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The Economic Effects of Catch Share Management: The Rhode Island Fluke Sector Pilot Program

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Abstract *In 2009, Rhode Island implemented a pilot catch share program around summer flounder, or fluke, a state-managed species that is jointly harvested with the Northeast Multispecies groundfish complex. A sector was given a fluke allocation to land when they wished, while the rest of the fleet was managed through sub-seasonal total harvest caps and daily trip limits. Sector members avoided fluke landings during seasonal fluke derbies, instead shifting landings to post-derby closures in the general fishery, when the price was higher. However, they also affected prices of species they targeted instead. We combine predictions of counterfactual 2009 daily landings by sector vessels with a panel model of trip-level ex-vessel prices for 25 products targeted by the groundfish fleet to project what revenues would have been in the absence of the sector program. We find the pilot program increased fleetwide revenues by over $800,000, including benefits of over $250,000 to non-sector vessels.*

Key words Catch shares, individual fishing quota, race-to-fish, sector management, New England groundfish.

JEL Classification Codes Q22, Q58.

Introduction

In January 2009, the director of the Rhode Island Department of Environmental Management (RIDEM) approved a proposal advanced by an industry group to initiate a pilot catch share management program for summer flounder (*Paralichthys dentatus*), or fluke (RIDEM 2009). This Rhode Island Fluke Sector Pilot Program (RIFSPP) divided the fleet into two groups: eight mid-sized vessels of the Rhode Island Fluke Conservation Cooperative (RIFCC), and the rest of the fleet. The RIFCC was allocated a collective quota of 194,000 pounds (11.53% of RI's quota),[1] which they could harvest at any time

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[1] Allocation was based on 2004-2008 fluke catch histories.

they wished, provided they did not fish with gear capable of catching fluke once their allocation was met. Non-sector vessels were managed, as in recent years, by a system of seasonal sub-period fleetwide total allowable catch levels (TACs): Winter I (January through April), where predominantly large offshore trawlers pursue 54% of the annual quota; Summer (May through October), where a large number of smaller vessels using a variety of gear race-to-fish for 35% of the quota, largely in state waters; and Winter *II* (November and December). Within each sub-period, fluke is managed by daily (or weekly, in Winter) possession limits, typically hundreds or thousands of pounds during the Winter sub-periods, and ranging from 100 to as low as 50 pounds during the Summer derby. Non-sector vessels catching fluke in excess of the daily limit, or after the current period's quota is exceeded, must discard. This article presents analysis testing the hypotheses that *i)* RIFCC members changed their harvesting behavior in response to this regulatory change; *ii)* that they were able to make themselves better off through the change; and *iii)* that they did not do so at the expense of non-sector vessels.

Spearheaded by a prominent harvester, the RIFCC is an incorporated non-profit pursuing "safe, stable and sustainable fishing practices" (RIOSS 2008). The eight members are known for being innovative and active in management and cooperative research within a small state, but they are different ages, have different histories in non-fluke fisheries, and do not all share other family or community ties. As a private business entity, the RIFCC guarded many internal operations in a charged political environment. They effectively managed their collective 2009 fluke allocation as an individual fishing quota (IFQ), intending for each member to catch his historical share of the allocation. When it became clear some members would not catch their share late in the season, they "gave" their shares to other members. In catching their quota, the RIFCC emphasized improved harvest timing and a "return to the way we used to fish" before seasonal derbies with strict trip limits as primary benefits, and efforts were made to coordinate landings to ensure a range of dealers had a steady supply of fluke. Other activities common in cooperatives, such as information sharing, cost reduction, effort coordination, revenue pooling, and joint marketing/advertising, were not a focus of RIFCC activities (Uchida *et al*. 2010).[2]

While a program affecting eight vessels landing only 1.8% of the coastwide quota may not seem to be of wide interest, it is a pilot with broad implications for both the design and analysis of larger sector-based catch share programs. From the design perspective, through a fluke of summer flounder management, the RIFSPP gives a year-ahead window into the way the federal sector Northeast Multispecies groundfish fishery might operate. Although it is jointly harvested with the Northeast Multispecies complex in Southern New England, fluke has a range that spans the New England and Mid-Atlantic Fishery Management Councils' jurisdictions. As such, even though fluke is harvested in federal waters it is managed by the individual states, coordinated through the Atlantic States Marine Fishery Commission (ASMFC). Therefore, Rhode Island's state program allows testing hypotheses regarding sectors on the grounds on which most federal Northeast Multispecies sectors would fish, based around a depressed groundfish stock, and with the trawl gear most federal boats use.[3] In addition, it provides a valuable data point in the national trend of extending catch share management to ever more complex fisheries.

The key hypothesis to be tested is the extent to which harvesters are able to effectively control the mix of species they catch throughout the year in response to cumulative caps and market opportunities. This is an underlying premise of catch share management systems. The argument that harvesters have limited ability to target among groundfish

[2] As the RIFCC has evolved after 2009, some members have emerged as leaders in developing Wild Rhody Seafood, a joint marketing venture designed to directly supply local seafood to restaurants and consumers.

[3] The Cape Cod Commercial Hook and Georges Bank Fixed Gear Sectors, which are allocated cod quota, have operated successfully for several years and provided a partial framework for the operation of other federal sectors. However, they consist of smaller vessels using more selective gear and fishing nearer shore than the bulk of the Northeast Multispecies fishery.

species has shaped management in the Northeast Multispecies fishery, which has favored input restrictions (*e.g.*, gear restrictions and days-at-sea limits) to methods that halt mortality on species whose guideline harvests have been exceeded (and, consequently, species jointly harvested with closed species). However, the 2006 reauthorization of the Magnuson-Stevens Fishery Conservation and Management Act now requires fisheries to have landings-based shutdown provisions, introducing targeting incentives that were not present before. In addition, new technology, better records, and an improved ability to share information on the location of fish (to harvest or to avoid) provide harvesters new tools to respond to these incentives. The RIFCC argued that, while it would indeed be necessary to redeem some of their fluke quota while targeting jointly harvested species, they could use the balance to target fluke when the market price is particularly high, especially when the common pool fluke fishery is closed. Thus, the flexibility of harvest amount and timing allowed under the RIFSPP would allow the RIFCC to adhere to mortality-reducing regulation while becoming more profitable.

Despite the push from within the industry and the scientific value of a pilot, the Rhode Island Marine Fisheries Council (RIMFC), which has legislative authority to make recommendations to the RIDEM director, voted (4–3) against the pilot proposal in 2009, much as it had similar proposals from the same group in the previous three years. Three categories of arguments were presented by the well-organized, vocal opposition. First, there was concern that the sector program would not be good for, or even be bad for, the fluke stock. Sector opponents feared the sector members were designing the program such that they would be able to easily skirt the restrictive rules. In particular, they were concerned sector members would discard small or low-value fluke in violation of RIFSPP rules, increasing mortality over current regulations (cf. King and Sutinen (2010) on perceived compliance in this fishery). In response to this, the sector regulation required extensive discard reporting, 25% onboard observer coverage (more than 10 times the norm for the vessels involved), and extensive testing for discarding behavior.

Second, harvesters not interested in joining the sector were concerned that they would be made worse off by the landing behavior of sector members. One often-expressed concern was that sector members, exempt from daily trip limits and required to land all legal-size fluke, would land their allocation in a few huge landings, driving down the price for non-sector vessels on those days. Another was that the lack of daily trip limits would incentivize the sector members to take a small number of low-cost trips to the fertile inshore grounds frequented by recreational and small hook-and-line commercial harvesters in Summer, wiping the inshore grounds clean with their trawls. RIFCC members countered that they do not fish inshore under current regulations, and that the value of the quota is in flexibility of joint harvesting with other species, so harvesting during the common pool opening or in a small number of trips was not in their interest.

Third, many harvesters were opposed to allocating a share of a public resource to a particular group of users. Some of this opposition arose from the specific years chosen to determine the sector's share; indeed, the RIFCC's allocation was a larger share of the RI fluke quota than they had harvested in the most recent qualification years. However, the more frequently voiced argument was philosophical opposition to catch share management, with many harvesters expressing the view that it is not fair (or in accordance with the state constitution)[4] to exclude them from accessing a portion of a public trust resource by allocating part of it to a

[4] Presenters of this argument cite Section 17 of Article I of the RI Constitution: "The people shall continue to enjoy and freely exercise all the rights of fishery, … and they shall be secure in their rights to the use and enjoyment of the natural resources of the state." It further specifies that, "it shall be the duty of the general assembly to provide for the conservation of the air, land, water, plant, animal, mineral and other natural resources of the state, and to adopt all means necessary and proper by law to protect the natural environment of the people of the state by providing adequate resource planning for the control and regulation of the use of the natural resources of the state and for the preservation, regeneration and restoration of the natural environment of the state." *Riley v. Rhode Island Department of Environmental Management*, 941 A.2d 198 (R.I. 2009) establishes that the state may both limit access to fisheries through the issuance of licenses, and through allocation among licensees.

select group of individuals (cf. Macinko[5] and Bromley 2002). This remains an active tension in state management, but an explicit objective of the pilot is to provide an assessment of the benefits that can be achieved by allocating resource use rights in a more focused way.

In addition to providing critical tests of some underlying principles used to design catch share programs, the RIFSPP provides a platform for innovations in the theoretical and empirical frameworks used to test for conjectured behavioral responses to, and analyze the effects of, the change in management structure. Two innovations are necessary. First, theoretical models of fishery management have emphasized the interseason stock externality and how the choice of annual harvest level affects recruitment into following years. In the fluke fishery, however, the extent of the interseason externality is established by ASMFC and not affected by the RIFSPP. Rather, the RIFSPP follows a trend in contemporary fishery management by presenting incentives for harvesters to alter targeting and market timing *within* the 2009 season: the primary unit of analysis must be the daily targeting decision and consider the rate of quota use throughout the year, with externalities assessed on a daily time scale. This requires a conceptual framework wherein daily decisions are made subject to cumulative annual constraints and an empirical strategy that leverages trip-level data.

Second, all models of which we are aware apply a single management system to a fishery, but the RIFSPP establishes two management systems that operate concurrently. Thus, in deciding when to use their quota, harvesters operating within the RIFSPP must consider not only the harvesting strategies of others operating under RIFSPP rules, but also those of non-sector harvesters. Accordingly, the counterfactual policy environment against which the RIFSPP will be assessed must recognize the strategic effects of the within-group and between-group strategic game and take into account the shifts in targeting and market timing behavior that not only reflect changes in the rules that apply to sector members, but also the different rules under which non-sector harvesters are operating. A framework for analyzing such multiple-managed fisheries is useful not only for the RIFSPP, but also for the many management arrangements that will arise under federal Multispecies sectors; in other catch share programs; and in transboundary fisheries, including boundaries between nations, states, or state and federal waters.

This article uses the arguments presented for and against the fluke sector as a basis for developing and testing hypotheses about the effect of the RIFSPP, as implemented by the RIFCC in 2009. The next section lays out our conceptual framework around which we structure an analysis of daily targeting decisions, deriving economic hypotheses against which many of the arguments serve as alternatives. Outcomes in the 2009 fluke fishery are described in the third section. Following this, the Methods section presents our empirical framework; first an econometric model of trip-species specific prices for 25 fish products targeted by Multispecies fishery vessels, and then two methods used to establish counterfactual 2009 landings for sector vessels in the absence of the RIFSPP. These models are then combined in the Results section to calculate the economic effects of the RIFSPP accruing to sector and non-sector vessels.

Conceptual Framework

A conceptual framework is necessary to identify the relationships among harvest, market effects, and management incentives affecting sector and non-sector vessels that will govern the structure of the empirical analysis. The essential problem we wish to examine is the individual daily targeting and landings choice subject to a specific regulatory environment and the decisions of other harvesters. As a starting point we consider the classic dynamic optimization framework, where individual harvesters seek to maximize profit subject to biological, regulatory, and time constraints (*e.g.*, Smith (1969) and Clark

[5] Macinko is a member of the RIMFC, along with author Anderson.

(1980)). In accord with Homans and Wilen (1997), stock recruitment and mortality considerations may be excluded as the empirical analysis takes place within a single year.

An ex-vessel price dependent on aggregate daily landings is perhaps an initial point of departure from the majority of relevant theoretical models (cf. Fell 2009). In this environment, the contemporaneous dependence of price on total daily landings means prices are lower on days with higher landings. If the daily discount rate is negligible, the social planner maximizes fishery rent when daily harvest is spread evenly (equated) throughout the available season: if a day has high landings, those landings could be shifted to a day with lower landings, increasing the price he receives and the price received by others on the high landings day. While those landings on the previously lower-landings day receive a lower price, it affects fewer landings and is more than offset by the increased price on the previously higher-landings day.[6]

In a competitive environment, the total landings—and thus price—are determined by the aggregate effects of individual decisions, and in Nash equilibrium harvesters take into account the decisions of others in making their own choices. In well-studied static common pool environments, Walker, Gardner, and Ostrom (1990) observe outcomes much closer to Nash equilibrium than to the social optimum in an unregulated experimental game. Played out over a season, this means that because individual harvesters do not have a secure claim on fish they do not harvest, they race-to-fish and catch the entire TAC quickly, landing large amounts each day until the season is closed, despite the lower prices (cf. Homans and Wilen 2005). In a model that looks at harvester incentives similar to those presented by the RIFSPP, Huang and Smith (2010) use a seasonal-level dynamic game with contemporaneous production and intertemporal stock externalities to model the allocation of shrimping effort throughout the season. Conditioned on observed fishing behavior being consistent with the Nash equilibrium of the dynamic game, they find evidence of a net positive congestion externality, though large losses result from the dynamic stock externality.

Under the RIFSPP, the sector no longer needs to participate in the race-to-fish to capture its share of the TAC; it can determine its own rules for harvesting its quota. The RIFCC's approach is best approximated by IFQ management. This type of management system provides each harvester a secure claim on their individual annual landings quantity through their quota, encouraging harvest at the time when it yields the highest return. If all harvesters have this flexibility, then each follows the landings timing logic of the social planner, striking a balance between the discount rate and the negative price externality. The resulting Nash equilibria daily harvest levels of the competitive individual quota game correspond to the social planner's solution, maximizing rent from the fishery.[7]

The RIFSPP establishes a situation where not all harvesters are operating under the same set of rules, so neither the TAC-managed nor the IFQ-managed scenario applies in its entirety. Solving for closed-form Nash equilibria of this dynamic game with multiple concurrent management systems is beyond the scope of this empirical work, but comparing the equilibrium strategies outlined above with the stories the RIFCC presented for how they would benefit from the RIFSPP, establishes expectations of the changes in harvest behavior likely to be observed under the pilot program and the framework and comparisons needed to test for the economic effects of the RIFSPP.

The presence of some quota-managed harvesters does not resolve the race-to-fish in the common pool fishery that controls 88.5% of the fluke TAC, so non-sector vessels will still fish as intensively as is feasible until the common pool quota is exhausted and the fishery closed. This presents an opportunity for RIFCC members to reduce their harvest during the spring—at the times of highest aggregate landings, when they get low prices—

[6] This is necessarily the case if $\frac{dp_t}{dq_t} < 0$ and $\frac{d^2 p_t}{dq_t^2} \leq 0$, where p_t is price on day t, and q_t is total landings on day t.

[7] It should be noted that if the stock is heterogeneous, costs are stock dependent, or if demand is seasonal then IFQs fail to fully internalize all externalities and fishery rent is some fraction of the maximum (Costello and Deacon 2007; Holland 2004; Fell 2009). These factors are not dominant in the RI fluke fishery.

shifting them instead to the late Summer, when the rest of the fishery is closed and the sector is the only group that can land and receive much higher prices.

In application, this story is complicated by the fact that both RIFCC members and non-members harvest fluke as part of multispecies operations (cf. Abbott and Wilen 2009). Thus, the RIFCC cannot use its entire fluke quota during the Summer closure, as some is used in joint harvesting at other times of the year. However, if harvesters have the ability to adjust their targeting and time the market, we would expect RIFCC members to avoid landing fluke during the common pool fishery opening, and instead focus on landing it when the general fishery is closed (in late Summer). Non-sector vessels, in contrast, would continue to race-to-fish. As a result, RIFCC members will receive higher average prices for fluke, and the common pool fluke harvesters will also receive slightly higher prices as a result of the sector's shift out of the common pool fishery. However, the RIFCC will likely target other species during the common pool fluke openings, increasing daily supply and thus reducing prices on those particular days. How these multiple offsetting effects aggregate to produce total RIFSPP impacts depends on the relative price flexibilities of the species pursued by each vessel and the fleet overall.

The 2009 Rhode Island Fluke Fishery

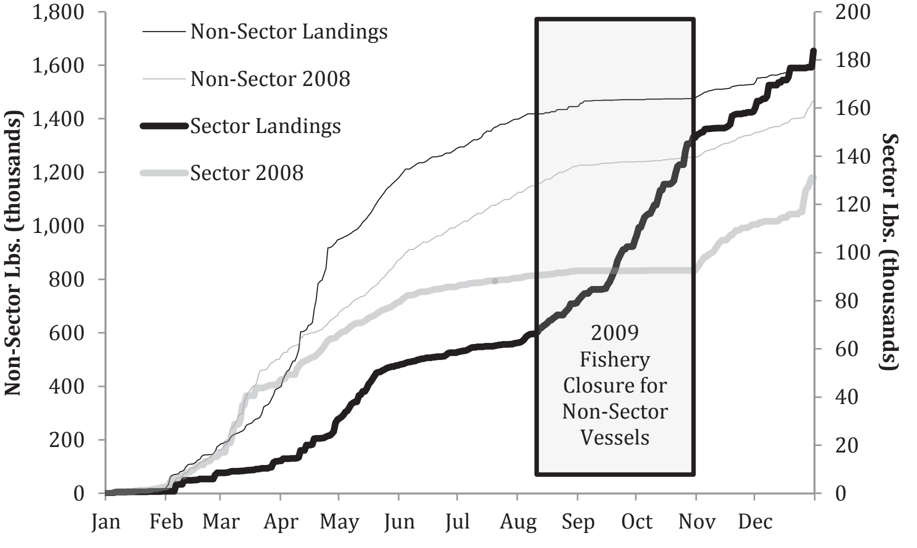
Figure 1 depicts the timing of sector and non-sector fluke landings in 2008 and 2009. Several features agree with harvest timings suggested by our dynamic game conceptual framework. First, the non-sector vessels timed their landings similarly in the two years, with medium and large trawlers dominating the Winter sub-periods and smaller vessels racing to fish during the Summer sub-period before a closure. Second, the RIFCC vessels responded to the pre-RIFSPP management incentives in the same way as other medium and large trawlers in 2008, landing the majority of their fluke during the Winter sub-periods, when fluke mix with other groundfish. Third, in 2009 RIFCC vessels reduced their Winter I fluke harvest, saving the quota until the Summer fluke closure, when no one else could land.[8] This strategy achieved higher value for their quota because the portion used in Winter supported joint harvest of other high-value species, and that reserved for the common pool closure obtained higher prices. Overall, the RIFCC averaged \$2.76 per pound for fluke and \$2.97 per pound during the Summer closure. The rest of the fleet averaged \$2.40 per pound.[9]

Interpreting the consequences of these changes in harvesting behavior for the fluke stock requires understanding discard behavior, which is a significant component of fluke mortality under current regulations. Fears that high-grading by sector vessels—in violation of RIFSPP rules—would offset stock benefits were a primary argument against the RIFSPP. RIDEM (2010) compared size compositions of RIFCC fluke landings on observed and unobserved trips and concluded that the RIFCC was indeed keeping all legal fish, as required.[10] Comparing RIFCC behavior with that of trips observed in 2008, RIDEM concluded that RIFCC vessel fluke discards were 98% lower than in the general fishery, and thus that the RIFSPP "had a positive effect on the summer flounder resource by dramatically reducing discards" (p. 14).

While the RIFSPP induced changes in fluke landing patterns, it similarly caused RIFCC vessels to alter their landings patterns of other species. Table 1 presents an overview of RIFCC and non-sector annual landings of target species in 2008 and 2009. Within each section, species are sorted by 2008 revenue ranking to RIFCC vessels to facilitate easy identification of important shifts in targeting behavior. Consistent with expectations

[8] Although the regulatory process did not allow the RIFSPP to officially commence until April 12th, sector members anticipated the program and harvesting behavior was altered throughout the year.
[9] RIFCC ex-vessel fluke prices during 2009 common pool sub-period openings were less than 5% higher than those received by federally permitted non-sector vessels.
[10] The RIFCC was required to discard undersized fluke. They were also permitted to discard unsellable damaged fluke, provided they reported the mortality and counted it against their quota.

based in the conceptual framework, the non-sector vessels did not meaningfully change their overall harvesting strategy in response to the RIFSPP; only herring (*Clupea harengus*) rose more than two ranks, and only winter flounder (*Pseudopleuronectes americanus*) (due to the imposition of a 50-pound bycatch possession limit) and black sea bass (*Centropristis striata*) (due to decreased TAC) fell more than two ranks.



Note: Rhode Island fluke TACs were approximately 1.5 and 1.7 million lbs. in 2008 and 2009, respectively.

Figure 1. Cumulative Fluke Landings by RIFCC (sector) and Non-Sector Vessels

However, as suggested by the conceptual framework, RIFCC members did change their targeting of non-fluke species in response to the change in fluke management. To avoid fluke during Winter I, sector members focused on herring, cod (*Gadus morhua)*, and other species of flounder more than they had in previous years, increasing their revenue importance. During the Summer sub-period fluke opening, sector vessels targeted spiny dogfish (*Squalus acanthias*) and whiting (*Merluccius bilinearis*), which each rose seven ranks. After the fluke fishery closure on August 9th, sector members targeted spiny dogfish, butterfish (*Peprilus triacanthus*), and whiting, in addition to fluke. During the Winter II sub-period, RIFCC vessels continued to fish their fluke allocation as well as butterfish and scup (*Stenotomus chrysops*). Targeting of long-finned squid (*Loligo pealei*), skates (primarily *Leucoraja* sp.), and monkfish (*Lophius americanus*) continued in their previous timing patterns, although reduced in aggregate quantity.

In addition to fears about stock effects, opponents of the RIFSPP were concerned that sector landings patterns would lead to lower prices for non-sector vessels. The RIFCC did not have any extremely large landings that "crashed" the daily fluke price for other boats, or engage in intensive inshore fishing, as was feared when daily trip limits were lifted. However, prices did decrease between 2008 and 2009, as total fishery revenues (excluding shellfish and lobster) fell from $40.8 million in 2008 to $37.6 million. Table 1 shows prices fell for every species, and while sector prices for fluke fell also, it was much less so than for non-sector vessels, galvanizing opposition to the RIFSPP as a policy that makes a few vessels better off at the expense of the rest of the fleet.

Table 1

Total Quantity, Average Price per Pound, and Revenue Rank of each Product considered in the Analysis for RIFCC and Non-Sector Vessels

RIFCC Vessels							Non-Sector Vessels					
2008 (Pre RIFSPP)			2009				2008			2009		
Total Quantity	Avg. Price	Rank	Total Quantity	Avg. Price	Rank	Species	Total Quantity	Avg. Price	Rank	Total Quantity	Avg. Price	Rank
131,171		2	183,739		1	**Fluke**	1,342,799		3	1,610,463		3
37,620	3.69		57,681	3.02		**Fluke (jumbo)**	359,962	3.64		452,871	2.75	
68,527	3.33		86,417	2.89		**Fluke (large)**	755,346	3.33		871,615	2.71	
24,487	2.24		39,370	1.93		**Fluke (medium)**	208,307	2.46		274,684	2.06	
						Federally Regulated Multispecies						
173,309	*1.88*	*5*	*42,174*	*1.67*	*11*	**Winter Flounder**	*464,487*	*1.90*	*7*	*288,433*	*1.53*	*11*
54,966	2.14	8	61,301	1.65	9	**Yellowtail Flounder**	311,085	1.80	11	397,640	1.43	10
37,429	2.18	9	80,983	1.84	7	**Cod**	195,524	2.00	13	256,963	1.64	12
14,242	0.53	15	12,575	0.51	16	**Windowpane Flounder**	38,092	0.41	20	24,743	0.37	20
961	2.39	20	254	1.79	21	**Grey Sole**	57,931	3.09	15	86,792	2.57	15
9,804	*0.20*	*21*	*24,167*	*0.17*	*18*	**Hake**	616,362	0.24	16	419,374	0.22	18
						Other						
568,321	1.04	1	419,036	1.02	2	**Squid**	14,100,000	1.02	1	10,700,000	1.01	1
3,436,343		*3*	*1,888,433*		*6*	**Skate**	5,670,444		8	6,062,349		8
133,453	0.43		67,323	0.42		**Skate (wings)**	1,053,300	0.40		1,472,654	0.37	
3,302,890	0.09		1,821,110	0.09		**Skate (rounds)**	4,617,144	0.09		4,589,695	0.09	
193,360	1.82	4	119,240	1.77	5	**Monkfish**	5,102,311	2.09	2	4,398,620	1.82	2
1,197,440	*0.16*	*6*	*2,274,220*	*0.15*	*3*	**Herring**	*3,306,981*	*0.16*	*12*	*7,253,841*	*0.15*	*7*
154,863	1.11	7	170,802	0.80	8	**Scup**	1,998,710	1.18	5	3,447,964	0.74	5
91,185	0.47	10	191,187	0.38	10	**Mackerel**	2,293,986	0.58	6	8,866,136	0.45	4
38,378	*0.90*	*11*	*465,592*	*0.53*	*4*	**Whiting**	3,198,532	0.82	4	3,176,572	0.67	6
51,691	0.33	12	57,786	0.29	13	**Bluefish**	363,308	0.39	17	439,596	0.30	16
4,257	3.74	13	3,867	3.42	15	**Black Sea Bass**	*222,808*	*3.44*	*9*	*124,214*	*3.28*	*13*
3,319	*3.24*	*14*	*777*	*3.11*	*19*	**Striped Bass**	242,690	3.05	10	234,013	2.92	9
3,087	2.06	16	2,479	1.97	17	**Tautog**	44,940	1.94	18	48,776	1.84	19
6,491	*0.80*	*17*	*24,152*	*0.68*	*14*	**Butterfish**	414,759	0.70	14	432,275	0.60	14
1,920	1.61	18	614	1.56	20	**Weakfish**	7,783	1.56	21	5,672	1.43	21
13,220	*0.19*	*19*	*229,611*	*0.16*	*12*	**Spiny Dogfish**	225,410	0.19	19	710,258	0.16	17

Note: Sorted by 2008 revenue rank to RIFCC vessels. Products that changed more than two ranks (2008–2009) are in *italics*.

Disentangling the effects of the change in harvest timing of RIFCC vessels induced by the RIFSPP from the macroeconomic, biological, and management factors that affected the fishery as a whole requires a more nuanced analysis of what would have happened in the 2009 fishery had the RIFSPP not been in place. The next section describes our framework for analyzing this problem.

Methods

Figure 2 diagrams the key components of our approach to ascertaining the aggregate and distributional revenue impacts of the RIFSPP.[11] The methodology can be broken into three main steps: price modeling, counterfactual generation, and comparison of predicted revenues. The price modeling step estimates the relationship of ex-vessel prices and landings quantities for all species in table 1, whose daily aggregate landings are potentially affected by the incentives of the RIFSPP. The counterfactual generation step constructs what RIFCC vessel landings would have been in 2009 in the absence of the RIFSPP, using two methods to assess robustness. The final revenue comparison step applies the price prediction model to the actual and counterfactual landings to assess the revenue differences arising out of program-induced, trip-level ex-vessel price changes.

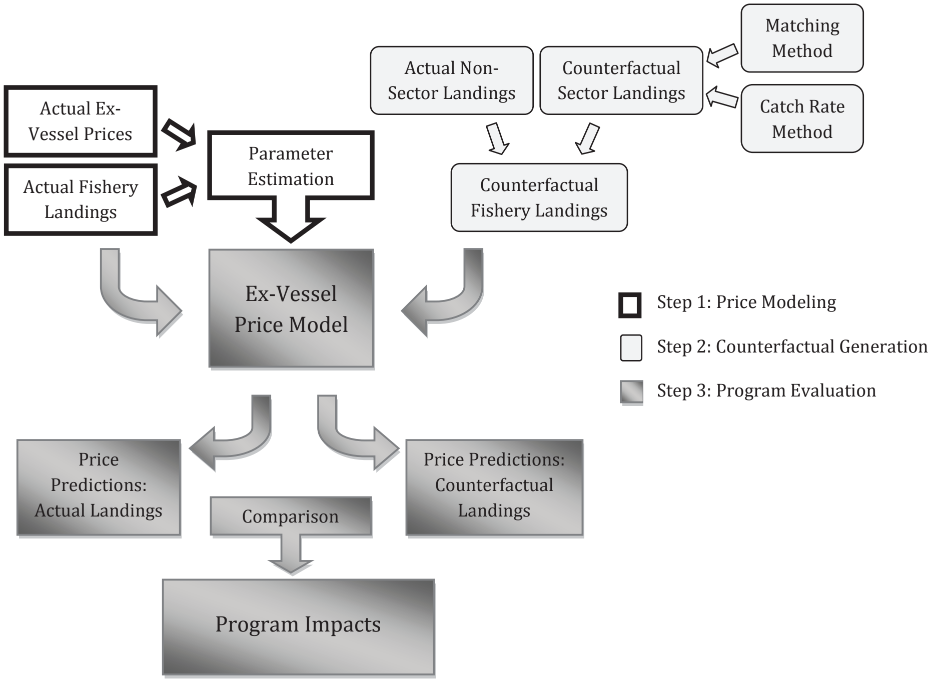


Figure 2. Analytical Approach

[11] Revenue is the focus of this analysis and serves as a proxy for profit. RIFCC vessels took roughly the same number of trips of similar duration in 2009 as in 2008 and did not report any other changes in fishing behavior that would affect fixed or variable fishing costs. This analysis does not incorporate the costs of operating the RIFCC, which exceeded $100,000 in legal fees and required industry-funded observer costs.

Price Modeling

In order to predict the revenue effects of changes in daily targeting and landings behavior, and to capture the extent of the price externality in the conceptual framework, we first estimate the relationship between landings quantity and price. Since preliminary data analysis reveals considerable daily price fluctuations (*e.g.*, the average within-week standard deviation of fluke prices was over 75 cents per pound in 2009) that may be associated with a daily-scale price externality, it was determined that price modeling should occur at the individual landing level. This is a significant reconceptualization of the market for ex-vessel fish, recognizing that individual dealers have relationships and contracts down the supply chain, as well as processing economies of scale and diseconomies of scope that can lead to significant day-to-day, dealer-to-dealer price variation for highly perishable products. This variation is typically aggregated away, either through grouping species together or averaging prices over all landings in a week, month, or year (*e.g.*, Felixson, Allen, and Storey 1987; Herrmann 2000; Muhammad *et al.* 2010). However, because it is precisely these variations in daily prices that the RIFCC is predicted to exploit, they must be integrated into an assessment of the RIFSPP.

In Rhode Island, landing-specific ex-vessel prices are set by individual fish dealers at which vessels make landings. Thus, the price model uses Electronic Dealer Reports (eDR) from the Standard Atlantic Fisheries Information System (SAFIS), which include landed quantities and ex-vessel prices for each market category of each species landed by each vessel at each dealer each day. It uses 648,506 price observations representing 116,863 landings at Rhode Island dealers from 2005 to 2009.[12] In addition, the federal license database was accessed for vessel characteristic information.

Equation 1 provides the general structure of the inverse demand equation estimated for each species. The price received by vessel *i* for product *j* from dealer *k* on day *t* is modeled as a function of own landing quantity, q_{ijkt}; same day and product dealer quantity, q_{jkt}; statewide same-day aggregate quantity of that product, q_{jt}, and all products, $\mathbf{q}_{-jt}$; dealer inventory, $\mathbf{I}_{jkt}$; New Bedford daily average auction price, $\mathbf{N}_{jt}$; quality variables, $\mathbf{L}_{ijkt}$; and time variables, $\mathbf{D}_{t}$. Since there were over 500 vessels and over 50 active dealers in 2009, vessel-dealer, η_{ijk}, or dealer, μ_{jk}, fixed effects were included to control for idiosyncratic features of bilateral captain-dealer relationships (Matthiasson and Valsson 2000).[13]

$$\begin{aligned} g_j(p_{ijkt}) = \beta_0 + \beta_1 f_j(q_{ijkt}) + \beta_2 f_j(q_{jkt}) + \beta_3 f_j(q_{jt}) + \boldsymbol{\beta_4} \boldsymbol{f_j}(\mathbf{q_{-jt}}) + \boldsymbol{\beta_5} \boldsymbol{f_j}(\mathbf{I_{jkt}}) \\ + \boldsymbol{\beta_6}\mathbf{N_{jt}} + \boldsymbol{\beta_7}\mathbf{L_{ijkt}} + \boldsymbol{\beta_8}\mathbf{D_t} + \eta_{ijk} + \mu_{jk} + \varepsilon_{ijkt}. \end{aligned} \tag{1}$$

An independent fixed-effects regression of this form was run for each product listed in table 1, each containing 50 to 80 independent variables. Dealer interviews and initial data inspection indicated that the functional forms for price flexibilities may differ among products, especially when comparing frozen and fresh market species. Therefore species-specific transformations $g_j(\cdot)$ and $f_j(\cdot)$ were selected from linear (untransformed)

[12] Harvesters whose total 2009 landings were more than 10% lobster or who had taken fewer than 10 trips in 2009 were excluded, though their landings were included in daily total quantities and inventories. Four catcher-processor vessels owned and operated by a large vertically integrated frozen seafood producer were also excluded, as their reported ex-vessel prices were frequent outliers because they were not set through the type of vessel-dealer transaction that characterizes the rest of the data.

[13] Likelihood ratio tests were computed at the vessel, dealer, and vessel-dealer levels to establish where heterogeneity of price was significant; 21 equations were paneled by vessel-dealer and four by dealer. RIFCC vessel-dealer fixed effects in ex-vessel fluke price equations did change slightly when the model was fit excluding 2009 RIFCC landings, though the average change in coefficients across fluke categories, jumbo, large, and medium, was offsetting and does not result in a measurable change of estimated program impacts. We choose to include this data because the race-to-fish season offers few times of low market supply.

or log-transformed based on a root mean squared error criterion, a method used to test prediction accuracy, implicitly overweighting large prediction errors (Kennedy 2003).[14]

More highly aggregated previous modeling has consistently documented a strong connection between changes in quantity and ex-vessel price (Crutchfield 1983; Gates 1974; Lin, Richards, and Terry 1987; Matulich, Mittelhammer, and Greenberg 1995). Furthermore, it has been shown that prices, landings, and revenues are correlated in fisheries characterized by joint production (Thunberg, Bresnyan, and Adams 1995). Consequently, quantity of the individual landing, dealer landings, and statewide daily landing quantities for all products modeled were included in each ex-vessel price regression with corresponding coefficients β_1, β_2, and β_3 and coefficient vector $\boldsymbol{\beta_4}$ from equation 1. Additionally, the coefficient vector, $\boldsymbol{\beta_5}$, represents, for each product j, ex-vessel price response to a change in short-run inventory and supply expectations. Product inventory by dealer k was included as both a sum of landings of product j bought by dealer k from four to two days prior and as a three-day moving average, providing a "rational expectations" estimate of expected inventory, which would capture landings anticipated based on boats at sea or weather forecasts.

In addition to current, statewide, recent, and anticipated quantities, interviews with fish dealers suggested several other variables affect price. The effect of the published average ex-vessel price of product j at the morning's Whaling City Seafood Display Auction in New Bedford, MA, which many dealers reported using as a reference, is captured in $\boldsymbol{\beta_6}$. An indicator is included if there was no reported price in the auction (Whaling City Seafood Display Auction 2010). Including this same-product price in the model importantly alters the interpretation of β_1, β_2, and β_3, as predicted price is now partially determined by another price, in addition to quantities. Rather, the model captures state-level deviations from the regional price as a function of statewide and dealer-level landings; β_3 is more accurately described as a local price flexibility in the multi-level market.

While we do not have detailed quality assessments for each landing, rough quality is captured by indicators for market category (species-specific market categories like size), grade (product form), and harvest gear, with their effect on price measured by the vector $\boldsymbol{\beta_7}$. The coefficient vector, $\boldsymbol{\beta_8}$, captures the effect of indicator variables that reflect shifts in demand and biological availability based on day of the week, month, and season (Herrmann and Lin 1988).

The disaggregated nature of this analysis has few precedents in the literature and precludes application of several standard techniques for estimating demand. First, when modeling systems of price equations for potentially related products, individual transactions are typically aggregated to construct a dataset with observations on every variable in every period, facilitating estimation of a seemingly unrelated regression model (Zellner 1963). In trip-specific data, on the other hand, not every species is landed, and thus not every price is observed. Thus, this analysis estimates 25 independent product-specific equations. The resulting estimates are consistent, and the loss in efficiency is inconsequential at the available sample sizes.

A perhaps greater concern is the potential simultaneity of the ex-vessel price of a product and its supply: if changes in price drive contemporaneous changes in supply (which, in turn, drive changes in price), consistent estimation of price flexibilities requires a systems modeling approach. However, features of the data generation process suggest simultaneity may not be a significant consideration at the trip level. First, the market structure for ex-vessel fish makes it difficult for harvesters to respond to same-day prices, as prices are not posted even after a landing is made. Rather, dealers set harvester payments for a landing only after selling it, often several days later (they have up to 10

[14] Structured forms were not considered due to the inherent uncertainty in fishing (*e.g.*, biological and weather conditions) coupled with detail of the data used (Newell, Sanchirico, and Kerr 2005).

days to post prices in SAFIS).[15] Second, possibly as a result of the opacity of the pricing system, harvesters often focus on harvesting what they know is biologically available in areas they know well, rather than optimize against price (*e.g.*, Holland and Sutinen 1999, 2000). Third, it is very difficult to build a behavioral supply model that captures the product targeting decision. Observable inputs (days, crew, or vessel characteristics) do not vary day-to-day with target species, and there are many factors that constrain daily harvest, including biological availability and regulatory restrictions, particularly trip limits, that limit harvesters' ability to respond to price. As a result, most product models in this fishery aggregate across species and time where endogeneity is a more prominent consideration (*e.g.*, Sutinen and Soboil 2006).

Preliminary estimation to test for simultaneity reveals that daily average price is a poor predictor of statewide landings.[16] At a more disaggregated level, Hausman tests suggest endogeneity in eight of twenty-five price equations when instrumenting for q_{ijkt}, the individual landing quantity, both with all other exogenous variables or lagged values. Performing two-stage least squares on these eight equations, we find only minor differences between the distributional and aggregate effect estimates with and without instruments.[17] The contemporaneous error correlation is associated with same-product quantities at all levels of aggregation, reflecting systematically poor prediction when landings are low, and is most prevalent in fresh market products. While nearly all frozen and fresh products have somewhat distinct seasons, out-of-season fresh market landings exhibit a much higher degree of variability in price. Fresh products must be moved through supply channels and into retail markets quickly, making unexpected landings either quite desirable if distribution channels are present and there is an unmet demand, or hard for dealers to sell if seasonal outlets are not present. Unfortunately, the drivers of price variation at times of particularly low average supply in fresh markets are idiosyncratic, and although there are detectable levels of contemporaneous error correlation in fine-scale price observations, it most likely arises from supply chain functions for which no suitable data or instruments exist.

Therefore, this analysis proceeds to address the policy questions raised by the RIFSPP by following common practice in multispecies fisheries in estimating a set of independent price equations (*e.g.*, Holland 2007). The resulting estimates can be used to predict the landing-specific price for every product in table 1, given information on recent, anticipated, and same-day statewide landings. The next section discusses how counterfactual landings scenarios were constructed.

Counterfactual Landings

To make valid retrospective conclusions on a policy's true treatment effect, a proper counterfactual environment is absolutely crucial (cf. Smith, Zhang, and Coleman 2006). When evaluating the revenue effects of the RIFSPP, it is necessary to understand what 2009 landings would have been in the absence of the RIFSPP. Consistent with the model, and with observations in figure 1 and table 1, non-sector vessels did not change their behavior in response to the RIFSPP. Therefore, their actual 2009 landings patterns can be taken to reflect what their behavior would have been. In addition, responses of non-sector vessels to 2009-specific biological, regulatory, and macroeconomic conditions can be used as a basis for predicting counterfactual 2009 RIFCC vessel behavior. Two different

[15] Date of sale, landed poundage, and product grade/market category are required to be entered in SAFIS with price information.
[16] The average R-squared of the supply equations (regressing total daily RI landings, q_{jt}, on average daily RI price, $\mathbf{p}_t$) in a simultaneous equations model of key species is around 0.01, reflecting that RI landings are determined primarily by factors other than the RI price.
[17] Differences are attributed to poor prediction in the first stage of two-stage least squares (average R-squared of .17) resulting in bad instruments in the second stage.

methods are used to construct counterfactual landings time series; one based on covariate matching and one based on comparative harvest timing.

The covariate (nearest neighbor) matching method, following Abadie *et al.* (2004), was used to associate each RIFCC vessel with three similar non-sector vessels based on 2008 fishing behavior and vessel characteristics. The associated 2009 non-sector vessel behavior serves as a basis for predicting what the sector vessels' landings would have been in the absence of the RIFSPP.[18] For purposes of matching, products were grouped by fluke, herring and mackerel, and all other species. For each sub-period and product group, each sector boat was matched to the most similar three non-sector vessels from a pool of 94 federally permitted vessels.[19] Covariates matched upon included: landing volumes for each product within the product group, number of trips taken, gross tons, and horsepower. Vessel capacity characteristics were included to match vessels capable of fishing similarly; exact matching was implemented for gross tons in fluke and other species.[20]

Counterfactual 2009 landings for RIFCC vessel i, $\hat{q}_{ijt}^{09}$, are constructed as the daily average of vessel i's matched non-sector boat landings for product j, q_{mjt}^{09} :

$$\hat{q}_{ijt}^{09} = \frac{1}{3}\sum\nolimits_{m=1}^{3} q_{mjt}^{09}. \tag{2}$$

To establish the robustness of any conclusions, a second set of counterfactual RIFCC landings was developed based on the timing of fleetwide landings of each species. The catch rate method benchmarks the RIFCC's 2008 cumulative harvest quantity at day t to the fleet's 2008 harvest quantity on that same day. Then, on the 2009 day on which the fleet achieves that same fraction of the annual total, the RIFCC's landings are set to maintain the 2008 ratio. Thus, the counterfactual 2009 cumulative harvest of the RIFCC at time t is given by:

$$\sum_{\tau=1}^{t}\sum_{l\in FCC}\hat{q}_{lj\tau}^{09} \Bigg/ \sum_{\tau=1}^{365}\sum_{l\in FCC} q_{lj\tau}^{09} = \left[\sum_{\tau=1}^{t}\sum_{l\in FCC} q_{lj\tau}^{08} \Bigg/ \sum_{\tau=1}^{366}\sum_{l\in FCC} q_{lj\tau}^{08}\right]\left[\frac{\sum_{\tau=1}^{t}\sum_{l\notin FCC} q_{lj\tau}^{09} \Big/ \sum_{\tau=1}^{365}\sum_{l\notin FCC} q_{lj\tau}^{09}}{\sum_{\tau=1}^{t}\sum_{l\notin FCC} q_{lj\tau}^{08} \Big/ \sum_{\tau=1}^{366}\sum_{l\notin FCC} q_{lj\tau}^{08}}\right]. \tag{3}$$

Each component ratio is the portion of cumulative harvest at day t in its respective year. The rightmost term measures whether non-sector vessels have harvested their eventual 2009 take of product j earlier or later than in 2008. The left-hand term accounts for whether RIFCC vessels caught product j faster or slower than the rest of the fleet. Counterfactual daily landings are then calculated based on daily differences in cumulative landings and distributed among RIFCC vessels.[21]

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[18] Propensity score matching was tested following Dehejia and Wahba (2002). However, matches were poor because propensity to join the sector was not strongly correlated with fishing patterns.

[19] One RIFCC vessel could not be matched because it lacked a federal permit, and thus key data for matching. For the matching method, its actual 2009 landings were used as the counterfactual; a catch rate method counterfactual was constructed for it. Its revenue is not included in reported effects under either counterfactual method for comparability, as its share of the fluke harvest was negligible.

[20] "Exact matching" is done by increasing the weight of 'exact' covariates relative to the weights placed on other covariates in the weight matrix, increasing the importance of those variables in the match (Abadie *et al.* 2004).

[21] Under both methods landings were randomly assigned to a dealer based on dealer shares of 2008 RIFCC landings.

Under the matching method, where the counterfactual RIFCC catch was an average of similar non-sector vessels' catch in 2009, both the timing and quantity of landings are altered. This reflects harvesting behavior of vessels thought to fish similarly to sector members when under identical regulations. However, these estimates are only as good as the matches, and because the Rhode Island trawl fleet is small and relatively heterogeneous, matches are imperfect. Conversely, the catch rate method uses actual total RIFCC landings in 2009, and thus does not capture changes in the aggregate species mix that may have arisen from RIFSPP incentives, focusing instead on strategic timing incentives. While neither is ideal, these two methods complement each other and ensure robust conclusions across both methods are reliable.

Results

Results from the price model estimation are presented first, emphasizing patterns that were drivers of harvester behavior. This model is then combined with the counterfactual landings predictions to estimate the effects of the RIFSPP.

Price Results

The price model incorporates quantity variables at several levels: individual landings; dealer inventory; dealer expected inventory; and total landings in the state, as well as the New Bedford price, which reflects the market throughout the Northeast. Table 2 shows the partial price flexibilities—calculated at the mean of all variables if the equation is not of log-log form—associated with changes in daily statewide quantity, the variable most affected by the incentives of a state management plan. The bolded cells of the diagonal are the own-price flexibilities. They are predominantly negative and statistically and economically significant, reflecting (inverse) demand curves that are downward sloping at the statewide landings level.[22] For example, at average values of all variables a 1% increase in daily statewide landings of large fluke results in a 0.035% decrease in price. This negative partial own-price flexibility, in agreement with the implied price externality outlined in the conceptual framework, indicates a potential market opportunity for harvesters to shift landings from days with higher aggregate landings to days with lower aggregate landings, if management makes it possible to do so. As a result, RIFCC members could get higher prices for fluke by shifting their landings to days with lower total Rhode Island landings; non-sector vessels would also benefit, as landings on days from which the RIFCC shifted landings would be lower. However, negative demand slopes for the species the RIFCC pursued instead—especially whiting (–0.035%), herring (–0.008%), and butterfish (–0.030%)—indicate that non-sector vessels harvesting those species may have received lower prices.

The off-diagonal elements capture the cross-price flexibilities of the different products. These flexibilities in dealer-paid ex-vessel prices could arise either from consumer demand (*i.e.*, substitute products) or through complementarities in processing or distribution through the supply chain by the dealers. For example, at mean values, a 1% increase in yellowtail flounder (*Pleuronectes ferruginea*) landings results in a 0.004% decrease in the price of large fluke, because the two are close substitutes (often sold simply as "flounder" or "sole"). Cross flexibilities are, in general, negative, indicating substitutability among seafood products.

[22] A few price equations had significantly positive statewide landings own-price flexibilities, each arising from idiosyncratic features of the product. Daily statewide fluke landings, in total, exhibit a negative relationship with price; however, age-structured biological migratory conditions result in jumbo fluke (+0.013%) landings, which are low during the Summer (when there are high overall fluke landings and a low price) and high during Winter II (when there are low overall fluke landings and a high price). Striped bass (+0.071%) is occasionally landed in very large quantities by fish trap harvesters who sell to premium markets and command a large price premium. Spiny dogfish (+0.008%) and skate rounds (+0.007%) are primarily frozen products benefiting from economies of scale in processing.

Table 2
Rhode Island Statewide Price Flexibilities

Quantity Lbs.	R^2	Equation Form	Price: Fluke Jumbo	Fluke Large	Fluke Medium	Fluke Unknown	Spiny Dogfish	Skate Rounds	Skate Wings	Herring
Fluke (jumbo)	0.3593	Linear	**0.013*****	0.020**	0.009***	0.025	–0.003	0.001	–0.005	–0.005
Fluke (large)	0.4373	Linear	–0.027***	**–0.035*****	–0.013***	–0.065**	0.004	0.001	0.018**	0.000
Fluke (medium)	0.4556	Linear	–0.026***	–0.019***	**–0.026*****	0.023	–0.002	–0.001	0.002	0.001
Fluke (unknown)	0.2086	Log-Log	–0.012***	–0.008***	–0.007***	**0.000**	0.001	0.000	–0.005***	–0.002
Spiny dogfish	0.1521	Log-Log	–0.014***	–0.012***	–0.007***	0.003	**0.008*****	0.000	–0.004*	– 0.002
Skate (rounds)	0.0644	Log-Log	0.001	–0.005***	–0.005***	–0.001	–0.001	**0.007****	0.016***	0.000
Skate (wings)	0.2924	Log-Linear	0.003**	0.001	0.002*	0.000	–0.003*	0.000	**–0.020*****	–0.003
Herring	0.1828	Log-Log	0.000	–0.001***	– 0.001*	–0.003	0.001*	0.000	–0.002***	**–0.008**
Monkfish	0.4443	Linear	–0.005**	0.003*	0.001	–0.010	–0.002	–0.003*	–0.013***	0.007
Cod	0.4684	Linear-Log	0.000	–0.001**	–0.001***	–0.001	0.001	0.001	0.003**	–0.003
Hake	0.3784	Log-Log	0.000	–0.001*	0.001	–0.003	–0.001	0.002**	0.000	0.001
Whiting	0.3647	Log-Log	0.014***	0.015***	0.012***	0.004	0.000	–0.002**	–0.003	–0.006
Striped bass	0.1492	Log-Log	–0.003***	–0.001	–0.002**	–0.002	0.000	–0.002**	0.003**	0.008
Black sea bass	0.4107	Linear-Log	0.013***	0.012***	0.016***	0.013***	–0.002**	0.002***	–0.004	0.004*
Bluefish	0.2934	Log-Log	–0.006***	–0.008***	–0.005***	0.002	–0.003**	–0.002*	0.016***	0.003
Scup	0.6169	Linear-Log	–0.006***	–0.006***	–0.007***	–0.002	0.004***	0.000	0.002	–0.001
Weakfish	0.3182	Log-Log	–0.004***	–0.003***	–0.005***	0.003	–0.001	–0.001	–0.001	–0.005
Tautog	0.2928	Linear	0.005***	0.004***	0.007***	0.002	0.001	0.000	– 0.002	0.000
Mackerel	0.1967	Log-Linear	–0.001***	–0.001***	–0.001***	–0.001	0.000	–0.002***	– 0.001	–0.002
Butterfish	0.2875	Log-Log	0.001	0.000	0.000	–0.009	0.003	0.002	0.002*	0.005
Windowpane flounder	0.2450	Log-Log	0.001**	0.001***	0.003**	0.000	0.000	–0.002***	0.005***	0.003
Gray sole	0.4067	Log-Log	0.000	0.000	0.000	–0.002	–0.001	0.000	0.000	– 0.001
Winter flounder	0.3155	Log-Log	0.006***	0.006***	0.000	0.001	0.000	0.001	–0.005	0.002
Yellowtail flounder	0.6048	Log-Log	–0.004***	–0.004***	–0.001	0.003	0.000	–0.001**	–0.010***	0.001
Squid	0.2669	Log-Log	–0.005***	–0.003***	–0.003***	–0.004	0.003*	0.000	–0.008***	–0.008**

Note: Significance levels are denoted as: * = 10%, ** = 5%, and *** = 1% levels. Price flexibilities are calculated at the mean of all variables if the equation form is not log-log. Own-price flexibilities are in **bold**.

Table 2 (continued)
Rhode Island Statewide Price Flexibilities

Quantity Lbs.	R^2	Equation Form	Price: Monkfish	Cod	Hake	Whiting	Striped Bass	Black Sea Bass	Bluefish	Scup	Weakfish	Tautog
Fluke (jumbo)	0.3593	Linear	–0.010***	–0.009**	0.012**	0.000	–0.004	–0.001	0.010***	–0.006***	–0.013***	0.009*
Fluke (large)	0.4373	Linear	0.021***	0.011**	0.011*	0.006	0.007	0.002*	–0.004	0.013***	0.005	–0.012**
Fluke (medium)	0.4556	Linear	–0.020***	0.001	0.008***	– .005*	0.013***	–0.006***	0.001	–0.006***	0.004	0.003
Fluke (unknown)	0.2086	Log-Log	–0.001**	0.002	0.000	0.001	0.002	0.001*	0.002*	0.001**	0.001	0.009***
Spiny dogfish	0.1521	Log-Log	–0.005***	0.000	–0.006***	–0.015***	–0.006***	–0.001	0.001	– 0.003***	–0.002	–0.002*
Skate (rounds)	0.0644	Log-Log	0.008***	0.001	–0.001	–0.001	0.002	0.001	0.001	0.002***	0.002*	0.003
Skate (wings)	0.2924	Log-Linear	–0.003**	0.000	0.005*	0.002	–0.003	0.002**	–0.001	0.005***	0.004	0.003*
Herring	0.1828	Log-Log	–0.001	0.001*	0.000	0.002	–0.006**	0.001	0.002	–0.002***	–0.001	0.000
Monkfish	0.4443	Linear	**–0.002**	–0.005	– 0.026***	0.008**	0.002	–0.002	–0.007***	– 0.006***	0.000	–0.014***
Cod	0.4684	Linear-Log	–0.001**	**0.005**	0.009***	0.000	–0.005***	–0.002***	–0.001	0.000	–0.003**	–0.001
Hake	0.3784	Log-Log	0.000	–0.001	**–0.033*****	0.022***	–0.004	0.002***	0.001	0.012***	0.002	0.002
Whiting	0.3647	Log-Log	0.002	0.006**	0.002	**–0.035*****	0.003	–0.001*	0.003*	–0.009***	–0.002	0.002
Striped bass	0.1492	Log-Log	–0.002**	– 0.004**	0.000	–0.007***	**0.071*****	0.000	0.010***	0.005***	–0.001	–0.006***
Black sea bass	0.4107	Linear-Log	0.011***	0.003**	–0.005***	0.004**	0.007**	**–0.024*****	–0.006***	–0.002***	0.004**	0.010***
Bluefish	0.2934	Log-Log	0.005***	0.004***	0.001	0.008***	0.009	0.006***	**–0.056*****	0.006***	–0.001	0.003
Scup	0.6169	Linear-Log	–0.003**	– 0.003**	0.009***	–0.006***	–0.001	0.001**	– 0.004***	**– 0.078*****	0.001	–0.015***
Weakfish	0.3182	Log-Log	0.001	–0.001	–0.007***	0.000	0.000	0.002***	0.008***	0.011***	**0.001**	0.001
Tautog	0.2928	Linear	0.001	–0.002	0.002	–0.002*	–0.002	0.002***	–0.004***	0.003***	–0.004***	**–0.009***
Mackerel	0.1967	Log-Linear	–0.001***	–0.002*	0.001	0.001	–0.003*	0.002***	–0.001	–0.002***	– 0.003**	0.000
Butterfish	0.2875	Log-Log	0.000	0.003	0.017***	0.011***	0.018***	–0.002**	–0.013***	–0.001	– 0.004	–0.004***
Windowpane flounder	0.2450	Log-Log	–0.001	–0.004*	–0.002	0.004**	–0.003*	0.000	0.002**	0.001	0.001	–0.002**
Gray sole	0.4067	Log-Log	0.002***	–0.001	0.001	0.003*	0.003	0.000	–0.004***	–0.001*	–0.002	0.001
Winter flounder	0.3155	Log-Log	0.001	–0.002	–0.006**	–0.006**	–0.011***	–0.001	0.004**	–0.002***	–0.005*	0.002
Yellowtail flounder	0.6048	Log-Log	0.000	0.001	–0.003	0.001	0.003*	0.000	0.002*	0.004***	0.002	0.001
Squid	0.2669	Log-Log	–0.010***	–0.008***	–0.023***	–0.012***	–0.021***	0.002**	–0.004**	–0.009***	–0.005*	–0.004***

Note: Significance levels are denoted as: * = 10%, ** = 5%, and *** = 1% levels. Price flexibilities are calculated at the mean of all variables if the equation form is not log-log. Own-price flexibilities are in **bold**.

Table 2 (continued)
Rhode Island Statewide Price Flexibilities

Quantity Lbs.	R^2	Equation Form	Price						
			Mackerel	Butterfish	Windowpane Flounder	Gray Sole	Winter Flounder	Yellowtail Flounder	Long-finned Squid
Fluke (jumbo)	0.3593	Linear	–0.064***	0.001	0.002	0.002	–0.002	–0.007**	0.004**
Fluke (large)	0.4373	Linear	0.116***	0.007*	0.002	–0.007	0.000	0.004	0.000
Fluke (medium)	0.4556	Linear	–0.048***	–0.006***	0.002	0.003	0.006***	0.004**	–0.005***
Fluke (unknown)	0.2086	Log-Log	0.003	0.000	0.005**	–0.001	–0.001*	0.002**	0.003***
Spiny dogfish	0.1521	Log-Log	0.008*	0.005***	0.000	–0.002	– 0.001	– 0.005***	0.000
Skate (rounds)	0.0644	Log-Log	0.013	0.000	0.002	0.000	–0.001	–0.001	–0.001
Skate (wings)	0.2924	Log-Linear	0.001	0.001	0.001	0.001	0.007**	–0.005**	–0.002**
Herring	0.1828	Log-Log	0.010*	0.001	–0.001	–0.001	0.000	0.000	0.002***
Monkfish	0.4443	Linear	–0.003	0.000	0.011**	0.003	–0.003	–0.002	–0.001
Cod	0.4684	Linear-Log	–0.003	–0.001	0.001	0.000	0.001	0.001	–0.002***
Hake	0.3784	Log-Log	–0.005	0.000	–0.005	–0.008*	–0.002	–0.006***	–0.006***
Whiting	0.3647	Log-Log	0.009	0.008***	0.010***	–0.002	0.004**	0.004*	0.007***
Striped bass	0.1492	Log-Log	0.003	–0.001	–0.007***	0.003	0.000	–0.002*	0.001*
Black sea bass	0.4107	Linear-Log	–0.019**	–0.001	0.002	0.005*	0.004***	0.003**	–0.001*
Bluefish	0.2934	Log-Log	–0.008*	0.002	0.001	0.001	0.000	–0.003**	0.002**
Scup	0.6169	Linear-Log	–0.006	– 0.002*	0.005**	–0.001	0.006***	0.007***	0.001**
Weakfish	0.3182	Log-Log	0.004	0.002	–0.009***	–0.002	–0.005***	0.000	0.003***
Tautog	0.2928	Linear	0.005	–0.003***	–0.008***	–0.002	–0.008***	–0.004***	0.001**
Mackerel	0.1967	Log-Linear	**0.002**	0.001	0.002	0.003	0.002**	0.001	0.000
Butterfish	0.2875	Log-Log	–0.003	**–0.030*** **	–0.008**	–0.002	0.005***	0.002	0.008***
Windowpane flounder	0.2450	Log-Log	0.006	0.001	**0.003**	–0.005*	0.000	0.006***	0.003***
Gray sole	0.4067	Log-Log	0.001	0.002**	–0.003*	**–0.001**	–0.003***	–0.001	0.000
Winter flounder	0.3155	Log-Log	–0.037***	0.000	–0.016**	–0.009	**–0.021*** **	–0.022***	–0.001
Yellowtail flounder	0.6048	Log-Log	0.003	0.000	0.001	0.006	0.002	**0.002**	0.003***
Squid	0.2669	Log-Log	0.007	0.004*	–0.009***	0.003	–0.010***	–0.003	**–0.026*** **

Note: Significance levels are denoted as: * = 10%, ** = 5%, and *** = 1% levels. Price flexibilities are calculated at the mean of all variables if the equation form is not log-log. Own-price flexibilities are in **bold**.

Counterfactual Landings

Figure 3 shows the actual RIFCC landings of fluke in 2009, the counterfactual 2009 landings by both the matching and catch rate methods, and the actual 2008 rate of RIFCC vessels. The 2008 series is a useful reference for the 2009 counterfactuals, because they are designed to capture what RIFCC vessel landings would have been had they been managed as in 2008; the 2008 series is below the counterfactuals because the fluke TAC increased in 2009, and the RIFCC caught a larger share. Broadly, both counterfactual methods predict roughly the same pattern of cumulative harvest—significant landings in early spring, modest landings during the Summer sub-period, and an increase in landings during Winter II. The primary difference between the two methods is the total fluke landings predicted. Total landings in the matching method are lower than actual 2009 landings because the best-matched vessels landed less fluke than did the RIFCC vessels in 2009, while the catch rate method holds 2009 landings for each vessel fixed and only adjusts the timing of those landings. Despite this difference, the counterfactuals are similar and contrast significantly with the RIFCC's landings patterns under the RIFSPP. These patterns are also reflected in the other species harvested.

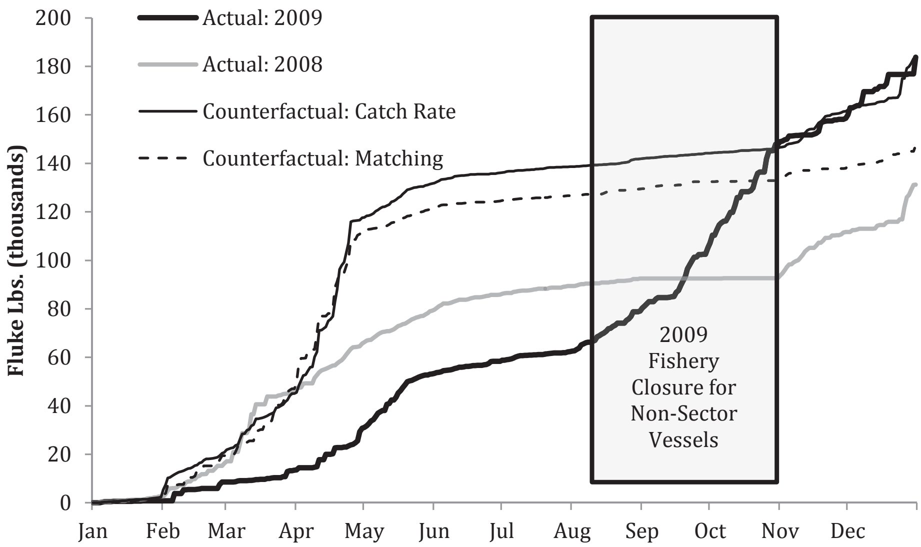

Figure 3. Cumulative Fluke Landings by RIFCC Vessels (actual and counterfactual)

Aggregate Effects of the RIFSPP

The revenue effects of the RIFSPP are determined by taking the difference between revenues predicted in the actual 2009 fishery and those predicted in each counterfactual 2009 fishery. Aggregating across vessels and species, the RIFSPP led to a total increase in RI fishery revenue of $823,829 (standard error of $52,588) using matching method counterfactuals, and $808,347 ($52,417) using catch rate counterfactuals. Although the state experienced a decline of $3.2 million in total (non-shellfish or lobster) fishery revenues, revenues would have been yet lower in the absence of the RIFSPP.

Overall, 64–69% of this benefit accrued to members of the RIFCC. Table 3 shows the average per-vessel effects of the RIFSPP on RIFCC vessels. Both counterfactual methods reflect that RIFCC vessels saw statistically and economically significant gains from the RIFSPP. A sector vessel earned from $22,000 to $27,000 more revenue from fluke and $52,000 to $55,000 more in revenue from other species combined, on average.[23] That the two counterfactual methods generate similar values suggests the majority of revenue effects arose from market timing, since it is reflected in both methods, while differences in landing volumes and targeted species would be captured only in the matching method.

Table 3
RIFCC Average Vessel Revenue Effects

	Average Effect	
	Fluke ($)	Other ($)
Matching method	+27,209 (318.8)	+55,035 (3,176.8)
Catch rate method	+21,960 (266.7)	+52,288 (2,234.1)

Note: Standard errors and confidence intervals throughout the article were calculated based on 1,000 draws of $\beta \sim N(\beta,\sigma^2)$.

Table 4 shows that the feared losses to non-sector vessels did not materialize, with roughly one-third of the overall benefit being distributed among non-RIFCC vessels that, on average, experienced significant benefits. Federally permitted non-sector vessels, which are similar to RIFCC vessels in physical characteristics and fishing patterns, experienced a slight increase in fluke revenue ($138–$163) and a larger increase from other targeted species ($2,184–$2,781). Among non-federally permitted vessels, which are typically smaller and target fluke mainly during the Summer sub-period, fluke revenue decreased by a statistically and economically insignificant amount ($11–$20), but that loss was offset by an increase from other species ($45–$107). These vessels did not experience the increase in fluke prices suggested by our conceptual framework because the RIFCC vessels land a very small portion of the fluke during the Summer sub-period opening.

Table 4
Non-Sector Average Vessel Revenue Effects

	Federally Permitted		Non-Federally Permitted	
	Fluke ($)	Other ($)	Fluke ($)	Other ($)
Matching method	+138 (21.1)	+2,184 (381.3)	–20 (1.5)	+107 (18.1)
Catch rate method	+163 (19.8)	+2,781 (423.5)	–11 (1.5)	+45 (27.3)

Note: standard errors and confidence intervals throughout the article were calculated based on 1,000 draws of $\beta \sim \mathrm{N}(\beta,\sigma^2)$.

[23] As expected, RIFCC vessel gains disproportionately came from fluke; 30% of total gains were fluke, while typical annual revenues are only 20% fluke. The opposite is true of federally permitted non-sector vessels (6% and 10%).

Distributional Effects of the RIFSPP

While non-sector vessels may have benefitted in aggregate, it is possible that the benefits were inequitably distributed, supporting some of the arguments opposing the RIFSPP and suggesting some elements of the program require modification. Figure 4 shows the distribution of vessel revenue effects arising from the RIFSPP (note nonlinear *x*-axis scale).[24] The range of effects among federally permitted vessels includes a few that were negatively affected, but more than 20% of vessels experienced an increase of more than \$5,000, leading to a high average benefit. Many of these high beneficiaries were large off-shore vessels that landed fluke during the Winter I sub-period and received higher prices because the RIFCC boats were landing less than usual in order to use their quota later in the year. Among non-federally permitted vessels, the majority (35% or more) experienced negligible revenue impacts from the RIFSPP, and non-negligible impacts were balanced between relatively small positive and negative effects.

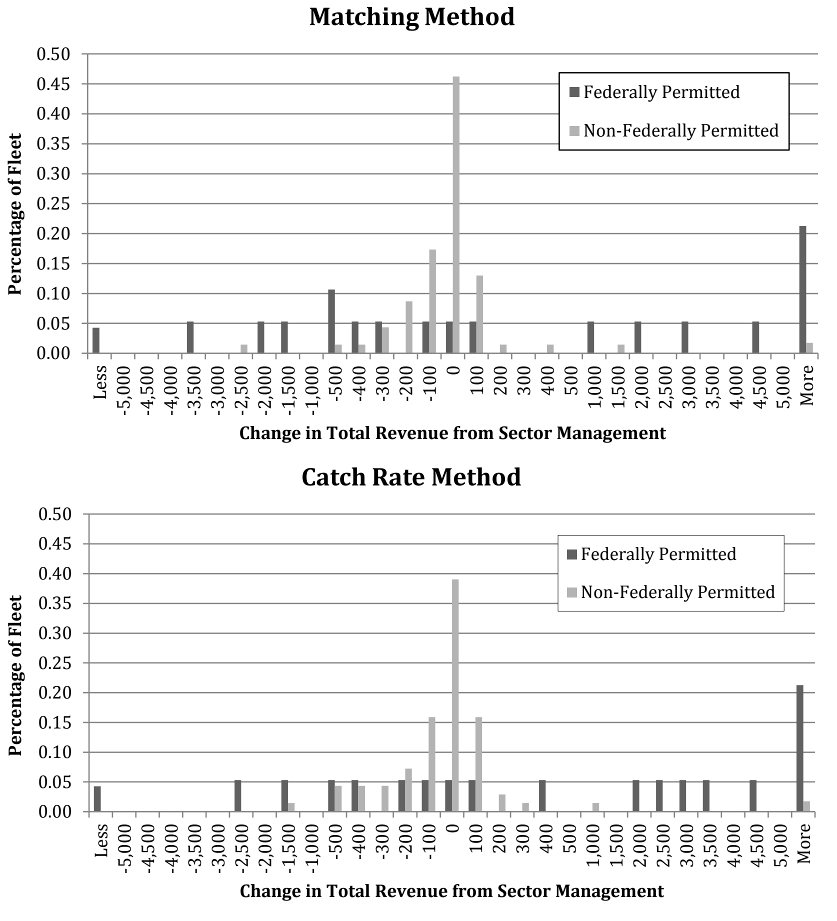

Figure 4. Distributional Effects on Individual Non-Sector Vessels (aggregated to groups of five)

[24] Vessels were ranked by individual revenue effect and then aggregated into groups of five to preserve confidentiality. The figures show the groups of five, where each group is shown with average revenue effect of the group members.

A key factor in determining whether an individual non-sector vessel experienced an increase or decrease in revenue as a result of the RIFSPP was their species targeting. In general, when RIFCC members were avoiding fluke, they targeted species with relatively inflexible prices (herring, squid, skate, and spiny dogfish are predominantly frozen products with relatively constant prices), but there are certain landings patterns that contributed to increases and decreases in vessel revenues. Relative shares of aggregate gains and losses contributed by non-fluke species among federally permitted and state-permitted vessels are shown in figure 5.

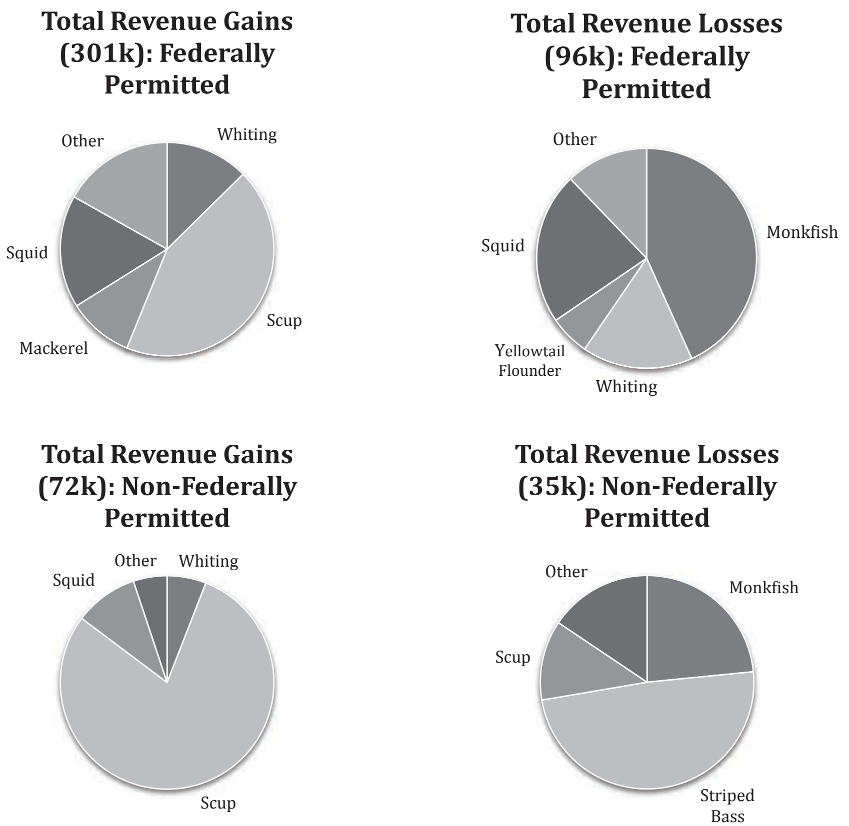

Figure 5. Non-Sector Revenue Effect Shares
(non-fluke species using the matching method)

Among non-fluke species that led to gains in annual revenue (left-hand column of graphs), scup dominated, followed by squid and whiting. Among non-fluke species where losses were experienced (right-hand column of graphs), monkfish and striped bass (*Morone saxatilis*) accounted for the largest share of losses to federally and non-federally permitted vessels, respectively. While these dominant contributors to non-sector gains and losses were not widely targeted by the RIFCC, the effects arose through cross-price flexibilities and targeting changes as predicted by our counterfactuals. For example, when non-sector vessels landed scup, RIFCC vessels landed scup at lower average daily levels (negative own-price flexibility), large fluke at higher average daily levels (positive cross-price flexibility), and whiting and winter flounder at lower average daily levels (negative cross-price flexibility) than predicted in our counterfactuals. Non-sector losses in monkfish and striped bass were the result of large contemporaneous spiny dogfish landings by RIFCC vessels not predicted in the counterfactuals. These predicted losses highlight a notable pattern of negative cross-price flexibilities between products marketed fresh and those marketed frozen, which potentially arises from economies of scale in processing or marketing primarily fresh or frozen products on a single day.

Discussion

The eight members of the RIFCC were able to change their harvest timing of fluke and other species to increase revenue by an average of over $70,000 per vessel, while reducing fluke discards by 98% relative to non-sector vessels. This revenue increase may have been damped by poor macroeconomic conditions, as much of it came from premium products whose prices could have been yet higher in a better economy. In agreement with hypothesized behavioral shifts developed in our conceptual framework, the RIFCC reduced fluke landings at times when non-sector landings were high and prices were low, using their quota instead when prices were high or it allowed landing of highly valued jointly harvested species. Shifting when and how they focused on fluke also allowed them to concentrate effort on other species not targeted in previous years, which contributed further to revenue gains. These strategic targeting shifts by RIFCC members did affect the prices received by non-sector vessels for fluke and other products. In aggregate, these effects were positive, totaling a quarter million dollars. However, specific vessel outcomes varied, depending on which product markets the non-sector vessels targeted and when. Most non-sector vessels benefited (especially federally permitted vessels landing fluke in Winter I) or were not meaningfully affected (as was typical for state-permitted vessels), but those targeting certain species at certain times did experience small losses.

Our conclusion that the introduction of collective property rights enhanced fishery rents, is in line with recent empirical findings; however, the mechanism we posit to be rent generating, namely market timing, is a unique contribution to the existing literature. Andersen, Andersen, and Frost (2010) analyze Danish fisheries post ITQ implementation and find rent gains by way of harvesting efficiency improvements, although gains are noted as weak. Nielsen, Flaaten, and Waldo (2012) use a bioeconomic model with variable effort when estimating current rent levels closer to theoretical maximums in Nordic fisheries under co-management and ITQ regimes than those managed with effort restrictions or non-transferable individual quota. Tveteras, Paredes, and Peña-Torres (2011) provide observation and conjecture that IVQs in the Peruvian anchovy fishery created rents through product enhancement despite weak institutions. It is indeed the case that during a transition to property rights, rents may be generated by a variety of means both affecting costs and revenues, though the authors suspect that in a multispecies fishery with flexible prices, rent gains will likely be most visible initially through market timing advantages.

While the argument that such catch share systems are improper because they limit access to a publicly owned resource is not factual in basis and cannot be refuted *per se*, this analysis quantifies the extent to which some underlying principles in this line of reasoning are violated. First, the rules of the RIFSPP did indeed prevent other licensed harvesters from landing any share of the RIFCC's quota allocation in 2009, an acknowledged inequity in access. However, the reduction in mortality benefited these excluded vessels (as well as recreational anglers) through healthier stocks, higher quotas in future years, and possibly improved monitoring arising from increased data demands of catch share systems (Nowlis and Van Benthem 2012). Second, price changes induced by RIFCC landings strategies did affect other vessels, some negatively, although the daily price variability was comparable to that arising when different numbers of vessels independently choose whether to take a trip on a particular day and influence that day's price in a competitive market. Third, non-fishing Rhode Islanders (and other seafood buyers internationally) were likely affected by the RIFSPP; higher ex-vessel prices likely corresponded to higher retail or restaurant prices, though the welfare loss here may be offset by a longer season of availability. How to best balance concerns and aspirations among these groups is a problem for the political process, though it is worth noting that, in general, only commercial and recreational harvesters actively participate in RIMFC meetings.

Early versions of this analysis were used to inform RIDEM in continuing the RIFSPP in 2010 and 2011. It was projected that expanding the single-sector pilot to include additional federal boats, as was done in 2010 and 2011, would further smooth fluke landings throughout the year, generating higher aggregate fluke revenue. However, under this scenario the benefits would be distributed more evenly between sector and non-sector vessels, as more landings would shift from March and April to August and September, increasing the price received by non-sector Winter I harvesters and decreasing the price received by sector members during the Summer closure. If the expanded sector program had incorporated Summer sub-period vessels, it would have benefitted state-permitted vessels, moving some effort from the early Summer derby into the late Summer closure period. Shifts in state management toward lower trip limits, or higher state allocations, may reduce (but not eliminate) the value of the sector program, since there is no time when only the sector is landing. In fact during both 2010 and 2011 there was no Summer closure to the common pool, but still opportunities for sector vessels to exploit several weeks with very low fluke trip limits. Secondary market effects, where members joining the expanded sector would change their targeting of other species, might offset or amplify revenue gains. If they followed the RIFCC's pattern of switching to frozen processed products, with locally inflexible prices set by national markets, the consequent decreases in other products' prices would likely not nullify gains from a better-timed targeted fluke fishery.[25] Following a "summit" on sector management, a new RIDEM director discontinued sector management.

While RIDEM's objective in the RIFSPP was to evaluate adopting this form of catch share management at the state level, the pilot also carries important lessons for the 2010 implementation of sector-based management in the Northeast Multispecies fishery. Like the RIFSPP, the federal program has self-identifying groups of harvesters being allocated a fixed quota of each regulated species based on their history. Unlike the RIFSPP, the federal program encompasses 15 species, has 17 separate sectors accounting for over 95% of the quota of most species, and prohibits common pool catch in excess of quota limits.

The first lesson is that, especially in fresh market species, there are opportunities in the groundfish fishery to improve landings timing so that higher revenue is drawn from a fixed quota. Second, many of these opportunities arise at a local or dealer level with a daily frequency, as each dealer or processor has lines to keep busy and fresh market contracts to fulfill. Third, given the incentive to do so, large trawlers can adjust their landings composition, though perhaps primarily by adjusting when they fish, to take advantage of market timing opportunities. The extent to which this is possible depends on the behavioral characteristics of the target and the species with which it is jointly harvested. RIFCC's proof-of-concept was a relatively easy case, with one quota-managed species—for which there is ample quota and which does not heavily intermix for part of the year—and readily identifiable timing opportunities in the Summer closure. Finally, exploiting market timing opportunities in one fishery also means finding alternative species to harvest when other landings are too high or when species intermixing is prohibitive. Following the RIFCC, Northeast Multispecies sectors may target non-Multispecies stocks with relatively inflexible prices, putting pressure on squid, herring, mackerel, skate, spiny dogfish,

[25] Net effects when considering all cross-price flexibilities are uncertain.

lobster (*Homarus americanus*), or scallop (*Placopecten magellanicus*) stocks. Vessels dependent on these stocks may see spillover effects from the sector program; having effective management of substitute stocks is critical.

The RIFSPP represents a rare attempt by a regulatory agency to implement a small-scale pilot program. In environmental management, it is far more common for all users of a resource to be switched from one management regime to another, and then to another if the first change does not meet management goals. This has particularly been the case for New England groundfish harvesters, who have experienced five new management regimes since 1993. The RIFSPP allowed RIDEM to explore the benefits and costs of a proposal without establishing a political consensus for it amid great uncertainty. Indeed, this is an important aspect of catch share management, as it allows individual groups within a fishery to develop and test novel management systems, establishing an evolutionary process that will allow sectors with rules that best serve their members to persist. This is a more scientific approach to management; however, it presents a challenge to fisheries economists and fisheries scientists. New models and techniques will be needed to assess resources being managed by multiple methods concurrently, and they will have to identify whether sectors generating greater benefits are exploiting flaws in other sectors, or whether the benefits accruing to the small group will scale if the management system is applied to a greater portion of the resource users.

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