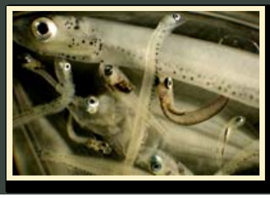

Exploring Links Between Ichthyoplankton Dynamics and the Pelagic Environment in the Northwest Gulf of Alaska

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INTRODUCTION

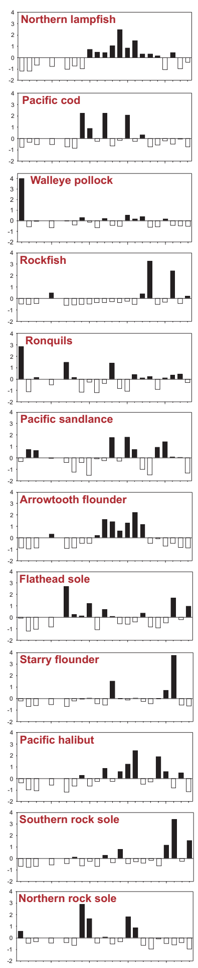
The impact of climate on marine fisheries is highly variable and year-to-year recruitment is subject to a complex interplay of influences. Potentially, much of this complexity stems from the impact of environmental conditions during the early life history of marine fish species. The present study focuses on a 21-year time-series in abundance of numerically dominant larval fish species in late-spring surveys from 1981 through 2003 in the northwest Gulf of Alaska. In combination with basin and local-scale measures of the state of the atmosphere and ocean in the Gulf of Alaska during these years, links between fish early life history dynamics and the physical environment may be explored.

HYPOTHESIS

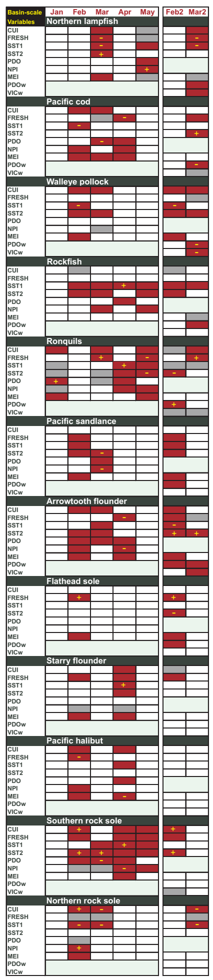
Interannual variation in the observed abundance of ichthyoplankton species in the northwest Gulf of Alaska may reflect interannual variation in the timing and quantity of local egg and larval production, egg mortality, larval survival and growth, and the transport of eggs and larvae into and out of the study area. It is hypothesized that these early life history dynamics are species-specifically linked to unique combinations of environmental variables.

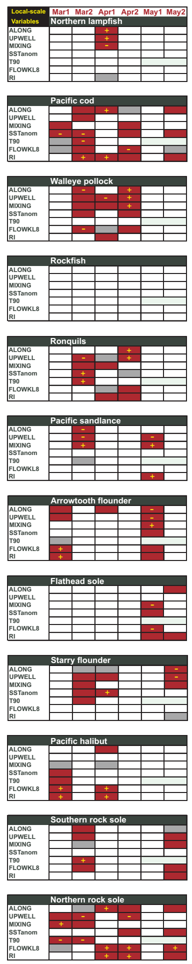
RESULTS

LATE SPRING (MAY 16-JUNE 6) TIME-SERIESOF NORMALIZED LARVAL FISH ABUNDANCE ANOMALIES



SIGNIFICANT ENVIRONMENTAL VARIABLES IN BEST FIT GAMS (WITH R^2 (ADJ.)>0.50) OF LATE SPRING LARVAL ABUNDANCE VERSUS TIME-LAGGED INDEPENDENT VARIABLES





No model run | P<0.05 | P>0.05 | + Positive response apparent | - Negative response apparent

Feb2 and Mar2: PDOw and VICw replace PDO and NPI in the model runs

SPECIES-VARIABLE ASSOCIATIONS

Northern lampfish — Strong decadal pattern in abundance with positive anomalies 1990-99.
Significant association with basin-scale variables (mainly temperature derived) in March and May. Winter PDO and VIC important.
Weak association with local-scale variables; wind indices for April only.

Pacific cod — Several years of strong positive anomalies in abundance, 1989-95.
Strong association with each basin-scale variable at least once for Feb-April.
Negative response to winter PDO.
Local scale variables important March-May.
Strongest association with SSTanom (negative for March) and RI (positive for mid-March to mid-April).

Walleye pollock — Super abundance in 1981 and positive anomalies intermittantly 1989-2000.
Basin scale variables CUI, SST1 & 2, and MEI show strong association in Feb and/or March only. Negative association with winter PDO and VIC.
On the local scale, wind indices, SSTanom and FLOWKL8 important mid-March through April.

Rockfish — Strong positive anomalies in abundance in 1998 and 2001.
Strong association with basin-scale SSTs Feb through May and NPI in Mar and May.
Winter and April PDO important.
No significant association with local-scale variables.

Ronquils — Abundance peak in 1981 and to a lesser extent 1987 and 1993.
Significant links with high diversity of basin-scale variables Jan through May - most influential in April-May. Positive association with winter PDO.
Local-scale variables signficant mid-March through April. Positive link with late March temperatures and late April winds.

Pacific sandlance — Cyclical pattern in abundance apparent with positive anomalies during early 1980s, mid-1990s and 1999-2002.
Basin scale variables (other than CUI and VICw) important in Feb and to a lesser extent March.
Significant association with local wind indices in late March and early May, and with the retention index in early May.

Arrowtooth flounder — Decadal pattern in abundance apparent with persistent postive anomalies 1991-1997.
Strong association with Feb-April basin-scale variables and with winter PDO and VIC.
Except for alongshore winds in April, strong links with local scale variables restricted to early March and early May. Positive association with early March FLOWKL8 and RI.

Flathead sole — Most persistent positive anomalies in abundance 1987-1993 with further positive values in 1997, 2001 and 2003.
Few links with basin-scale variables in Feb only. Winter PDO significant.
Local-scale variables signficant for May only.
Early and late May retention indices signficant.

Starry flounder — Exceptionally high levels of abundance in 1993, 2000 and especially 2001.
Significant association with Feb FRESH and MEI and with most basin-scale variables in April.
At the local-scale, wind indices and temperature show significance for late-March and/or early April and a further link is apparent with late May wind indices.

Pacific halibut — Decadal pattern in abundance apparent with persistent postive anomalies 1993-2000.
A variety of basin-scale variables were linked signficantly for Feb and April values.
At the local scale, early March temperature and transport variables were signficant with a further positive association with FLOWKL8 and RI in early April.

Southern rock sole — Strong positive anomalies in abundance in 2000, 2001 and 2003.
Strong association with monthly basin-scale variables, for Feb through May. Persistent and positive association with SST.
Local-scale variables significant for late March and late May only. Positive association with late March temperature below 90m.

Northern rock sole — Strong positive anomalies in abundance in 1989, 1990, 1995 and 1996.
Strong association with basin-scale variables for Feb and to a lesser extent March.
Persistent negative association with SST1.
Significant link to local-scale variables for all periods except early May. Negative response to March temperature below 90m. Positive association with transport variables in April.

METHODS

Ichthyoplankton data

Ichthyoplankton data were collected during spring ichthyoplankton surveys conducted by the Recruitment Processes Program at the Alaska Fisheries Science Center of NOAA Fisheries, from 1981 through 2003. Samples were collected by oblique tows, predominantly from 100 m depth to the surface using 60 cm Bongo nets. Data were selected from an area and time (May 16-June 6) that had the highest sampling density and the most consistent sampling over the years (Fig. 1 and Fig. 2). Mean annual abundances for the selected area were calculated for individual larval fish species, weighting the data for each station according to the geographic area that it represents. Numerically dominant species were chosen for inclusion in the analysis (Table 1).

Environmental data

The environmental data time-series used include climate indices, and atmospheric and oceanographic variables (Table 2) representative of both the broader basin of the Gulf of Alaska and northeast Pacific Ocean and the local study area. The influence of environmental conditions on the abundance and survival of various species of fish larvae are likely to be significant from the initial production of the eggs (predominantly winter to early spring in the Gulf of Alaska) through the period of late larval development, weeks to months later. Consequently, both time-lagged and survey time values of the environmental time-series are included in the analysis (Table 2).

Data analysis

Relationships between larval fish abundance and environmental factors were examined using Generalized Additive Models (GAM). GAM is a form of non-parametric multiple regression that models a response variable as a function of several predictor variables. For each group of environmental variables (basin and local-scale), GAMs were run for individual species with every possible combination and subset of variables. Best-fit models were selected using generalized cross validation methods (Green and Silverman, 1994).

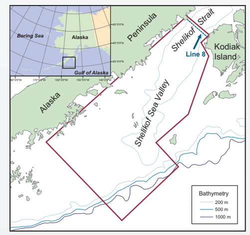


Figure 1.

Table 1. Numerically dominant species of fish larvae included in the study, ranked according to percentage occurrence in the study area for all years combined.

Species	Common name	% Occurrence	Mean abundance no./10m^2
Theragra chalcogramma	Walleye pollock	90.18	362.11
Hippoglossoides elassodon	Flathead sole	76.57	50.01
Ammodytes hexapterus	Pacific sandlance	75.15	33.38
Bathymaster spp.	Ronquils (genus *Bathymster*)	66.43	99.42
Gadus macrocephalus	Pacific cod	49.78	14.65
Lepidopsetta polyxystra	Northern rock sole	35.05	5.29
Stenobrachius leucopsarus	Northern lampfish	33.03	5.88
Sebastes spp.	Rockfishes	30.99	29.03
Lepidopsetta bilineata	Southern rock sole	20.55	2.77
Atheresthes stomias	Arrowtooth flounder	18.79	7.32
Platichthys stellatus	Starry flounder	18.56	3.24
Hippoglossus stenolepis	Pacific halibut	10.00	1.07

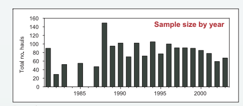


Figure 2.

Table 2. Environmental variables included in analysis (abbreviation on left), and source of data.

1. Basin Scale Variables		Source
	Monthly	
CUI	Coastal Upwelling Index at 60 N 155.5 W	NOAA / PFEL
FRESH	GOA River Discharge	Tom Royer
SST1 SST2	Sea Surface Temperature (SST) 57.5N,155.5W & 57.5N,149.5W	NOAA / NCEP Reanalysis
PDO	Pacific Decadal Oscillation (Leading PC of SST)	Mantua et al., 1997
NPI	North Pacific Index (sea level pressure)	Trenberth and Hurrell, 1994
MEI	Multivariate ENSO Index	NOAA / CDC
	Preceding Winter	
PDOw VICw	Leading Principal Components for Winter (Nov-Mar) SST	Bond et al., 2003

2. Local Scale Variables		Source
	Semi-monthly (observed)	
ALONG UPWELL MIXING	Alongshore Wind Index Upwelling-favorable Wind Index Wind Mixing Index (wind speed cubed)	Stabeno et al., 2004
SSTanom	Normalized SST anomalies, Shelikof, based on 1950-2003 mean	NOAA / NCEP Reanalysis
	Seasonal (observed)	
T90	Shelikof temperature below 90 m Feb-Apr mean	NOAA / AFSC Jennifer Boldt
	Semi-monthly (model-derived)	
FLOWKL8	Flow through Line 8, Kodiak side	Hermann and Stabeno, 1996; Computed from the SPEM model
RI	Retention Index (Percent particles released in upper 100m of study area not lost to advection in 14 days)	

CONCLUSIONS

- For the time-series, unique patterns of periodicity and amplitude of variation in abundance are apparent among species. Some commonality is observed, however, especially for the deepwater spawners (Northern lampfish, Arrowtooth flounder and Pacific halibut), that display a decadal trend of enhanced abundance during the 1990s.
- Species-specific seasonality is apparent in the associations between late spring larval abundance and environmental variables. There is, however, a general trend indicating that basin-scale environmental conditions in February through April, and local-scale conditions in late-March through early-April, are most influential in terms of prevalence of larvae in late spring.
- Observed species-specific patterns of association between late spring larval abundance and environmental variables seem to reflect geographic distribution and early life history patterns among species. For example, the deepwater spawners arrowtooth flounder and Pacific halibut (whose larvae are associated with the continental slope) show a common, strong connection with the Shelikof water transport variables (FLOWKL8 and RI) that probably reflects their dependence on advection (onto the shelf) and retention processes in this area for successful larval survival. Another example is the opposite response of northern and southern rock sole to the temperature variables, reflecting their different geographical distributions.
- Further work is required at the individual species early life history level to investigate potential mechanisms underlying the observed links between species and environmental variables.
- This type of ichthyoplankton time-series study shows good potential for identifying levels of resilience or vulnerability of individual species early life history patterns to fluctuating oceanographic conditions.

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