2005 Pollock Year-Class Prediction: Average Recruitment

31 August 2005

DATA

This forecast is based on five data sources: three physical properties and two biological data sets. The sources are:

1. Observed 2005 Kodiak monthly precipitation. The Kodiak Weather Service Office (http://padq.arh.noaa.gov/) prepares monthly precipitation totals (inches) from hourly observations. Data for 2005 were obtained from the NOAA National Climate Data Center, Asheville, North Carolina.

2. Wind mixing energy at [57°N, 156°W] estimated from 2005 sea-level pressure analyses. Monthly estimates of wind mixing energy (W m^{-2}) were computed for a location near the southwestern end of Shelikof Strait. To make the estimates, twice-daily gradient winds were computed for that location using the METLIB utility (Macklin *et al.*, 1984). Gradient winds were converted to surface winds using an empirical formula based on Macklin *et al.* (1993). Estimates of wind mixing energy were computed using constant air density (1.293 kg m^{-3}) and the drag coefficient formulation of Large and Pond (1982).

3. Advection of ocean water near Shelikof Strait inferred from drogued drifters deployed during the spring of 2005.

4. Rough counts of pollock larvae from a survey conducted in late May–early June 2005.

5. Estimates of age-2 pollock abundance and spawner biomass from the 2005 assessment.

ANALYSIS

Kodiak Precipitation*:* Kodiak precipitation is a proxy for fresh-water runoff that contributes to the density contrast between coastal and Alaska Coastal Current water in Shelikof Strait. The greater the contrast, the more likely that eddies and other instabilities will form. Such secondary circulations have attributes that make them beneficial to survival of larval pollock.

The season began with typical precipitation during January (Table 1). For all contributing winter and spring months, precipitation was near or above normal, with February being the wettest (at 153% of the 30-yr February average.

TABLE 1. Kodiak precipitation for 2005.

Month	% 30-yr average
Jan	104
Feb	153
Mar	111
Apr	103
May	139
June	104

Based on this information, the forecast element for Kodiak 2005 rainfall has a score of 2.21. This is "average to strong" on the continuum from 1 (weak) to 3 (strong).

Wind Mixing*:* Following the decadal trend established in the late 1990s, wind mixing at the southern end of Shelikof Strait was again below the long-term average for all winter and spring months of 2005, except March.

TABLE 2. Wind mixing at the exit of Shelikof Strait for 2005.

Month	% 30-yr average
Jan	46
Feb	48
Mar	114
Apr	74
May	39
June	39

Strong mixing in winter helps transport nutrients into the upper ocean layer to provide a basis for the spring phytoplankton bloom. Weak spring mixing is thought to better enable first feeding pollock larvae to locate and capture food. Weak mixing in winter is not conducive to high survival rates, while weak mixing in spring favors recruitment. This year's scenario produces a wind mixing score of 2.29, which equates to "average-to-strong".

Advection*:* From an examination of drifter trajectories and wind forcing, the transport in Shelikof Strait for spring of 2005 was strong until mid April and then weak, which would support a prediction of an average to strong year class.

We have hypothesized that very strong transport is bad for pollock survival, that moderate transport is best, and that very weak transport, while not as disastrous as strong transport, still is detrimental to larval survival. Advection was given a score of 2.29.

Relating the Larval Index to Recruitment: As in last year's analysis, a nonlinear neural network model with one input neuron (larval abundance), three hidden neurons, and one output neuron (recruitment) was used to relate larval abundance (CPUA, average catch, m^{-2}) to age-2 recruitment abundance (billions). The model estimated six weighting parameters.

The neural network model, which used the 19 observation pairs of Table 3 to fit the model, had a very low R^2 of 0.054. A plot of the observed recruitment (actual) and that predicted from larval abundance (predicted) are given in Fig. 1, where row number corresponds to the rows of the data matrix given in Table 3.

TABLE 3. Data used in the neural network model.

Year Class	Mean CPUA	Recruit
1982	71.14483	0.206506
1985	80.42379	0.539391
1987	329.7428	0.361222
1988	217.9464	1.60372
1989	537.2899	1.04255
1990	373.8137	0.418636
1991	54.21859	0.239326
1992	562.7872	0.141279
1993	185.3388	0.212236
1994	126.5823	0.828361
1995	605.2316	0.402497
1996	477.6918	0.172455
1997	568.421	0.179436
1998	74.29526	0.266972
1999	119.071	1.17074
2000	492.0364	0.734729
2001	171.3022	0.103318
2002	175.6366	0.074741
2003	133.4611	0.188679

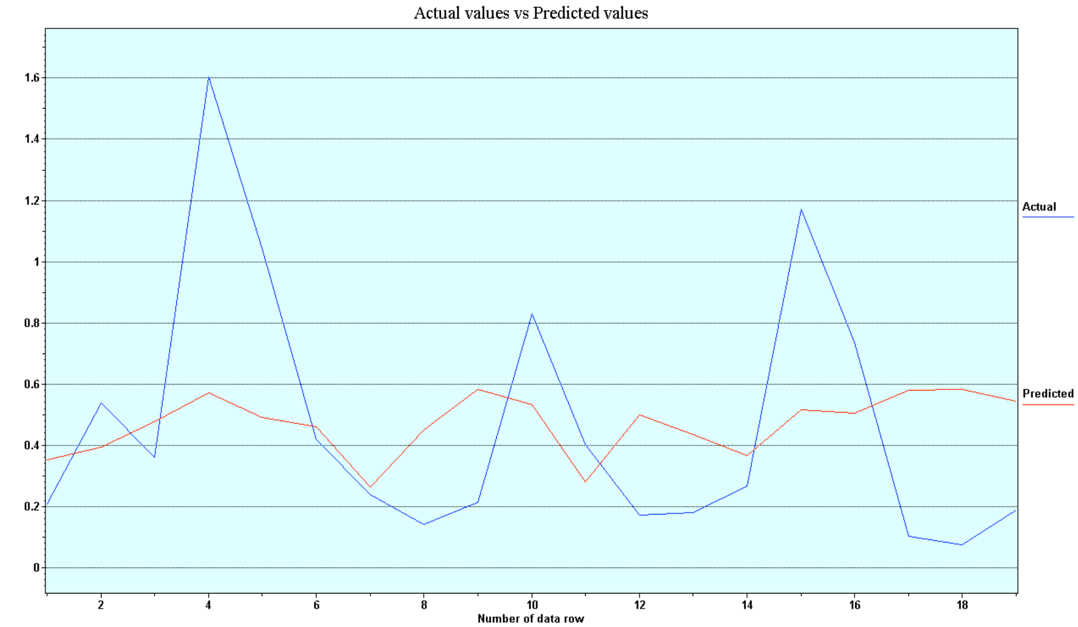

FIGURE 1. Observed and predicted recruitment values from the larval index-recruitment neural network model.

The trained network was then used to predict the recruitment for 2004 and 2005. The predictions are given in Table 4.

TABLE 4. Neural network model predictions for 2004 and 2005.

Year	Actual Recruitment	Predicted Recruitment
2004	n/a	0.248256
2005	n/a	0.339102

These values, using the 33% (0.335393) and 66% (0.70132) cutoff points given below, correspond to a weak 2004 year class and an average 2005 year class.

Larval Index Counts: Plotting the data by year and binning the data into catch/10 m^2 categories (given below) provides another view of the data. The pattern for 2005 (based on rough counts) show patterns similar to last year in that most of the data fall into the three lowest binning categories, but there were some data observation occupying the higher density bins. These patterns indicate that the 2005-year class may be below average.

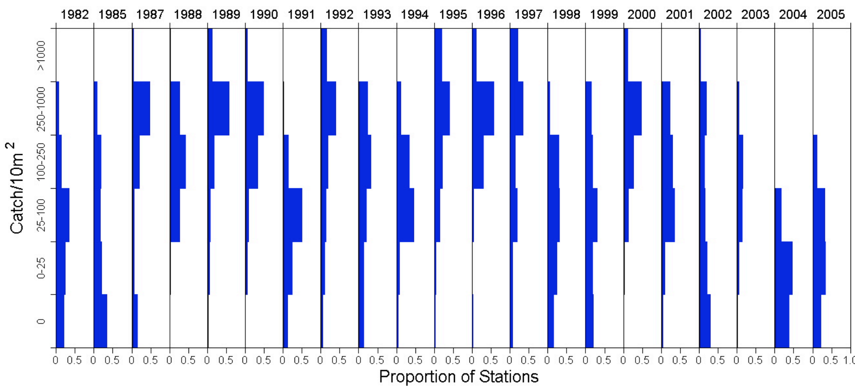

FIGURE 2. A series of histograms for larval walleye pollock densities in late May from 1982 to 2005. Data were binned into catch/10 m^2 categories. The data from 2000-2005 are rough counts taken at sea, and the 2005 data are from the 6MF05 cruise that was completed on June 3.

The data for Figure 3 and 4 are taken from a reference area that is routinely sampled and that usually contains the majority of the larvae. This year's distribution of pollock (Fig. 4) appears to be centered in the typical reference area, and the larval abundance figures in the middle of the reference area seem to be average. Also, the distribution of larvae in 2005 (Fig. 4) are further to the west compared to 2004 (Fig.3) suggesting that some of the Shelikof larvae might be in their nursery area at the time of the survey. Comparing the two maps shows that the 2005 rough counts seem to be higher compared to 2004. Given these two pieces of information, the score for larval index is set to average or 2.0.

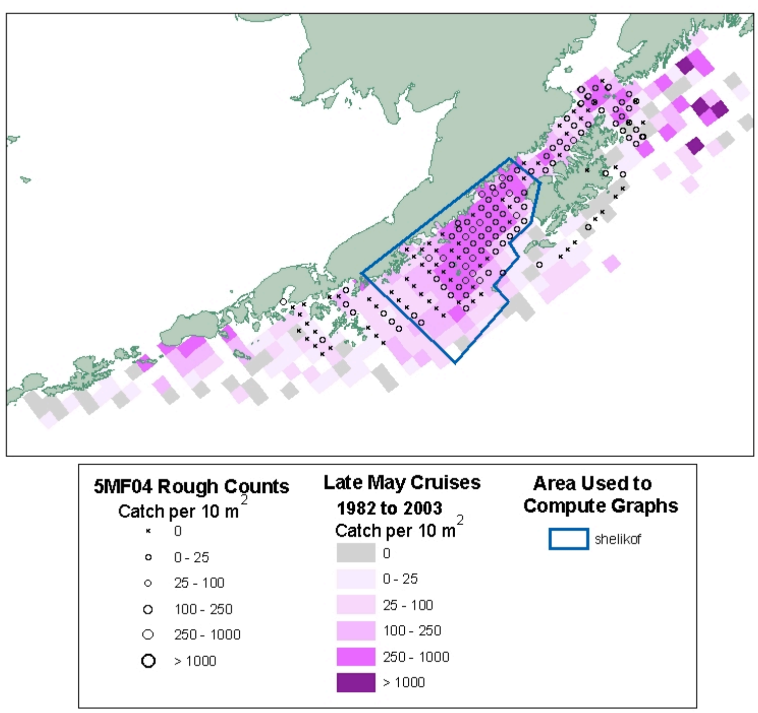

FIGURE 3. Mean catch per 10 m^2 for late May cruises during 1982-2004

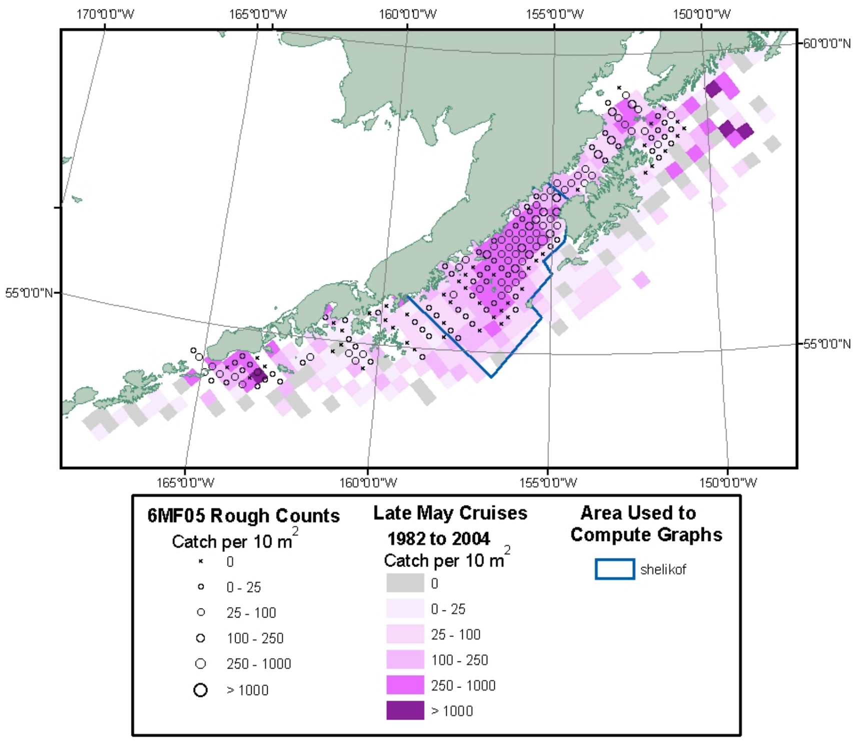

FIGURE 4. Mean catch per 10 m^2 for late May cruises during 1982-2005.

***Recruitment Time Series**:* The time series of recruitment from this year's assessment was analyzed in the context of a probabilistic transition in time. The data set consisted of age 2 abundance estimates from 1961-2005, representing the 1959-2003 year classes. There were a total of 45 recruitment data points. The 33% (0.335393 billion) and 66% (0.70132 billion) percentile cutoff points were calculated from the full time series and used to define the three recruitment states of weak, average and strong. The lower third of the data points were called weak, the middle third average and the upper third strong. Using these definitions, nine transition probabilities were then calculated:

1. Probability of a weak year class following a weak
2. Probability of a weak year class following an average
3. Probability of a weak year class following a strong
4. Probability of an average year class following a weak
5. Probability of an average year class following an average
6. Probability of an average year class following a strong
7. Probability of a strong year class following a weak
8. Probability of a strong year class following an average
9. Probability of a strong year class following a strong

The probabilities were calculated with a time lag of two years so that the 2005 year class could be predicted from the size of the 2003 year class. The 2003 year class was estimated to be 0.188679 billion and was classified as weak. The probabilities of other recruitment states following a weak year class for a lag of 2 years (n=45) are given below:

TABLE 5. Probability of the 2005 year class being weak, average and strong following a weak 2003 year class.

2005 Year Class		2003 Year Class	Probability	N
Weak	follows	Weak	0.093	4
Average	follows	Weak	0.070	3
Strong	follows	Weak	0.139	6

The probability of a strong year class following a weak year class two years later had the highest probability. We classified this data element as a strong, giving it a score at the low end of strong 2.34.

Spawner/Recruit Time Series*:* The data from the previous analysis only looked at the time sequence of the recruitment data points. This section looks at both the recruitment (R) and the spawning biomass (SB) in the context of transition probabilities after Rothschild and Mullin (1985). The benefit is that it is non-parametric and it provides a way to predict recruitment without applying a presumed functional spawner-recruit relationship. It involves partitioning the spawning stock into N-tiles and the recruitment into N-tiles, classifying the stock into NxN states. I used the 50% percentile of the data to calculate the median spawning biomass (0.269 million tons) and recruitment (0.435 billion). These values were used to partition the spawner-recruit space into 4 tiles, state 1:low SB-low R, state 2:low SB-high R, state 3:high SB-low R, and state 4:high SB-high R. The classification then makes it possible to study the probability of any state and the transitions between the states.

The time series of recruitment data and the 2x2 spawning biomass-recruitment plot are shown in Figure 5.

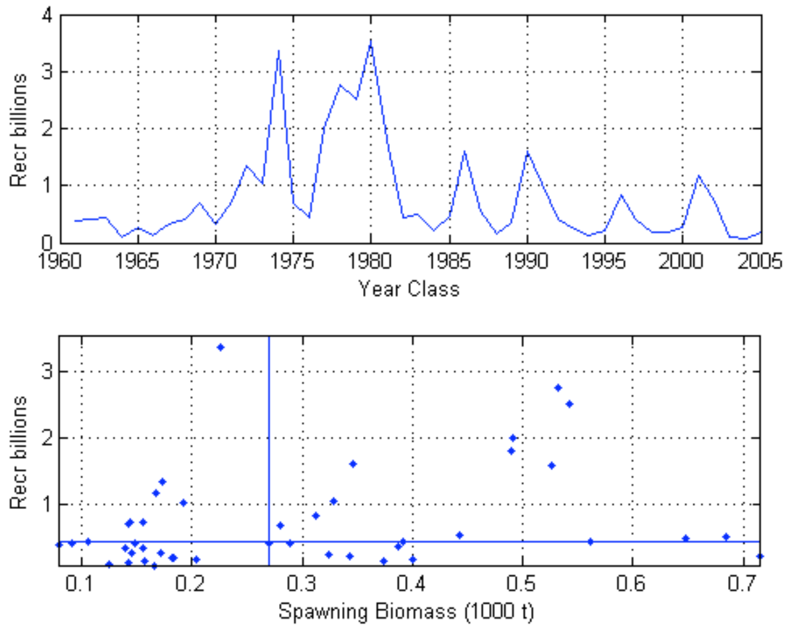

FIGURE 5. Time series of recruitment and the 2x2 classification of the spawning biomass and recruitment data.

TABLE 6. Transition matrix calculated from data in Figure 5.

Transition Probability matrix	To state1	To state 2	To state 3	To state 4
From state 1	0.692	0.308	0.000	0.000
From state 2	0.375	0.500	0.000	0.125
From state 3	0.125	0.000	0.500	0.375
From state 4	0.000	0.000	0.267	0.733

To calculate the score from Figure 5 takes two steps. First, we determine which state is the current state by taking the estimate of spawning biomass in 2005 (0.1827 million tons) and note that it falls below the median value of 0.269. We can see that in 2005 we are in either state 1 or state 2. The probabilities of transitioning from state 1 or state 2 to other states are given in the first two rows of Table 6.

If we are in state 1, then recruitment can either be below (a recruitment score of 1) or above the median (a recruitment score of 3). Note the probability for transitioning from state 1 to state 3 or 4 is 0.0 and from state 2 to state 3 is 0.0. If we start in state 1, then the combined recruitment score would be the weighted average of the recruitment scores for each possible transition, where the weighting factors are the probabilities. So, the calculations for the second step proceed as described below.

The weighted recruitment score (given we start in state 1) is the recruitment score for staying in state 1 (recruitment below the median, score=1) times the weight (the probability of transitioning from state 1 back to state 1) plus the recruitment score for transitioning from state 1 to state 2 (recruitment above the median, score=3) times the weight (the probability of transitioning from state 1 to state 2), all divided by the sum of the weights.

$$= \frac{(1*0.692)+(3*0.308)}{(0.692+0.308)} = 1.61$$

Similarly, the weighted recruitment score (given we start in state 2)

$$= \frac{(1*0.375)+(3*0.5)+(3*0.125)}{(0.375+0.5+0.125)} = 2.25$$

We average over these two weighted scores because stating from either state 1 or state 2 is equally likely if the starting spawning biomass in 2005 is below the median, giving a final score of 1.97, or the middle range of average.

CONCLUSION

A low weighting score of 0.1 was assigned to the larval index data element because the recruitment variability explained by larval abundance was very low. Each of the remaining data elements were weighted equally.

Based on these six elements and the weights assigned in Table 7, below, the FOCI forecast of the 2005 year class is average.

TABLE 7. Final 2005 pollock recruitment forecast.

Element	Weights	Score	Total
Time Sequence of R	0.18	2.34	0.4212
Rain	0.18	2.21	0.3978
Wind Mixing	0.18	2.29	0.4122
Advection	0.18	2.29	0.4122
Larval Index-abundance	0.10	2.00	0.2000
Spawner-Recruit Data	0.18	1.68	0.3024
Total	**1.00**		**2.1458= Average**

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