Challenges in communicating uncertainty of production and timing forecasts to salmon fishery managers and the public

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The views expressed do not necessarily represent those of NOAA
PICES FUTURE Science Program’s Big Question

- What is the future of the North Pacific given current and expected pressures of climate change?

FUTURE Advisory Panel on Status, Outlooks, Forecasts, and Engagement (SOFE)

- Aims to engage human societies by providing useful products on ecosystem change
How can we provide useful products on ecosystem change? Four steps...

1. Identifying **problems in need of solutions** with **climate driven ecosystem services**

2. Understanding and defining **processes** and **relationships** between climate, fish behavior and fishery performance

3. Developing **research products** based on the **relationships**

4. Operationalizing research: developing **timely reliable communication** with stakeholders
Southeast Alaska pink salmon
2,000 streams

Chinook salmon
transboundary river

Yukon River

Alaska

Hawaii
Southeast AK: Pink salmon purse seine fishery
Variable harvest: 2-95 million fish (97% wild stock)

Step 1. **Problem**: historical uncertainty in pre-season pink forecasts, valuable fishery, & is a major ecosystem component
In Alaska fisheries of the Gulf of Alaska & coastal waters in 2013, the relative biomass of pink salmon in the total landings (673,479 MT) was 46% (21% SEAK).
Step 2. Understanding and defining processes and relationships between climate, fish behavior and fishery performance.

- Climate?
- Juvenile abundance?
- Ocean distribution?
- Competitors?
- Predators?
- Prey?
- Adult production?
Working hypothesis of processes impacting pink salmon marine survival

Mortality during pink salmon early marine life history is high, variable, and affects year class strength...

Thus, after this critical period, surveys assessing juveniles in seaward migration corridors can predict year class strength...

However...Ocean state suitability can also impact fish during annual ocean residence...
Southeast Alaska Coastal Monitoring (SECM) monthly sampling: May-Aug, 1997-2013
SECM pre-season pink salmon harvest forecasts to SEAK: past 10 years

Physical data

Zooplankton biomass/diet

Catches (CPUE)

Size & growth

Stock comp

Predation
SECM monitoring stations along the primary seaward migration corridor in Southeast Alaska

Pink salmon have simple ocean life history, spend only one winter.
Climate connection between the MEI (winter) and Icy Strait 20-m integrated °C (summer)

Relationship between the winter MEI Index (Nov-Mar, yr-1) & the summer Icy Strait Temperature Index "ISTI" (1-20 m temperature May-Aug, yr)

Warm ocean year anomaly

R² = 0.36

PearCor = 0.60
P-value = 0.01
The graph shows a significant relationship between SECM juvenile pink catch and the next year's harvest of adults from 1998 to 2013. The equation for the trend line is:

\[ \text{Harvest} = 16.2x - 3.5 \]

with \( R^2 = 0.84 \).

In 2005, there was a poor ocean year, and in 2012, there was a great ocean year.

The y-axis represents the Southeast harvest (millions), and the x-axis represents the juvenile pink salmon peak June/July Ln(CPUE+1).
Step 3. Developing **research products based on the relationships**

Two “misses”
Can we incorporate more ecosystem metrics to address misses (2006 & 2013) & help stakeholders better understand forecast uncertainty?

1) Used six environmental variables significantly correlated with harvest the next year--qualitative measure of uncertainty

2) Each metric assigned traffic light colors by correlation score:
   - Green "high" (top 1/3)
   - Yellow "average" (middle 1/3)
   - Red "low" (bottom 1/3)

3) Ranked scores were averaged across each year:
   - Traffic light
     - "Traffic light" High harvest
     - Average harvest
     - Low harvest

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Finally, we compared the average traffic light annual scores to past & future SEAK harvests.

Traffic light rank #13 for 2014 forecasts 27.8 M fish.
Step 4. Operationalizing research: developing timely reliable communication

1) Share SECM survey metrics with Alaska Dept. of Fish & Game for their forecasts (10 months prior to the fishery)

2) Present annual pre-season pink salmon forecast to resource stakeholders at the SEAK Purse Seine Task Force Meeting (7 months prior to fishery)

3) Provide a pink salmon forecast web site with links via other web sites (SECM, NOAA Fish Watch, etc.)
NOAA data shared with AK Dept. Fish & Game and used in exponential smoothing forecasts

Figure 4. Annual harvest of pink salmon in Southeast Alaska compared to the ADF&G pre-season harvest forecast, 1998–2013. The 2007–2014 ADF&G harvest forecasts were adjusted using NOAA’s juvenile pink salmon data.
EMA: Forecasting Pink Salmon Harvest in Southeast Alaska

Understanding how ocean conditions and climate impact salmon year class strength is an objective of the Auke Bay Laboratories (ABL) Southeast Alaska Coastal Monitoring (SECM) project. The SECM project has collected a time series of indexes that include juvenile salmon and their associated biophysical data in coastal Southeast Alaska (SEAK) since 1997.

Pink salmon returns are notoriously difficult to forecast because their two-year life history cycle only involves one ocean winter and precludes the use of younger returning age classes to predict cohort abundance. Moreover, year-class success varies widely, with harvests ranging from 3 to 95 million fish annually in SEAK since 1960.

Fortunately, direct measures of juvenile pink salmon abundance at sea from SECM sampling have provided a powerful tool to improve forecasts. Juvenile salmon marine mortality is reported to be high and variable during their initial spring nearshore residency. The SECM sampling of juveniles, which occurs later in the summer in seaward migration corridors, has proven to be an effective index for use in pink salmon forecast models for SEAK.

SECM has been using juvenile pink salmon catch and associated biophysical data to forecast adult pink salmon harvest in SEAK since 2004. Several models have been used in this annual forecasting. However, the primary biophysical factor correlated with harvest each year is the post-compensation growth (CPG) in 3-age analysis.

2014 NOAA Forecast
29.9 million pink salmon
with an 80% bootstrap confidence interval of 26-38 M
Forecast linked to NOAA FishWatch.gov
Yukon River: Commercial gillnet & subsistence Chinook fishery disaster declarations 2010-2012
The Yukon Chinook Salmon Fishery is highly valued by humans inside and outside the watershed

- International treaty agreement with Canada
- Major subsistence resource for 43 villages: commercial, personal use and sports fisheries
- Historic low abundance: federal disaster relief
- Chinook salmon trawl bycatch controls fisheries: annual billion $ Bering Sea pollock & other salmon
- High profile/value: fishery managers welcome help
Step 1: A problem in need of a solution, Yukon Chinook run timing observed, 1980-2013

Fishery managers need pre-season run timing information to set regulations.
Step 1: Identifying a climate driven ecosystem service

Environmental Mediation of Timing 1961 - 1980

Preliminary analysis published in 1982

- **1 = Ocean feeding**
- **2 = Staging area**
- **3 = Spawning migration**

http://water.usgs.gov/nasqan/docs/yukonfact/images/fig1.jpg
Step 2. Understanding and defining processes and relationships between climate, fish behavior and fishery performance

Working Hypothesis:
Timing of marine exit is linked to climate and weather through effects on the location and stability of temperature-salinity fronts at river’s mouth.

Mundy & Evenson (2011) ICES JMS
Identifying local environmental factors

APRIL MEAN AIR TEMP

MAY MEAN SST model

FISHING AREAS

SPRING ICE COVER
Model Timing = (-0.410)AIRT + (-1.638)SST + 17.357

Observed Timing 1961-2009

Only 3 years had forecast error > 7 days
Step 3. Developing research products based on the relationships

Outlook

• Synopsis of Spring conditions: ice, air, ocean to assess an “EARLY”, “AVERAGE”, or “LATE” designation based on historical averages
• Uncertainty shown as percent of years EARLY, AVERAGE & LATE under similar conditions

Forecast

• Dates of 15th, 25th, and 50th percentiles
• Weekly updates of model percentages in season
• Uncertainty estimates based on linear models
How do the products work?

Dates when the 15th & 50th percentiles of Chinook test fishery CPUE observed vs. the dates forecasted on 31 May, over the years 2010-2013

<table>
<thead>
<tr>
<th>Year</th>
<th>Percentile</th>
<th>Date observed</th>
<th>Date forecasted</th>
<th>Error (days)</th>
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</tbody>
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*2012 latest migration in the 52 yr time series, 1961-2013
Step 4. Operationalizing research: developing **timely reliable communication**

- The **AOOS web site** is the focal point for getting the outlook, forecasts, and daily updates on Chinook run timing and environmental conditions to the public.

- Linked via other web sites (ADF&G, NOAA, etc.) thus provides sharing of environmental and fishery data among users.
ADFG uses AOOS data to predict late Chinook run for Yukon delta
The forecast for 2013 is for a late run similar to that experienced in 2012. Click to read the complete outlook and more about development of the forecast.

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Conclusions:

- Forecast prediction uncertainty will occur in a changing ocean climate, longer time series help build baselines needed to identify annual anomalies.

- Communicating forecast “track records”, working hypotheses, and updated web sites are necessary to effectively reach a broad range of stakeholders.

- Pink salmon pre-season harvest forecasts benefit stakeholders with both a quantitative and a qualitative measure of significant ecosystem metrics.

- Chinook salmon run timing forecasts provide managers and harvesters with an important tool to predict 2 to 4 week ahead “in-river” return times.
Conclusions:

- Our projects demonstrates the validity of the FUTURE premise....

It is indeed possible to deliver useful products on ecosystem change to resource stakeholders
Thanks for financial & material support...

Alaska Ocean Observing System

Alaska Dept. of Fish & Game

Northern Fund of the Pacific Salmon Comm.

NOAA