



# Effect of the timing and location of the spawning on transport of walleye pollock in the Gulf of Alaska: An individual-based model study

## Introduction

Walleye pollock, an important fishery in the Gulf of Alaska (GOA), is characterized by spatially disaggregated spawning and nursery habitats. Historically, a large part of the egg production has been associated with Shelikof Strait and advected southwest along the Alaska Peninsula where by summer and through early fall juveniles arrive at the Shumagin Islands nursery area.

An individual based model (IBM) of young walleye pollock coupled with a Nutrient/Phytoplankton/Zooplankton model and a Regional Ocean Modeling System physical model aimed to i) study transport patterns in the western GOA including the identification of spatial and temporal spawning-nursery area connectivity based on realistic initial conditions of egg release, ii) extract IBM pre-recruitment indices, and iii) compare these indices with recruitment.

## Methods

The IBM model was forced with spatial and temporal (seasonally variable) climatological initial conditions (IC) synthesized from 31 years of egg distribution data in the GOA from Alaska Fisheries Science Center ichthyoplankton samples (Figure 1B, C and D).

- The release times were between March and June, every 2 weeks (8 periods), for all years from 1996 to 2011.
- The release depth was set at 200-250 m, except where bottom depth was <200 m.
- Total number of particles released for 8 periods x 16 years x 10,000 particles was 1,280,000.
- Preliminary analysis of the connectivity matrices, based on a IBM grid (Figure 1E), generated for all model simulations led to the identification of seasonal and interannual variability in early ontogeny drift pathways, based on variable spawning areas (sources) and resultant nursery grounds (sinks).
- Empirical Orthogonal Functions analysis explored variance in the pre-recruit indices generated by the various IBM simulations. IBM indices were extracted and compared with recruitment estimates. This study is being developed under the framework of Gulf of Alaska Integrated Ecosystem Program.

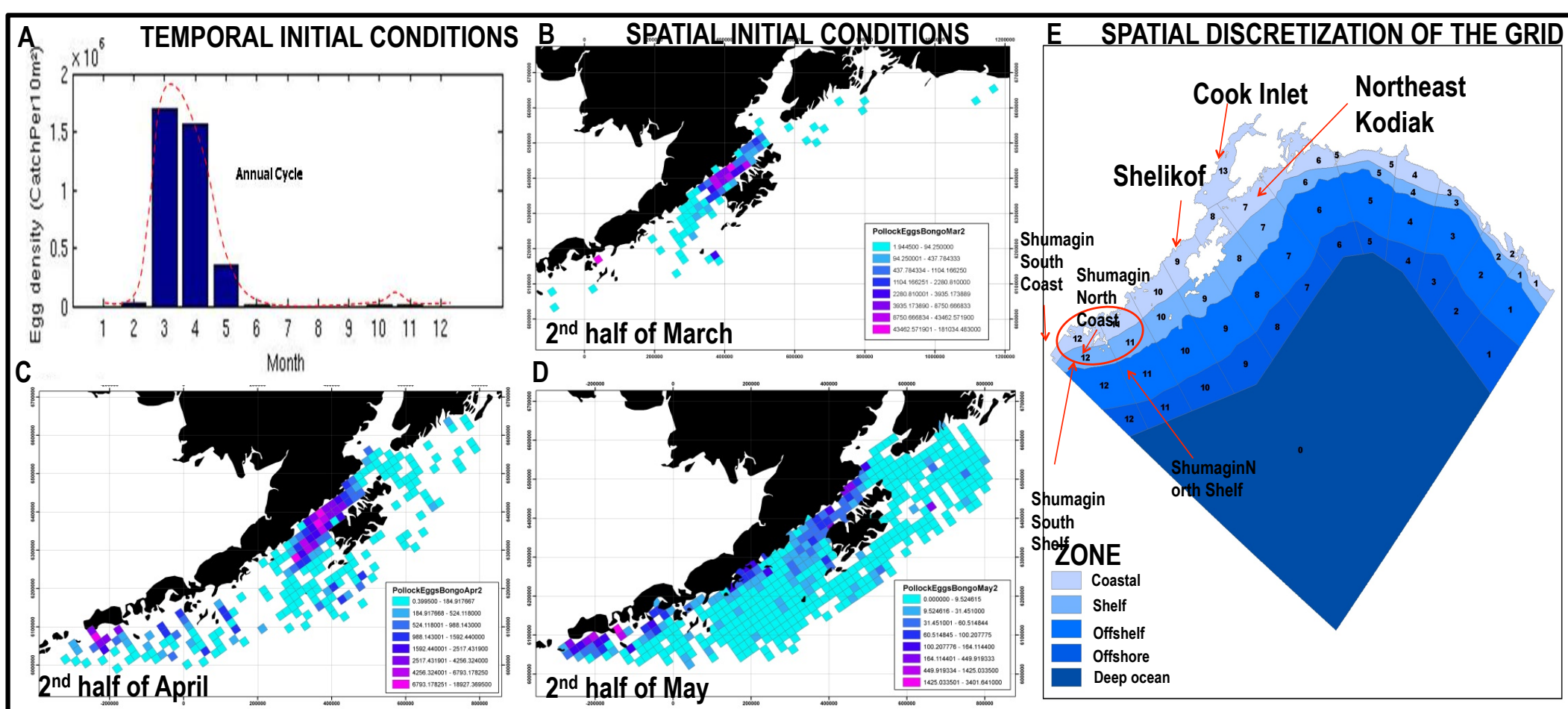


Figure 1. A. Temporal annual cycle of spawning. B, C and D are examples of spatial climatological initial conditions (synthesized from 31 years) of egg distribution data in the GOA from Alaska Fisheries Science Center ichthyoplankton samples from March to May integrated fortnightly. E. Spatial discretized domain where connectivity and IBM indices are assessed.

## Results

The model connectivity results in terms of connectivity for each biweekly initial condition was averaged over years. The results indicate different connectivity patterns between areas. These are characterized in Figure 2 and separated according the type of connection.

An EOF analysis was done on the spatial and temporal connectivity variability (each 2 weeks) for all years. The results showed that the spatial mode 1 explains 79.2% of the variance. The most relevant connectivity patterns were type A and B, linking Shelikof Strait and the Shumagin region. Retention in Shelikof and the Shumagins is observed. The 2<sup>nd</sup> spatial mode (5.7%) shows the same connectivity type as mode 1, but in addition type E and F where Cook inlet is connected to the Shumagins via coastal and shelf pathways. Retention is evident in Cook Inlet, the Shumagins and Shelikof Strait.

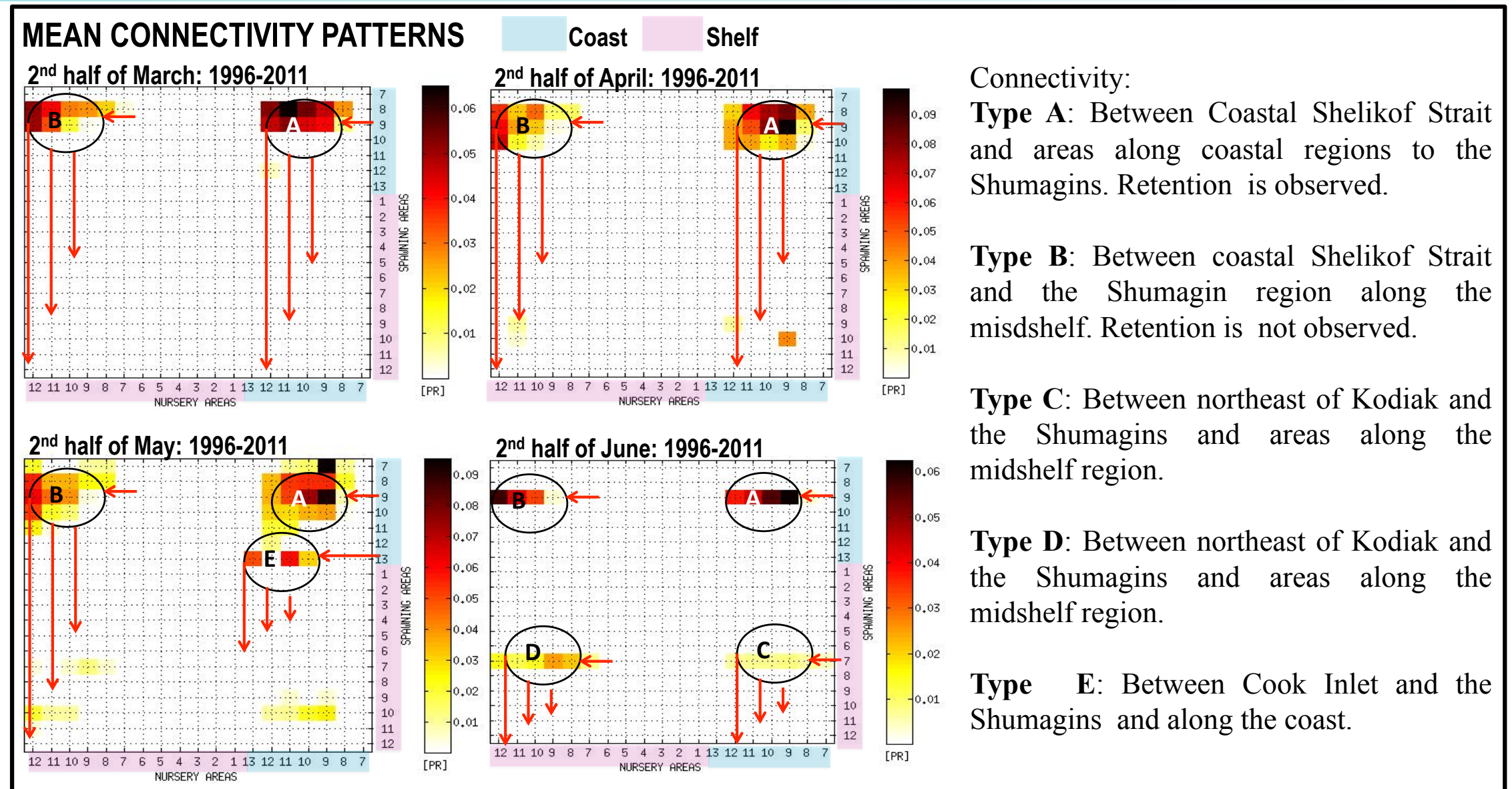


Figure 2. Mean connectivity patterns calculated from March to June integrated for years 1996 to 2011, showing types of connectivity.

The temporal first mode (PC1) shows interannual variability in connectivity with a clear annual pattern. The annual cycle obtained from PC1 shows 2 connectivity peaks associated with particles released in April and June. Those peaks are linked to the first spatial modes (types A and B). This implies that those timings of release are mostly contributing to types A and B connectivity.

In addition, indices were extracted from the IBM defined as the proportion of particles (alive) reaching a given region from the total released that year. Those indices were compared to pollock recruitment (see Figure 3).

## INDICES EXTRACTED FROM IBM AND COMPARISON WITH RECRUITMENT ESTIMATES

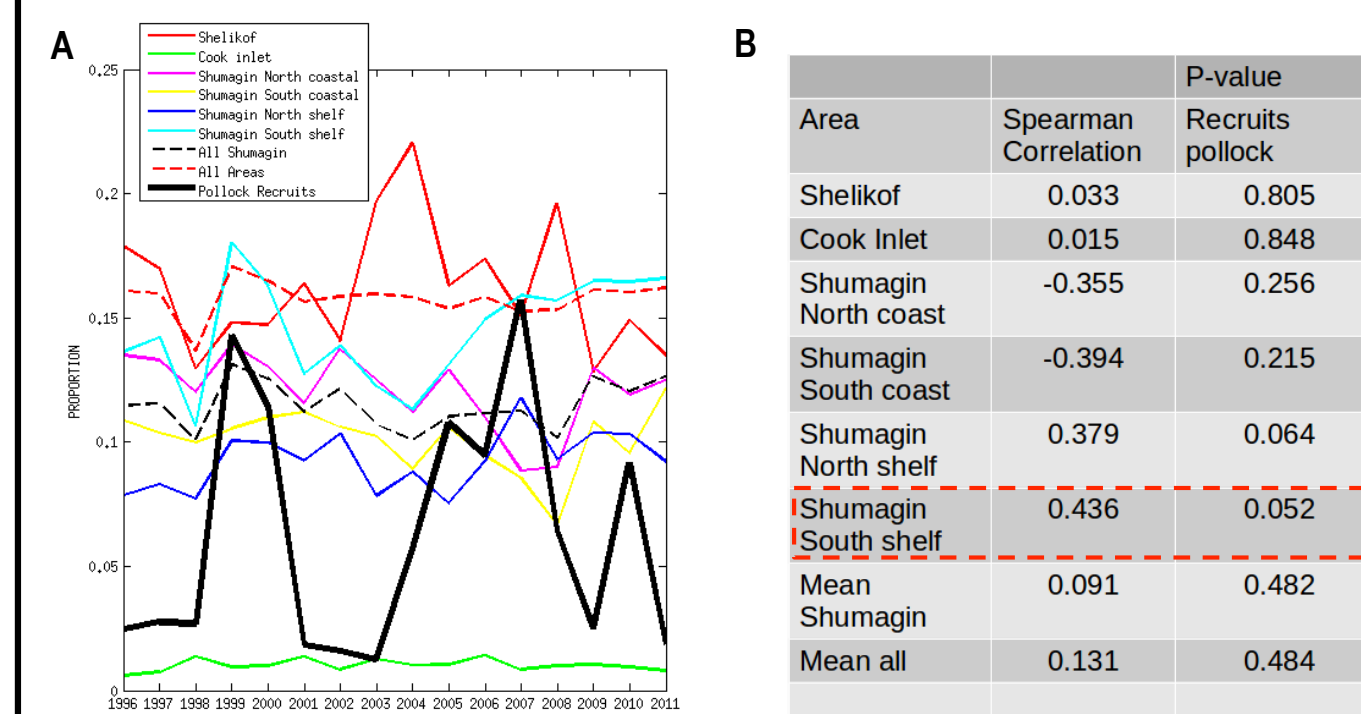


Figure 3. IBM indices extracted and correlated with recruitment estimates.

## Conclusions

- The connectivity, EOF, correlation, and Dirichlet (not shown here) analyses show connections between Shelikof and the Shumagins via types A and B connectivity.
- The model shows that spawning in the Shelikof region appears to be the source of juveniles in the Shumagin area nursery grounds, which has been hypothesized by several authors before. Retention was evident in the Cook Inlet, Shelikof and Shumagin regions.
- In addition, temporal initial conditions of the spawning showed higher levels of connectivity for spawning occurring in April and June (2 peaks from EOF analysis). This means that the model shows that, on average, most of the juveniles in the Shumagin nursery area are derived from spawning in April and June.
- Pollock recruitment is correlated to the proportion of live individuals reaching the Shumagin region ( $R^2=0.46$ ).

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