Bering Sea Fishery Simulation Model

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RESEARCH ADVANCE

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The Bering Sea fishery simulation model was developed as a quantitative means for estimating the impacts of management actions contemplated by the North Pacific Fishery Management Council (Council). The model uses the most recent information available and attempts to estimate resulting future changes in catch and bycatch. Actual fisheries, however, are not static but exist in a dynamic state that changes with weather, fish biomass, market conditions, management actions, and individual expectations along with a host of other factors. The model uses data, which to some extent, reflect the unique dynamics of each particular year. The regimes anticipated to be in place in the near future are then applied to that data, and the results, which reflect a static state, can help provide an answer to "what if?" Of course, other non-modeled, real-world variables can greatly alter results projected by the model.

Amendments to fishery management plans (FMPs) require an estimation of net benefits to the nation that might result from the proposed amendments. Thus, the economic impacts of alternatives to the status quo must be included as a section of Environmental Assessment/Regulatory Impact Review documents that amend the FMPs. A fishery simulation model developed by T. Smith[1] has been used to perform these analyses. This Bering Sea fishery simulation model estimates changes in catch and bycatch resulting from alternative management actions, accrues the value of the catch, and subtracts the value of the bycatch to arrive at an estimate of the total net benefit to the nation.

Funk (1990) converted the original spreadsheet model to a SAS[2] program to estimate benefits or costs resulting from proposed Bering Sea groundfish trawl closures that would protect Pacific herring *Clupea pallasi*. This program was later modified and used by the Alaska Department of Fish and Game to make quantitative estimates of the likely consequences resulting from proposed alternatives for chinook salmon *Oncorhynchus tshawytscha* bycatch in Amendment 21b (NPFMC 1994a). The Bering Sea fishery simulation model, as modified, was also used to analyze options in the Pribilof Islands groundfish trawl closure, Amendment 21a (NPFMC 1994b), and in amendments pertaining to Pacific halibut *Hippoglossus stenolepis* bycatch allocations and Inshore/Offshore allocations.

The Bering Sea fishery simulation model was last used in 1992 (preliminary analyses for Amendments 21a and 21b) with data from 1990 and 1991. A current proposal under consideration would close a portion of Bristol Bay to groundfish trawling to protect red king crab *Paralithodes camtschaticus* stocks. The recommended economic analysis by the simulation model, however, required further model changes because data through 1994 are now available and numerous regulatory changes have occurred since 1992. To provide the necessary changes and to make the model more user-friendly, the model was converted into a database-oriented model using Borland's Paradox[2] database program and object-oriented programming. The SAS format was very complex and used multidimensional arrays to track catch and bycatch. In addition, the iterative processes in that model were difficult to decipher. The database format, on the other hand, performs data queries much more easily, and the object-oriented framework allows compartmentalization of the routines and thus easier tracking through each model subprocess.

A baseline model run was conducted in both the SAS version and the new Paradox version using the same data and same model assumptions used in 1992. The new model results were essentially identical (<1% greater) to the old model results, except that the new model provided about 5% more directed catch of mid-water trawl walleye pollock *Theragra chalcogramma* and a bycatch composed of about 54% fewer red king crab, 16% more Pacific herring, and 6% more chinook salmon. Groundfish catches varied little between models, but some of the bycatch estimates varied to a greater degree because of slight differences in the computational algorithm which assigns closure dates, and because bycatch is harvest rate-driven.

The Paradox model was then updated with current fisheries regulations. Regulatory changes incorporated in the new model include: (1) the formation of the Catcher Vessel Operational Area (CVOA) where fishing by only the shoreside processing fleet is

[1] National Marine Fisheries Service, Northeast Science Center, 166 Water Street, Woods Hole, MA 02543-1097.
[2] Mention of a trade name does not imply endorsement by the author or the Alaska Department of Fish and Game.

allowed during specific times of the year; (2) designation of portions of the fleet as offshore or inshore and the assignment of a walleye pollock quota to these fisheries; (3) creation of the Pribilof Islands habitat savings area that prohibits trawling near the Pribilof Islands; (4) creation of the chum salmon *O. keta* savings area that prohibits trawling in an area near Unimak Island during August or after a cap of 42,000 fish has been reached; (5) changes in the identification numbers of statistical areas; (6) the adoption of small areas for closure to protect chinook salmon after a cap of 48,000 fish has been reached; (7) changes in the seasonal allocations of walleye pollock, Pacific halibut, and other species to different fisheries; (8) changes in the apportionment of the total allowable catch (TAC) of Pacific cod *Gadus macrocephalus* to the jig, longline/pot, and trawl fisheries; and (9) changes in fishery opening dates and areas designated for closure.

The structure of the data has also changed significantly since the model was last used. Previously, catch and bycatch data, strictly from processor reports, were summarized by fishery, month, and statistical area. Additional haul-by-haul observer data were summarized to the nearest block (1/2º latitude by 1º longitude). The means of processing raw data has changed to a method that combines processor and observer data to estimate catch and bycatch values. These data are now summarized for the model by week instead of by month. In addition, because several of the previously or newly defined areas do not conform to blocks (e.g., irregularly shaped or smaller than blocks), the formation of non-block areas is possible from haul-by-haul observer data for which location is known to the nearest minute of latitude and longitude.

The model essentially takes the data from a previous year and applies the current and proposed management regimes. The differences in results between the current regime (status quo) and the proposed regimes estimate the magnitude of the positive or negative impacts of the proposed alternatives.

The data for each fishery, area, and week of the year include the estimated total (all groundfish species) catch (both retained and discarded), total retained catch, wholesale value, retained and discarded catch by groundfish species, and estimated bycatch of halibut, herring, chinook salmon, other salmon (mostly chum salmon), Tanner crab *Chionoecetes bairdi*, and red king crab. Target fisheries are defined according to the predominate groundfish species in the catch; however, the catch of each groundfish species is tracked regardless of the directed fishery from which it came. The model compares the accumulated weekly species catch and bycatch to the TAC of groundfish or to the prohibited species cap (PSC) of bycatch and closes the appropriate fisheries that have exceeded these limits. Catch from closed areas is apportioned to open areas within a target fishery in proportion to the catch within each of the open areas. The various areas defined in the model include National Marine Fisheries Service 3-digit statistical areas, closures defined through the Council process (e.g., Zone 1, which includes several 3-digit statistical areas), and subportions of areas that either result from the overlapping of different areas (e.g., the overlapping of Area 517 with the crab bycatch Zone 1) or from the formation of new areas proposed for closure.

The basic steps for each weekly iteration of the model are generally as follows (Figure 1): (1) select data from the main data set for the week in question, (2) determine if the cumulative catch or bycatch to date would close any of the fishery-area combinations based on TACs or PSCs and close the areas if criteria are met, (3) calculate the catch and bycatch from open areas and closed areas separately, (4) calculate the ratio of catch in closed areas to catch in open areas (foregone catch ratio), (5) add the catch and bycatch from open areas to the cumulative catch and bycatch, and (6) multiply the catch and bycatch from open areas by the foregone catch ratio and add this amount to the cumulative catch and bycatch from open areas.

The various interrelated rules and groupings under the current management scenario create a very complex pattern to integrate into the model. For example, attainment of a TAC for a species will close the directed fishery for that species, but the amount that is compared against the TAC is the total retained and discarded species catch across all target fisheries. Similarly, the bycatch of a species can be accumulated under several fisheries, yet the resultant PSC closure might only affect a subset of the fisheries contributing to the bycatch.

The ability of the Bering Sea fishery simulation model to accurately predict the effects of alternative bycatch management measures is severely limited for the reasons listed below.

1. As was discussed in Amendment 21b, there are several limitations in the model's ability to predict the effects of alternative bycatch management measures. The model is based on catch and bycatch data collected up to the current year and contains management, regulatory, and participatory actions that may have occurred in each year.

2. Temporal and spatial variability of bycatch rates introduce large amounts of uncertainty in an analysis of the effects of alternatives on bycatch, and

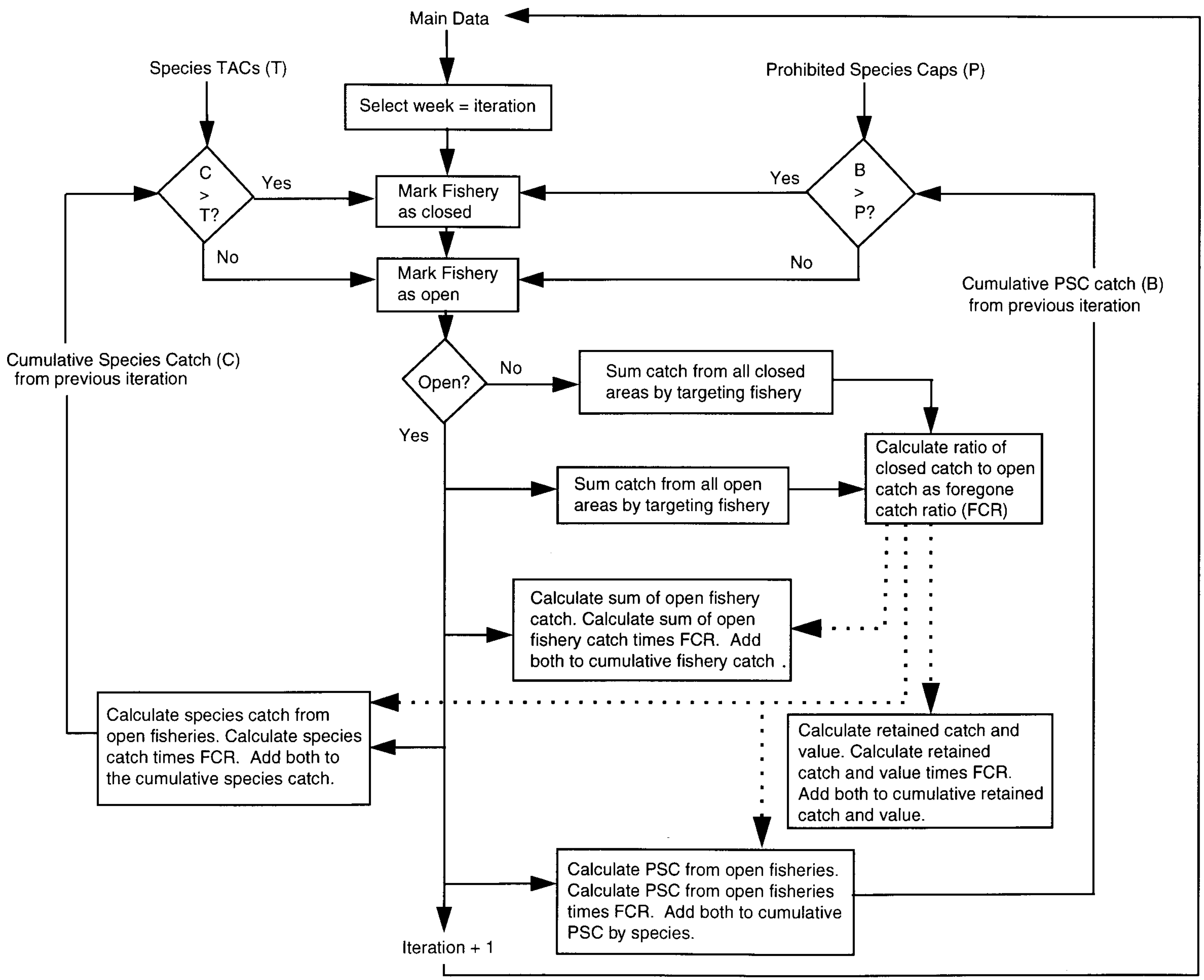

Figure 1. Flow diagram for the Bering Sea fishery simulation model.

catch estimates are likewise affected by the uncertainty about future TACs and their distribution among fisheries, times, and areas.

3. Variability in product prices, product recovery rates, discard rates, and other factors that determine the gross and net value per unit of groundfish catch result in large amounts of uncertainty with respect to the estimates of economic performance.

4. Variability of factors that determine impact costs per unit of bycatch provoke uncertainty about bycatch-related costs associated with each set of bycatch-management measures.

5. The use of historical catch data to predict the distribution of future catch by time and area means that there are no data from areas and times that were closed. As a result, the model is less useful when evaluating the results of constraint removal. For data that are relatively homogenous across years, the model provides a reasonable simulation of what might be expected to occur in future years. However, for data such as annual bycatch levels, for which there is a high degree of variability across years, the model may not accurately predict future conditions. Movement of effort into areas that were not heavily fished for a given target species will not be accurately predicted by the model.

6. The model redistributes effort and catch of a fishery among areas in response to bycatch-induced closures, but it does not redistribute catch among fisheries.

7. The model does not estimate the change in groundfish harvesting costs that would occur when a bycatch-induced time and/or area closure redistributes effort and catch among areas. But if it is assumed that the fleets choose to fish in the most profitable areas, the redistribution caused by the closures would tend to increase harvesting costs. Therefore, the model tends to understate reductions in the net value of the groundfish catch associated with increasingly restrictive PSC limits or area closures.

8. Sensitivity of the model to conditions contained in the data from historical management actions suggests that only data from the most recent years should be used because of the myriad of changes that occur each year.

9. The model uses only commercial product wholesale values from the directed salmon, halibut, herring, and crab fisheries for calculating the total bycatch value per species. This can lead to an underestimated value of bycatch to non-groundfish harvesters, given the unstated values for the recreational and subsistence fisheries that also utilize these species.

10. Among the costs that are not included in the model analysis are the unknown costs of any threats to conservation of a resource that may occur as a result of bycatch. For instance, the biological value of “saved” female crabs, as contributors to the stock, are not included. The economic estimates provided by the model will be conservative in the face of resource endangerment.

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