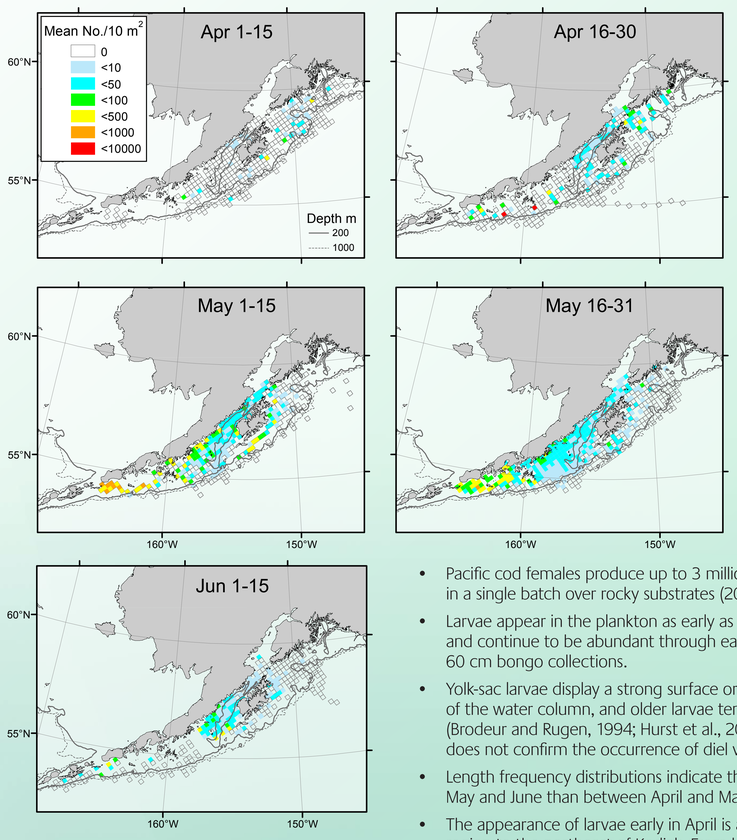
Building Early Ontogeny Pelagic Exposure Profiles for GOA-IERP Species based on Historical Ichthyoplankton Data—Pacific Cod

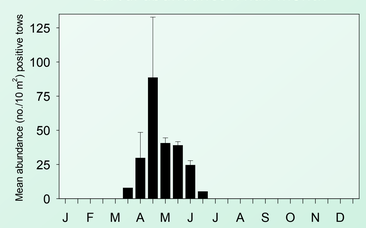
Miriam Doyle Joint Institute for the Study of the Atmosphere and Ocean, College of the Environment, University of Washington, Seattle, WA
Alaska Fisheries Science Center, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, Seattle, WA

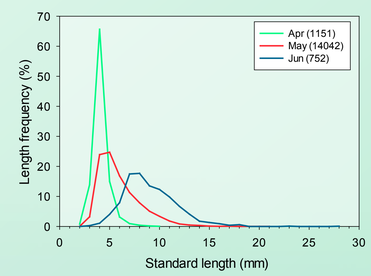
Seasonal Patterns

Seasonal Progression in Distribution of Larvae



Larval abundance x half month



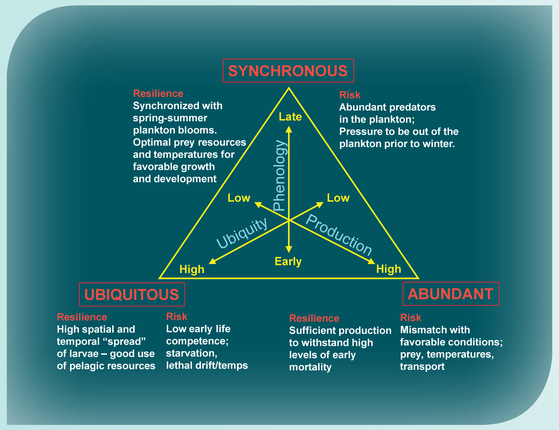


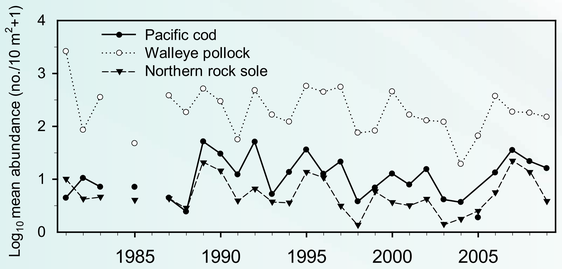
- Pacific cod females produce up to 3 million negatively buoyant eggs that are deposited in a single batch over rocky substrates (20-200 m depth) during late winter.
- Larvae appear in the plankton as early as March, peak in abundance during late April, and continue to be abundant through early June. Larvae >15 mm are uncommon in the 60 cm bongo collections.
- Yolk-sac larvae display a strong surface orientation, move rapidly to the upper 50 m of the water column, and older larvae tend to be most abundant in the upper 30 m (Brodeur and Rugen, 1994; Hurst et al., 2009; EcoFOCI data). Limited MOCNESS data does not confirm the occurrence of diel vertical migration.
- Length frequency distributions indicate that growth rates of larvae are higher between May and June than between April and May.
- The appearance of larvae early in April is associated with the shelf and Amatuli trough region to the northeast of Kodiak. From late April through mid June, larvae are abundant from the Kodiak region and Shelikof Strait along the Alaska Peninsula to the southwest, and occurrence of larvae in the Amatuli region diminishes. Larvae are most abundant on the shelf between the Shumagin Islands and Unimak Pass.

Multispecies Perspective

Early Life History (ELH) Exposure-Response Framework

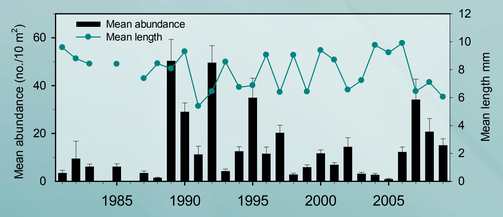
Doyle and Mier (in prep)





- Pacific cod larvae belong to a shelf assemblage of larval fish species that prevails April-June in the WGOA (Doyle et al., 2002).
- Timing of occurrence in the GOA plankton, including hatching (March-April), peak period of larval abundance (mid-April to May), and larval duration are very similar for Pacific cod, walleye pollock, and northern rock sole, indicating similar patterns of temporal exposure to the pelagic environment.
- The affinity of these three species is also apparent in a principal component analysis of GOA species by numerically expressed early life history and ecological traits (Doyle and Mier, in prep). Pacific cod, walleye pollock, and northern rock sole belong to an end-point "Abundant" group that is characterized by high production of eggs/larvae with peak abundance of larvae in April, relatively limited larval duration, and moderate to high spatial ubiquity of larvae.
- Synchronicity is observed in the abundance of Pacific cod, walleye pollock, and northern rock sole larvae across the time-series.

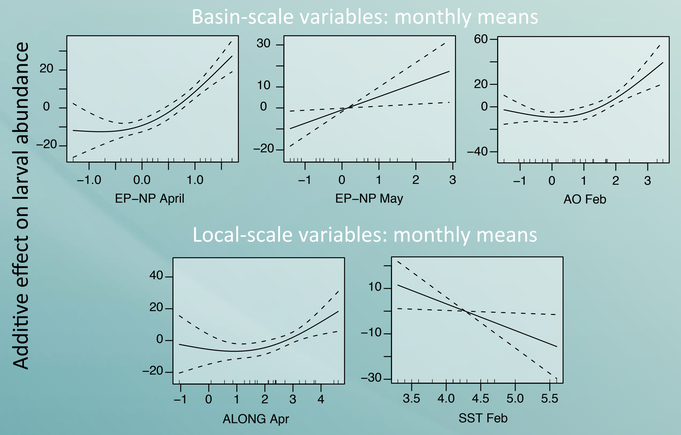
Interannual Patterns: Late-Spring Shelikof Time-Series



- The late-spring GOA time-series shows the occasional occurrence of anomalously high levels of abundance during the years 1989–97 and 2007–09. (Missing data 1984 and 1986)
- There is no significant relationship between mean abundance and mean larval length from this time-series (non-linear model; R^2 = 0.103) suggesting that variability in abundance is not primarily due to a shift in timing of larval production over the years.
- GAM-generated links between the larval abundance time-series (1981-2003; Doyle et al., 2009) and groups of basin-scale and local-scale environmental variables indicate that spring atmospheric forcing, including strength and direction of alongshore winds, has a significant effect on abundance of larvae during late spring. In addition, a positive association between February values of the Arctic Oscillation index and a negative association with February sea surface temperatures indicates that higher levels of larval abundance in late spring are associated with cooler winters.

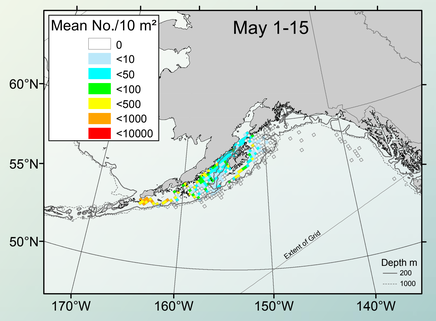
Generalized Additive Modeling

Larval abundance vs. groups of environmental variables

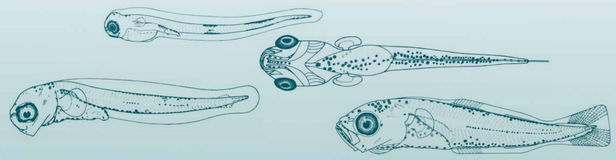


- Partial regression plots from best-fit GAMs showing additive effects of monthly mean values of environmental variables on the late-spring abundance of Pacific cod larvae (1981-2003). Above panel shows the effect of April and May values of the East Pacific-North Pacific teleconnection index, and the February Arctic Oscillation index; lower panel shows the effect of April alongshore winds and February temperatures. From Doyle et al. (2009).

Eastern vs. Western GOA



- Since FOCI surveys began (1970s), 159 stations have been sampled with 60 cm bongo nets in the GOA east of 148°N (March to July). Pacific cod larvae were recorded at only two of these stations: 3 larvae at 59.53°N, 146.75°W on April 7th 1984; 1 larva at 59.49°N, 141.35°W on March 31st 1986.
- During the spring 2010 GOA-IERP pilot survey in the EGOA (April 15-24), a total of 6 newly hatched Pacific cod larvae were recorded at two stations on the shelf in the vicinity of Cross Sound.
- During the spring 2011 GOA-IERP survey in the EGOA (May 3-17), no Pacific cod larvae occurred in the ichthyoplankton samples.
- During the historical seasonal peak in abundance of larvae in the WGOA, Pacific cod larvae seem to be rare in the EGOA.



Synthesis

- **Temporal Exposure** of Pacific cod larvae is characterized by a narrow spring peak in abundance - likely coincides with early to peak production in GOA zooplankton.
- **Spatial Exposure** extends throughout WGOA shelf waters and the area from the Shumagin Islands to Unimak Pass seems to be a hot spot for larval production.
- **Vertical Distribution** of larvae indicates that circulation models representing the upper 50 m (primarily upper 30 m) of the water column during April-June will be most suitable for describing potential transport pathways for larvae.
- The **ELH strategy** common to Pacific cod, walleye pollock, and northern rock sole results in sufficient production of eggs and larvae to withstand high levels of early mortality but with limited larval duration that may risk potential mismatch with peaks in food resources, or exposure of the bulk of the larval population to other unfavorable conditions (e.g. sub-optimal temperatures and transport).
- **Pelagic exposure-response coupling:** Evidence in support of this is provided by the synchrony observed among the above three species in the time-series of larval abundance and similarities in links with environmental variables (Doyle et al., 2009; Doyle and Mier, in prep.).
- WGOA ichthyoplankton and environmental **time-series illuminate mechanistic linkages** between larval abundance and conditions in the pelagic ecosystem during critical periods of Pacific cod spawning and ELH exposure.
- Occurrence and abundance of larvae seems diminished in the **EGOA** relative to the **WGOA**.
- **Gaps in ELH knowledge:**
  - Spawning areas and ELH habitat in the EGOA
  - Larval feeding ecology
  - Larval predation
  - Age-0 through juvenile stage ecology

References

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