2006 Pollock Year-Class Prediction: Average Recruitment

28 September 2006

DATA

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

1. Observed 2006 Kodiak monthly precipitation. The Kodiak Weather Service Office (http://padq.arh.noaa.gov/) prepares monthly precipitation totals (inches) from hourly observations. Data for 2006 were obtained from the NOAA National Climate Data Center, Asheville, North Carolina.

2. Wind mixing energy at [57°N, 156°W] estimated from 2006 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 2006.

4. Rough counts of pollock larvae from a survey conducted in late May–early June 2006.

5. Estimates of age-2 pollock abundance and spawner biomass from the 2006 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 lower than normal precipitation during January, February and March (Table 1). This decreased the potential for formation of baroclinic instabilities prior to and during spawning. April and May brought a return toward normal, however the potential for instabilities forming from increased freshwater input to coastal water was still lower than expected. June was wet (at 151% of the 30-yr June average), and this may have presented favorable habitat for late larval- and early juvenile-stage walleye pollock.

TABLE 1. Kodiak precipitation for 2006.

Month	% 30-yr average
Jan	44
Feb	63
Mar	69
Apr	92
May	77
June	151

Based on this information, the forecast element for Kodiak 2006 rainfall has a score of 1.72. This is "weak to average" recruitment on the 5-category continuum from 1 (weak) to 3 (strong), and “average” using three categories.

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 2006, except June.

TABLE 2. Wind mixing at the exit of Shelikof Strait for 2006.

Month	% 30-yr average
Jan	30
Feb	85
Mar	52
Apr	65
May	56
June	140

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 1.98, which equates to "average".

Winds and Transport in Alaska Coastal Current: The transport in the Alaska Coastal Current is strongly correlated with along shore winds. While the winds in March 2006 were moderate for the time of year, April had 3-4 major storms that resulted in strong currents in the Alaska Coastal Current This flow would tend to advect the larvae downstream out of the preferred nursery grounds in the Shelikof Sea valley and into the basin. Conditions in May were calmer resulting in weaker transport, and retention of larvae in the sea valley and along the Alaska Peninsula.

Observations from two satellite-tracked drifters that entered Shelikof Strait in the spring of 2006 support this pattern. One drifter quickly traveled down the strait in April and exited the sea valley by mid-May.

Based on these observations, the 2006 pollock year-class prediction has a score of 1.72, which equates to weak to average based on transport in the Alaska Coastal Current

***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 eight weighting parameters.

The neural network model, which used the 20 observation pairs of Table 3 to fit the model, had a very low R^2 of 0.078. 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	71.14	0.206506
1985	80.42	0.554497
1987	329.74	0.376806
1988	260.21	1.610350
1989	537.29	1.004960
1990	335.00	0.401599
1991	54.22	0.239704
1992	562.79	0.145232
1993	185.34	0.219996
1994	126.58	0.853329
1995	610.33	0.406418
1996	477.69	0.174581
1997	568.42	0.158482
1998	72.20	0.230184
1999	96.14	0.951485
2000	492.04	0.794435
2001	171.30	0.140742
2002	175.64	0.155498
2003	135.36	0.150900
2004	21.22	1.320550

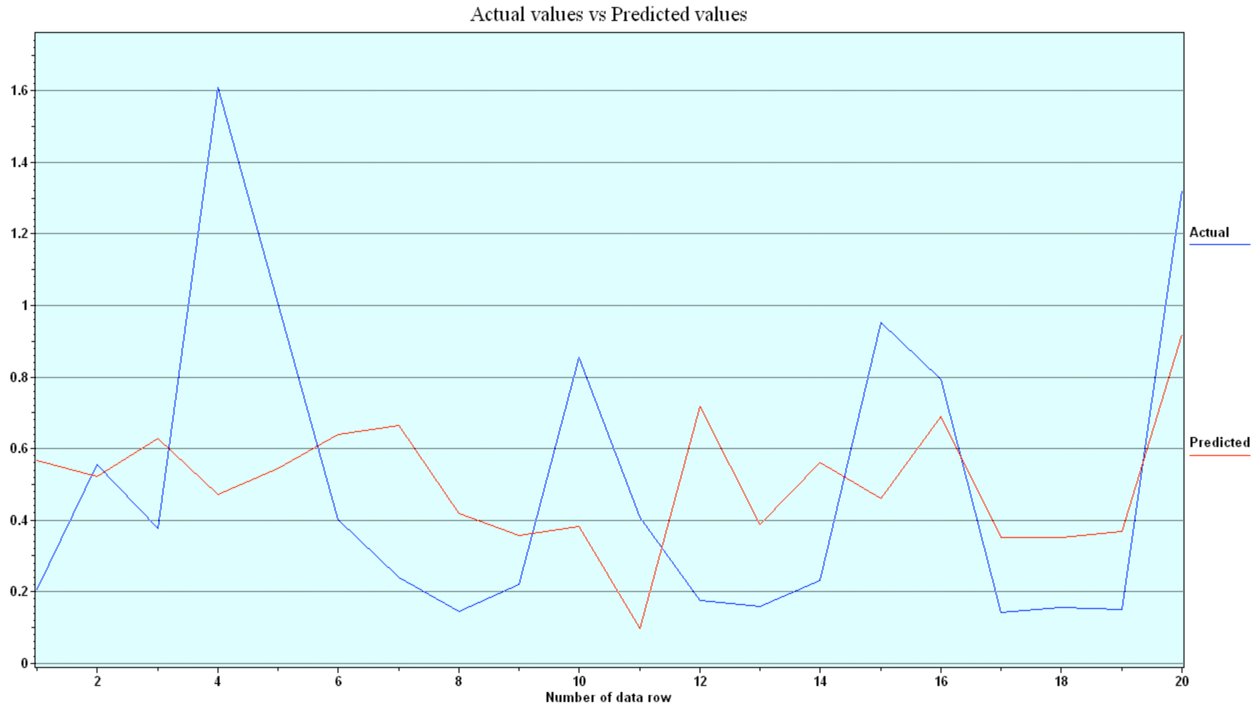

FIGURE 1. Observed and predicted recruitment values from the larval index-recruitment neural network model.

The trained network was then used to predict the recruitment for 2005 and 2006. The predictions are given in Table 4.

TABLE 4. Neural network model predictions for 2005 and 2006.

Year	Actual Recruitment	Predicted Recruitment
2005	n/a	0.542462
2006	n/a	0.623431

These values, using the 33% (0.3469) and 66% (0.7340) cutoff points given below, correspond to an average 2005 year class and an average 2006 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 2006 (based on rough counts) show patterns different from last year in that the frequency distribution is skewed towards the higher binning categories (Figure 2). These patterns indicate that the 2006 year class may be above average.

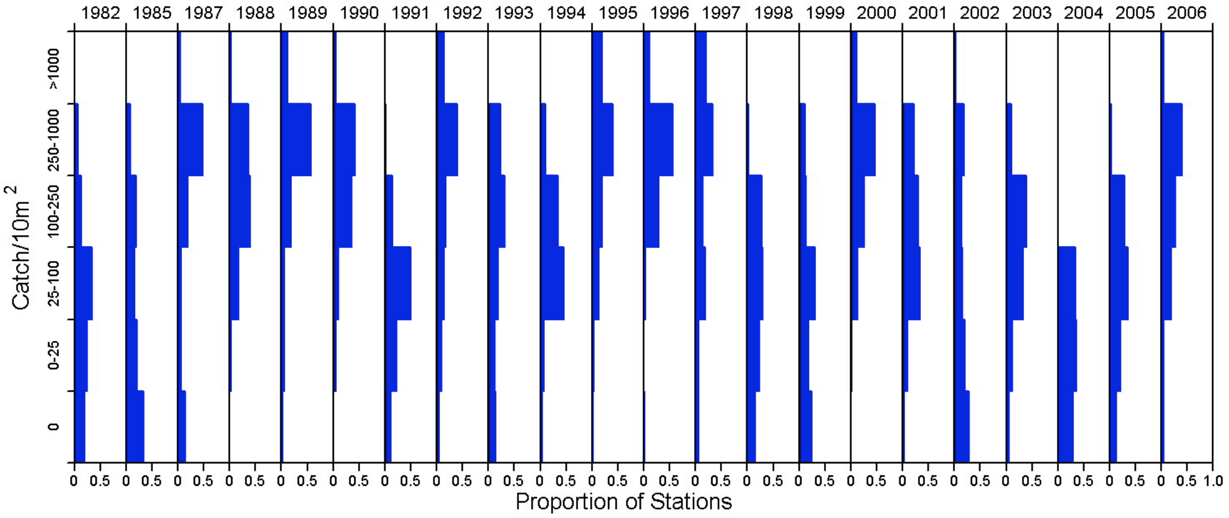

FIGURE 2. A series of histograms for larval walleye pollock densities in late May from 1982 to 2006. Data were binned into catch/10 m^2 categories. The data from 2000-2004 are actual verified larval counts, 2005 are unverified counts from the Polish plankton Sorting Institute, and 2006 data are rough counts from the 4MF06 cruise that was completed in late May.

The data for Figures 3, 4, and 5 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. 5) 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 three maps shows that the 2006 rough counts seem to be higher compared to 2005 and the distribution of larvae at high densities was spatially broader. Given these two pieces of information, the score for larval index is set to the high end of average or 2.33.

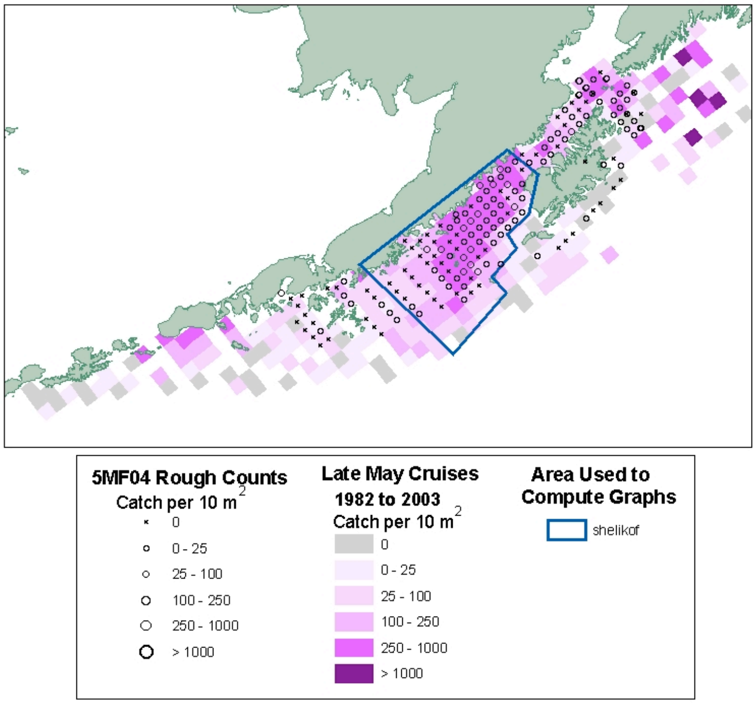

FIGURE 3. Mean catch per 10 m^2 for late May cruises during 1982-2003, with observed rough counts overlayed for 2004.

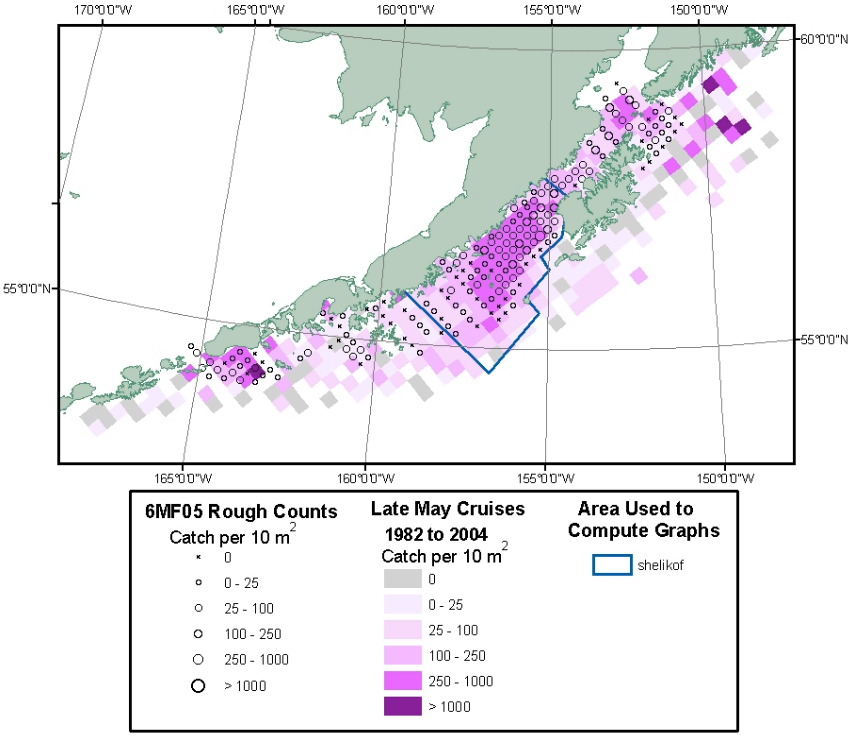

FIGURE 4. Mean catch per 10 m^2 for late May cruises during 1982-2004, with observed rough counts overlayed for 2005.

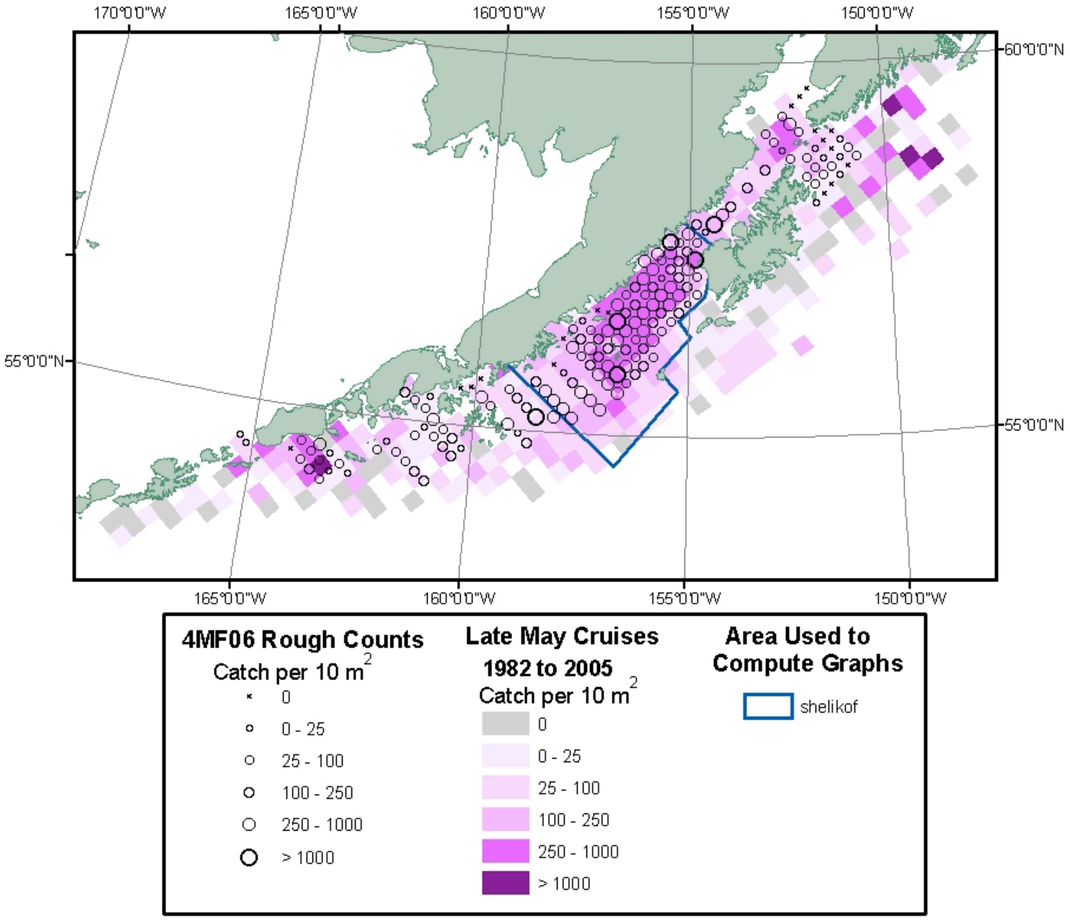

FIGURE 5. Mean catch per 10 m^2 for late May cruises during 1982-2005, with observed rough counts overlayed for 2006.

***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 1961-2006, representing the 1959-2004 year classes. There were a total of 46 recruitment data points. The 33% (0.3469 billion) and 66% (0.7340 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 2006 year class could be predicted from the size of the 2004 year class. The 2004 year class was estimated to be 1.3206 billion and was classified as strong. The probabilities of other recruitment states following a strong year class for a lag of 2 years (n=46) are given below:

TABLE 5. Probability of the 2006 year class being weak, average and strong following a strong 2004 year class.

2006 Year Class		2004 Year Class	Probability	N
Weak	Follows	Strong	0.11364	5
Average	follows	Strong	0.11364	5
Strong	follows	Strong	0.11364	5

The probability for all possibilities were the same. We classified this data element as a neutral, giving it a score of average or 2.0 but we will use a weighting factor of 0.0 since it does not contribute any information to the forecast.

***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. We used the 50% percentile of the data to calculate the median spawning biomass (0.2531 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. These areas correspond to the lower left, upper left, lower right, and upper right quadrants of the lower panel in Figure 5. 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.

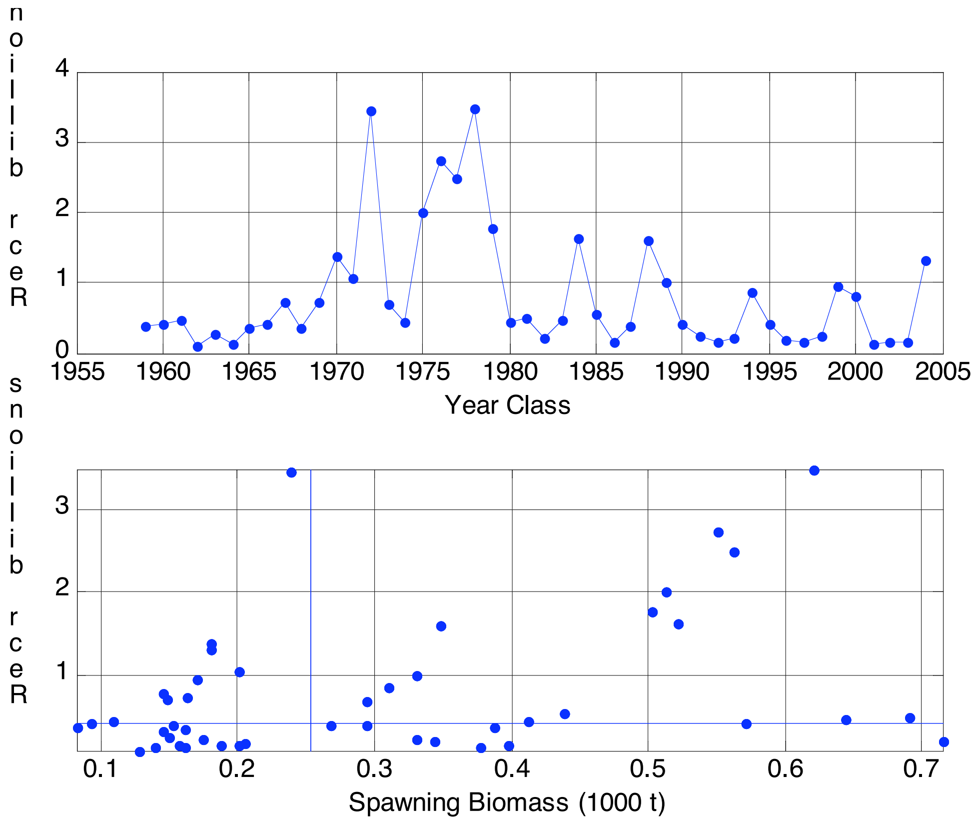

FIGURE 5. Time series of recruitment and the 2x2 classification of the 2006 spawning biomass and recruitment data.

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

Transition Probability Matrix	To state 1	To state 2	To state 3	To state 4
From state 1	0.6429	0.3571	0.0000	0.0000
From state 2	0.3750	0.5000	0.0000	0.1250
From state 3	0.1112	0.0000	0.4444	0.4444
From state 4	0.0000	0.0000	0.3571	0.6429

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 2006 (0.1803 million tons) and note that it falls below the median value of 0.2531. We can see that in 2006 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. 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 transition 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.

$$= \frac{(1 * 0.6429) + (3 * 0.3571)}{(0.6429 + 0.3571)} = 1.714$$

Similarly, the weighted recruitment score (given we start in state 2) is the recruitment score for staying in state 2 (recruitment above the median, score=3) times the weight (the probability of transitioning from state 2 back to state 2) plus the recruitment score for transitioning from state 2 to state 1 (recruitment below the median, score=1) times the weight (the probability of transitioning from state 2 to state 1), plus the recruitment score for transitioning from state 2 to state 4 (recruitment above the median, score=3) times the weight (the probability of transitioning from state 2 to state 4) all divided by the sum of the weights.

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

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 2006 is below the median, giving a final score of 1.98, or average.

One final calculation from these data is the expected first passage time or the number of years on average that a stock and recruitment system in a particular state will take to return to a particular state. These data are given in Table 7. For example, it would take 7.75 years for Gulf of Alaska pollock in State 2 to return to State 1.

TABLE 7. Expected First Passage Time.

State	1	2	3	4
1	3.7679	2.8000	22.0000	19.2000
2	7.7500	5.2750	19.2000	16.4000
3	20.2000	23.0000	4.6889	5.6400
4	23.0000	25.8000	2.8000	3.0143

CONCLUSION

A very low weighting score of 0.0 was assigned to the time sequence of recruitment because the results were neutral and did not contribute any information to the forecast. The larval index data element was weighted low (0.1) because the recruitment variability explained by larval abundance was very low. The advection element was weighted higher than the low elements (0.14) but lower than the quantitative elements. Rain, wind and spawner-recruit time series elements received the highest weighing scores because their forecast was based on quantitative data.

Based on these six elements and the weights assigned in Table 8, below, the FOCI forecast of the 2006 year class is average.

TABLE 8. Final 2006 pollock recruitment forecast.

Element	Weights	Score	Total
Rain	0.22	1.72	0.3784
Wind Mixing	0.22	1.98	0.4356
Advection	0.14	1.72	0.2408
Larval Index-abundance	0.10	2.00	0.2000
Larval Rough Counts and Distribution	0.10	2.33	0.2330
Time Sequence of R	0.00	2.00	0.0000
Spawner-Recruit Time Series	0.22	1.98	0.4356
Total	**1.00**		**1.9324= Average**

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