate the implications of this type of market structure for various management scenarios with a simple model of resource stochasticity and fishing effort. We show that contracts are associated with risk when periodic stock is stochastic, leading to inefficiencies and excess effort in the short run when resource conditions are temporarily poor. However, the results suggest that bilateral production agreements between fishermen can absolve a significant proportion of these inefficiencies, with broader partnership schemes offering further gains. Fishing cooperatives – which are often designed to facilitate the joint marketing of fish products – are an obvious tool in alleviating the inefficiencies associated with small-scale, contract-driven marketing.

### INTRODUCTION

The ex-vessel supply chain is increasingly seen as an important determinant of the total surplus associated with fisheries production, as well as the distribution of that surplus. For instance, a sizable portion of the rent generation associated with institutional fishery reform has been attributed to improvements along this margin (e.g., ITQs have led to longer fishing seasons, which in turn have shifted product from frozen to the more valuable fresh market) [1].

Responding to thin or informationally-constrained wholesale markets<sup>a</sup> [2] and changing patterns in seafood demand, many fishers have begun to bypass the wholesale market altogether, instead developing enduring exchange relationships with intermediate or final consumers, such as restaurants, supermarkets, and members of the public. This process has been aided by coordination among fishers – either organically or as a result of institutional design (e.g., sectors) [3] – along both production and marketing margins, as well as encouragement from Sea Grant extension programs and others in the US [4]<sup>b</sup>. Benefits to fishers of direct marketing include higher (in general) ex-vessel prices (due to internalized value generation and market niche effects), stable income, reduced cost (depending on where consumers are located), and the potential for a broader political coalition due to increased interaction with consumers [5]. However, markets exist for a reason, and there are many hurdles to overcome to successfully operate in a direct-marketing structure [4]. Some of the price improvement is due to the capture of value-adding activities formerly associated with other parts of the supply chain, such as

maintaining freshness, processing of whole fish, etc. Developing and maintaining relationships with consumers is time-consuming and requires skills and techniques that are potentially far removed from the experience of commercial fishers. In other words, there may be need for additional investment in human and physical capital. Further, in some jurisdictions, there are institutional barriers (e.g., health and safety regulations) requiring permitting and legal expertise. Finally, in bypassing wholesale markets, direct marketing constitutes a threat to those entities further up the supply chain. In these circumstances, engaging in direct marketing may create tension if the goal is to continue to maintain access to wholesale markets [5].

In this paper, we focus on a particular aspect of direct marketing that has not been fully investigated. Specifically, we examine how the presence of explicit or implicit fixed-output contracts might alter both biological and economic outcomes for fisheries in which some participants engage in direct marketing. The traditional manner in which economists model fishing behavior is through the lens of profit maximization and aggregate effort adjustment. Fishers are assumed to maximize profits subject to technological constraints, and enter or exit the industry based on profitability. Non-equilibrium models of stochastic resource growth are more explicit in their treatment of periodic fishing behavior. For instance, Reed [6] and a number of subsequent authors consider a fishery in which participants face an infinitely-elastic demand curve in a discrete-period setting. It is assumed fishing will continue until the biomass-dependent unit cost of fishing is equal to price. This structure leads to a “constant escapement” strategy, whereby the optimal (socially and privately) periodic harvest is a linear function of the observed periodic stock. This modeling strategy relies on the assumption that fishers are able to adjust harvests at the margin, and that there are no countervailing incentives. We utilize this model, and posit that if some fishers engage in fixed-output contracts, there may be instances in which contract-maintenance incentives dominate immediate profitability calculations, which could lead to short-term over-exploitation.

The paper proceeds as follows. In the next section, we develop a simple theoretical model of fishery exploitation in a patchy environment. We then parameterize the model and simulate fishery outcomes using the NetLogo agent-based modeling software package<sup>c</sup>. This work is very preliminary, and thus our goal is not to make definitive statements regarding the effects of output contracts on resource exploitation, but simply introduce our basic methodology. In this light, we provide some discussion of results, and conclude with caveats and a description of future research goals.

## THEORETICAL MODEL

We assume a fishery is prosecuted by  $i = 1, 2, \dots, n$  fishers in discrete periods. At the beginning of each period  $t = 1, 2, \dots, \infty$ , the resource stock  $x_t$  is distributed randomly across  $n$  patches – each of which corresponds to a unique fisher – such that  $x_{it} \sim N(\bar{x}, \sigma^2)$ . Shaefer harvesting technology is assumed in the form  $h_{i\tau} = qx_{i\tau}z_{i\tau}$ , where  $\tau$  is used to index instantaneous, intra-period harvests and stock,  $z_{i\tau}$  is an aggregate effort variable with constant marginal cost  $c$ , and  $q$  is the catchability

coefficient. As harvests,  $h_{it}$ , remove biomass from each patch over a given period, stock-dependent costs increase such that total period harvest costs are given by

$$\int_{x_{it}-h_{it}}^{x_{it}} \frac{c}{qs_i} ds \quad (\text{Eq. 1})$$

In period  $t = 1$ , fishers are classified as either “wholesale” or “contract.” Wholesale fishers face a perfectly-competitive market with perfectly elastic demand at a price of  $p^l$ . Contract fishers are assumed to engage in fixed-volume contracts to directly supply their product to consumers (i.e., restaurants and retail markets). Bypassing the wholesale market allows contract fishers to command a higher price,  $p^h > p^l$ ; however, they must meet their contracted quota,  $\hat{h}$ , to maintain the contract in future periods. If a contract fisher fails to meet the contract in a given period, the contract is automatically cancelled for all future periods, and the fisher reverts to the wholesale market. Contract fishers earn  $p^h$  for  $h_{it} \in (0, \hat{h}]$  and  $p^l$  for  $h_{it} > \hat{h}$ . In the simplest case, we assume the harvest contract is structured so that  $\hat{h} = \bar{x} - \frac{c}{p^h q}$ ; that is, contracts are designed so that when patch stock is “average,” the contract yields the profit maximizing periodic harvest that would have been chosen by fishers facing  $p^h$  but without a contract.

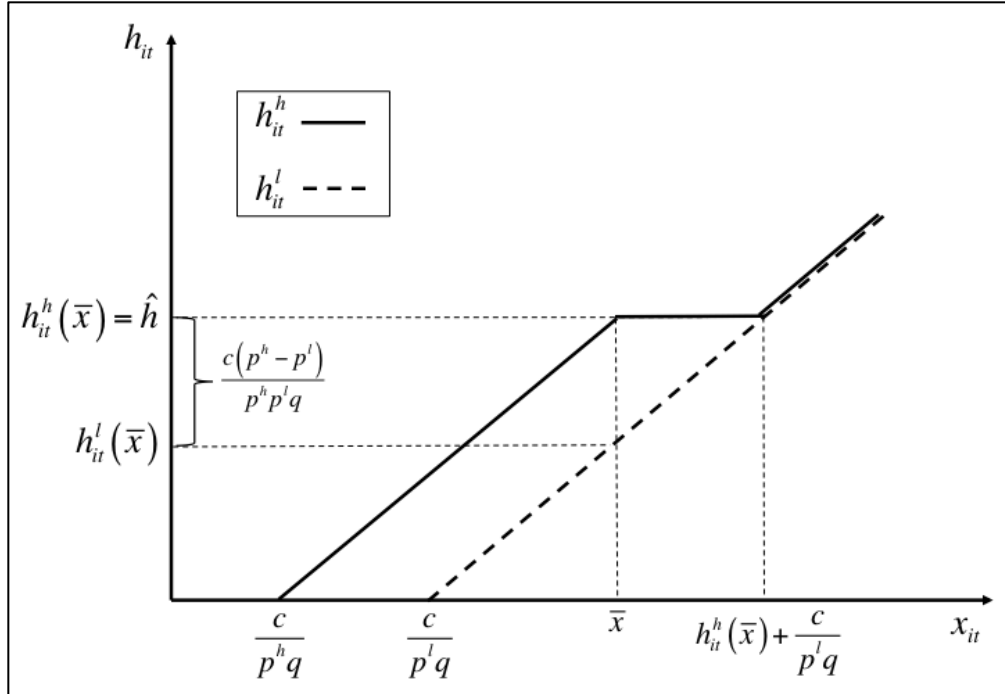
Define “escapement,”  $e_{it} = x_{it} - h_{it}$ , as the stock left in patch  $i$  by a profit-maximizing fisher. Periodic profits for the wholesale fisher are

$$\pi(x_{it}, p^l) = \max_{e_{it}} p^l(x_{it} - e_{it}) - \int_{e_{it}}^{x_{it}} \frac{c}{qs_i} ds \quad (\text{Eq. 2})$$

We ignore density-dependent growth, yielding

$$h_{it}^l = \begin{cases} x_{it} - \frac{e_{it}^l}{\overline{c}} & \text{if } x_{it} > \frac{c}{p^l q} \\ 0 & \text{if } x_{it} \leq \frac{c}{p^l q} \end{cases} \quad (\text{Eq. 3})$$

as the optimal harvest for the wholesale fisher. Fishers with a non-binding supply contract with consumers will follow a similar rule, with  $p^h$  replacing  $p^l$  for  $h_{it} \leq \hat{h}$ . The harvest functions for the two groups are depicted in Figure 1.



**Figure 1. Harvest choices as a function of realized stock. This figure assumes contract fishers are not required to meet fixed output contracts.**

The discontinuity in the high-price harvest function results from the assumption that the high price only applies to harvests up to the quota amount. Contract fishers only find it profitable to supply additional product to the wholesale market when realized stock is exceptionally high.

To evaluate the effect of a binding contract on the decisions of contract fishers, we restrict foresight to a single future period. When contract fishers experience  $x_{it} < \bar{x}$ , they must decide whether to meet their quota or default. The cost of meeting the quota when  $x_{it} < \bar{x}$  is equal to  $(\pi(x_{it}, p^h) - \pi(x_{it}, p^h, \hat{h})) > 0$ , and the benefit is equal to  $B(p^h, p^l) = \delta[\pi(\bar{x}, p^h) - \pi(\bar{x}, p^l)]$ , or the gain in expected profit next period associated with the contract<sup>d</sup>. With these restrictions, there are four possible outcomes for contract fishermen: harvest nothing and default, harvest less than  $\hat{h}$  and default, harvest  $\hat{h}$ , or harvest more than  $\hat{h}$ . These outcomes correspond to the following conditions:

$$h_{it}^h = \begin{cases} 0 & \text{if } \left( -\pi \left( \frac{c}{p^h q}, p^h, \hat{h} \right) \right) > B(p^h, p^l) \\ \overbrace{x_{it} - \frac{c}{p^h q}}^{< \hat{h}} & \text{if } \left( \pi(x_{it}, p^h) - \pi(x_{it}, p^h, \hat{h}) \right) > B(p^h, p^l) \text{ and } x_{it} > \frac{c}{p^h q} \\ \hat{h} & \text{if } \left( \pi(x_{it}, p^h) - \pi(x_{it}, p^h, \hat{h}) \right) \leq B(p^h, p^l) \text{ and } (x_{it} - \hat{h}) < \frac{c}{p^l q} \\ \underbrace{x_{it} - \frac{c}{p^l q}}_{> \hat{h}} & \text{if } x_{it} - \hat{h} > \frac{c}{p^l q} \end{cases}$$

In the first case above,  $x_{it} = \frac{c}{p^h q}$ , meaning the stock is so low it is not profitable to harvest anything this period, even at the high price. Further, the loss associated with meeting the contract is insufficient to cover the expected next-period benefits of maintaining the contract,  $B(p^h, p^l)$ . In the second case, the contract fisher defaults, but finds some positive harvests to be optimal. In the third case, it is advantageous to fulfill the contract, but not profitable to supply additional product to the wholesale market. The transition from the second to third cases is denoted by point *A* in Figure 2, and represents the point at which the costs of maintaining the contract – in terms of forgone current-period profits – are exactly equal to the next-period benefits. Finally, in the fourth case the stock is so large that not only is the contract filled, but additional harvests are supplied to the lower-price wholesale market.

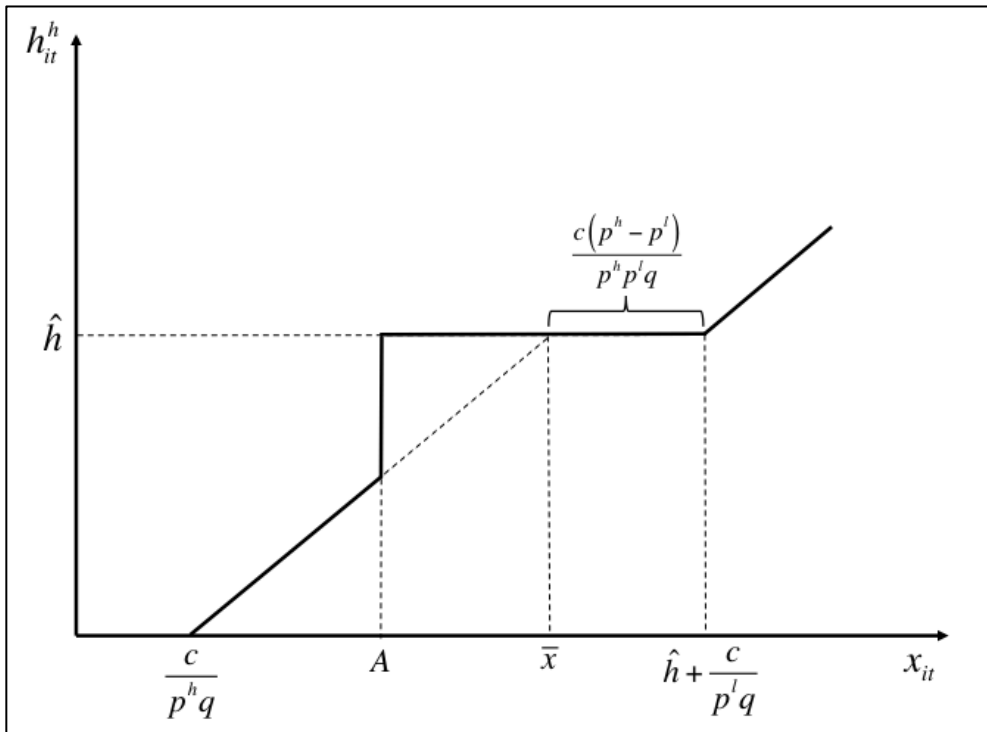


Figure 2. Harvest choices as a function of stock for fishers with contracts.

The inefficiency of contracts is represented by the area between point  $A$  and  $\bar{x}$ . When realized stock falls between these two points,  $\hat{h} > x_{it} - \frac{c}{p^h q}$ , and meeting the contract requires fishing the stock down below  $\frac{c}{p^h q}$ . This result is similar to that which we would expect if fishers engage in “revenue targeting,” which can lead to negative labor supply elasticities in the short run [6,7].

The model above can be examined to suggest a number of outcomes regarding the inefficiency introduced by contracting (i.e., contract fishers fishing beyond their “optimal” level for the purpose of maintaining a contract). As mentioned above, this inefficiency will grow as  $A$  falls. The value of  $A$  will fall as  $p^h$  (the contract price) increases. In this circumstance, the benefits of maintaining the contract,  $B(p^h, p^l)$ , will increase, and the costs of meeting the contract in a “low-stock” period will fall. Likewise, as  $p^l$  increases,  $B(p^h, p^l)$  will fall and  $A$  will rise.  $A$  will also rise with the discount rate, as contract fishers assign less value to profits next period. As the cost of effort rises, or the catchability coefficient falls, unit costs of fishing will rise more rapidly as stock is drawn down in a given period, which will both increase the cost of meeting the contract in a “low-stock” period, and reduce  $B(p^h, p^l)$ , thereby leading to an increase in the critical point  $A$ . Finally, as  $\sigma$  (the standard deviation of the normally-distributed random stock variable) increases, we would expect contracts to lead to more inefficiency; however, that relationship is likely non-monotonic, and also does not account for the possibility that there is a relationship between resource variability and the likelihood of fishers engaging in contracts in the first place. In the next section, we parameterize our simple model and simulate fishery outcomes.

## SIMULATION OF FISHERY OUTCOMES

To evaluate the impact of contracts on fishery outcomes, we utilize the NetLogo agent-based modeling (ABM) software package. Agent-based modeling is a useful way to model complex systems in which a number of individual “agents” interact with each other and their environment. Models are structured from the bottom up, with agents assumed to act according to a well defined set of rules. While our model is simple enough to be run in excel or other statistical packages, the goal is to gradually impose further complexity that will, we believe, not allow for analytical solutions. Figure 3 offers a snapshot of the NetLogo interface<sup>e</sup>.

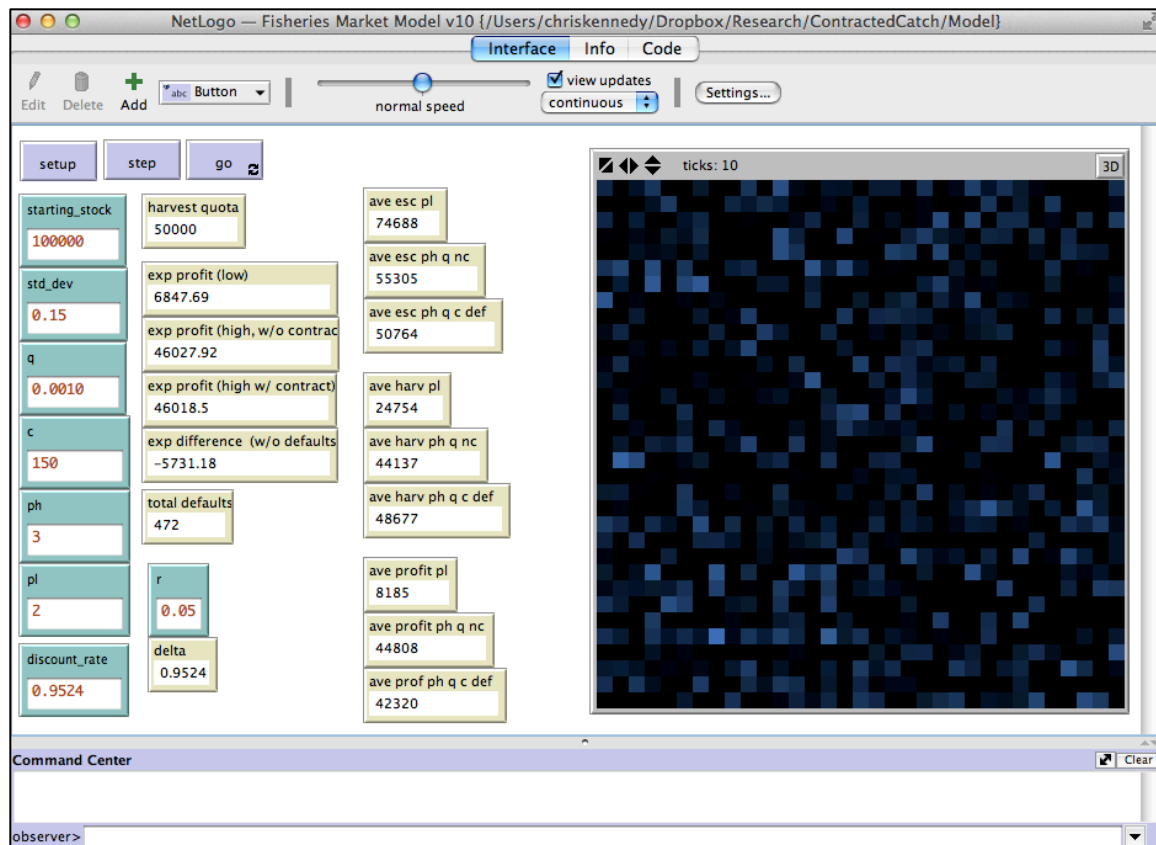
In the most basic model, fishers are the agents, and they interact with their environment but not with each other. In each period, fishers are randomly assigned to patches in a grid containing a locally-exclusive, randomly drawn (from normal distribution) stock of fish, and harvest under three scenarios: wholesale price, contract price (up to quota) without contract, and contract price with contract. In other words, our model essentially assumes  $n$  different fisheries, each prosecuted by a single fisher, with stochastic stock regeneration that is independent of local or aggregate fishing effort. Our parameterization is provided in Table I.

Table I. Parameterization for the basic model.

Parameters	
Grid size	33x33
# fishers/patches	1,089
<b>Economic</b>	
$c$	150
$q$	0.001
$p^h$	3
$p^l$	2
$r$ (interest rate)	0.05
$\delta$	0.9524
<b>Biological</b>	
$\bar{x}$	100,000
$\sigma$ (standard deviation)	15,000

The result of this parameterization is  $\hat{h} = 50,000$  and  $h_{it}^l = 25,000$ . In other words, in an “average” period, the contract fishers will harvest half the stock, and the wholesale fishers will harvest a quarter. Further, point  $A$  in Figure 2 occurs at  $x_{it} = 72,490$ , or when realized stock is approximately 27.5% below average. When  $x_{it} < 72,490$ , contract fishers find the cost of meeting the contract to outweigh the benefits. When  $x_{it} < 50,000$ , contract fishermen harvest nothing ( $x_{it} < 75,000$  for wholesale fishers). Given the numerical solution for  $A$ , we can estimate that approximately 3.5% of contract fishers will default ( $z$ -score of -1.83).

We are interested in evaluating the extent to which contracts might undermine biological and/or economic outcomes in the fishery. For this reason, we primarily focus on harvest and escapement outcomes between contract fishers and non-contract fishers with the contract pricing structure. For each randomly-stocked patch in each iteration, we calculate expected escapement and harvest under the low price, the high price, and the high price with the contract<sup>f</sup>. We also count the number of “defaults” in each iteration that would have occurred if all 1,089 fishers were under contract.



**Figure 3. The NetLogo interface. The left side of the screen contains parameters and outcomes of interest, while the right side displays a simulated landscape of stock values. Lighter colors are less dense, and darker colors are more dense. Above the right side is a “ticks” box, which represents the iteration count.**

A few numerical results are worth pointing out. First, our model does converge numerically to confirm our assertion of 3-4% of stock realizations resulting in default. Second, the average additional harvest associated with binding contracts is approximately 10% (49,000 vs. 45,500 for high-price, non-contract fishers). Contracts are also associated with reduced profit, on average (\$40,000 vs. \$45,000), but still dramatically outperform average low-price profits of \$6,800, per period.

Examining the results of this model also reveals how fishers might manage some of the risk associated with direct marketing. For instance, our assumption of uncorrelated resource uncertainty suggests bilateral partnerships would always offer efficiency gains, so long as those partnerships are of the contract-contract or contract-wholesale variety. Wholesale-wholesale partnerships offer no gains, as fishing technology/skill is identical across individuals. We can also posit that contract-wholesale partnerships, whereby fishers with contracts partner with wholesale fishers to supply product when own-patch conditions are poor, will generally offer greater efficiency gains than contract-contract partnerships, as the opportunity cost of sub-contracting in the latter is higher. Finally, it is straightforward to show that ITQs represent a limiting case of the partnership scheme, in



which all fishers are partners (i.e., part of a cooperative with and output-sharing arrangement).

## CONCLUSION AND FUTURE DIRECTIONS

This paper has introduced a basic model of output contracts for seafood products. As with many other industries, the fishing industry has begun to take advantage of increasing demand for locally produced, sustainable products by contracting with end consumers directly. This process of “direct marketing” is furthered, in some circumstances, by the “thin” nature of many seafood markets, for which there are only a few wholesale buyers and/or limited transaction information, thus leading to unfavorable wholesale pricing structures. However, in bypassing the wholesale market, fishers may be taking on resource risk that is traditionally mitigated by the increased liquidity of wholesale markets. Specifically, our model assumes fishers must meet output “contracts,” and that if those contracts are not met, they automatically revert back to the wholesale market.

We have made a number of simplifying assumptions<sup>6</sup>. Regarding resource dynamics, we have ignored any stock effects associated with harvesting. This is clearly unrealistic for most resources (although some crop species, such as shrimp, may only experience very weak stock effects). Further, we have assumed the stock is not correlated across patches, or across time within patches, and we have ignored the possibility of an overarching stock uncertainty; that is, the expected value of the stock in each patch is equal to  $\bar{x}$ . We have implicitly assumed a homogeneous product, whereas there is evidence some direct marketers cater to customers that require a higher-than-average product quality [4,5]. Regarding fishing behavior, we have assumed fishers are risk-neutral. While there is evidence suggesting fishers may in fact be either risk-averse or risk-loving (perhaps validating our assumption), risk-neutrality in this context leads to a more salient secondary assumption; namely, that contracts will be structured so that in an “average” period, the contracted harvest quantity coincides with the profit-maximizing level of production. It seems reasonable that many fishers would instead prefer to contract for a quantity lower than what they expect to harvest in an average period, to avoid the risk associated with a particularly deleterious stock realization. We have also assumed fishers only consider two periods when making decisions about meting contracts. This means the cost of losing a contract indefinitely is artificially low, as one would expect fishers would capitalize contract benefits from multiple future periods when making decisions. On the other hand, we have assumed that not meeting the contract results in a permanent loss of the contract, also unrealistic. We have also neglected to consider the important issue of the cost of contracting. As mentioned in the introduction, there are significant logistical hurdles involved in successfully direct-marketing. These include the need for potentially significant investments in human and physical capital related to the establishment and maintenance of client accounts, integration of value-added processes typically handled by wholesalers, processors, and/or distributors, and navigation of administrative and regulatory hurdles. It is likely the majority of these costs are fixed in nature, and it is not clear how, ex ante, these would impact the model presented here.

Near-term extensions to this model include the introduction of “meta-stock” dynamics, in which aggregate fishing pressure impacts the growth or deterioration of  $\bar{x}$ , as well as an explicit consideration of spatial resource dynamics, in which local patch stock is both path-dependent and subject to diffusion processes among adjacent patches, in the spirit of [8]. On the economic side of the model, we plan to model a constrained market for contracts, in which lost contracts are picked up by fishers from the wholesale pool. Further, we plan to more closely examine the assumptions regarding the contracted harvest quantity. To evaluate the potential for fishers to manage the risk associated with harvest contracts (and the implications of this type of incentive structure for fishery management) we plan to evaluate a number of regulatory structures, including a system of ITQs, randomly assigned partnerships, and spatial management. Finally, we hope to calibrate the model to a specific fishery that has a measurable degree of direct contracting activity in an effort to determine the relative importance for resource outcomes.

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<sup>a</sup> For our purposes, we use the term thin to describe wholesale markets characterized by wholesaler market power and/or small numbers of buyers/sellers. For instance, Wilson shows that the theoretical efficiency of the New England fresh fish market is seriously undermined by slow dissemination of information and other informational and market failures, leading to long-term bilateral arrangements between fishers and wholesalers.

<sup>b</sup> See <https://afs.confex.com/afs/2010/webprogram/Session1108.html> for a list of abstracts from a 2010 American Fisheries Society conference session on local/direct marketing of seafood, and <http://www.localcatch.org/resources.html> for an overview of community supported fishery (CSF) programs.

<sup>c</sup> The software is freely available at: <http://ccl.northwestern.edu/netlogo/>.

<sup>d</sup> Since profits are a linear function of harvests, and harvests are a linear function of stock, expected profit is equivalent to profit at expected stock  $\bar{x}$ .

<sup>e</sup> To request a copy of our code, please contact Steve Scott.

<sup>f</sup> Note that due to the non-interactive nature of the model as presented here, an iteration in the model can be thought of as 1,089 random draws.

<sup>g</sup> We focus on those that are related to our specific model or otherwise depart from the literature.