

Appendix XVI

Analytic Techniques

1.0 Biomass Projection Methodology for Index Species.

The following report describes the methodology used for projection of biomass and catches for index stocks. "Index" stocks or species typically lack sufficient age-based information to allow application of standard assessment models. For some species, the information content of the data does not support the estimation of reliable surplus production parameters. The index assessment methodology is described in detail in NEFSC 2002. Underlying the methodology is a linear model of population growth that characterizes the population response to varying levels of fishing mortality. The model can be used to estimate the level of relative fishing mortality at which the population is likely to be stable. Fishing mortality rates greater than this value lead to population decline, values in excess lead to population increase. The magnitude of positive or negative population growth rates increases proportionately with relative fishing mortality rates below or above the stable value.

The index methodology can be extended to allow population projections under various scenarios. The basic approach can be summed up as follows. The population growth rate can be expressed as a linear function of the relative fishing mortality rate. The product of population growth rate and current population size projects the population to the next time step. Catch is estimated as the product of relative fishing mortality rate and the index population size. This sequence of computations is applied recursively to forecast population sizes up to the target biomass level (expressed in index units, e.g., kg/tow). Once the population attains the target level, relative fishing mortality is set at the level sufficient to keep the population size constant. The predicted catch when the population is at the target level serves as a proxy for the MSY. The details of this computational approach are summarized in outline form below:

- A. Estimate the parameters for initial population size, current relative fishing mortality rate, and relative fishing mortality rates necessary to achieve targets. For all of the stocks considered in this exercise the NEFSC fall trawl survey was used as the primary index of abundance.

1. Estimate relative abundance index for terminal year

$$\bar{I}_{Fall,2001} = \frac{I_{99} + I_{00} + I_{01}}{3}$$

$$\bar{I}_{Spring,2002} = \frac{I_{00} + I_{01} + I_{02}}{3}$$

2. Estimate relative F for terminal year

$$rel\bar{F}_{01} = \frac{relF_{99} + relF_{00} + relF_{01}}{3}$$

3. Estimate the population growth rate associated with the current relative F.

$$\hat{I}_{01} = \exp(a + b \ln(rel\bar{F}_{01}))$$

4. Compare ratio of current stock size to target stock size and estimate the population growth rate necessary to increase current stock to target within T years.

$$I^T = \frac{I_{Target}}{I_{Current}}$$

Where T is the duration of the rebuilding period (7 years, 2003-2009)

5. Compute the annual rate of increase corresponding to the rebuilding strategy

$$I_{Rebuild} = \exp\left(\frac{\ln(I_{Target}) - \ln(I_{Current})}{T}\right)$$

6. Compute the level of relative F necessary to rebuild the population at $\lambda_{Rebuild}$ from

$$\ln(I_{Rebuild}) = (a + b \ln(relF_{Rebuild}))$$

such that

$$relF_{Rebuild} = \exp\left(\frac{\ln(I_{Rebuild}) - a}{b}\right)$$

where a and b are regression parameters derived from analysis of replacement ratio vs relative F for the period 1963 (spring) or 1968 (fall survey) onward, as appropriate.

B. Project the population and catches corresponding to the selected scenario

1. Compute the population index estimate for 2002

$$\hat{I}_{02} = \mathbf{I}_{01} \bar{I}_{01}$$

2. Compute the predicted catch in 2002 based on the selected scenario

$$\hat{C}_{02,scenario} = rel\tilde{F}_{02,scenario} \hat{I}_{02}$$

3. Compute the Index and catches recursively for each scenario.

$$\hat{I}_{t+1} = \mathbf{I}_{t,scenario} \hat{I}_t$$

$$\hat{C}_{t,scenario} = rel\tilde{F}_{t,scenario} \hat{I}_t$$

4. Attenuate the population size at the index target. Set the maximum catch level equal to the target population value multiplied by the relative F at replacement.

$$C_t = \begin{cases} relF_t \hat{I}_t & \text{if } I_t < I_{Target} \\ relF_{Target} I_{Target} & \text{if } I_t \geq I_{Target} \end{cases}$$

5. Compute the constant quota strategy. This approach requires an iterative solution to find the constant level of catch that will allow rebuilding to occur over the specified time interval. A numerical optimization method was used to estimate $C_{constant}$ in the following set of equations:

$$\frac{C_{\text{constant}}}{I_t} = \text{rel}F_t$$

$$I_t = \exp(a + b \ln \text{rel}F_t)$$

$$I_{t+1} = I_t I_t$$

$$\frac{C_{\text{constant}}}{I_{t+1}} = \text{rel}F_{t+1}$$

etc.

subject to: $I_T = I_{T \text{ target}}$

C. Scenarios

1. No Action: Let $F_t = F_{2001}$ for all t where $I_t < I_{\text{Target}}$. Let $F_t = F_{\text{Target}}$ when $I_t \geq I_{\text{Target}}$
2. Status quo: Let $F_t = 0.85 F_{2001}$ for all t where $I_t < I_{\text{Target}}$. Let $F_t = F_{\text{Target}}$ when $I_t \geq I_{\text{Target}}$
3. Rebuild F: Find constant F that allows rebuilding to target index level between 2002 and 2009. If stock is currently rebuilt, let $F_t = F_{\text{Target}}$.
4. Constant Quota. Find C such that $I_{2009} = I_{\text{Target}}$

D. Results

The index projection model was applied to the following stocks:

Gulf of Maine haddock
 Pollock
 White hake
 Georges Bank winter flounder
 Northern windowpane flounder
 Southern windowpane flounder
 Ocean pout
 Mid Atlantic yellowtail flounder

2.0 Economic Analysis - Prices

The price and demand analysis departs somewhat from the traditional approach used in most plans and amendments, including the New England multispecies plan. The NEFSC recently funded a statistical analysis of the relationships among groundfish dockside prices through the CMER (Cooperative Marine Education and Research) Program with the University of Rhode Island. Researchers in the Department of Environmental and Natural Resource Economics found that with the exception of windowpane flounder and redfish, the prices of large mesh groundfish species were cointegrated (Roheim in prep). That is, the prices of several species move together over long time periods. Further, the price of Atlantic cod determines the prices of haddock and flounders. These results mean that it is reasonable to aggregate the landings of most species into composite products when modeling dockside demand, and that the dockside price of cod is an exogenous variable in the demands for most other species. The role of cod prices is new for dockside demand analysis, but researchers have long suspected that most groundfish were close substitutes in markets for whitefish (Bockstael 1976).

The dockside demand model was specified as a system of price equations. The model reflects management's focus on principal stocks, practical considerations having to do with available data, and the cointegration results. There are separate price equations for Atlantic cod, haddock, and yellowtail flounder. The price of redfish was also modeled separately because it was neither dependent on cod prices nor co-integrated with the other large mesh species. The remaining large mesh species - i.e., haddock, white hake, winter flounder, American plaice, witch flounder, windowpane flounder, and pollock - were aggregated in a single equation for the analysis of most management alternatives. The one exception to this composite product was an industry proposal that required a separate equation for American plaice.

Dockside prices (current dollars per pound) were regressed on annual landings (pounds, live weight) in the Northeast Region. The prices of cod and redfish were also regressed on year (1977, 1978, ..., 2001; n=25) which serves as a proxy for all unknown factors which are related to time and influence price (e.g., more than 99 percent of the variation in disposable per capita income in New England is explained by year). A contractor who recently applied co-integration analysis to specify a tilefish demand model also used year to explain movements in tilefish prices. The prices of haddock, yellowtail flounder, American plaice, and the composites were also regressed on cod price. These species' prices are influenced indirectly by year through cod price. All functional forms are linear in prices and regressors.

Georgianna and Dirlam (2000) report that domestic landings of groundfish are part of the New England fresh fish market. The effects of groundfish imports on domestic dockside prices could not be captured, however. Imports of fresh whole groundfish and fillets were specified in various ways (e.g., by species or in aggregate, different time horizons), but import quantities (after converting to live weights) either tested insignificant or the coefficient was positive which is contrary to the substitution effect. The positive relationship probably results because low domestic landings and high dockside prices induce processors to find other sources of product,

including imports from Canada and Iceland. A proper investigation of the impacts of fresh groundfish imports on domestic prices probably requires a multi-market analysis that captures simultaneous relationships that most likely changed during the 25 year period. A multi-market analysis requires data on the movement and marketing of groundfish products which are not available, including input substitution of Pacific cod for Atlantic cod (Georgianna and Dirlam 2000).

The general form of a price equation is:

$$\text{Price}_{i,t} = a_i + b_i \bullet \text{Landings}_{i,t} + c_i \bullet Z_t + e_t$$

where Z is either year or the price or cod, the subscripts denote species i and year t , a , b , and c are parameters to be estimated, and e is the residual process. The demand model was estimated in two stages. Autocorrelation is common in time series data, so in the first stage OLS (ordinary least squares) was used to estimate the first order correlation parameters for each equation. These parameters were used to transform each variable in the model (Kennedy 1979). In the second stage, SUR (seemingly unrelated regression) was used to estimate the demand system in transformed variables.

Two models (Table 1) were estimated one for where projections for all stocks were available (Model A) and one to be used when evaluating the phased-F rebuilding strategy where projections for four stocks were available (Model B). The weighted R^2 s indicate that three-quarters of the price variability is explained by the models. Prices are inversely related to landings (e.g., a reduction in landings will increase price), although the parameter in the redfish model is not statistically significant. Cod prices increased nearly 3 cents per pound a year after accounting for the effects of landings. Cod price is a significant determinant of the prices of other species identified in the cointegration study.

The Durbin-Watson (DW) tests (Kennedy 1979) on the SUR residuals suggest persistent autocorrelation in the residuals of the yellowtail flounder and redfish equations in both models, and in the plaice and composite equations in the model used to evaluate the industry alternative (Table 1) Low DW values combined with high R^2 s suggest that the model is misspecified in an unknown way (e.g., incorrect functional form, missing variable(s), non-stationarity in time-series). Glejster tests performed on the residuals from the SUR results (absolute values of residuals regressed on explanatory variable) further indicate that heteroskedasticity is present in most equations.

Autocorrelation and heteroskedasticity can cause the estimates of parameters to be biased. Biased parameters that result in good fits to the data would not affect estimates of revenues or related quantities (producer surplus, industry) which depend on predictions of price. However, they could bias the estimates of consumer surplus and, therefore, total net economic benefits. The practice of comparing net benefits between alternatives will nullify some of this effect, though. Further investigation of this model residuals is somewhat inhibited by relatively few observations and the dearth of information on markets and product distribution.

Predicted prices in time t were standardized by multiplying the observed price in 2001 by the ratio of the predicted price in time t to the predicted price in 2001. In this manner predicted prices were converted to real or current 2001 relative prices. Estimates of consumers surplus were obtained by calculating the area under the demand function from zero to the quantity supplied and subtracting total revenues paid to vessels.

Price equation	Model A (weighted R ² =0.78)					Model B (weighted R ² =0.76)				
	Intercept	Landings	Year	Price of cod	DW	Intercept	Landings	Year	Price of cod	DW
Atlantic cod	-55.117 (-4.99)	-0.00000000249 (-2.19)	0.028123 (5.10)	-	1.50	-54.603 (-5.05)	-0.00000000259 (-2.33)	0.0278 7 (5.16)	-	1.49
Haddock	0.833 (7.43)	-0.0000000110 (-5.76)	-	0.5010 (4.02)	1.94	0.813 (7.34)	-0.0000000105 (-5.64)	-	0.5220 (4.23)	1.91
Yellowtail flounder	0.785 (4.90)	-0.00000000618 (-3.13)	-	0.4921 (2.69)	1.18	0.792 (5.19)	-0.00000000626 (-3.70)	-	0.4826 (2.71)	1.18
Composite (white hake, pollock, plaice, winter flounder, witch flounder, windowpane flounder)	0.702 (5.22)	-0.00000000333 (-3.89)	-	0.4409 (3.95)	1.27	-	-	-	-	-
Composite (white hake, pollock, winter flounder, witch flounder, windowpane flounder)	-	-	-	-	-	0.550 (4.70)	-0.00000000281 (-3.29)	-	0.5421 (5.06)	1.13
American plaice	-	-	-	-	-	0.775 (5.89)	-0.0000000118 (-3.94)	-	0.4901 (3.55)	1.11
Redfish	-11.939 (-0.91)	-0.00000000581 (-1.29)	0.00625 (0.95)	-	1.10	-11.635 (-0.90)	-0.00000000549 (-1.24)	0.0061 0 (0.94)	-	1.09

Table 1 - Parameter estimates from SUR (seemingly unrelated regression) estimation of linear demand systems.

T-statistics are in parentheses. Model B is compatible with industry proposal. DW is the Durbin-Watson test for autocorrelation. The intercepts were calculated from intercept estimates in the transformed-variables specifications that were used to correct for first-order autocorrelation. See text for more explanation.

3.0 Modeling of the Hard TAC Alternatives

The TAC model is designed specifically for modeling the impacts of a Hard TAC system as proposed in the Amendment 13 document as a supplement to the use of the closed area model. Alternatives 2 and 3 utilize Hard TACs as a backstop measure to ensure other input controls meet management objectives. Alternative 4 employs Hard TACs as the primary management measure. Alternatives 2 and 4 utilize trip limits, employed after a certain percentage of the TAC is achieved, to lengthen the duration of the fishing year.

Hard TAC management may, if employed under ideal conditions, adequately meet mortality objectives. However, such measures have two fundamental impacts on fishing behavior that may hinder rebuilding. First, they encourage intense fishing pressure early in the fishing year (referred to as the “derby” effect). Because operators do not know the true duration of the fishery (which, upon achieving the TAC, will end in an area closure or species retention prohibition), they will find it advantageous to concentrate their fishing effort on high-revenue species early on in the fishing year. The second impact of a Hard TAC on fishing behavior is a high instance of regulatory discards in circumstances where area closures are not employed after a TAC is achieved, or when trip limits are employed to extend a TAC-limited fisheries’ duration. Alternatives 2 and 4 call for the use of trip limits after a threshold of between 70 and 90% of the TAC has been caught (Alternative 2 calls for specific trip limits for certain species as well).

The Derby Effect

To simulate the impact of increased fishing pressure early in the fishing year, stock-specific landings for 2001 were aggregated by week. These weekly landings were then sorted in descending order, from the highest weekly landing to the lowest. This allowed for a prediction of the approximate week that a particular species’ TAC, or threshold of that TAC, may be achieved.

Discards

For Alternatives 2 and 3, discards are assumed to begin once the TAC is achieved under the zero retention alternative. Under the area closure alternative, no further regulatory discards are assumed. For Alternative 4, discards are assumed to begin once the TAC threshold is achieved and will continue after the TAC is achieved if the zero retention alternative is selected.

To estimate the degree to which regulatory discards could increase, individual trips occurring during the weeks between when the threshold is achieved and when the TAC is reached (Alternative 4) and/or trips occurring after the TAC is reached (Alternatives 2, 3 and 4 under the zero retention alternative) were subjected to a profitability decision rule which takes effect upon on the implementation of a trip limit (or, in the case of the zero retention alternative, a trip limit of zero). Estimates of variable costs are made based on the size of the vessel (gross tonnage), type of gear, and duration of trip. Each trip is then assigned a number based on it’s profitability under the trip limit condition (ie., if the trip landed enough non-trip limit-limited species to recoup operating costs, or if the trip limit was sufficiently high to allow for a profit while fishing on the trip limit limited stock). Short-duration trips (less than 1.5 days absent) that were determined not to be profitable were assumed to be not made.

Landings

Landings are estimated as a combination of pre-threshold (or pre-TAC) landings and post-threshold landings. Up to the point where the threshold or TAC is achieved, landings and catch are assumed to be the same (regulatory discards based on existing species' size limits and existing trip limits are incorporated into the model's predicted TACs). The alternatives clearly state that the TAC is based on catch and not landings; therefore, total landings predicted by the model will often be significantly lower than the predicted TAC. Discards account for the difference.

Model specifications

Fishing year 2001 VTR reported landings are adjusted for anticipated changes in stock size for FY 2004. Assuming a linear relationship between stock size and catch rates, individual trip landings are multiplied by a factor proportional to the difference between FY01 and FY04 spawning stock biomass.

	FY01 SSB	FY04 expected SSB	Adjustment factor
GOMcod	22	26.75	1.22
GB cod	29.2	20.82	0.71
CCGOMyt	1.9	2.37	1.25
SNEyt	2.21	5.63	2.55
SNEwinter	7.6	6.82	0.90
Plaice	13.8	14.75	1.07

Table 2 – Adjustment factors for changes in SSB between FY01 and FY04.

Rebuilding Alternative 2 calls for specific gear changes affecting the CCGOMyt, GB cod and GOM cod stocks. As per the analysis provided in Section 3 of this document, Table 3 highlights the factors used to adjust catch rates for these gear changes. Furthermore, this alternative includes trip limit specifications for CCGOM yt, SNE yt, GOM cod and GB cod. GOM cod is subject to a 500 lbs/day trip limit under this measure; it was under a 400 lbs/day trip limit in FY01. A model increasing this trip limit is therefore not possible given these data and the 400 lbs/day trip limit serves as a proxy under the trip limit model. For the two yellowtail flounder stocks and GB cod, the specifications of the trip limits were modeled exactly.

	Adj factor
CCGOMyt raised footrope trawl	0.43
GOM cod haddock sep trawl	0.85
GB cod haddock sep trawl	0.70

Table 3 – Adjustment factors for required gear changes in Rebuilding Alternative 2.

Shortcomings of the model

- 1) The model uses trips and landings adjusted from fishing year 2001 (May 1, 2001 – April 30, 2002) and the fishing practices that resulted in those landings may not be ideal predictors for fishing year 2004.
- 2) The model is based on a single-stock approach to achieving TACs and thresholds; achieving a TAC for one species, and the consequent management measures enacted, has no impact on the modeled time it takes to achieve another species' TAC.

- 3) The model assumes there is no behavioral change as a response to trip limit or TAC-achieved scenarios.
- 4) Stacking the weeks by total landings may overestimate the impact of a “derby” fishery if the resource is unavailable in similar quantities or in similar locations to the time the actual trip took place.
- 5) If more vessels chose to target a particular species than they did in FY01, then the model may actually underestimate the impact of a “derby” fishery.

Model results

Detailed model results for rebuilding alternatives 2 and 4 can be found in Sections 3.6, 4.2.5 and 4.2.9 of this document. Additional data is provided here on both the sensitivity of the modeled trip limits and discards to the specified TAC threshold, and the potential derby impacts of a TAC-based fishery under perfect realization of target Fs.

Threshold	2004 Landings	2004 F_Rebuild TAC	Threshold	Weeks to threshold	Trip limit (per day)	Week TAC achieved	Month TAC Achieved	# DAS on stock	# DAS to threshold	Remaining DAS on stock	# DAS shifted off stock due to TAC	Predicted Landings under trip limits	Predicted Discards under trip limits	Total Landings	Total Mortality
0%	11,475	2,747	0	0	250 lbs	8	June	29,947	0	29,947	2,825	470	2,268	470	2,739
10%	11,475	2,747	275	<1	250 lbs	8	June	29,947	379	29,568	2,825	470	2,268	745	3,013
20%	11,475	2,747	549	<1	250 lbs	8	June	29,947	379	29,568	2,825	470	2,268	1,020	3,288
30%	11,475	2,747	824	1	190 lbs	6	June	29,947	379	29,568	3,331	249	1,672	1,073	2,744
40%	11,475	2,747	1,099	1	190 lbs	5	June	29,947	379	29,568	3,331	217	1,431	1,315	2,747
50%	11,475	2,747	1,374	2	145 lbs	6	June	29,947	1,217	28,730	4,002	139	1,234	1,513	2,747
60%	11,475	2,747	1,648	2	145 lbs	5	June	29,947	1,217	28,730	4,002	115	984	1,763	2,747
70%	11,475	2,747	1,923	3	100 lbs	6	June	29,947	2,136	27,811	4,666	58	766	1,981	2,747
80%	11,475	2,747	2,198	4	50 lbs	6	June	29,947	3,032	26,915	5,144	19	526	2,216	2,742
90%	11,475	2,747	2,472	4	50 lbs	6	June	29,947	3,032	26,915	5,144	10	258	2,483	2,740

Table 4 – GB Cod modeled at various TAC thresholds.

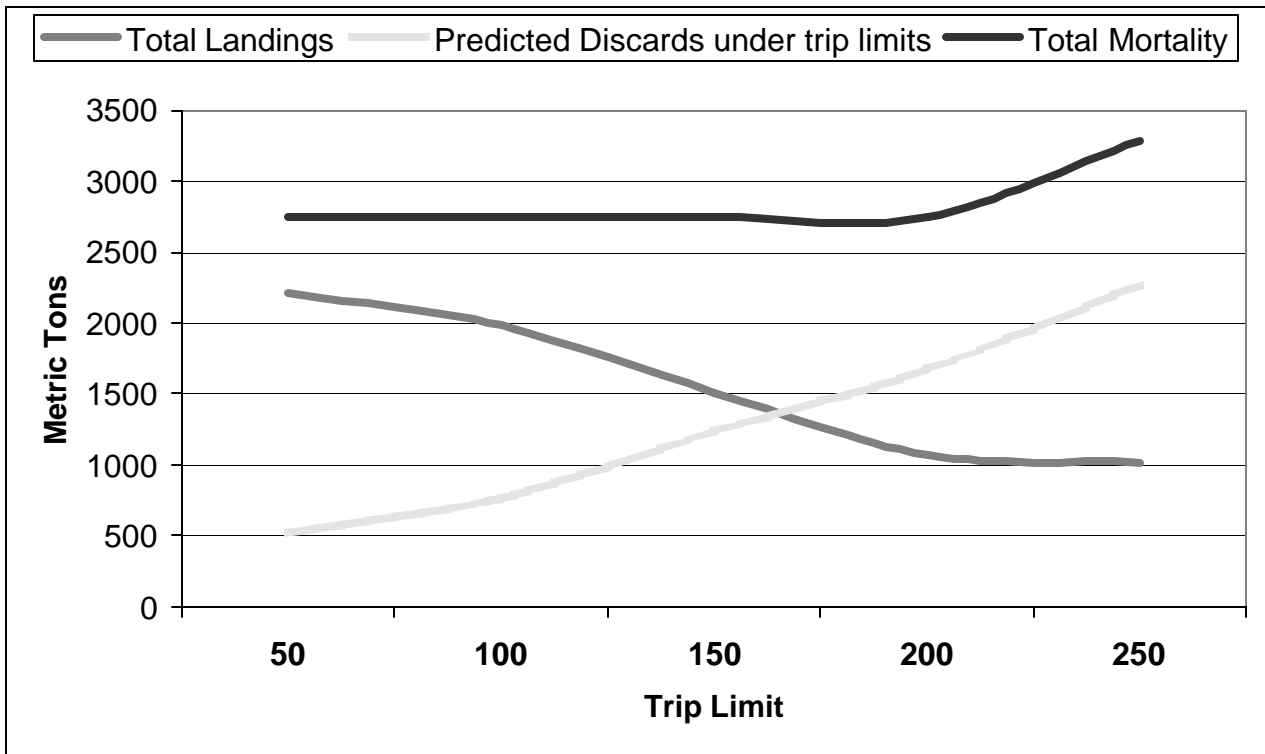


Figure 1 – Response of discards and landings to various trip limits.

Stock	2004 Modeled Landings	2004 F_Rebuild TAC	Threshold	Weeks to threshold	Month Threshold Achieved	Trip limit (per day)	Total landed after TL	Total discards	Total fishing mortality	Mortality/TAC	Week TAC achieved	Month TAC Achieved	# Trips under trip limit on stock	# Trips w/ discards	# Trips not taken	# DAS on stock	# DAS to threshold	Remaining DAS on stock	# DAS shifted off stock due to TAC	Predicted Landings under trip limits	Predicted Discards under trip limits
GOM cod	2,663	2,663	1,864	27	Nov	1250 lbs	1,346	93	3,303	124%	40	Feb	4,872	108	15	30,380	19,893	10,487	27	740	58
GB cod	2,747	2,747	1,923	27	Nov	470 lbs	1,430	1,891	5,244	191%	33	Dec	2,802	1,515	544	29,947	16,933	13,014	718	332	486
white hake	3,199	3,199	2,240	30	Nov	1340 lbs	883	180	3,303	103%	50	Apr	1,325	55	22	15,292	9,266	6,026	92	787	172
SNE winter fl	2,239	2,239	1,567	26	Oct	370 lbs	412	462	2,441	109%	44	Mar	1,997	625	511	18,189	8,875	9,314	683	276	395
CCGOM yellowtail*	235	235	164	23	Oct	65 lbs	128	477	770	328%	25	Oct	3,601	1,592	137	17,261	9,779	7,482	289	10	60
SNE yellowtail fl	645	645	452	15	Aug	140 lbs	64	156	672	104%	40	Feb	622	347	121	7,117	2,137	4,980	222	54	139
Am. plaice	2,311	2,311	1,618	29	Nov	800 lbs	1,229	135	2,981	129%	40	Feb	3,845	154	5	32,624	20,885	11,739	156	627	64

Table 5 – Impact of derby fishery assuming management measures perfectly achieve target F (FY04 landings = FY04 TAC).

