Exploring effects of fishing and migration on the distribution of Pacific halibut

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Abstract

Evidence of continuing migration beyond the age of recruitment to the fishery has recently led to the adoption of coastwide assessments of Pacific halibut. A coast-wide assessment currently in use has resulted in an estimated coast-wide harvest rate near the target. However, area-specific harvest rates are estimated to have been more than twice the target in eastern areas and less than the target in western areas. In order to illustrate the effects of migration and fishing on the distribution and population structure of Pacific halibut we developed a simulation model with a user-friendly graphical user interface (GUI). The GUI allows the user to specify different migration patterns and fishing levels, run scenarios and visualize results of the simulations. The underlying model of the GUI is an age and size structured migratory model. Scenarios using migratory and fishing patterns close to those observed for Pacific halibut suggest that the current spatial distribution of halibut differs from that expected under no fishing conditions or under a spatially uniform harvest rate, with higher levels of depletion in eastern areas relative to western areas. Preliminary results are consistent with recent and historical fishing patterns, recent coast-wide assessment estimates of realized harvest rates, and historical estimates of halibut distribution. Further work is needed to evaluate the effects of different levels of uncertainty and spatial variability in both population and fishery dynamics on the performance of alternative assessment approaches and harvest strategies for Pacific halibut.

Introduction

The Pacific halibut (*Hippoglossus stenolepis*) is widely distributed in the north Pacific from Hokaido, Japan to northern California, U.S. (Clark and Hare 2006). The International Pacific Halibut Commission (IPHC) studies and manages halibut from the Bering Sea to northern California (Fig. 1). Halibut abundance changes along its geographic range, with the current center of abundance located around Kodiak Island (Area 3A, Fig. 1) in the Gulf of Alaska (Clark and Hare 2006). There are also seasonal changes in halibut distribution resulting from spawning migrations. During summer, halibut are distributed on the continental shelf, but during the winter mature halibut migrate to spawning grounds located in deeper waters (St. Pierre 1984). Recent archival tagging has identified winter spawning migrations as long as 1200 km as well as some degree of site fidelity to summer areas (Loher 2008). After spawning, halibut eggs and larvae are carried by prevailing currents north and westward towards the western Gulf of Alaska and the Bering Sea. Juvenile halibut undertake an eastward-southward migration that counters the drift of eggs and larvae (Skud 1977, Hilborn et al. 1995). Until recently, it was assumed that this migration was completed by age six-seven when halibut become vulnerable to the fishery. However, recent passive integrated tagging (PIT) data have provided evidence of continuing ontogenetic halibut migration beyond age eight (Webster and Clark 2007).

The counterclockwise (northward-westward) drift of eggs and larvae and the clockwise (eastward-southward) ontogenetic migration of juvenile and adult halibut is a type of “compensatory emigration” (Dunlop et al. 1964; Best 1977; Skud 1977) or “migratory circuit” (Cushing 1976). This process is expected to have evolved along with other biological traits of Pacific halibut on an evolutionary time scale, and has strong implications for the population abundance and distribution. Another process affecting the abundance and distribution of Pacific halibut is fishing. A number of Pacific coast Indian tribes fished halibut long before the arrival of Europeans to the Pacific NW, but we expect that its impact on halibut dynamics was limited compared with the subsequent development of the commercial fishery. The Pacific halibut commercial fishery is considered to have started in 1888 near the area around Cape Flattery off the northwest coast of Washington State (current IPHC regulatory area 2A, Fig. 1). The fishery expanded rapidly, both in spatial extension and towards deeper waters as fishing areas became depleted and fishermen expanded toward new areas. Understanding the effect of the fishery on population structure, abundance, and distribution of halibut was identified as a crucial topic for halibut management early on the history of halibut research (Thompson 1916a, 1916b; Thompson and Van Cleve 1936). From a conservation point of view, it was recognized early that the quantitative distribution of the species must be considered since all possible sources of eggs and young are important, whether at the limit of the species range or at the center (Thompson and Van Cleve 1936). The IPHC harvest policy uses the same target harvest rate for all areas (except areas of special concern) with the goals of altering as little as possible the relative distribution of halibut along its geographic range, and to have halibut encounter the same exploitation rate wherever they might be fished. For several years this harvest policy was implemented using closed-area assessments under the assumption of no net migration of legal-sized fish between regulatory areas. In 2006, the IPHC staff and an external scientific peer review recognized the biases of the closed-area approach in light of the evidence of continuing migration of legal-size halibut, and moved to a coast-wide assessment approach (Clark and Hare 2007). The coast-wide assessment estimated recent coast-wide realized harvest rates near the target harvest rate. However, realized harvest rates on an area basis are estimated to have been more than twice the target in eastern areas, and less than the target in western areas.

The combination of complex migration throughout the halibut life history and varying temporal and spatial fishing effects set the canvas for several questions, such as:

Q1: Is the current relative distribution of halibut abundance similar to that expected under no fishing conditions?

Q2: Are the unbalanced harvest rates (lower in the west, higher in the east) estimated by the coast-wide model consistent with the dynamics and current population structure of the stock?

Q3: Does applying the same fishing mortality rate in all areas achieve the goal of not changing the relative distribution of abundance when taking into account migration?

Q4: What is the effect of fishing on “upstream” areas relative to effects of local fishing in “downstream” areas?

Answering these questions based solely on observed data or experimental results will be logistically prohibitive or impossible, even in a historically documented and data-rich fishery such as the Pacific halibut. In order to answer these questions we need more than observed quantities. An alternative approach is to use all the available information on halibut population and fishery dynamics to build a model of reality, with characteristics as close to reality as possible. We can then use this model to evaluate the effects of its different components and processes (such as migration, fishing) on observable quantities (such as abundance, age structure, etc) under different scenarios. In order to illustrate the effects of migration and fishing on the distribution and population structure of Pacific halibut, we developed a simulation model with a user-friendly GUI (Graphical User Interface) widget. The widget allows the user to specify different migration patterns and fishing levels, run scenarios and visualize the results of the simulations. This report describes the structure of the first released version of the widget as well as some preliminary results. Installation instructions are summarized in Appendix A. The first version of the widget has many simplifying assumptions and basic alternative options for relevant processes as described in following sections. A second version of the widget is under development at the time of writing of this report.

Model description

The widget consists of a GUI that allows the user to specify alternative scenarios with different levels of migration and fishing mortality rates using graphical elements such as buttons, tabs, and sliders (Figure 6). The computations associated with the specified scenario are done by an underlying simulation model and the results of the run are presented graphically on the widget. The widget's underlying model is an age-structured, multi-area model with migration. Sex-specific growth, maturity at age, and selectivity (survey and commercial) at size were assumed to be the same among areas. The model includes six areas corresponding to IPHC Regulatory Areas 4A, 3B, 3A, 2C, 2B, and 2A (Figure 1). These areas were selected based on data availability, but the model can be expanded to include the remaining regulatory areas. The model includes ages eight (recruits) to fifty, recruitment is assumed to be time-invariant and given by the average number of 8 year old halibut as estimated by closed-area stock assessments from 1996 to 2005 (Figure 2).

Migration is modeled as an annual movement of halibut between adjacent areas in an eastward direction only. Migration is assumed to occur instantaneously at the beginning of the year, before any source of mortality occurs. Analysis of traditional (Hoag et al. 1983; Quinn et al. 1985) and PIT tag (Webster and Clark 2007; Webster 2009) recoveries suggest that the fraction of fish migrating is a function of fish size/age, with smaller/younger fish more likely to migrate than smaller/younger fish. As a first approximation to describe declining migration rates by age, we used a modified logistic function illustrated in Figure 3 and described by the following equation:

$$\Theta_{a,i} = \hat{\Theta}_i \left[1 - \frac{1}{(1 + e^{-\alpha(a - A^{50\%})})} \right]$$

where a is halibut age, i is area, $\Theta_{a,i}$ is the annual migration rate out of area i at age a, $\hat{\Theta}_i$ is the annual migration rate out of area i at maximum migrating age, α is a measure of the slope of the curve (fixed at 0.4) and $A^{50\%}$ is the age at which migration rate drops to 50% of the maximum rate (i.e., when $\Theta_{a,i} = 0.5\hat{\Theta}_i$), $A^{50\%}$ is fixed at age 25. The user can change the migration rate ($\hat{\Theta}_i$) as a common or area-specific parameter.

The basic equation describing population dynamics is

$$N_{a+1,s,t+1,i} = e^{(M+S^f_{a,s}F_{t,i})}\left[N_{a,s,t,i} - N_{a,s,t,i}\Theta_{a,i} + N_{a,s,t,i-1}\Theta_{a,i-1}\right]$$

where $N_{a,s,t,i}$ is numbers at age a, sex s, year t, and area i; M is natural mortality (fixed at 0.15yr^{-1}, the value used in the assessments); $S^f_{a,s}$ is the selectivity of the commercial fishery for age a and sex s, $F_{t,i}$ is the fishing mortality rate for year t and area i. Selectivity curves at length (Fig, 4) are transformed to selectivity curves at age. The user can change fishing mortality rate as a single rate for all areas, or as area-specific rates as a percentage of the fishing mortality specified for area 3A. Area coefficients (i) are from west to east (4A to 2A). Since we defined migration as an eastward movement between adjacent areas, dynamics of Area 4A (i = 1) are reduced to:

$$N_{a+1,s,t+1,i} = e^{(M+S^f_{a,s}F_{t,i})}\left[N_{a,s,t,i} - N_{a,s,t,i}\Theta_{a,i}\right]$$

and dynamics of Area 2A (i = 6) are reduced to:

$$N_{a+1,s,t+1,i} = e^{(M+S^f_{a,s}F_{t,i})}\left[N_{a,s,t,i} + N_{a,s,t,i-1}\Theta_{a,i-1}\right]$$

Catch in numbers at age a, sex s, year t, and area i ($C_{a,s,t,i}$) is calculated using the Baranov catch equation:

$$C_{a,s,t,i} = \frac{F_{t,i}S^f_{a,s}N_{a,s,t,i}}{M + S^f_{a,s}F_{t,i}}\left[1 - e^{(M+S^f_{a,s}F_{t,i})}\right]$$

Catch in weight is given by:

$$Y_{a,s,t,i} = C_{a,s,t,i}w^f_{a,s}$$

where $w^f_{a,s}$ is the average weight at age a for sex s in the fishery. Female Spawning Biomass for year t and area i ($SBio_{t,i}$) is given by:

$$SBio_{t,i} = \sum_{a=8}^{50} N_{a,1,t,i}w^s_{a,1}Mat_a$$

where $N_{a,1,t,i}$ is the number at age a of females (s = 1) for year t and area i; $w^s_{a,1}$ is the average weight at age a for females and Mat_a is maturity at age (Figure 5). Exploitable Biomass for year t and area i ($EBio_{t,i}$) is given by:

$$EBio_{t,i} = \sum_{a=8}^{50} \sum_{s} N_{a,s,t,i} w_{a,s}^{f} S_{a,s}^{f}$$

Model scenarios are set to run for 100 years and under most scenarios it reaches equilibrium within 20 years. Run results are illustrated in the widget using several tabs (Fig. 6). A map is displayed with circles proportional to the fraction of coast-wide distribution of spawning biomass. The “SBio dist.” tab (Fig. 6) illustrates the distribution of spawning biomass projected under the scenario run as well as the percentage change from the distribution expected under the same migration scenario but without fishing. The “SBio depl.” tab (Fig. 7) illustrates area-specific (columns), coast-wide (black horizontal line) spawning biomass depletion and spawning biomass limit (20% of expected spawning biomass under no fishing, dashed horizontal line). The “Catch” tab (Fig. 8) illustrates the projected distribution of exploitable biomass and catch. Tabs “Ages Surv.” (Fig. 9) and “Ages Catch” (Fig. 10) illustrate the percentage of halibut older than 20 years in the IPHC survey and commercial catch as projected under the scenario run and observed in 2007. The “HR” tab (Fig. 11) illustrates area-specific harvest rates corresponding to the fishing mortality pattern specified in the scenario run and recent area-specific harvest rates estimated by recent coastwide assessments.

Preliminary widget runs

In order to illustrate the use of the widget, this section discusses a few scenarios relevant to the four questions asked in the introduction. It is important to note that the widget scenarios are based on simplified migration and fishing patterns, rates used to set up the scenarios should not be interpreted as final values but rather values consistent with results of ongoing research. A similar caveat applies to the widget results: the goal is to capture broad patterns in the dynamics and structure of the stocks and to explore the sensitivity of results to varying assumptions, rather than to obtain a definitive picture of a particular area.

Q1: Is the current relative distribution of halibut abundance similar to that expected under no fishing conditions?

Figure 12 shows widget results of a scenario with no fishing and with a migration pattern consistent with results of tag-recovery analyses of historical wire tags and recent PIT tags. Under this scenario, widget results suggest higher than currently observed relative halibut abundance in the eastern part of the stock, particularly in area 2B. Two differences regarding the percentage of older fish emerge between the widget projections and those observed. First, the widget projects much larger percentages of older fish in general than those observed (Fig. 13), which is expected since the projection is in the absence of fishing whereas the observed percentages reflect fishing effects. In addition, a larger percentage of older halibut is projected for the eastern part of the stock (Fig. 13) given the continued eastward migration of older fish. However, the observed percentage of older fish has the opposite pattern, with older fish in the western part of the stock.

In summary, preliminary explorations suggest that the relative distribution of halibut abundance differs from what would be expected under no fishing conditions, with lower than expected relative abundance of halibut in the eastern part of the stock (particularly in Area 2B).

In addition, whereas higher percentages of older fish would be expected in the eastern part of the stock, it currently holds much younger fish. This point leads us to the next question:

Q2: Are the unbalanced harvest rates (lower in the west, higher in the east) estimated by the coastwide model consistent with the dynamics and current population structure of the stock?

The scenario run previously resulted in differences between the widget projections and observed quantities of interest such as relative distribution of abundance and percentage of older fish between the eastern and western parts of the stock. Since the previous scenario did not include fishing, some of those differences are expected. To explore the potential effect of fishing on discrepancies between projections and observed quantities we can set up another scenario with fishing mortality set at $F = 0.23$ (corresponding to a harvest rate close to 0.20, the current target harvest rate for the Pacific halibut fishery). Under this scenario, the projected percentage of older fish in the western part of the stock is smaller than observed and the opposite happens in the eastern part of the stock (Fig. 14). This is expected since the eastern part of the stock has had a longer history of fishing than the western part of the stock. Additional scenarios with unbalanced fishing mortality rates, higher on the east than on the west, result in better concordance between widget projections and observed proportions of older fish. Harvest rates doubling (Areas 2C, 2A) or tripling (Area 2B) the target harvest rate are required to obtain projections with the low percentage of older halibut present in eastern areas. Harvest rates set at (Area 3A) or below (Areas 4A, 3B) the target harvest rate result in high agreement between projected and observed percentages of older fish (Fig. 15).

In summary, preliminary explorations suggest that unbalanced harvest rates between the west and the east on the same magnitude as estimated by the coast-wide assessment can explain the marked differences in age structure between the different parts of the stock. Projections under this level of unbalanced harvest rates result in marked departures of the spawning biomass distribution relative to unfished conditions (Fig. 16) and in highly heterogeneous depletion levels (Fig. 17).

Q3: Does applying the same fishing mortality rate in all areas achieve the goal of not changing the relative distribution of abundance when taking into account migration?

Projections using the same fishing mortality rate for all areas result in only marginal departures from the relative distribution of spawning biomass expected under no fishing. Only the case of applying an $F = 0.23$ (corresponding to a harvest rate close to 0.20, the current target harvest rate) is shown here (Fig. 18 and 19), but the pattern is similar under alternative migration patterns within the range of moderate migration rates of halibut and the target harvest rate levels used historically in its fishery.

Q4: What is the effect of fishing on “upstream” areas relative to effects of local fishing in “downstream” areas?

Preliminary explorations suggest that varying levels of fishing mortality in the western part of the stock does not alter the dynamics and age structure of eastern areas. Decreasing exploitation rates to zero (no fishing) in western areas 4A and 3B has no noticeable effect in the percentage of older fish in eastern areas if their own exploitation rates stay at the high historical levels. If anything, the relative spawning biomass contribution of eastern areas decreases given that unexploited western areas would increase their spawning biomass contribution (Fig. 20).

Discussion and on-going work

Preliminary explorations of the simulation model presented here suggest that the current distribution of halibut abundance differs from that expected under no fishing conditions. Simulations under the assumptions described in this work project higher abundances in the eastern part of the stock (particularly in Area 2B) in the absence of fishing. This is consistent with early estimates of relative distribution of halibut abundance during the development of the fishery (Thompson and Van Cleve 1936). Lower abundances and smaller percentages of older fish in the eastern areas are consistent with higher historical exploitation rates estimated by the coast-wide assessment approach. A common fishing mortality rate for all areas results in only marginal departures from the relative distribution of unfished spawning biomass under alternative migration patterns within the range of moderate migration rates of halibut and the target harvest rate levels used historically in its fishery. Varying exploitation rates in the western areas have little effect on the dynamics of eastern areas, if exploitation rates in the east remain as high as estimated by the coast-wide assessment.

The widget described here has many simplifying assumptions and basic alternative options for relevant processes such as same growth among areas, migration only by adjacent areas, time invariant recruitment, and fishing mortality rates. A second version of the widget is under development at the time of writing of this report. The new version includes additional options such as fully specified migration matrices among areas, alternative relationships between migration and age, temporal trends in exploitation rates and recruitment, alternative recruitment spatial distributions and area specific size at age relationships.

Glossary

This section provides a brief description of some of the terms used in this report:

Exploitable Biomass: Biomass of halibut selected by the fishery.
GUI: Graphical User Interface, interface that allows people to interact with computers by manipulating graphical elements such as icons, buttons, etc.
Juvenile: Halibut after larval development, ages 0 to seven.
Ontogenetic migration: Migration that occurs over the lifetime of an organism. In the case of Pacific halibut it is the ongoing migration resulting in the annual relocation of fish from one area to another, predominantly on an eastward-southward (clockwise) direction.
PIT: Passive Integrated Transponder.
PAT: Pop-up Archival Tag.
Recruit: Halibut age eight.
Spawning biomass: Biomass of mature female halibut.
Spawning biomass depletion: the percentage of current spawning biomass relative to the expected without fishing.
Spawning migration: Seasonal (summer-winter) migration of mature halibut.
Widget: element of a graphical user interface that displays information changeable by the user.

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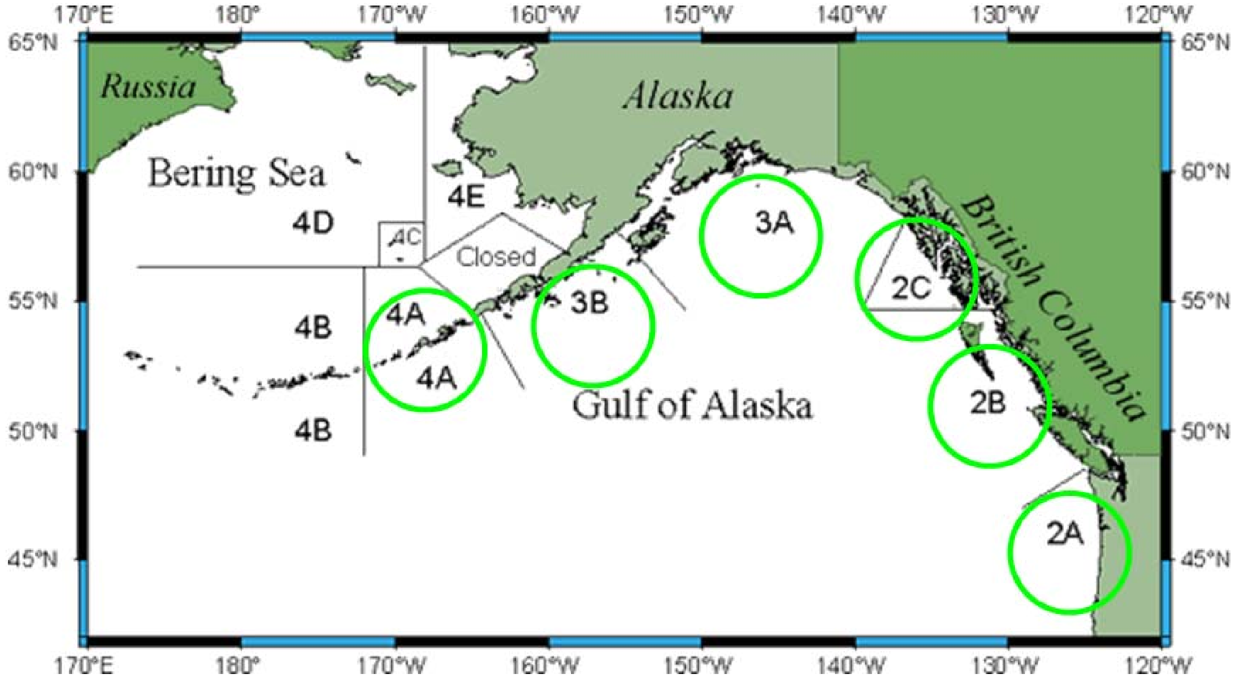


Figure 1. IPHC Regulatory Areas. Areas included in the "Migration and Fishing Widget" are circled.

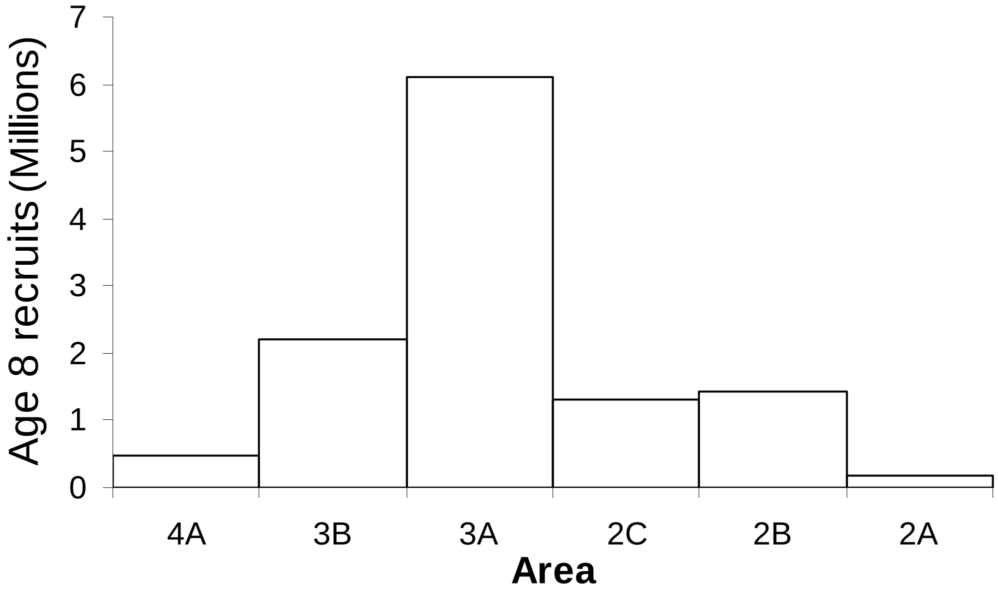


Figure 2. Recruits as the average number of age 8 halibut in the period 1996-2005 estimated by closed-area assessments for each of IPHC regulatory areas included in the widget.

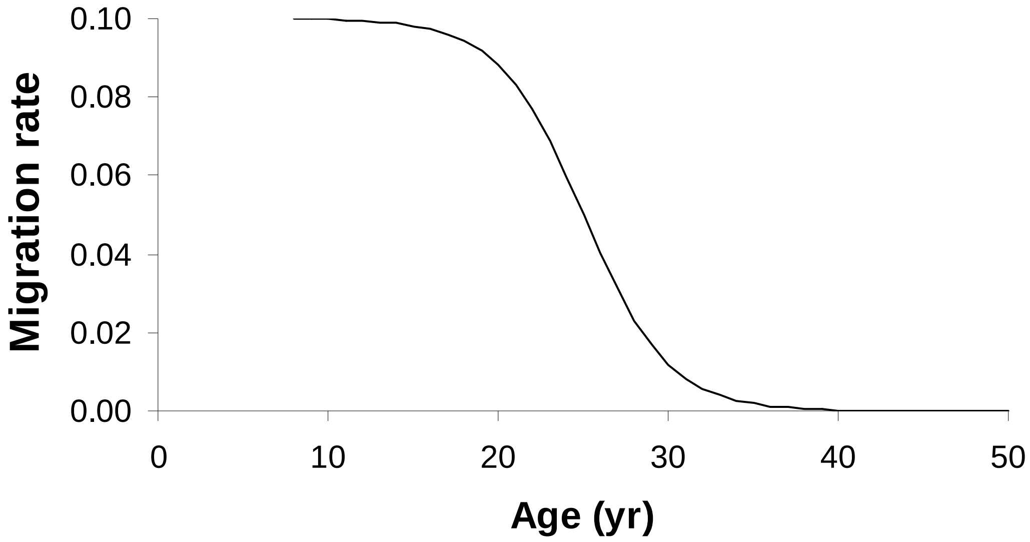


Figure 3. Migration rate as function of age, the line represents a generalized logistic (Richards sigmoid) function.

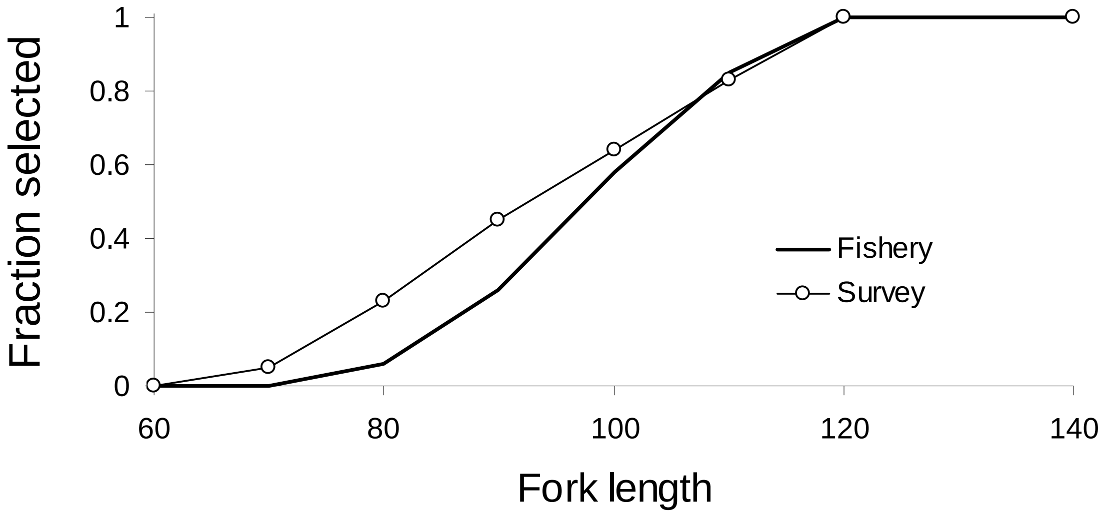


Figure 4. Selectivity to the commercial fishery and survey as a funtion of halibut size (Fork length in cm).

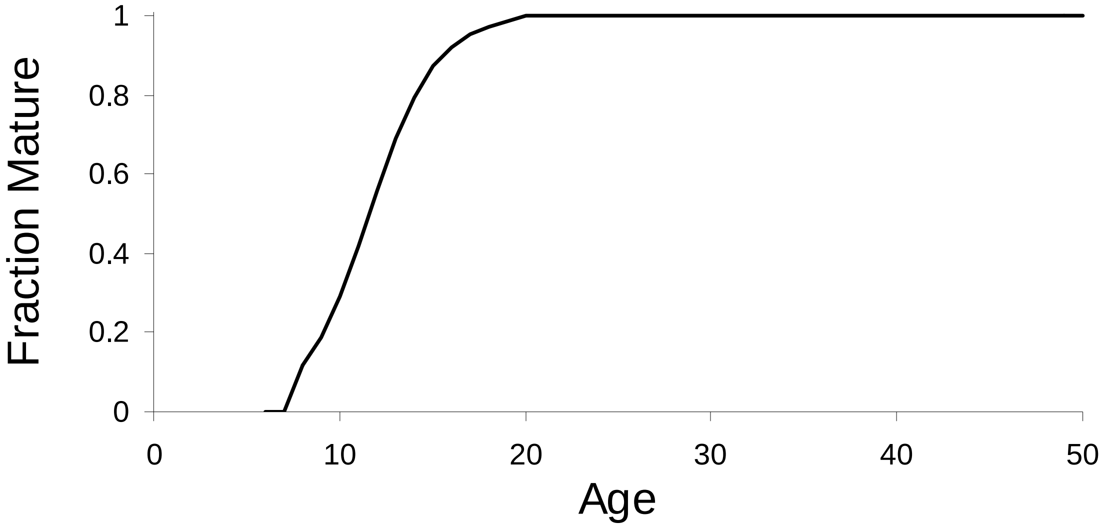
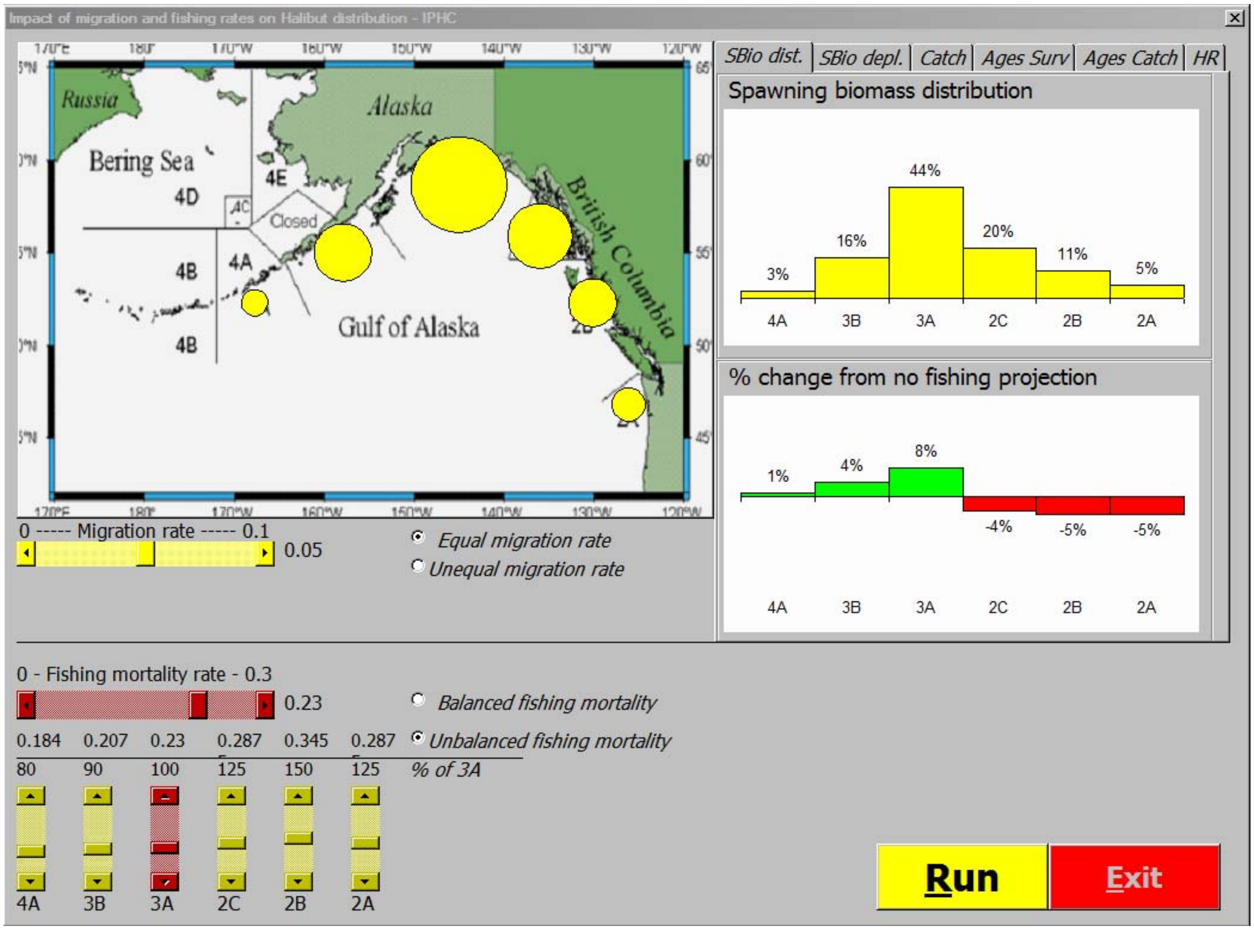


Figure 5. Maturity schedule of female halibut as a function of age.



0 ----- Migration rate ----- 0.1 0.05

● *Equal migration rate*

○ *Unequal migration rate*

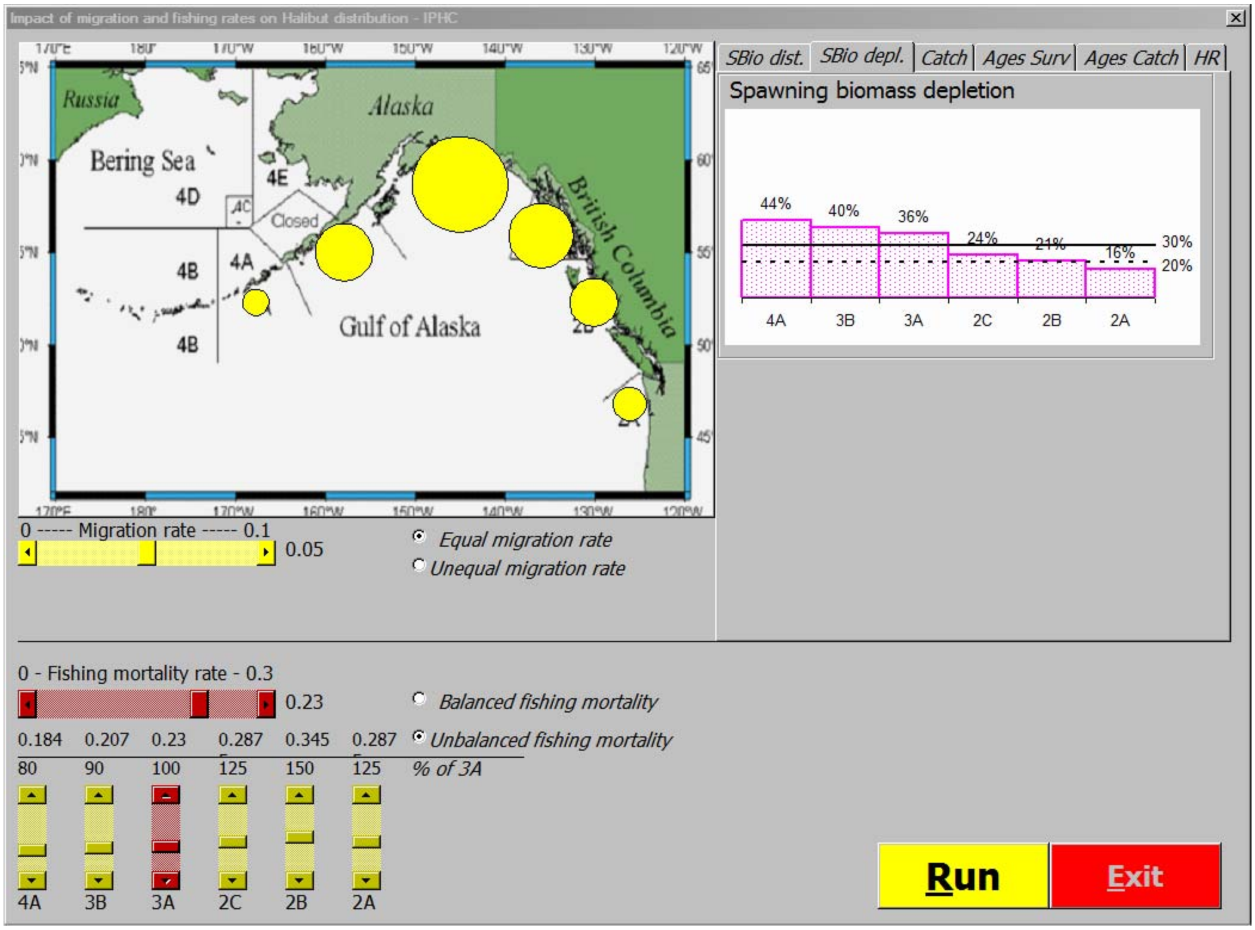
0 - Fishing mortality rate - 0.3 0.23

○ *Balanced fishing mortality*

● *Unbalanced fishing mortality*

4A	3B	3A	2C	2B	2A	
0.184	0.207	0.23	0.287	0.345	0.287	
80	90	100	125	150	125	*% of 3A*

Figure 6. Widget screenshot. The slider bars are user controls specifying migration and fishing mortality rates. The map displays the equilibrium distribution of spawning biomass. Results of the scenario run are illustrated under different tabs, in this case showing the distribution of spawning biomass and percentage change from a projection with no fishing.



0 ----- Migration rate ----- 0.1 0.05

● Equal migration rate

○ Unequal migration rate

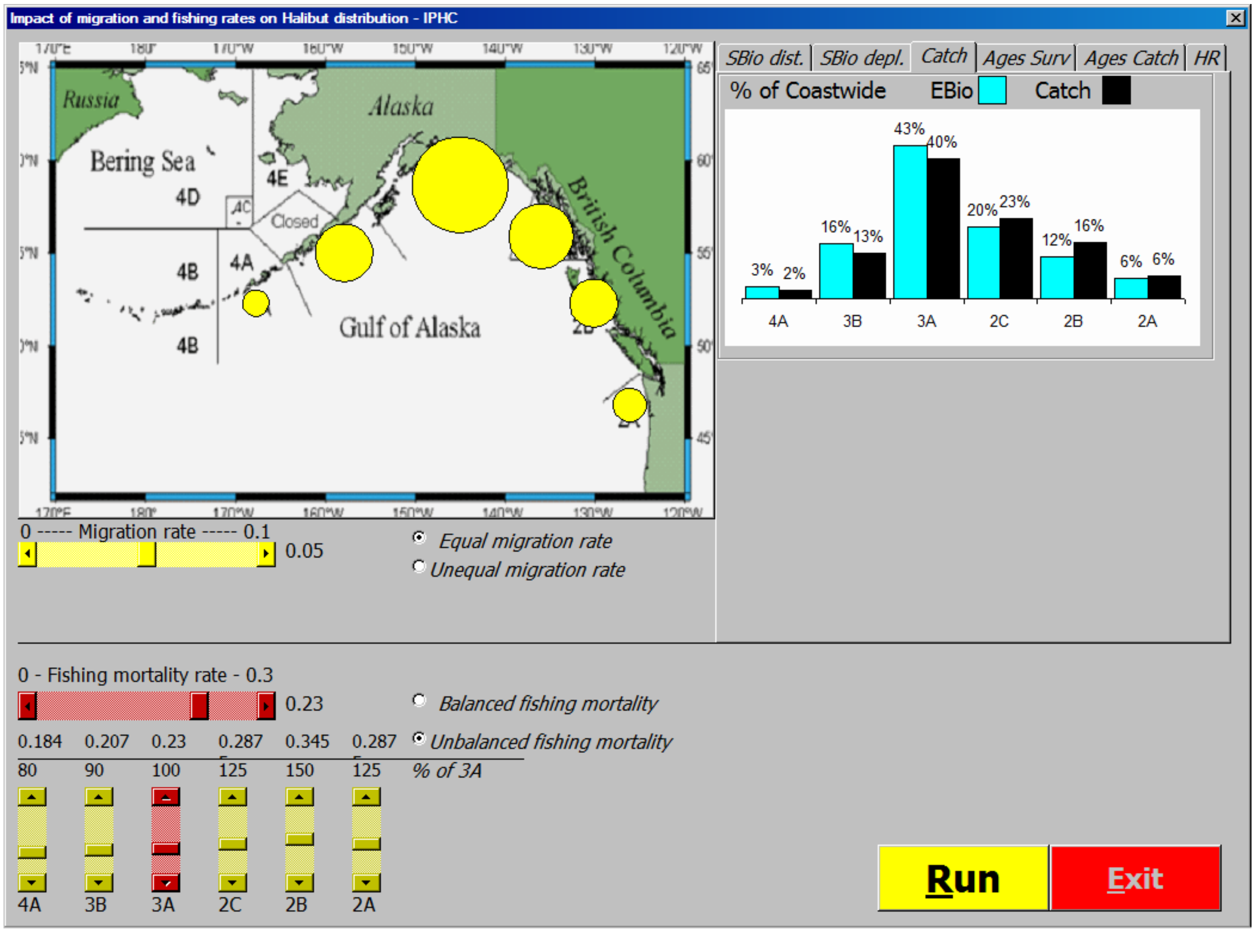
0 - Fishing mortality rate - 0.3 0.23

○ Balanced fishing mortality

● Unbalanced fishing mortality

4A	3B	3A	2C	2B	2A	
0.184	0.207	0.23	0.287	0.345	0.287	
80	90	100	125	150	125	% of 3A

Figure 7. Widget screenshot showing area-specific (columns), coastwide (black horizontal line) spawning biomass depletion and spawning biomass limit (20% of expected spawning biomass under no fishing, dashed horizontal line).



Impact of migration and fishing rates on Halibut distribution - IPHC

0 ----- Migration rate ----- 0.1 0.05

● Equal migration rate

○ Unequal migration rate

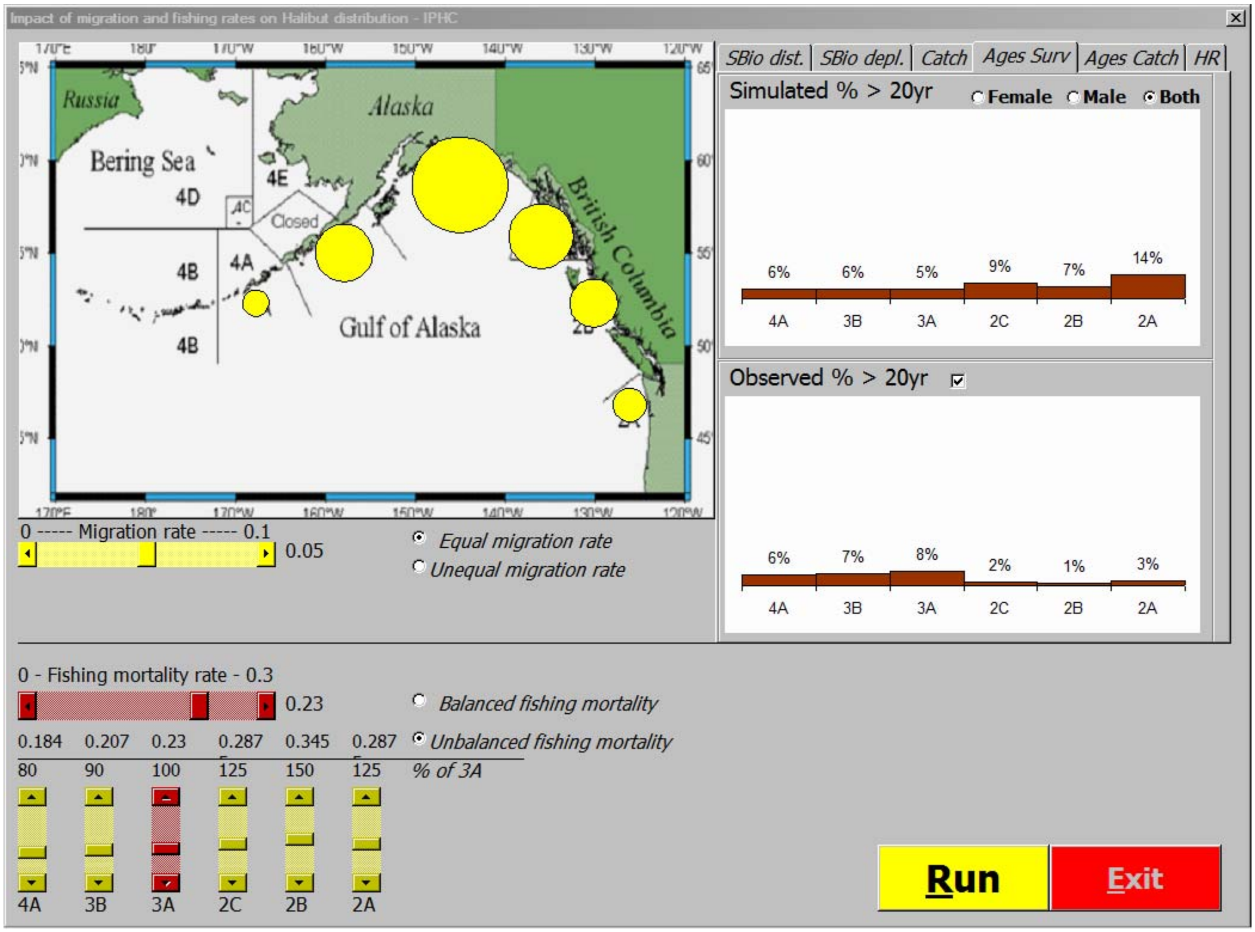
0 - Fishing mortality rate - 0.3 0.23

○ Balanced fishing mortality

● Unbalanced fishing mortality

0.184	0.207	0.23	0.287	0.345	0.287	
80	90	100	125	150	125	% of 3A
4A	3B	3A	2C	2B	2A	

Figure 8. Widget screenshot showing projected distribution of exploitable biomass and catch.



0 ----- Migration rate ----- 0.1
0.05

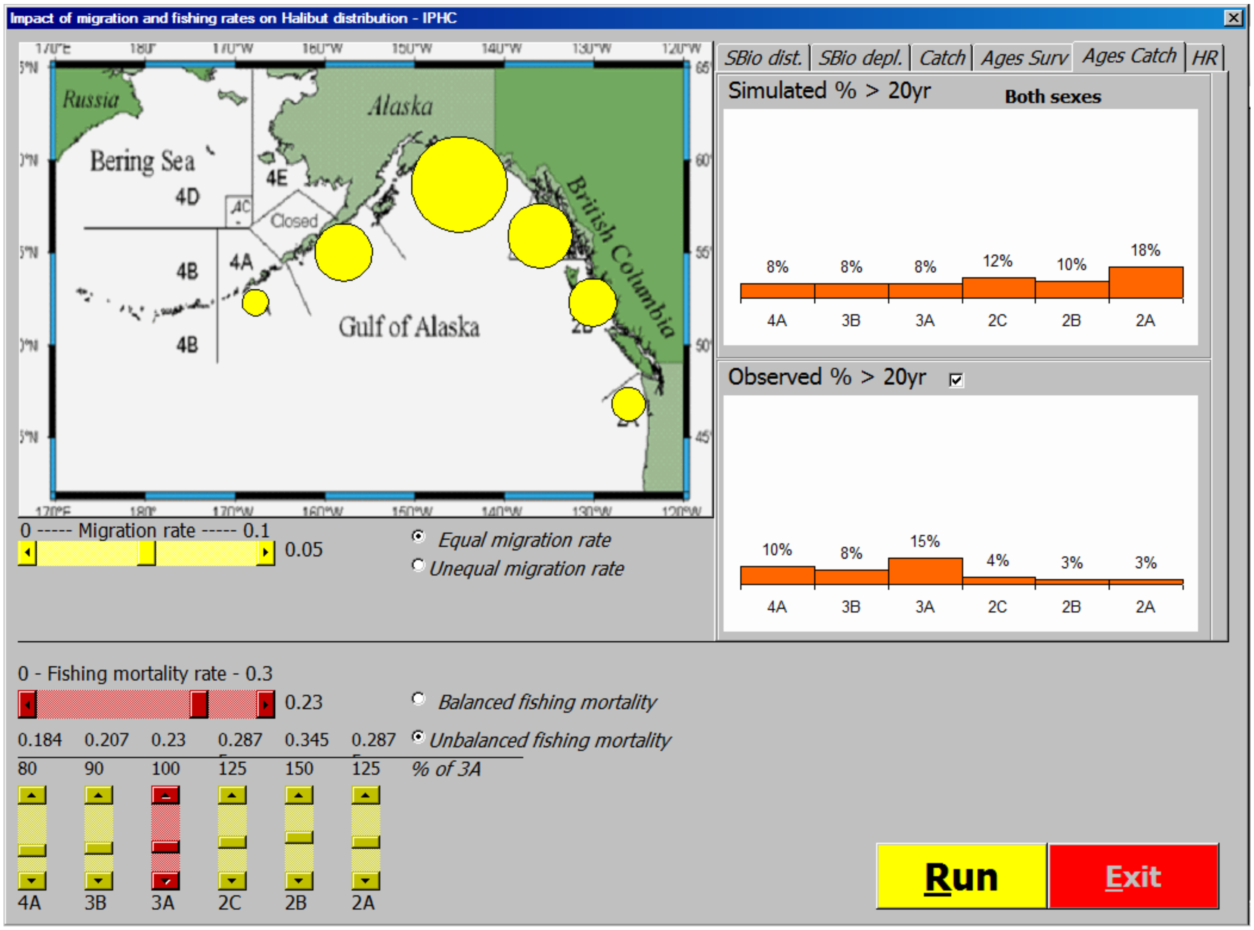
● Equal migration rate
○ Unequal migration rate

0 - Fishing mortality rate - 0.3
0.23

○ Balanced fishing mortality
● Unbalanced fishing mortality

4A	3B	3A	2C	2B	2A	
0.184	0.207	0.23	0.287	0.345	0.287	
80	90	100	125	150	125	% of 3A

Figure 9. Widget screenshot showing the area-specific percentage of halibut older than 20 years as projected under the scenario run and the percentages observed in the 2007 IPHC survey.



0 ----- Migration rate ----- 0.1 — 0.05

● Equal migration rate

○ Unequal migration rate

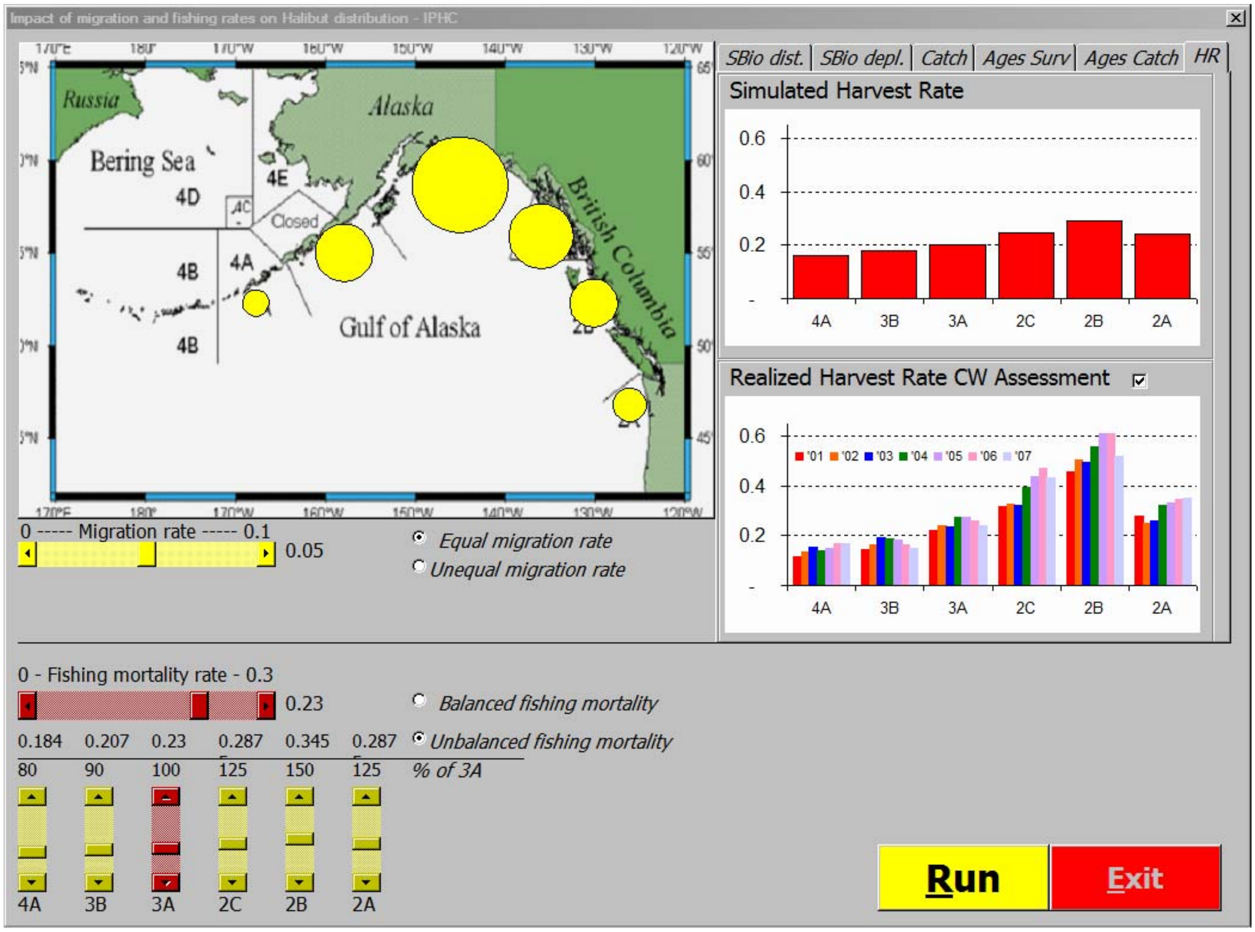
0 - Fishing mortality rate - 0.3 — 0.23

○ Balanced fishing mortality

● Unbalanced fishing mortality

0.184	0.207	0.23	0.287	0.345	0.287	
80	90	100	125	150	125	% of 3A
4A	3B	3A	2C	2B	2A	

Figure 10. Widget screenshot showing the area-specific percentage of halibut older than 20 years as projected under the scenario run and the percentages observed in the 2007 commercial catch.



Impact of migration and fishing rates on Halibut distribution - IPHC

0 ----- Migration rate ----- 0.1: 0.05

● Equal migration rate
○ Unequal migration rate

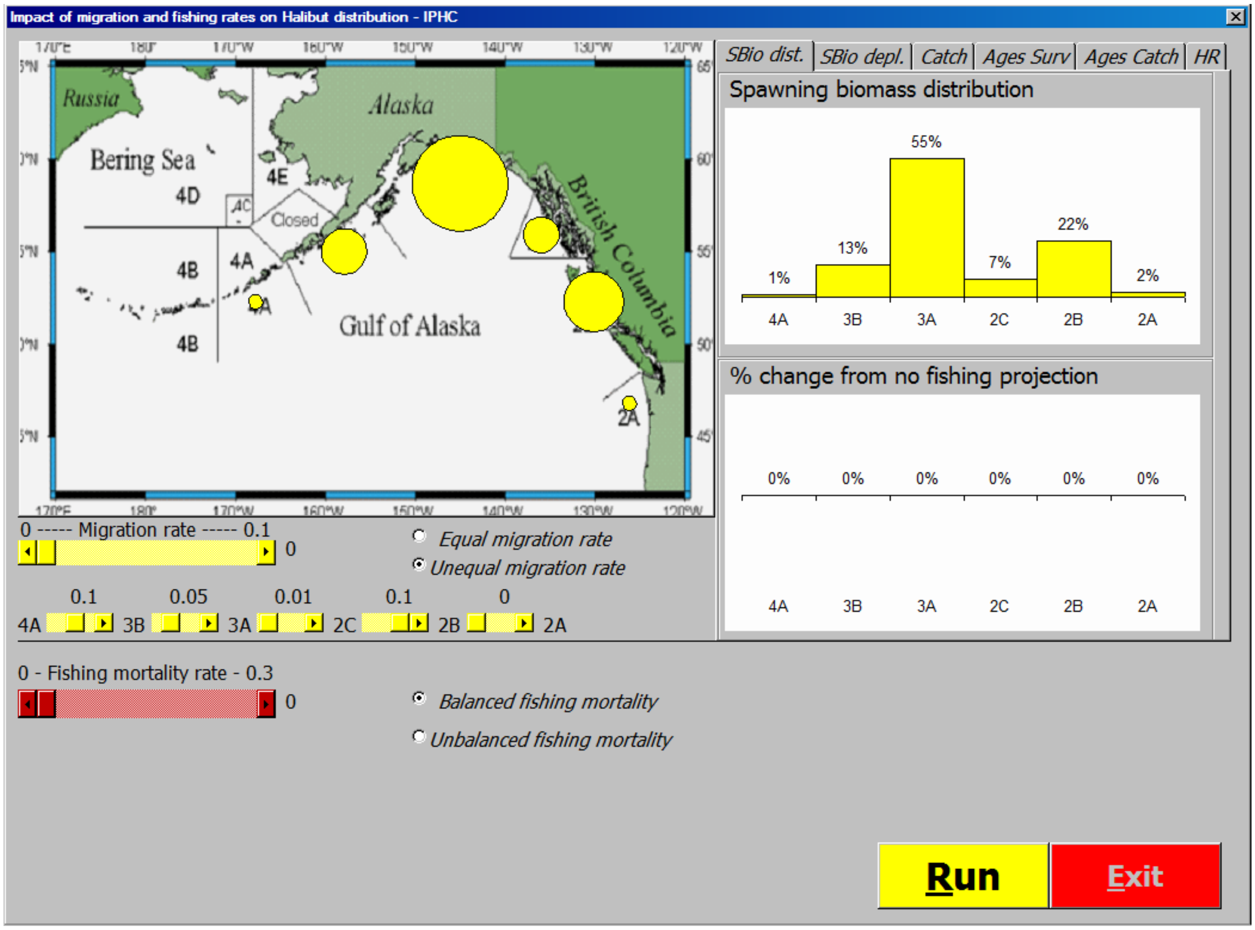
0 - Fishing mortality rate - 0.3: 0.23

○ Balanced fishing mortality
● Unbalanced fishing mortality

4A	3B	3A	2C	2B	2A	
0.184	0.207	0.23	0.287	0.345	0.287	
80	90	100	125	150	125	% of 3A

Realized Harvest Rate CW Assessment ☑

Figure 11. Widget screenshot area specific harvest rates corresponding to the fishing mortality pattern specified in the scenario run and recent area-specific harvest rates estimated by recent coastwide assessments.



Impact of migration and fishing rates on Halibut distribution - IPHC

0 ----- Migration rate ----- 0.1 0

○ Equal migration rate

● Unequal migration rate

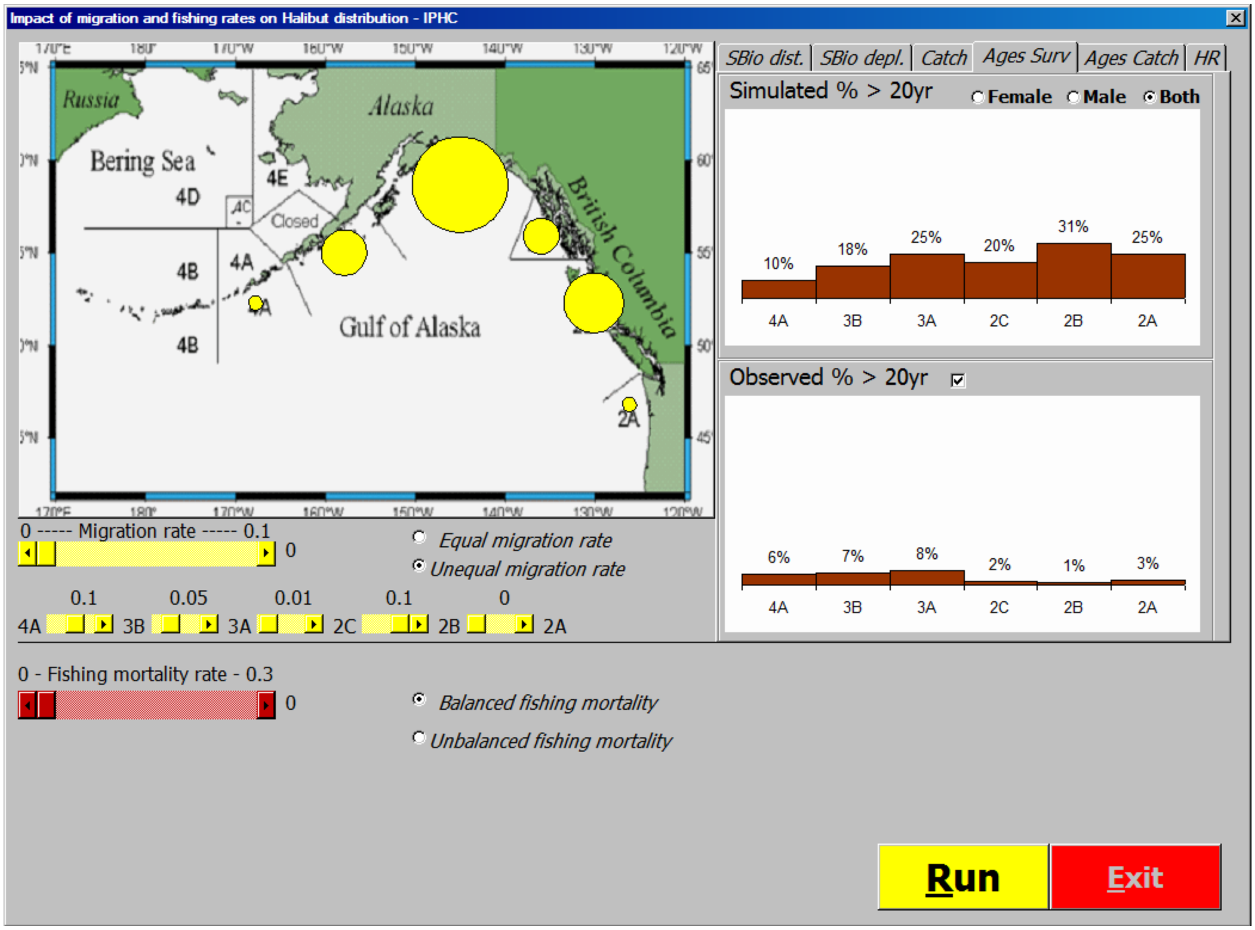
4A 0.1 3B 0.05 3A 0.01 2C 0.1 2B 0 2A

0 - Fishing mortality rate - 0.3 0

● Balanced fishing mortality

○ Unbalanced fishing mortality

Figure 12. Widget screenshot. Scenario with area specific migration rates and no fishing.



Impact of migration and fishing rates on Halibut distribution - IPHC

0 ----- Migration rate ----- 0.1 : 0

○ Equal migration rate

● Unequal migration rate

4A 0.1 3B 0.05 3A 0.01 2C 0.1 2B 0 2A

0 - Fishing mortality rate - 0.3 : 0

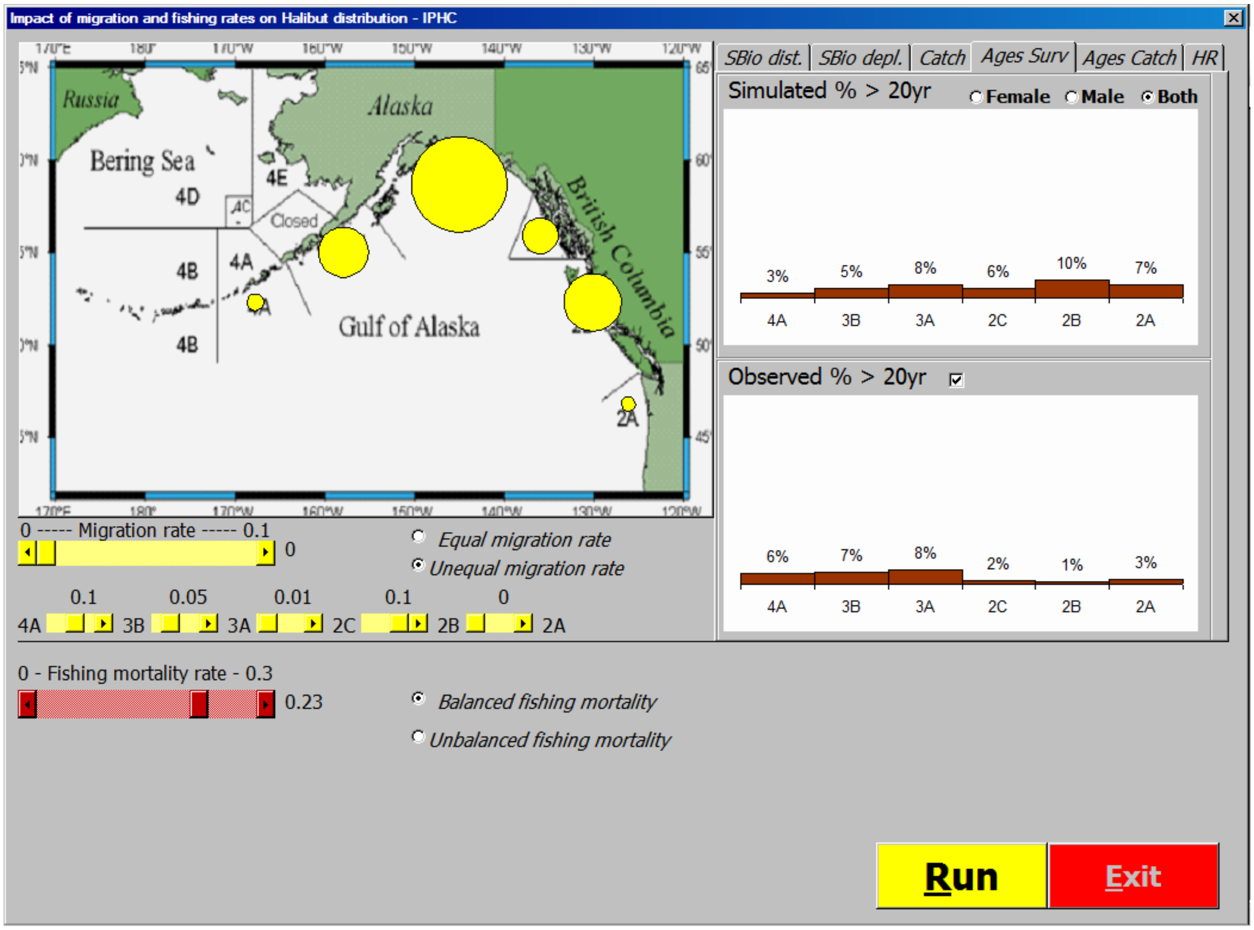
● Balanced fishing mortality

○ Unbalanced fishing mortality

Simulated % > 20yr ○ Female ○ Male ● Both

Observed % > 20yr ☑

Figure 13. Widget screenshot, projected and observed percentage of halibut older than 20 years under no fishing conditions.


Impact of migration and fishing rates on Halibut distribution - IPHC

0 ----- Migration rate ----- 0.1
0

○ Equal migration rate
● Unequal migration rate

0.1 0.05 0.01 0.1 0
4A 3B 3A 2C 2B 2A

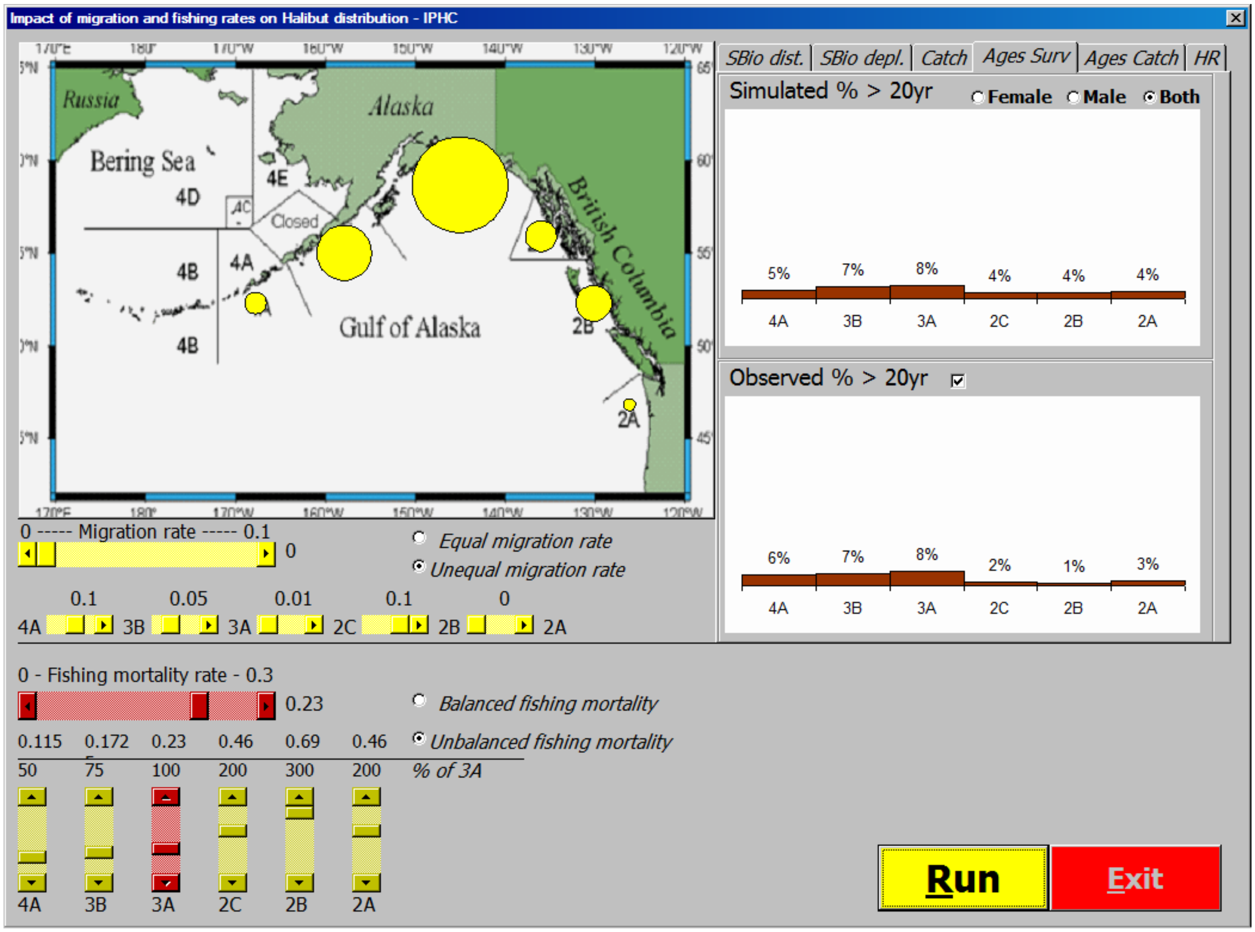
0 - Fishing mortality rate - 0.3
0.23

● Balanced fishing mortality
○ Unbalanced fishing mortality

Simulated % > 20yr ○ Female ○ Male ● Both

Observed % > 20yr ☑

Figure 14. Widget screenshot, projected and observed percentage of halibut older than 20 years with fishing under the same fishing mortality in all areas.



Simulated % > 20yr ○ Female ○ Male ● Both

4A	3B	3A	2C	2B	2A
5%	7%	8%	4%	4%	4%

Observed % > 20yr ☑

4A	3B	3A	2C	2B	2A
6%	7%	8%	2%	1%	3%

0 ----- Migration rate ----- 0.1 0

○ Equal migration rate
● Unequal migration rate

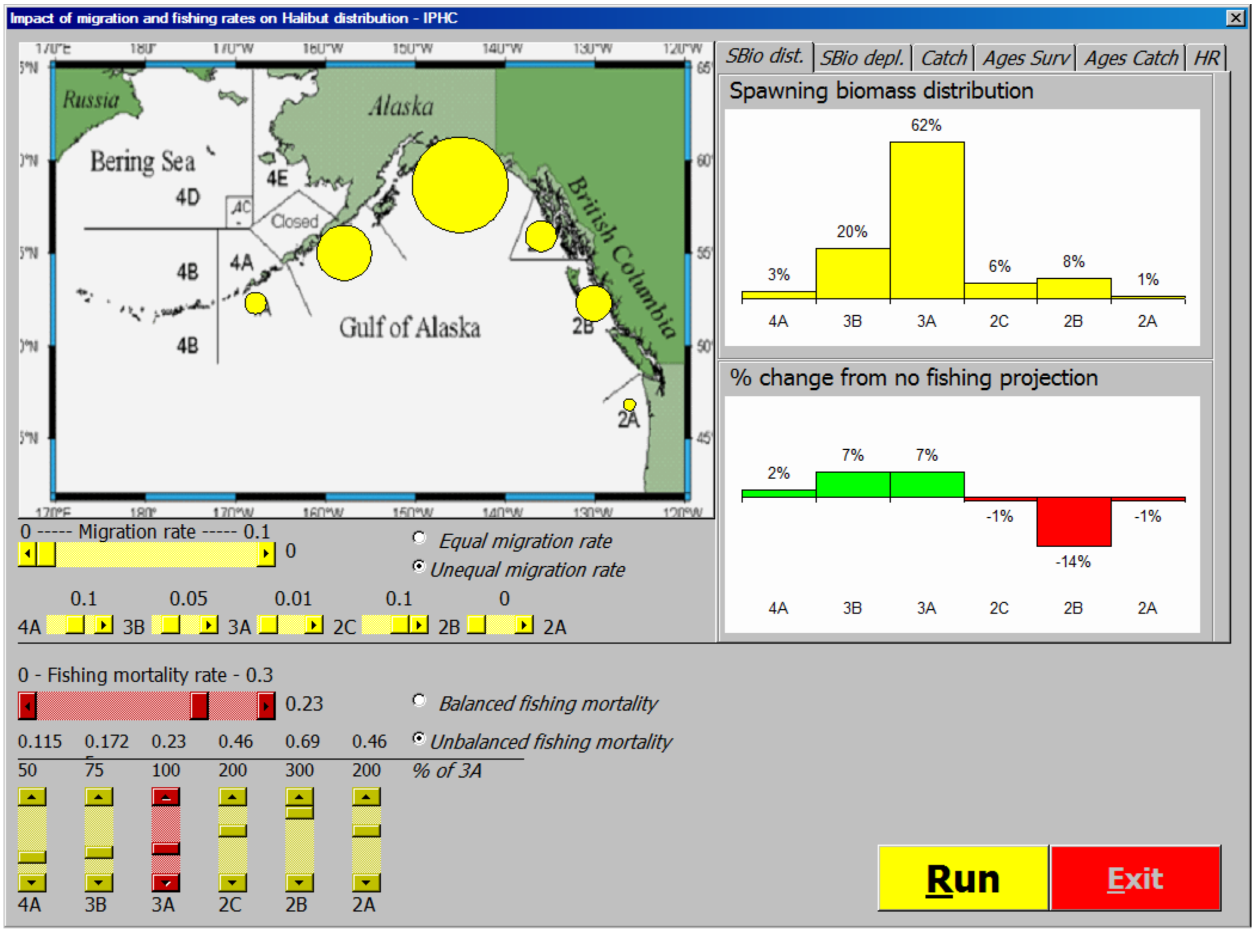
4A	3B	3A	2C	2B	2A
0.1	0.05	0.01	0.1	0	

0 - Fishing mortality rate - 0.3 0.23

○ Balanced fishing mortality
● Unbalanced fishing mortality

	4A	3B	3A	2C	2B	2A
	0.115	0.172	0.23	0.46	0.69	0.46
% of 3A	50	75	100	200	300	200

Figure 15. Widget screenshot, projected and observed percentage of halibut older than 20 years with fishing mortalities set at values close to those estimated by the coastwide assessment for recent years.


Impact of migration and fishing rates on Halibut distribution - IPHC

0 ----- Migration rate ----- 0.1: 0

○ Equal migration rate

● Unequal migration rate

4A 0.1 3B 0.05 3A 0.01 2C 0.1 2B 0 2A

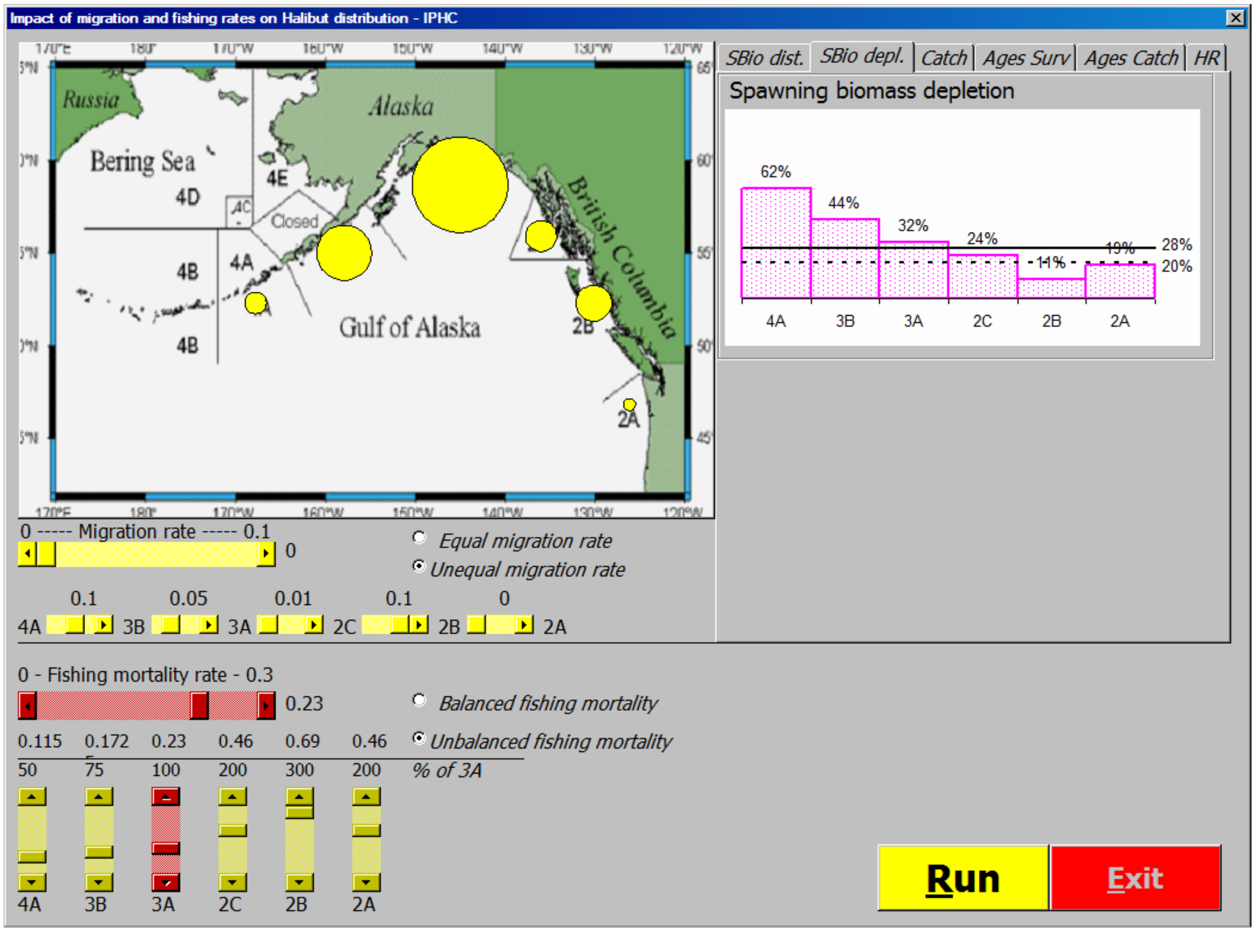
0 - Fishing mortality rate - 0.3: 0.23

○ Balanced fishing mortality

● Unbalanced fishing mortality

	4A	3B	3A	2C	2B	2A
	0.115	0.172	0.23	0.46	0.69	0.46
% of 3A	50	75	100	200	300	200

Figure 16. Widget screenshot, projected distribution of spawning biomass and change from no fishing projection under unbalanced fishing mortality rates.



Spawning biomass depletion

0 ----- Migration rate ----- 0.1 0

○ Equal migration rate

● Unequal migration rate

4A	3B	3A	2C	2B	2A
0.1	0.05	0.01	0.1	0	

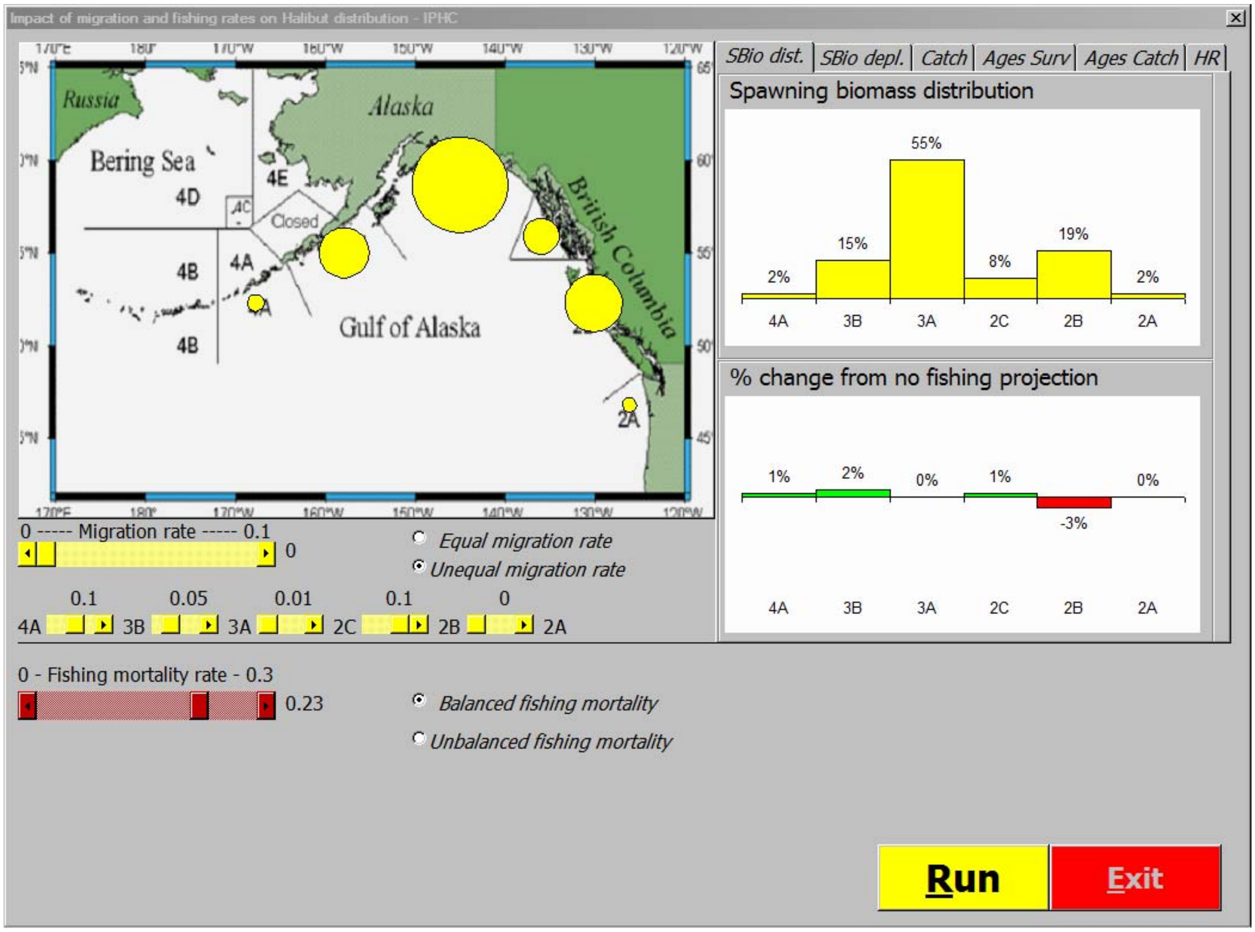
0 - Fishing mortality rate - 0.3 0.23

○ Balanced fishing mortality

● Unbalanced fishing mortality

	4A	3B	3A	2C	2B	2A
	0.115	0.172	0.23	0.46	0.69	0.46
% of 3A	50	75	100	200	300	200

Figure 17. Widget screenshot, projected spawning biomass depletion under unbalanced fishing mortality rates.



0 ----- Migration rate ----- 0.1: 0

○ Equal migration rate

● Unequal migration rate

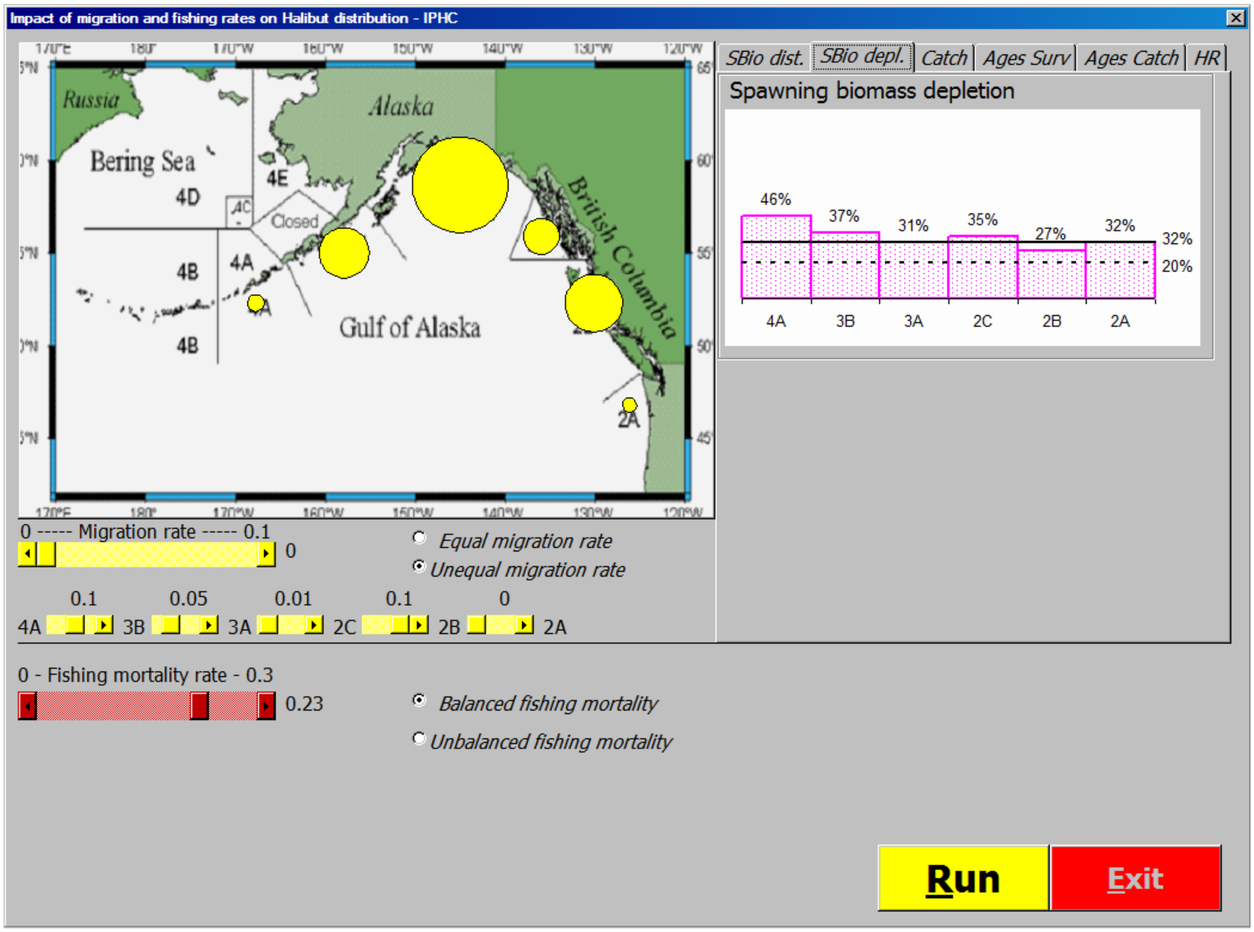
4A 0.1 3B 0.05 3A 0.01 2C 0.1 2B 0 2A

0 - Fishing mortality rate - 0.3: 0.23

● Balanced fishing mortality

○ Unbalanced fishing mortality

Figure 18. Widget screenshot, projected distribution of spawning biomass and change from no fishing projection when applying the same fishing mortality rate on all areas.



Impact of migration and fishing rates on Halibut distribution - IPHC

0 ----- Migration rate ----- 0.1 0

○ Equal migration rate

● Unequal migration rate

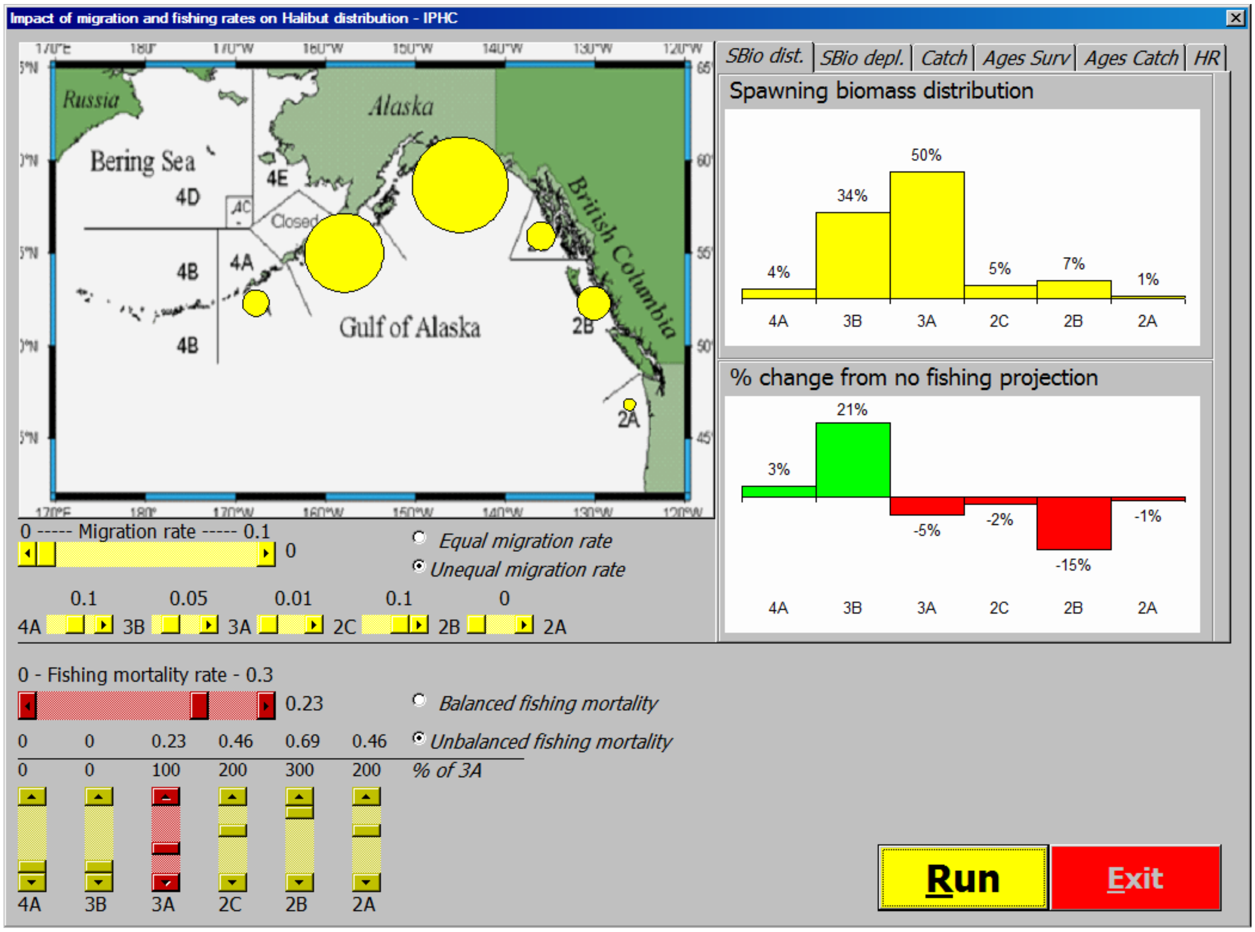
4A 0.1 3B 0.05 3A 0.01 2C 0.1 2B 0 2A

0 - Fishing mortality rate - 0.3 0.23

● Balanced fishing mortality

○ Unbalanced fishing mortality

Figure 19. Widget screenshot, spawning biomass depletion when applying the same fishing mortality rate on all areas.



0 ----- Migration rate ----- 0.1 0

○ Equal migration rate

● Unequal migration rate

4A 0.1 3B 0.05 3A 0.01 2C 0.1 2B 0 2A

0 - Fishing mortality rate - 0.3 0.23

○ Balanced fishing mortality

● Unbalanced fishing mortality

0	0	0.23	0.46	0.69	0.46	
0	0	100	200	300	200	% of 3A
4A	3B	3A	2C	2B	2A	

Figure 20. Widget screenshot, projected distribution of spawning biomass and change from no fishing projection when applying historically unbalanced fishing mortality rates in the eastern part of the stock and no fishing in areas 4A and 3B.

Appendix A

International Pacific Halibut Commission

Using IPHC Widgets

Widgets are a type of graphical user interface (GUI) that can be used to display information changeable by the user, such as a window or a text box. One of the advantages of a widget is to provide a single interactive tool to manipulate data, specify data inputs, model characteristics and view results. The International Pacific Halibut Commission developed two Widgets (Graphical User Interface) for the 2008 IPHC Biomass Apportionment Workshop held in Bellevue on September 4, 2008. The widgets were developed to illustrate:

a) How different indices affect biomass apportionment and what the resultant realized harvest rate would be.

b) How halibut distribution changes relative to unfished conditions under different migration and fishing mortality rates

Installation

Both widgets were developed with Visual Basic for Applications and use Microsoft Excel only to generate output graphs. The only requirement to use them is to have Excel (2003 or 2007) installed in your computer. For the widgets to run properly you need to take the following steps:

1) Open Microsoft Office Excel
2) Go to "Tools" > "Options" > "Security" > "Macro Security" and set the security level to "Medium"
3) Close Microsoft Office Excel

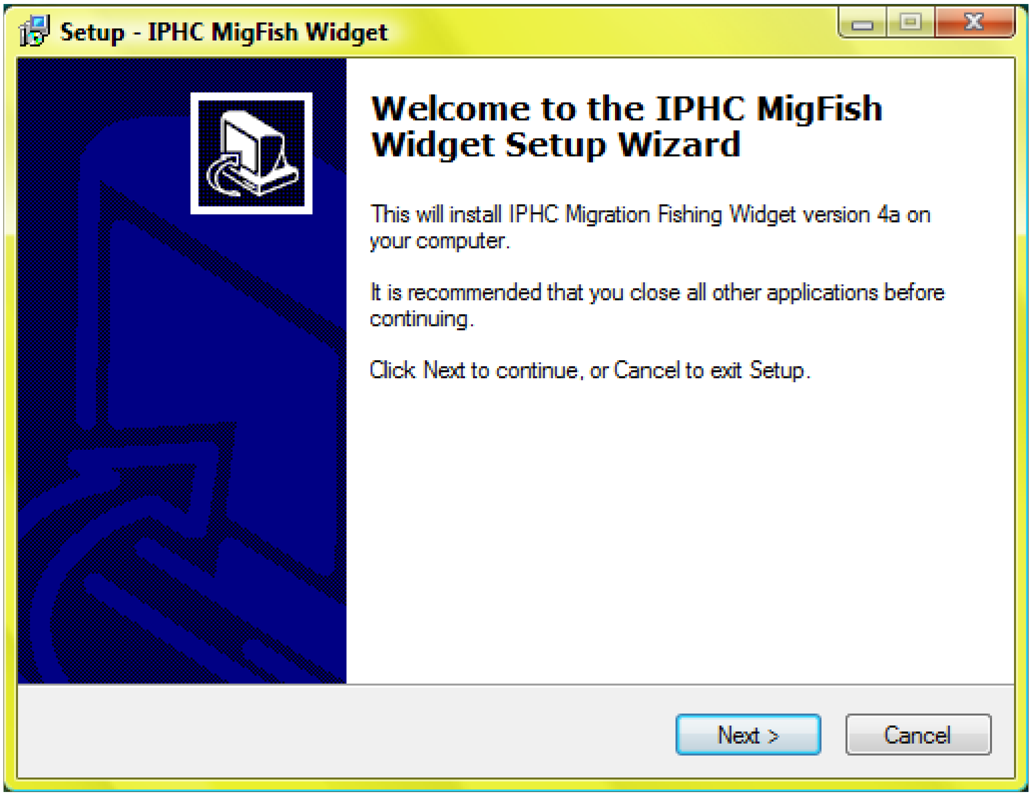
Now you can install the widgets by opening the following installation files:

Setup IPHC MigFish Widget.exe

Setup IPHC BioApp Widget.exe

The installation steps are basically the same for each widget, below it is illustrated the steps for installing the "IPHC MigFish Widget". The selected option for the default installation is highlighted in blue.

If you have any questions please contact Juan Valero: juan@iphc.washington.edu



Setup - IPHC MigFish Widget

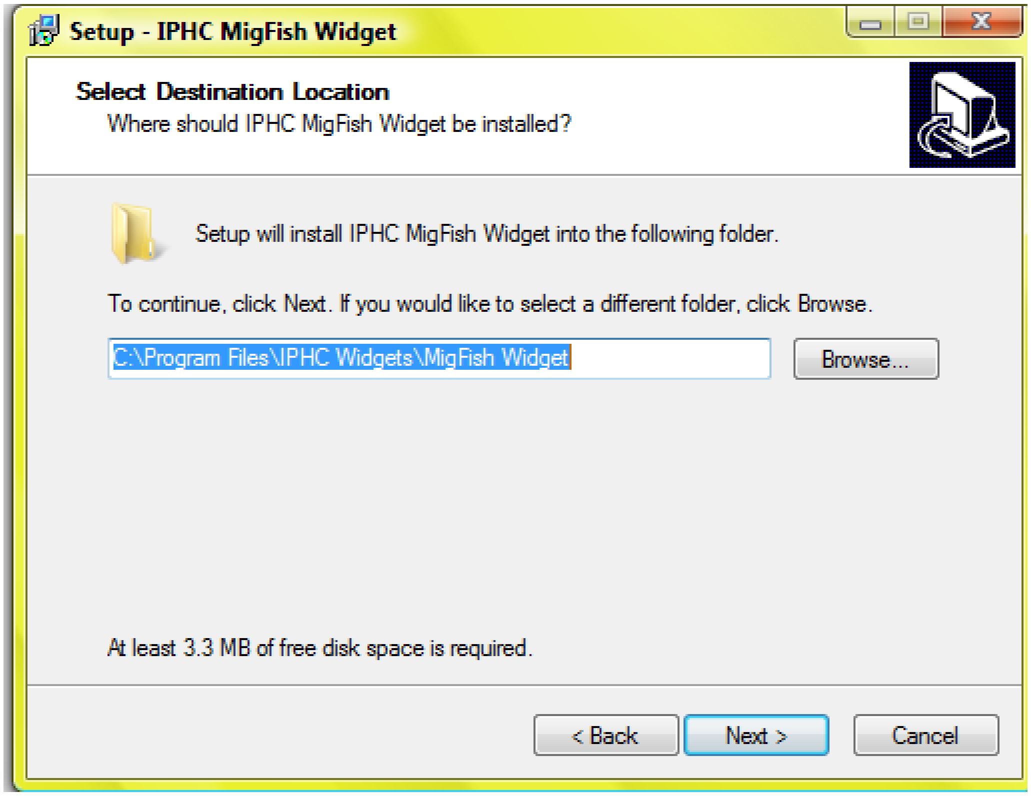
Welcome to the IPHC MigFish Widget Setup Wizard

This will install IPHC Migration Fishing Widget version 4a on your computer.

It is recommended that you close all other applications before continuing.

Click Next to continue, or Cancel to exit Setup.

Figure A1. Welcoming screen following clicking of the installer, to install click "Next".



Setup - IPHC MigFish Widget

Select Destination Location

Where should IPHC MigFish Widget be installed?

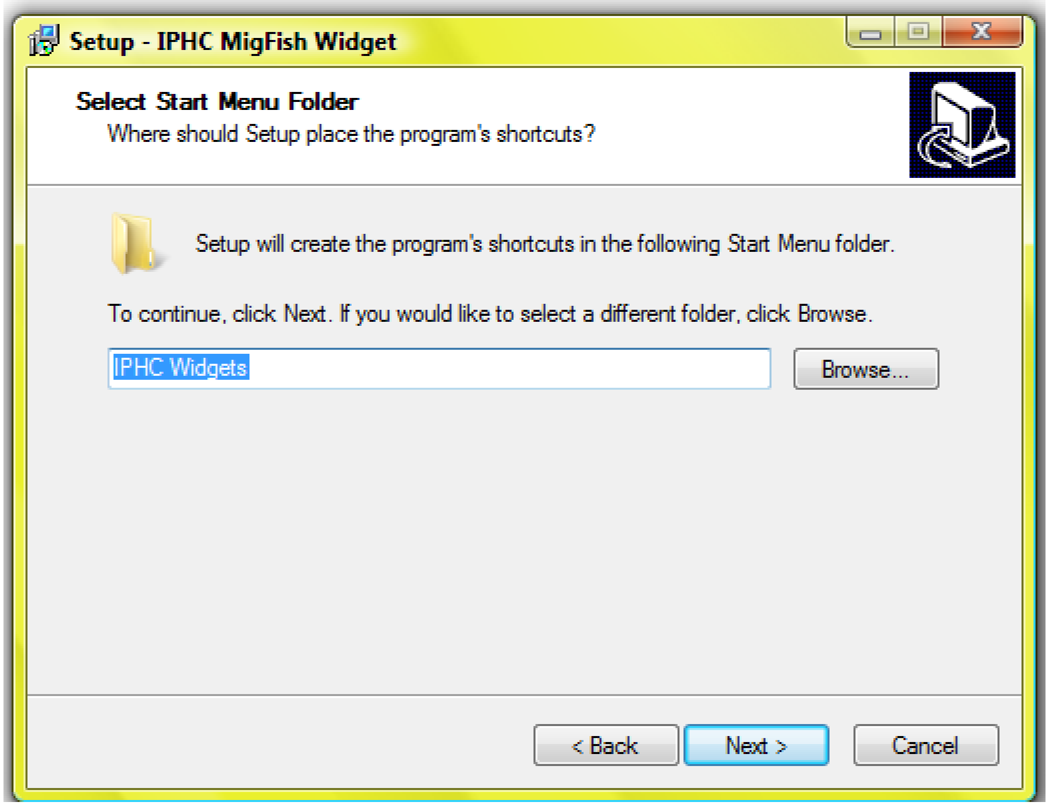
Setup will install IPHC MigFish Widget into the following folder.

To continue, click Next. If you would like to select a different folder, click Browse.

C:\Program Files\IPHC Widgets\MigFish Widget

At least 3.3 MB of free disk space is required.

Figure A2. Specification of folder where to install widgets, if using default folder hit "Next".



Select Start Menu Folder

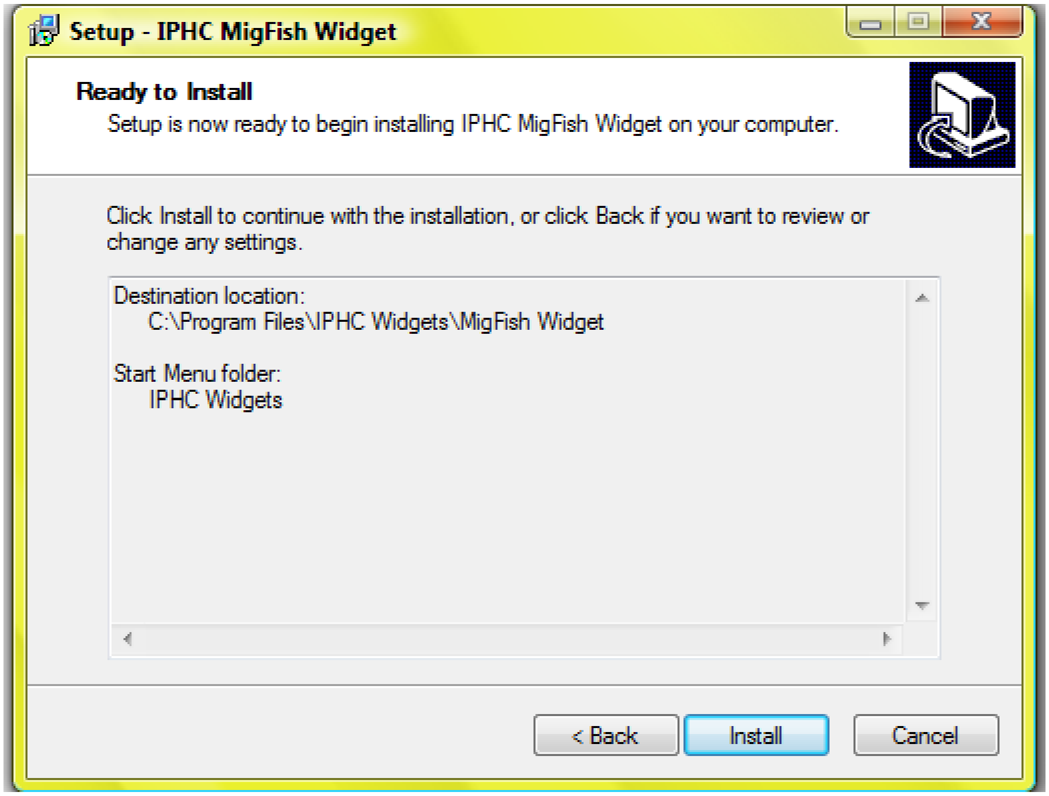
Where should Setup place the program's shortcuts?

Setup will create the program's shortcuts in the following Start Menu folder.

To continue, click Next. If you would like to select a different folder, click Browse.

IPHC Widgets

Figure A3. Specifying default Menu Folder, click "Next".



Ready to Install

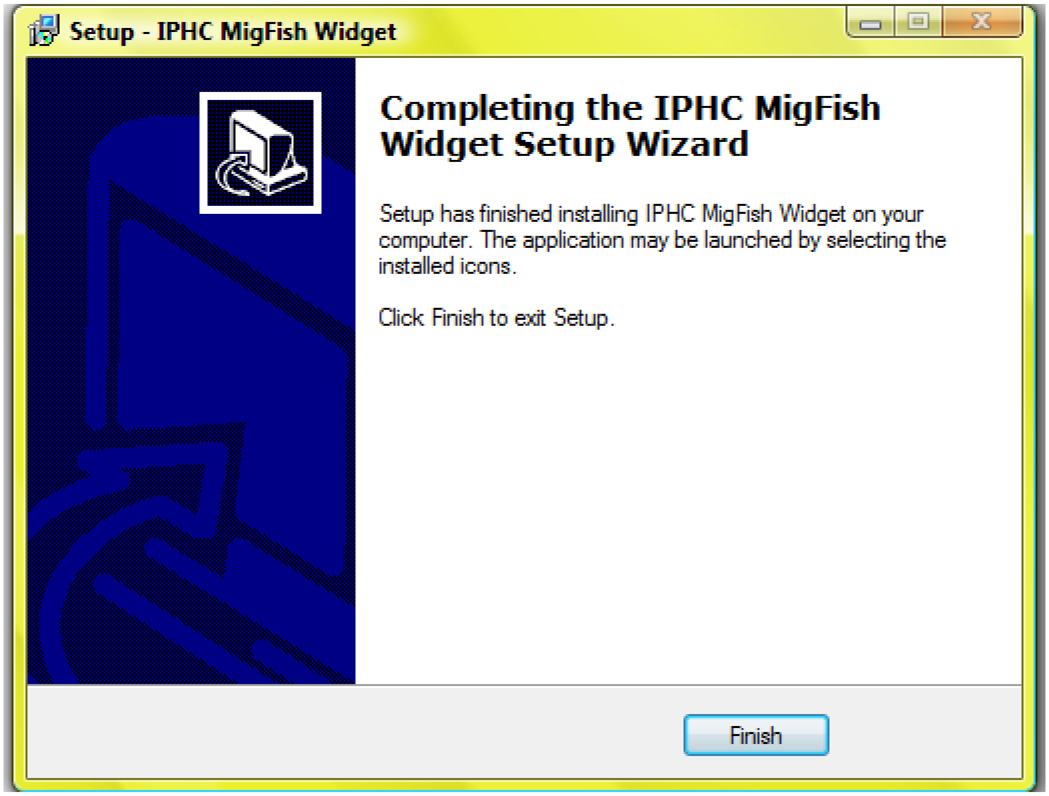
Setup is now ready to begin installing IPHC MigFish Widget on your computer.

Click Install to continue with the installation, or click Back if you want to review or change any settings.

Destination location:
C:\Program Files\IPHC Widgets\MigFish Widget

Start Menu folder:
IPHC Widgets

Figure A4. Reviewing installation directories, click “Install”.



Completing the IPHC MigFish Widget Setup Wizard

Setup has finished installing IPHC MigFish Widget on your computer. The application may be launched by selecting the installed icons.

Click Finish to exit Setup.

Figure A5. Final step of widget installation, click "Finish".

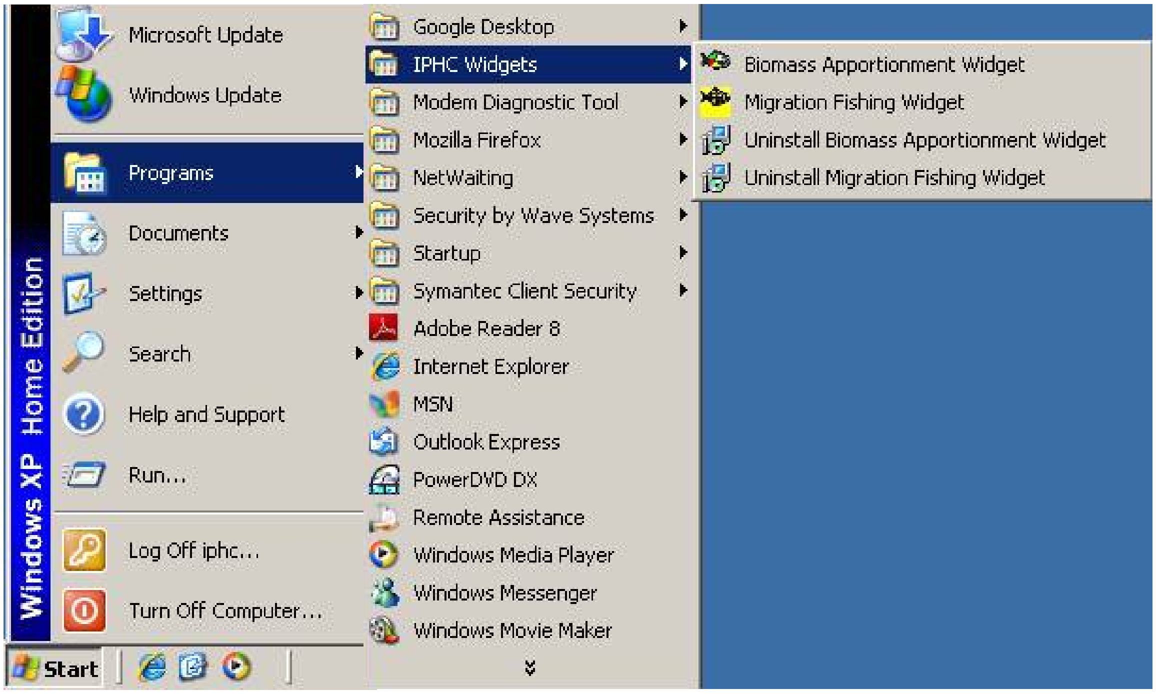
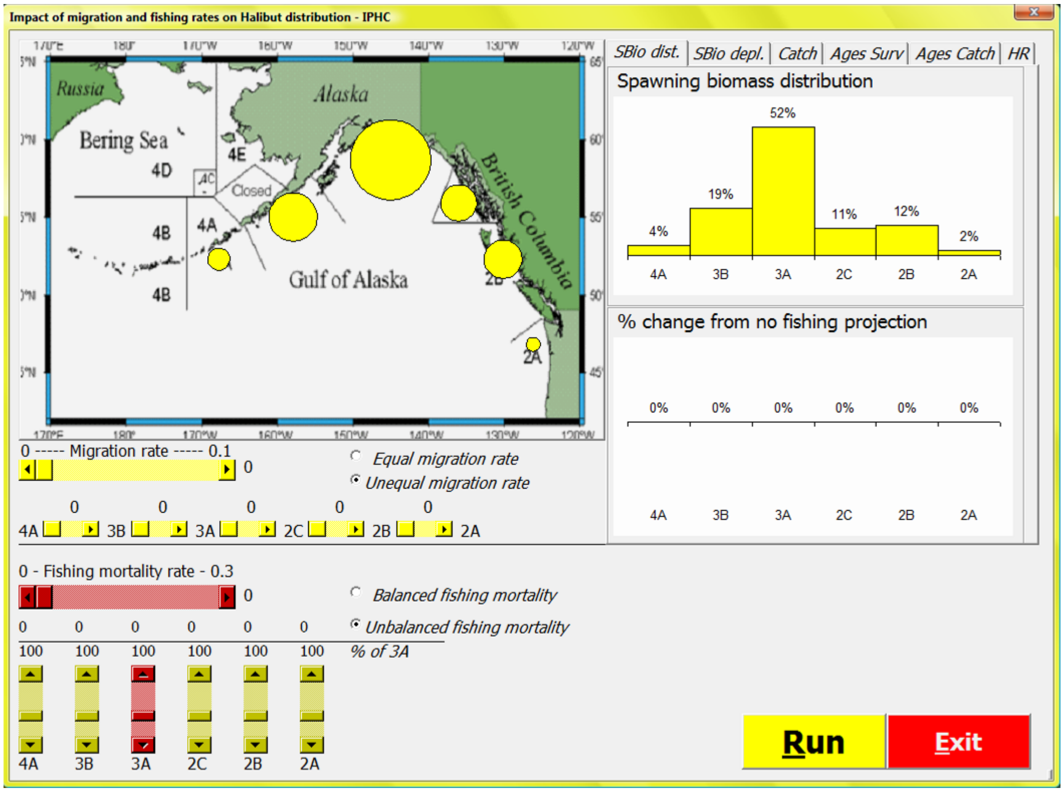


Figure A6. Screenshot illustrating how to start the widgets from the IPHC Widgets folder



0 ----- Migration rate ----- 0.1 0

○ Equal migration rate

● Unequal migration rate

4A 0 3B 0 3A 0 2C 0 2B 0 2A

0 - Fishing mortality rate - 0.3 0

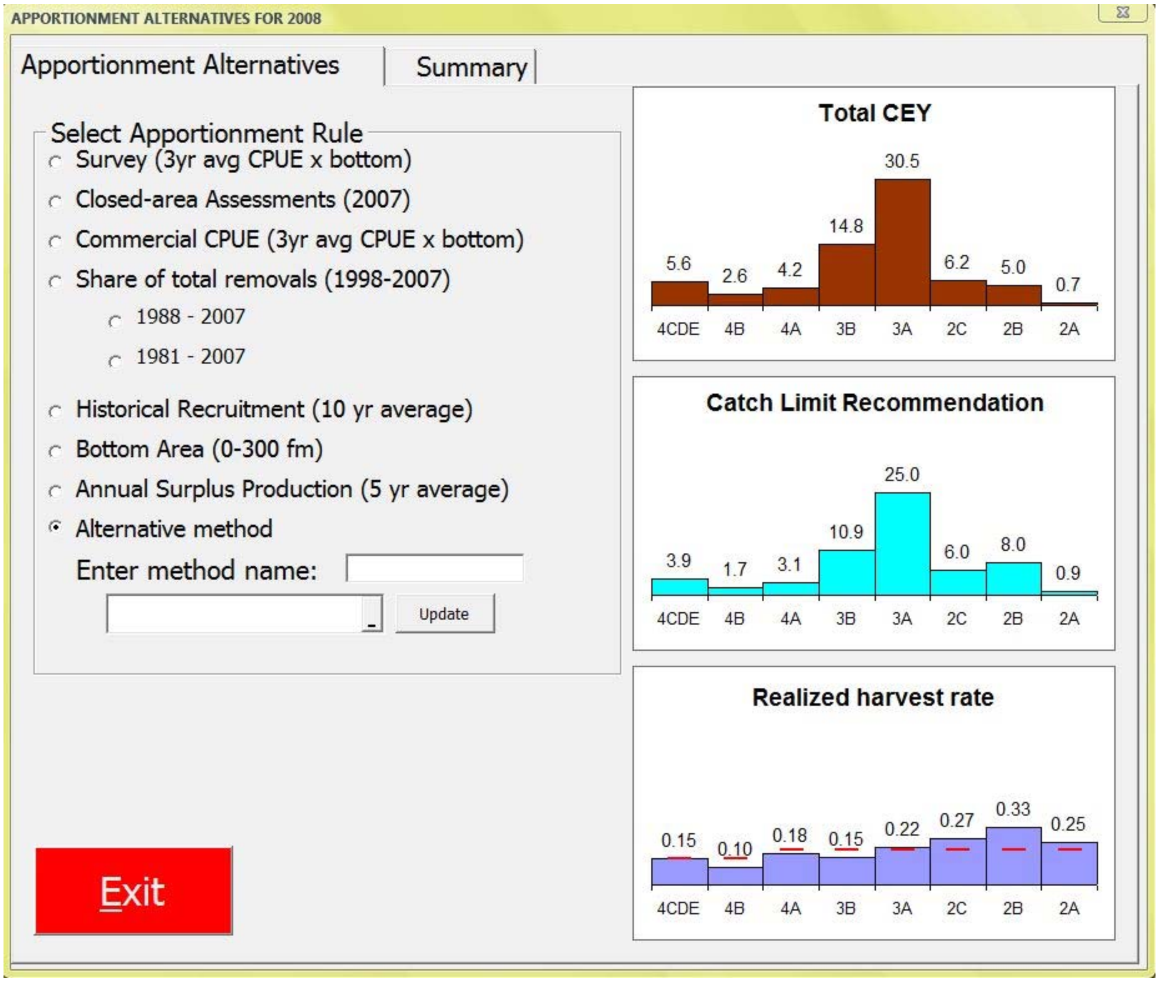
○ Balanced fishing mortality

● Unbalanced fishing mortality

% of 3A

4A	3B	3A	2C	2B	2A
0	0	0	0	0	0
100	100	100	100	100	100

Figure A7. Screenshot of the MigFish widget.



Select Apportionment Rule

- ○ Survey (3yr avg CPUE x bottom)
- ○ Closed-area Assessments (2007)
- ○ Commercial CPUE (3yr avg CPUE x bottom)
- ○ Share of total removals (1998-2007)
  - ○ 1988 - 2007
  - ○ 1981 - 2007
- ○ Historical Recruitment (10 yr average)
- ○ Bottom Area (0-300 fm)
- ○ Annual Surplus Production (5 yr average)
- ● Alternative method

Enter method name:

Figure A8. Screenshot of the BioApp widget.