EMPIRICAL ANALYSIS OF THE TRANSBOUNDARY DYNAMICS FOR GEORGES BANK GROUNDFISH

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ABSTRACT

This paper presents an empirical model of Georges Bank transboundary groundfish fishery, and reports results of a dynamic bioeconomic simulation used to evaluate the consequences of alternative management strategies for the multispecies fishery. Since the distribution of the stocks of the principal groundfish resources involves substantial movement and migration across the US-Canada boundary, the harvests of each country may reduce the benefits of the other. The model incorporates both the biological and economic characteristics of the fishery. The biological component of the model describes the population and spatial dynamics of the principle groundfish stocks that reflect the seasonal migration of the transboundary stocks. The economic component incorporates the harvest strategies of the US otter trawl fleet and the Canadian longline and otter trawl fleets. For each management alternative evaluated, the model simulates the change in profits for both countries jointly, as well as each country individually. We evaluate alternative fisheries management strategies to determine whether the current management is superior to any other strategy and, if not, what other strategies are better in terms of economic performance.

Keywords: Transboundary fisheries, fisheries management, bioeconomic simulation, multispecies fishery

INTRODUCTION

The spatial distribution, spawning, and migration patterns of the principal groundfish resources on Georges Bank create significant transboundary management concerns. A transboundary resource is one whose distribution spans a boundary and for which there is substantial migration and movement across the boundary. Georges Bank transboundary concerns stem from stock overlap and spawning distributions relative to the U.S.-Canada boundary. Since extending fisheries jurisdiction and settling their boundary dispute, the U.S. and Canada have taken different approaches to managing their groundfish fisheries in the region. The two countries' management practices have evolved differently due in part to variations in the structure and philosophies of the industry and administrate bodies.

Multiple species characterize the groundfish fisheries on Georges Bank, where vessels direct their effort at one species and also catch other groundfish species that inhabit the same areas. In 1986 the US developed a Multispecies Fisheries Management Plan that turned largely to input controls, namely area/season closures, mesh size, trip limits, etc. In addition, beginning in 1994, the US also implemented effort control measures to reduce fishing pressure on groundfish stocks. The key components of the effort control measures included a limited entry program and days-at-sea (DAS) program that reduced the amount of time a vessel owner can participate in the groundfish fishery. The US groundfish fishery is harvested almost exclusively by mobile gear vessels that use bottom otter trawl gear.

By contrast, Canada has embraced output controls principally catch quotas for regulation and developed reporting and monitoring systems to support it. Additional measures have included limited entry licensing, fleet allocations, mesh size/hook size regulation, area, season closures, third party 100% dockside monitoring that verify species and amounts landed, user pay at sea monitoring, minimum fish size through small fish protocol, mandatory reporting requirements and mandatory landing requirement (no discards). Primarily inshore vessels conduct the Canadian fishery; with the fixed gear (longline and gillnet) having the larger cod share and bottom otter trawl gear having higher haddock quotas.

Although both countries have implemented policies to manage these aquatic resources, neither has adopted policies that explicitly account for their transboundary nature. Three of the most important groundfish species on Georges Bank - both historically and economically - to the US and Canada are considered to be transboundary. They are Atlantic cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*) and yellowtail flounder (*Limanda ferruginea*). Other species landed by the US and Canadian groundfish fishery includes Acadian redfish *Sebastes fasciatus*, white hake *Urophycis tenuis*, Pollock *Pollachius virens*, windowpane flounder *Lophopsetta maculataa*, ocean pout *Macrozoarces americanus* and Atlantic halibut.

Since the distribution of the stocks of the principal groundfish resource is one where there is substantial movement and migration across the boundary, it suggests that the harvest of each county may reduce the benefits of the other. This raises several important questions for research. To what extent are the groundfish harvests of one country reducing the benefits of the other country? To what extent, if at all, are the groundfish management measures of the two countries in conflict? How can the two countries' management measures be more complementary and support each other's management objectives? And what are the potential gains from cooperative management of the groundfish resources on Georges Bank?

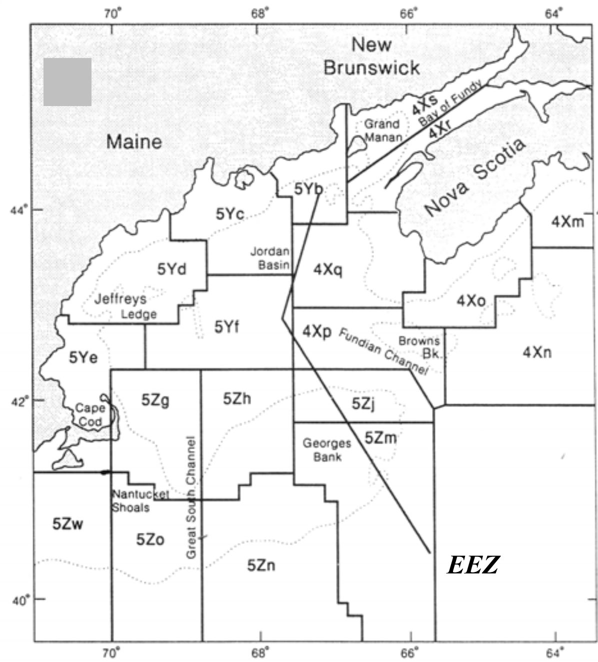

Figure 1. Statistical unit areas on Georges Bank

To help answer some of these questions we developed an empirical model of the transboundary fishery, and report results of a dynamic bioeconomic simulation used to evaluate the consequences of alternative management strategies. The model incorporates both the biological and economic characteristics of the fishery. The biological component of the model describes the population and spatial dynamics of the principle groundfish stocks. The economic component describes the production technology and harvesting strategy of each nation, and includes the harvest strategy for parts of the US otter trawl fleet as well as the Canadian longline and otter trawl fleets. I simulated alternative management strategies and determined whether the current management is superior to any other strategy and, if not, what other strategies are better in terms of economic performance. For each management alternative, the model simulated the change in profits for both countries jointly, as well as each country individually over a 20-year period, 2001 through 2020.

THEORETICAL MODEL

Stock dynamics

The premise behind all the models of the principle groundfish species is that there is seasonal movement of the stock between Canada and the US. If we postulate that in the spring a proportion of the US cod stock migrates into Canadian waters, we can express the Canadian spring cod stock size as:

$$x_{Can,S} = x_{Can,F} + \alpha x_{US,F} + F(x_{Can,F} + \alpha x_{US,F}) - h_{Can,F} \qquad \text{(Eq. 1)}$$

where $x_{Can,S}$ is the stock size in Canada during the spring, and $x_{Can,F}$ is the stock size during the fall. $x_{US,F}$ is the US stock size during the fall, and α is a migratory parameter that measures the proportion of the US stock that migrates into Canadian waters during the spring. $h_{Can,F}$ is the Canadian harvest during the fall. The stock growth function, $F(x_{Can,F} + \alpha x_{US,F})$ takes the following form:

$$F(x_t) = x_t + rx_t(1 - \frac{x_t}{K}) \quad \text{(Eq. 2)}$$

where x_t is the stock size in year *t*, *r* a growth parameter, and *K* the carrying capacity. $F(x_t)$ is a function that represents the natural growth rate of the stock.

The proportion of the cod stock remaining in the US in the spring would be:

$$x_{US,S} = (1-\alpha)x_{US,F} + F((1-\alpha)x_{US,F}) - h_{US,F} \quad \text{(Eq. 3)}$$

where $h_{US,F}$ is the US fall harvest. On the same note, if a proportion of the Canadian stock migrates into US waters during the fall, we can express the US cod stock size as:

$$x_{US,F} = x_{US,S} + \beta x_{Can,S} + F(x_{US,S} + \beta x_{Can,S}) - h_{US,S} \quad \text{(Eq. 4)}$$

where β is a migratory parameter that measures the proportion of the Canadian stock that migrates into US waters during the fall. $h_{US,S}$ is the US harvest during the spring. The proportion of the stock remaining in Canada during the fall would be:

$$x_{Can,F} = (1-\beta)x_{Can,S} + F((1-\beta)x_{Can,S}) - h_{Can,S} \quad \text{(Eq. 5)}$$

where $h_{Can,S}$ is the harvest by Canada during the spring.

Since the migratory patterns of the groundfish are different, we also constructed separate population dynamic models for haddock, yellowtail flounder as well as a fourth model that was the combination of all other species harvested by the US and Canadian fleets. We expressed the seasonal migration of haddock as:

$$x_{US,S} = x_{US,F} + \beta x_{Can,F} + F(x_{US,F} + \beta x_{Can,F}) - h_{US} \quad \text{(Eq. 6)}$$

$$x_{Can,S} = (1-\beta)x_{Can,F} + F((1-\beta)x_{Can,F}) - h_{Can} \quad \text{(Eq. 7)}$$

$$x_{Can,F} = x_{Can,S} + \alpha x_{US,S} + F(x_{Can,S} + \alpha x_{US,S}) - h_{Can,S} \quad \text{(Eq. 8)}$$

$$x_{US,F} = (1-\alpha)x_{US,S} + F((1-\alpha)x_{US,S}) - h_{US,S} \quad \text{(Eq. 9)}$$

And the seasonal migration of yellowtail flounder was expressed as:

$$x_{Can,S} = x_{Can,F} + \alpha x_{US,F} + F(x_{Can,F} + \alpha x_{US,F}) - h_{Can,F} \quad \text{(Eq. 10)}$$

$$x_{US,S} = (1-\alpha)x_{US,F} + F((1-\alpha)x_{US,F}) - h_{US,F} \quad \text{(Eq. 11)}$$

$$x_{Can,F} = (1-\beta)x_{Can,S} + F((1-\beta)x_{Can,S}) - h_{Can,S} \quad \text{(Eq. 12)}$$

$$x_{US,F} = x_{US,S} + \beta x_{Can,S} + F(x_{US,S} + \beta x_{Can,S}) - h_{US,S} \quad \text{(Eq. 13)}$$

For all other species there is no seasonal migration. The fish stock in each country can be expressed as:

$$x_{Can,t+1} = x_{Can,t} + F(x_{Can,t}) - h_{Can,t} \quad \text{(Eq. 14)}$$

$$x_{US,t+1} = x_{US,t} + F(x_{US,t}) - h_{US,t} \quad \text{(Eq. 15)}$$

Economic dynamics

Similar to the methodology used by Kirkley and Strand [4] we model the behavior of fishing vessels for the New England groundfish fishery by using a generalized Leontief revenue function. The generalized Leontief revenue function has since been applied to other studies that have used a dual-based approach to model multispecies fisheries; including the California multi-species trawl fishery [10] and others. The modified nonhomothetic generalized Leontief revenue function that was used to model Georges Bank groundfish fishery can be expressed as:

$$R(z,p,x) = \sum_i \sum_j \beta_{i,j} (p_i p_j x_i x_j)^{\frac{1}{2}} z + \sum_i \beta_i p_i z^2 x_i \quad \text{(Eq. 16)}$$

where *R(z,p,x)* is the revenue function, p_i is the output price of the *i*th species, x_i is the stock size for the *i*th species, and *z* is a composite input[a]. Applying Hotelling's Lemma, we obtain the input-compensated supply functions.

$$\frac{dR}{dp_i} = h_i = \beta_{i,i} z x_i + \beta_i z^2 x_i + \sum_j \beta_{i,j} (x_i x_j \frac{p_j}{p_i})^{\frac{1}{2}} z \quad \text{(Eq. 17)}$$

where the necessary symmetry condition requires:

$$\beta_{ij} = \beta_{ji},\ i \neq j,$$

The parameters for the following input-compensated supply equation were estimated for selected vessels classes in the US otter trawl, as well as the Canadian longline and otter trawl fleets. The three length classes used in the US model were (1) length<50 trawl; (2) 50<=length<70 trawl, and (3) length>=70 trawl. The four length classes used in the Canadian model were (1) length<45 longline; (2) 45<=length<65 longline; (3) Length<45 trawl, and (4) 45<=length<65 trawl. The length classes were categorized to reflect different operational strategies, and were consistent with Kirkley and Strand [4] who observed that smaller fishing vessels tend to harvest inshore, and larger fishing vessels offshore. The fleet categories are also consistent with the vessel size classes used by the National Marine Fisheries Service (NMFS) and Department of Fisheries and Ocean (DFO).

Each countries profit was determined by subtracting total costs from total revenue. The summation of the input-compensated supply functions multiplied by the ex-vessel demand in each vessel size class was used to estimate total revenue:

$$TR_i = \sum p_i h_i \quad \text{(Eq. 18)}$$

where TR_i is the total revenue for the *i*th vessel size class. The total costs in each class were estimated from the summation of variable and overhead costs as well as salaries and wages. Variable costs can be expressed as:

Variable Costs *= cost/day*DAS* (Eq. 19)

where *DAS* are the mean annual days-at-sea used by each vessel size class. In both the U.S. and Canadian fisheries wages have traditionally operated on the "lay" system, which divides the total revenue from each trip among crew, captain, and owner according to pre-set percentages[b]. Operating expenses are the responsibility of the crew and are subtracted after the total revenue has been divided. The crew share formula can be expressed as:

*Wages = 0.60*TR_i-Variable Costs* (Eq. 20)

From equation (31) and (32) the total costs in each vessel class can be expressed as:

*TC_i = 0.60*TR_i + Overhead Costs* (Eq.21)

where TC_i is the total cost for the *i*th vessel size class. In each country the fleets' total production depends on the total revenue and total costs for all vessel classes. From equations (18) and (19) the net profits in each country can be expressed as:

$$\pi_i = \frac{\sum TR_i - \sum \mathrm{TC_i}}{(1+r_i)^t} \quad \text{(Eq. 22)}$$

where π_i is the net profit, and *r* is the social discount rate for country *i*.

DATA

Both US and Canada undertake bottom trawl surveys to determine the abundance of groundfish stocks in statistical areas 5Z (Fig.1). The bottom trawl surveys helped determine the distribution of the principal groundfish stocks relative to the US/Canada maritime border, and provided a "snapshot" of the stocks during the spring and fall time periods. Mean catch and abundance data as well as the carrying capacity for each of the principle groundfish species was provided by NMFS and DFO, and was used to estimate the parameters used in the bioeconomic models. The gross annual groundfish landings as well as spawning stock biomass (SSB) for the period 1982 through 2001 were used to estimate the growth parameters.

The input-compensated supply equations were estimated using landings, price, effort and vessel data for the years 1997 through 2001. This data were provided at the fishing trip level for each specie grouping and vessel category. The spawning stock biomass used in this analysis was NMFS and DFO mean annual abundance data that had been prorated month-to-month.

Cost data was obtained from surveys of fleet sectors involved in catching groundfish on Georges Bank. The University of Rhode Island surveyed the small trawl vessel fleet in 1996 and the large trawl vessel fleet in 1997. Various components of the Scotia-Fundy groundfish fishing fleet were surveyed for vessel performance in 1990-1991. Both surveys collected data on fishing business costs that included both variable and overhead. The prices used in the simulations were mean fixed prices for the years 1997 through 2001

The data from all surveys were adjusted for inflation with the GDP implicit price deflator, and are in 2001 US dollars. In our calculation of net profit, for the US we assumed a discount rate of $r=0.07$, approved by the Office of Management and Budget (OMD). For Canada we assumed a discount rate of $r=0.07$. Current estimates of the GDP implicit price deflator as well as each country's discount rate were obtained from the Bureau of Economic Analysis [1].

ESTIMATION OF THE MODEL

The migratory parameters were estimated from the stock proportions found in areas 5Z during the spring and fall bottom trawl surveys. They were calculated in the following manner: given that 44% of the 5Z cod stock is found in Canada during the spring and 31% during the fall, there is a net loss of 13% of the stock that migrates from Canadian waters into US waters between spring and fall. The proportion of the spring stock remaining in Canada during the fall would therefore be 0.70. The migratory parameters estimated for all stocks are shown in Tables I through IV.

Once all the migratory parameters had been estimated, using ordinary least squares (OLS) we estimated the growth parameter, *r,* with SAS statistical software version 9.0. The US and Canadian growth parameter estimates are also shown in Tables I through IV. Once all the bioeconomic models had been estimated, we estimated the catch equations in the next step of the analysis.

Table I. Canadian parameter estimates of the bioeconomic model for spring migration

species	migration parameters		growth parameters		statistical values	
x	α	β	r	K	R^2	p-value
cod	0.2	0.38	0.06	173424	0.66	<.0001
haddock	0.27	0.16	0.064	295354	0.39	0.001
ylotail flounder	0.033	0.05	0.17	49392	0.56	<.0001
other species	0	0	-0.018	57860	0.042	0.3875

Table II. Canadian parameter estimates of the bioeconomic model for fall migration

species	migration parameters		growth parameters		statistical values	
x	α	β	r	K	R^2	p-value
cod	0.2	0.38	0.52	108390	0.88	<.0001
haddock	0.27	0.16	0.14	350420	0.61	<.0001
ylotail flounder	0.038	0.05	0.30	47040	0.52	<.0001
other species	0	0	-0.022	57860	0.024	0.4986

Table III. US parameter estimates of the bioeconomic model for spring migration

species	migration parameters		growth parameters		statistical values	
x	α	β	r	K	R^2	p-value
cod	0.20	0.38	0.18	260136	0.91	<.0001
haddock	0.27	0.16	0.17	205246	0.84	<.0001
ylotail flounder	0.033	0.05	0.45	68208	0.58	<.0001
All other species	0	0	0.41	57860	0.94	<.0001

Table IV. US parameter estimates of the bioeconomic model for fall migration

species	migration parameters		growth parameters		statistical values	
x	α	β	r	K	R^2	p-value
cod	0.20	0.38	0.45	325170	0.98	<.0001
haddock	0.27	0.16	0.39	150180	0.84	<.0001
ylotail flounder	0.033	0.05	0.54	70560	0.81	<.0001
All other species	0	0	0.70	57860	0.96	<.0001

The input-compensated supply equations were estimated by Zellner's seemingly unrelated regression technique with SAS version 9.0. In cases where landings for the species groups were zero, they were assigned the arbitrarily low value of 0.01 pound. Implicit ex-vessel prices for the species groups were estimated by dividing the total revenue by the quantity landed. Landings were estimated at the trip level for each species grouping and vessel category.

Since landings were estimated at the trip level, we first had to determine the mean number of trips by each vessel class seasonally. Multiplying the mean number of trips by the trip level landings we could calculate the total seasonal harvest by each vessel class. Summing the seasonal harvest's we could determine the total annual catch harvested by all vessel categories.

To measure the total annual catch by each country we had to estimate the proportion of the total annual catch that was harvested by all vessel classes. Once we had determined the ratio of mean annual catch to the vessel class landings, we could multiply this mean proportion to the total annual catch harvested by the vessel categories to estimate total overall landings. The mean number of trips as well as the proportion of total overall catch are shown in Tables V and VI.

Table V. The mean number of trips in each vessel class

Vessel categories	Cod spring	Cod fall	Haddock spring	Haddock fall	Yellowtail spring	Yellowtail fall	All other sp. spring	All other sp. fall
Length<45 long line	165	26.2	165.2	26.2	0.2	0	128.8	17
45<=length<65 longline	9.8	11.8	9.6	11.8	0	0	9.8	7.4
Length<45 trawl	153.6	49	148.6	39.4	129.4	41.4	170.8	53.4
45<=length<65 trawl	134.6	61.2	135.8	58.6	75.8	34.8	131.6	57.8
Length<50 trawl	23.2	69.2	31.6	2.2	43.2	23.6	73.8	26.8
50<length<70	108.4	251.2	141.6	40.8	319.2	161.6	402	202.2
Length<=70 trawl	322.6	802.4	586.4	179	641.6	260.8	727	407.8

Table VI. The proportion of the total annual catch in each country that was harvested by the vessel categories

Species	US	Canada
Cod	2.57	1.36
Haddock	1.67	1.29
Yellowtail flounder	1.13	1.06
All other species	0.80	0.23

SIMULATIONS & RESULTS OF SIMULATIONS

A bioeconomic model was developed that integrates stock and harvest relationships for several vessel length classes in the US and Canadian fleets. The model was used to simulate alternative management strategies and determine whether the current management is superior to any other strategy and, if not, what other strategies are better in terms of economic performance. Of special interest is whether there exists a combination of US and Canadian harvest policies that would make both countries better off, a so-call 'win-win' strategy.

For each management alternative, the model simulated the change in profits for each country over a 20-year period, 2001 through 2020. The simulations were based on an initial spawning stock biomass (SSB) taken from mean NMFS and DFO data for catch and abundance, and implemented in Microsoft Excel. Mean seasonal price, effort and vessel data were used to reflect the economic variables in the model.

First, we forecasted the discounted present value sum of profits given the current management strategy in each country. The results provided an initial condition for this 20-year experience with which we could compare with the economic performance of other strategies. The current policy is where the two loci cross, shown at point A (Fig. 2-5).

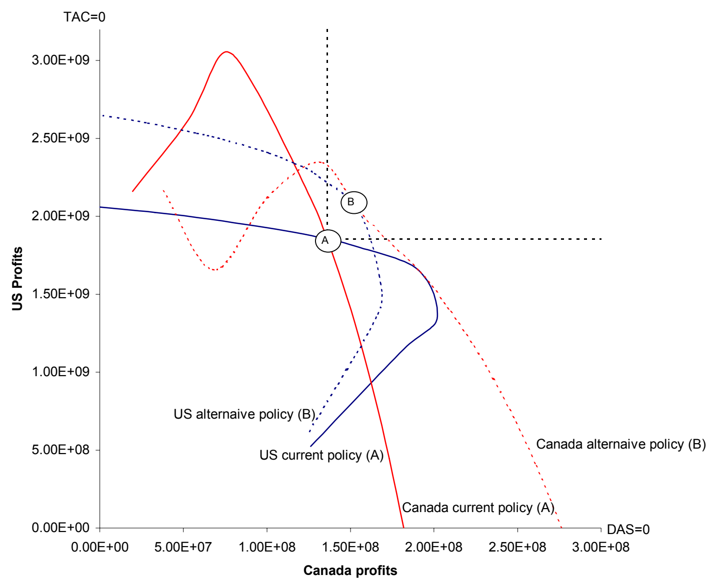

Figure 2. Discounted present value sum of profits for the US and Canada with a change in the TAC and DAS allocation. The current policy is where the two loci cross, shown at point A. The alternative policy is where the two

By making proportional adjustments to the total harvest of the relevant vessel length classes and species groupings in the Canadian fishery - keeping US DAS allocation constant - we were able to reflect Canadian policy changes that affect the overall TAC in that country, and derive the locus of US and Canadian discounted profits. Similarly, by adjusting the mean number of trips for all vessel classes to reflect US policy changes that affect DAS allocation - keeping Canadian TACs constant - we were able to derive the second locus.

As we proportionately decreased the Canadian TACs - given the current US policy - discounted profits declined in Canada and increased in the US. When we increased the Canadian TACs, discounted profits initially increased in Canada, and then began to decline as the overall stock became overfished. For the US an increase in the Canadian TACs always made that country worse off. A similar scenario occurred with a change in the US DAS allocation. An increase in the US DAS - given the current Canadian policy - caused Canada to become worse off. In the US, discounted profits initially improved then began to decline as the stock became overfished. When we reduced the DAS allocation Canada was always better off and the US worse off. The dotted black lines helped define the conditions under which the so called 'win-win' strategy could be achieved, and both countries become better off. To the left of the vertical dotted line Canada will become worse off, and below the horizontal dotted line, US will become worse off.

In the next step of the analysis we searched for an alternative management policy that would make both countries better off. Given that we were examining the sum of flows for a 20-year period, when we relaxed (increased) the TAC for Canada – then kept it constant - and proportionately adjusted the US DAS allocations, the red locus shifted out. Similarly, as the DAS allocation was relaxed (increased) – then kept constant - and proportional adjustments were made to the Canadian TACs, the blue locus shifted up (Fig. 2.). The point where the two loci meet, B, is the solution to an alternative management policy.

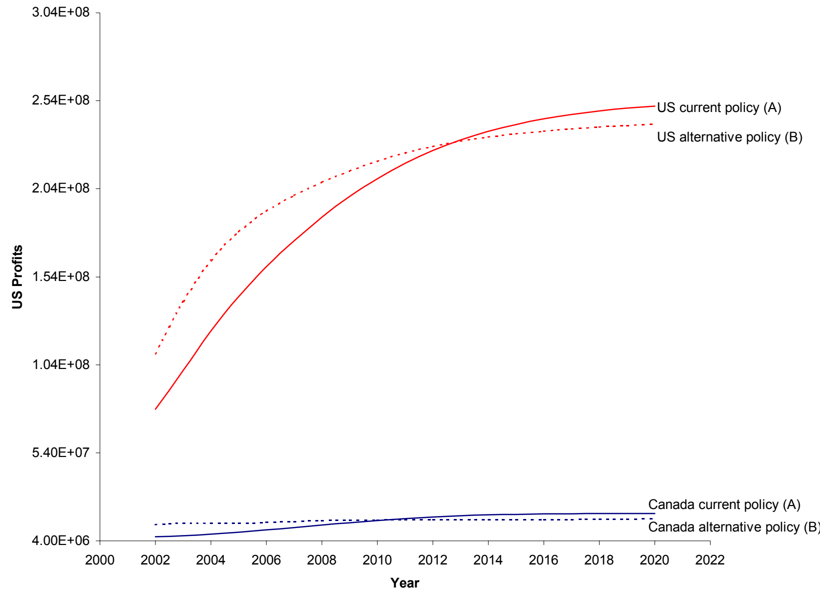

Figure 3. Nominal US and Canadian profits for the current policy (point A) vs. the alternative policy (point B).

In figures 3 we compare the nominal profits for the current policy (point A) to that for the alternative policy (point B). We see that for both the US and Canada there would be an initial improvement in nominal profits vs. the current policy, but profits are less for the alternative policy in later years. Despite this policy being better in terms of economic performance (15 percent increase in net profits in Canada and 10 percent increase in the US), when we examine the short-term adjustments for both Canada and the US we notice that this policy causes a decline in the groundfish SSB, principally cod and all other species (Canada only).

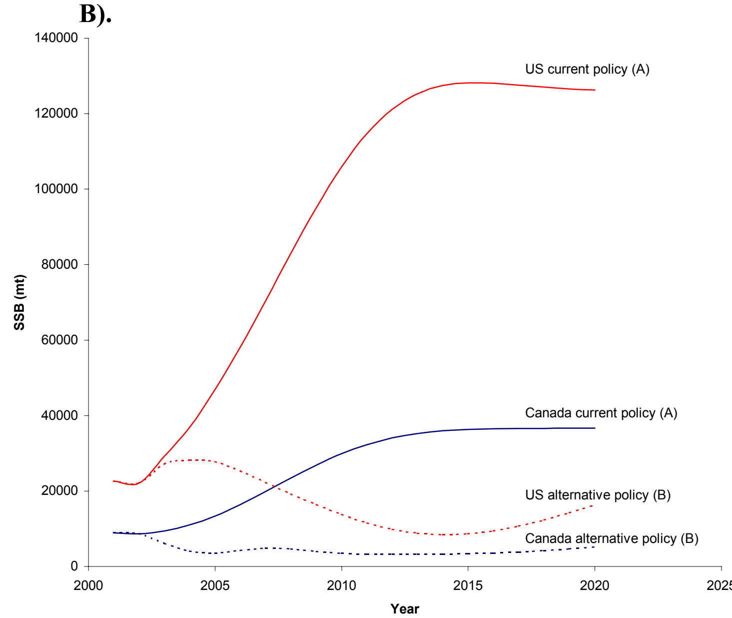

Figure 4. The SSB of cod in the Fall under the Current policy (A) vs. the Alternative Policy (B)

In figure 4 we compare the SSB of cod in the Fall for the two different policies. The fishing mortality that corresponds to the low stock biomass drops way below the overfishing threshold ($F_{3\%}$ vs, $F_{20\%}$) defined before Amendment 9 of the Magnuson-Stevens Act, suggesting that this policy will be unfeasible and lead to an unacceptable risk of stock collapse.

How can nominal profits rise continuously while the SSB of cod is dropping? There is a tradeoff between the rise in SSB of haddock and yellowtail flounder, and the decline in the SSB of cod. With the current policy the SSB of cod, haddock, yellowtail flounder and all other species reach equilibrium. With the alternative policy only haddock and yellowtail flounder reach equilibrium. There is much more fluctuation in the cod SSB, and equilibrium is not reached. As a consequence, nominal profits continue to rise as a result of increased haddock and yellowtail flounder biomass, but in later years begins to drop to a rate that is less than the current policy as a consequence of the decline in stock biomass of some of the species.

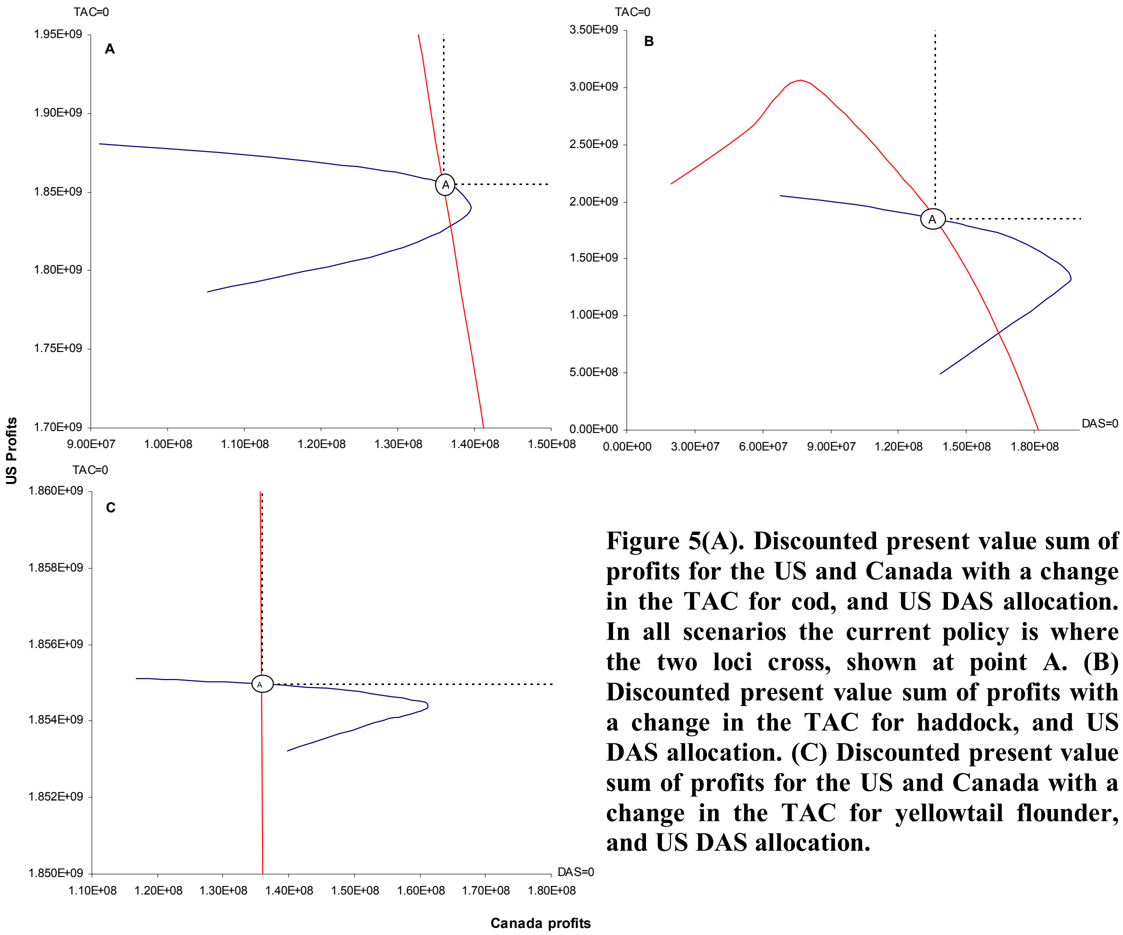

Figure 5(A). Discounted present value sum of profits for the US and Canada with a change in the TAC for cod, and US DAS allocation. In all scenarios the current policy is where the two loci cross, shown at point A. (B) Discounted present value sum of profits with a change in the TAC for haddock, and US DAS allocation. (C) Discounted present value sum of profits for the US and Canada with a change in the TAC for yellowtail flounder, and US DAS allocation.

Figures 5A-C provide a locus of solutions for which the individual TAC for cod, haddock and yellowtail fishery were changed respectively. Similar to the analysis used to determine whether the current management was superior to any other strategy with respect to changes in the overall TAC, we can define the conditions under which alternative outcomes may be achieved with changes in the individual TAC. Secondly, by analyzing the economic response to a change in the individual TAC we can begin to understand the transboundary effects and the extent to which the groundfish harvest of each country may be reducing the harvest of the other.

A change in the cod TAC, as shown in figure 5A, will improve net profits by only a small amount. Reducing the TAC to zero increases profits by 1.4% in the US, and reduces profits in Canada by 49.2%. A twofold increase in the TAC would improve economic conditions in Canada by only 2.3%. For Haddock reducing the TAC to zero increases profits by only 9.8% in the US, and reduces profits in Canada by 100.5%, as shown in figure 5B. A six-fold increase in the TAC would improve economic conditions in Canada by 43.5%. Finally for Yellowtail flounder, reducing the TAC to zero increases profits by only 0.01% in the US, and reduces profits in Canada by 16.4% (Fig. 5C.). Increasing the TAC fivefold will increase profits by 18.6%. A further increase in the cod, haddock and yellowtail flounder TAC will cause profits to decline, reflecting the backward bending nature of the loci. The economic and biological responses to these policy changes are discussed in the next section.

DISCUSSION

This paper presents an empirical model of Georges Bank transboundary groundfish fishery, and reports results of a dynamic bioeconomic simulation used to evaluate the consequences of alternative management strategies for the multispecies fishery. Of special interest was whether we could find a combination of US and Canadian harvest policies that would make both countries better off, the so-called 'win-win' strategy. The results suggest that although there may be economic benefits from alternative management strategies, these policies may be in violation of the US Magnuson-Stevens Act and Canada's Atlantic Groundfish Fishing Plan, and lead to groundfish harvests that become unsustainable.

The model aggregated the sum of profits for all groundfish fishing and estimated the potential gains from alternative management strategies. The "alternative policy" suggested that profits could be increased over the 20-year experience, and that we would find a solution that improves the economic performance in both countries. However, because of the decline in cod SSB, this policy would in fact become infeasible since it would be in violation of the Magnuson-Stevens Act national standard 1. Similarly, considering that a central element of Canada's Atlantic Groundfish Fishing Plan is to harvest the resource at a rate no greater than $F_{0.1}$, this harvest policy would not hold in Canada either.

There also have been recent developments by the international fisheries community that have incorporated a precautionary approach towards managing stocks. According to the Rio Declaration the Precautionary Approach declares that "in order for stocks and fisheries exploiting them to be within safe biological limits, there should be a high probability that 1) the spawning stock biomass is above the threshold where recruitment is impaired, and 2) the fishing mortality is below that which will drive the spawning stock to the biomass threshold which must be avoided" [3]. Application of the "alternative policy" would lead to increased harvests and would not be fulfilling the UN obligations.

A recent lawsuit won by the Conservation Law Foundation (CLF) charging that the NMFS violated federal law by risking further depletion of New England groundfish, resulted in additional DAS cutbacks. To make it viable for fishermen to remain in the fishery, there was a decision with the latest amendment (13) to allow transferable DAS, where fishermen could pool their DAS. This policy in theory would be similar to the outcome of transferable IFQs in Canada. There would be an overall total quota for DAS, and a price per quota, similar to a shadow price or an opportunity cost not to harvest that would reflect the market for the transferable DAS.

Would the new policy affect the results of the empirical analysis? If the policy change follows the theoretical change of implementing transferable quota, then in practice the results should differ. However, it would not be immediate for the policy to become effectively captured in the fundamental framework of the model. It may take considerable time before the order of magnitude of a change in the DAS will be observed. More important is that the underlying tradeoff will not change, so the relative policy adjustments can still be measured effectively; and because the total DAS are being reduced, the stocks will be healthier in the long term.

The tradeoff between a change in the US DAS or Canada's TAC seems to depend critically on two factors 1) the spatial dynamics of the stocks and 2) and current harvest rates. The scientific surveys suggest that cod on eastern Georges Bank (5Zjm) have a distinct seasonal migration pattern, westward between fall and spring and eastward between spring and fall. A similar migratory pattern emerges for cod on Georges Bank (5Z), but is not as distinct. The small amount of migration recognized in area 5Z conflicts somewhat with earlier tagging studies that suggested distinct east-west migratory patterns [8]. It has been suggested this may be the result of the small abundance of cod stocks in the area, and as the stocks grow a more distinct pattern of migration will emerge.

Due to the low abundance of cod there is very little directed cod fishery. In Canada; the cod that is caught is mostly an inevitable result of the bycatch of the directed haddock fishery. Since 1996 total landings on eastern Georges Bank have averaged only 3000t. At one time cod stocks were very abundant, in 1982 combined USA and Canada catches peaked at 26000t. Today the combined US-Canada catch is only 12% of the total catch that peaked in the early eighties. The combination of low harvest rates, and seemingly small amounts of cod migration on Georges Bank (5Z) may explain the small change in US profits with a reduction in the Canadian TAC.

For haddock, eastern Georges Bank total Canada/US removals have averaged over 5000t since 1998, with the Canadian catch being dominant. It has been recognized, by both US and Canada, that in recent years there has been considerable improvements in the health of these stocks. Similar to cod, Georges Bank (5Zjm) biomass surveys indicate a seasonal migration pattern, westward between fall and spring and eastward between spring and fall. This migratory pattern is not as obvious on Georges Bank (5Z). In fact an east-west migratory pattern emerges, which may partly be explained by the movements of a large percentage of the stock to the northeast peak of the bank during the fall [11]. The improved stock status and clear mixing of the stock between US and Canadian waters may explain the relatively large improvement in US profits, from a reduction in the TAC in Canada.

Tagging work on yellowtail flounder have indicated only limited movement from Georges Bank to adjacent areas [5,9]. Knowledge of seasonal movement of yellowtail flounder on Georges Bank is poor; however the seasonal surveys also recognized only minor patterns of migration between US and Canada. The Canadian directed fishery for yellowtail is a relatively recent development. The combined US/Canadian total removals have been increasing since 1995 and in 2001 were 6790t. The Canadian fishery occurs in a relatively limited portion of Georges Bank know as the Yellowtail Hole. The US fishery operates primarily in the southwest triangle outside of Closed Area II. There is also a yellowtail bycatch in the scallop fishery that continues to be an unresolved issue in the groundfish sector. Despite the bycatch and increasing harvests, the outlook for yellowtail flounder on Georges Bank remains positive and the population is responding well to the current policies. The considerably small change in US profits from a reduction in the Canadian TAC, therefore, seems to be point to the small amount of migration and mixing that is occurring between the two countries.

In order to better define the potential gains from cooperative management, other policy options still need to be considered. This may include simulations that change the time frame so that potential profits can be measured for both short and long-run experiences. Future research should also include developing specific models to examine alternative policy options that incorporate a more spatially dynamic stock interaction. And finally, when the economic data becomes available, to measure the economic tradeoffs on eastern Georges Bank that includes the benefits of Closed Area II.

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ENDNOTES

[a]I measured *z* by the product of length of vessel and days absent per vessel.

[b]For the US and Canadian groundfish fishery 60 percent of net revenues are divided between captain and crew and 40 percent goes to the boat (Repetto, 2002).