NOAA FISHERIES
Alaska Fisheries Science Center

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

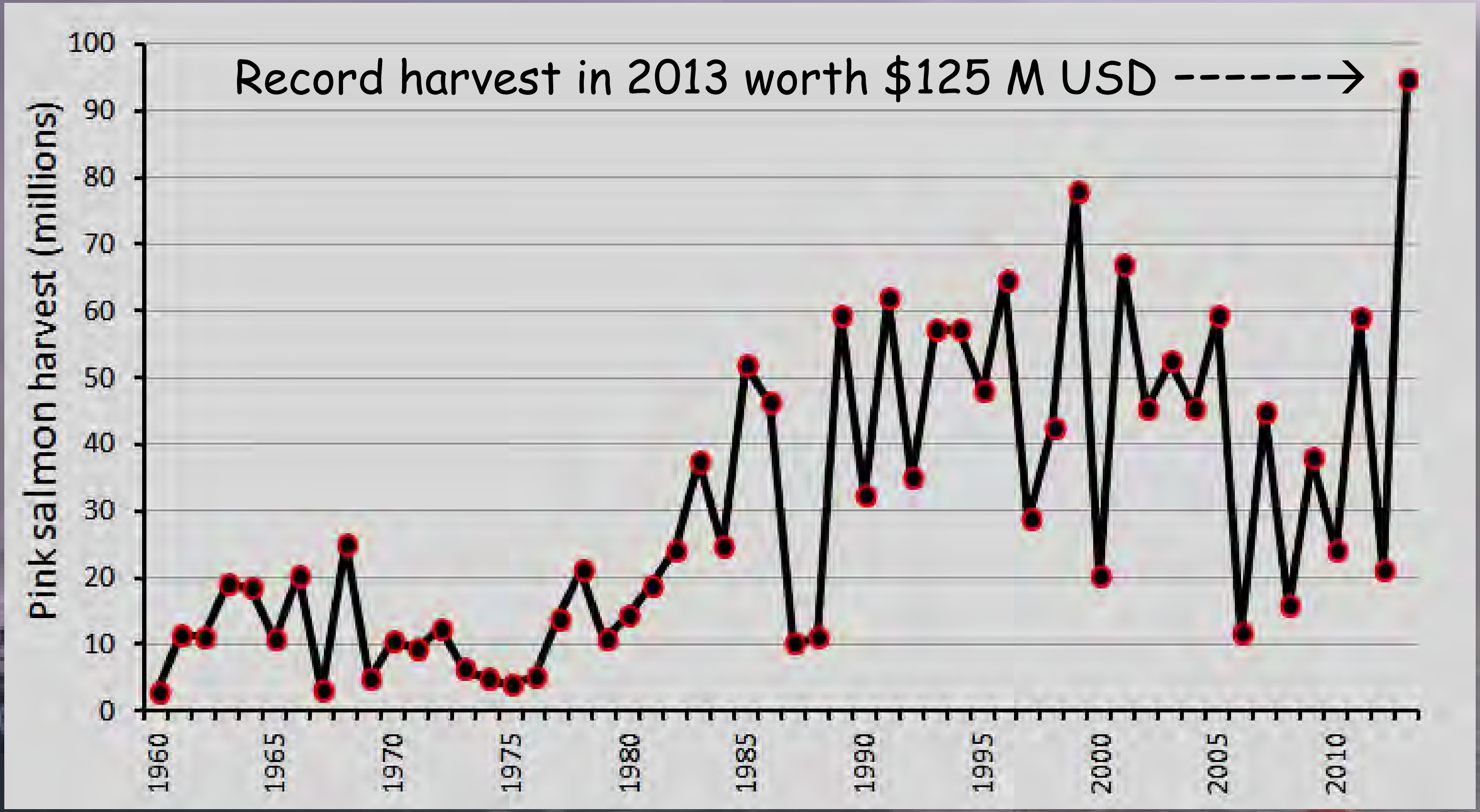
How can we provide useful products on ecosystem change? Four steps…

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


Arctic Ocean
Chukchi Sea
Beaufort Sea
Yukon
River
Bering Sea
Chinook salmon
transboundary river
Gulf of Alaska
Southeast
Alaska
pink salmon
2,000 streams
North Pacific Ocean
Alaska
Hawaii

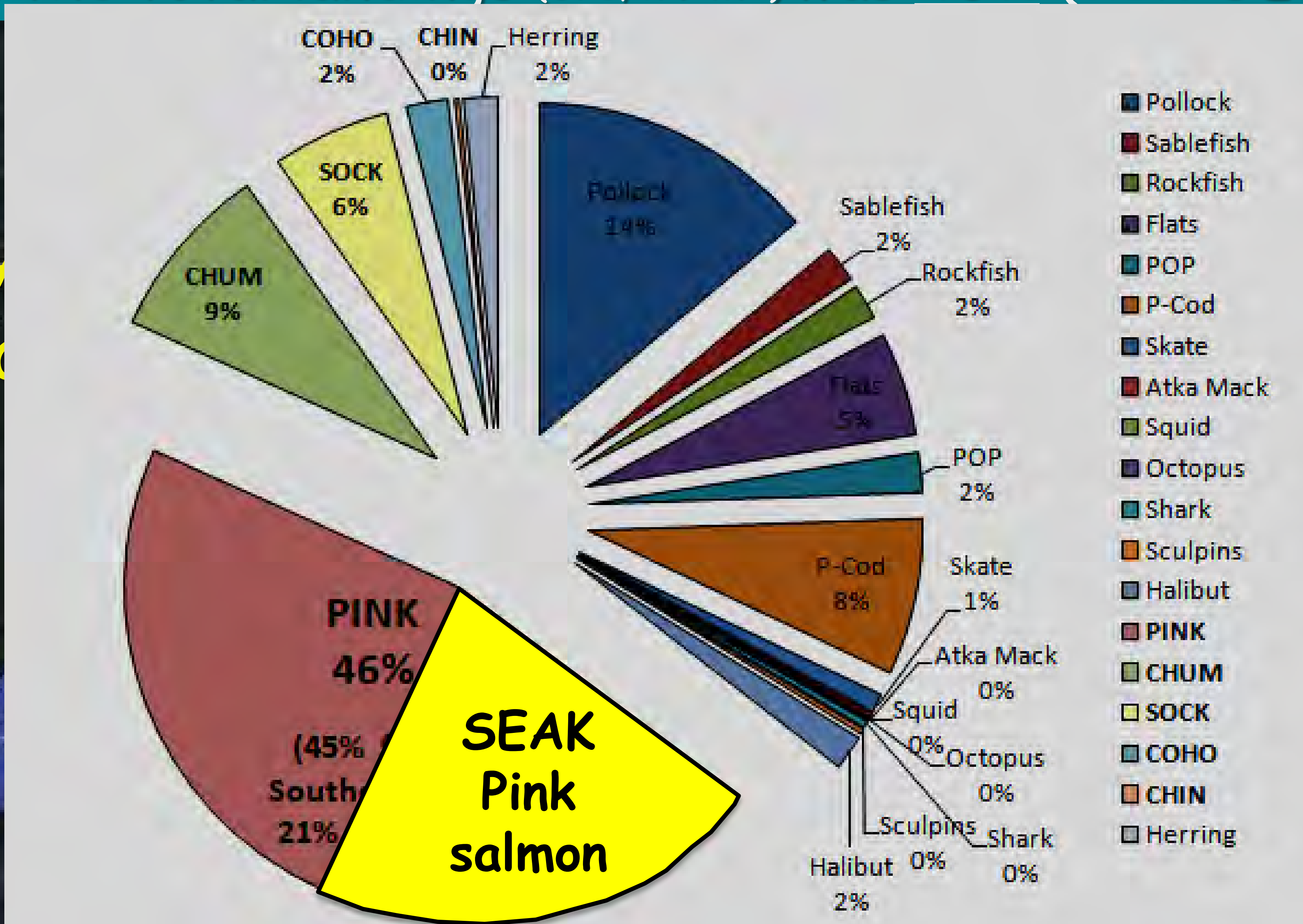
Southeast AK: Pink salmon purse seine fishery

Variable harvest: 2-95 million fish (97% wild stock)

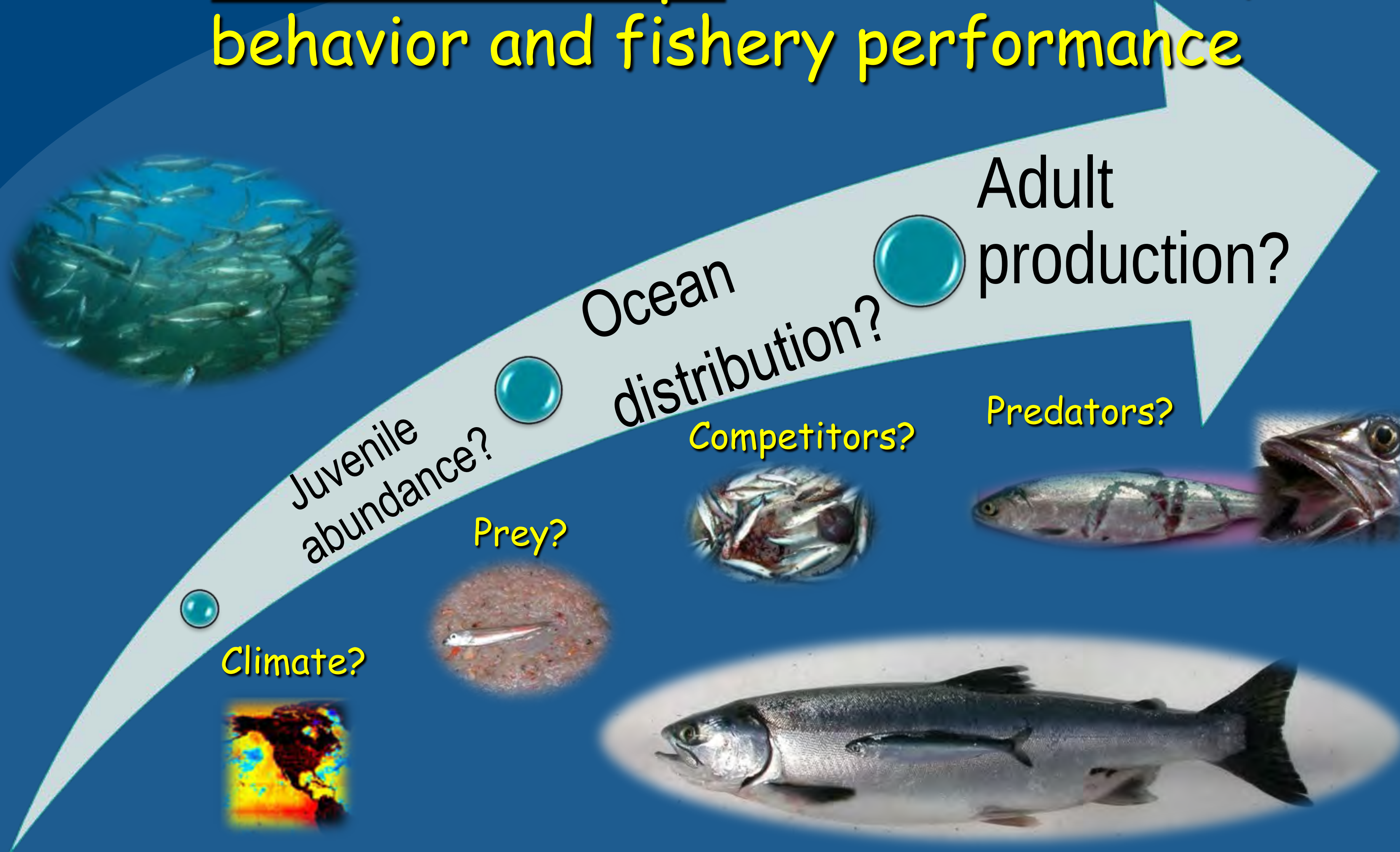


Step 1. <u>Problem</u>: historical uncertainty in pre-season pink forecasts, valuable fishery, & is a major ecosystem component

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



Working hypothesis of processes impacting pink salmon marine survival

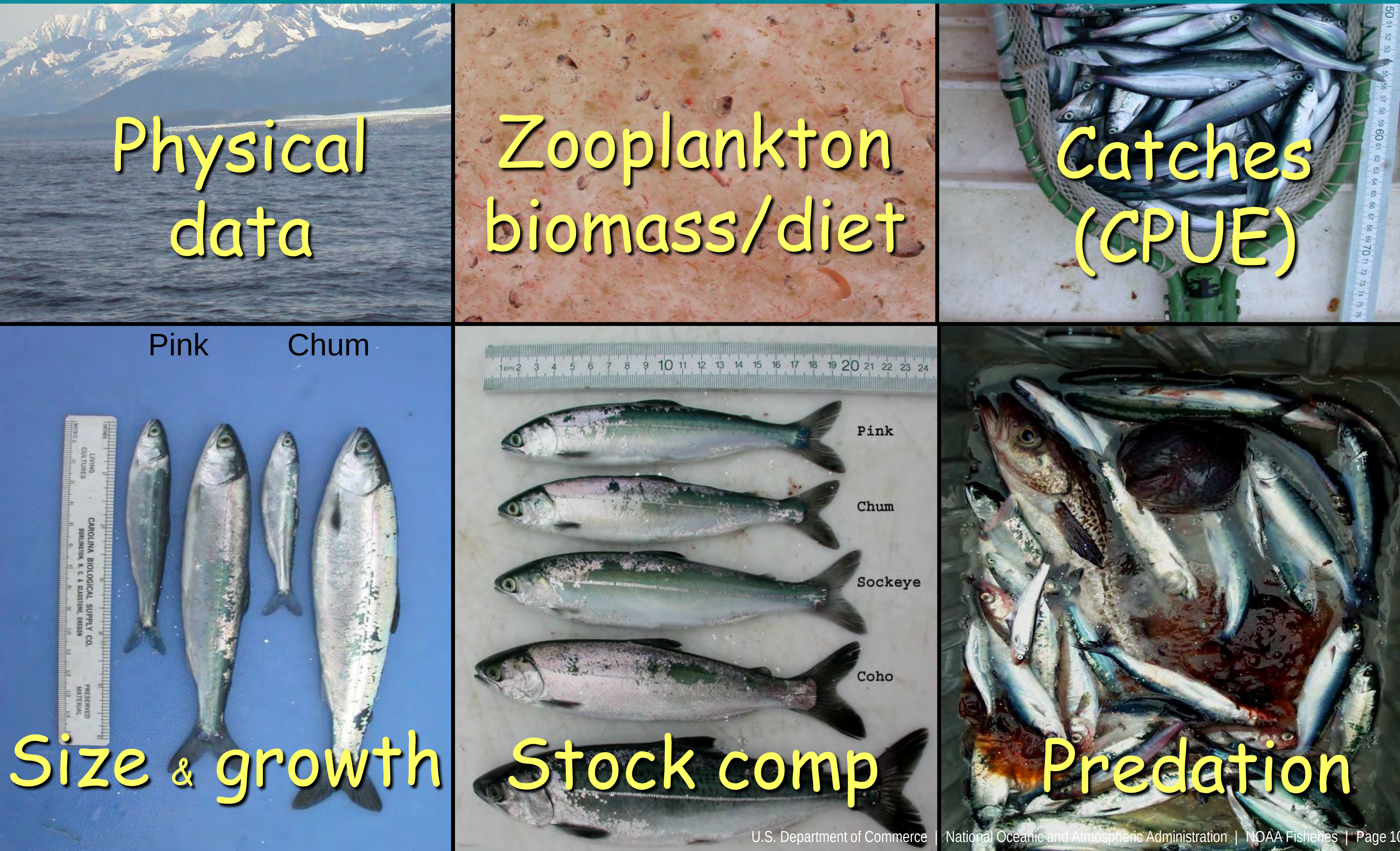
Mortality during pink salmon early marine life history is high, variable, and affects year class strength…

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

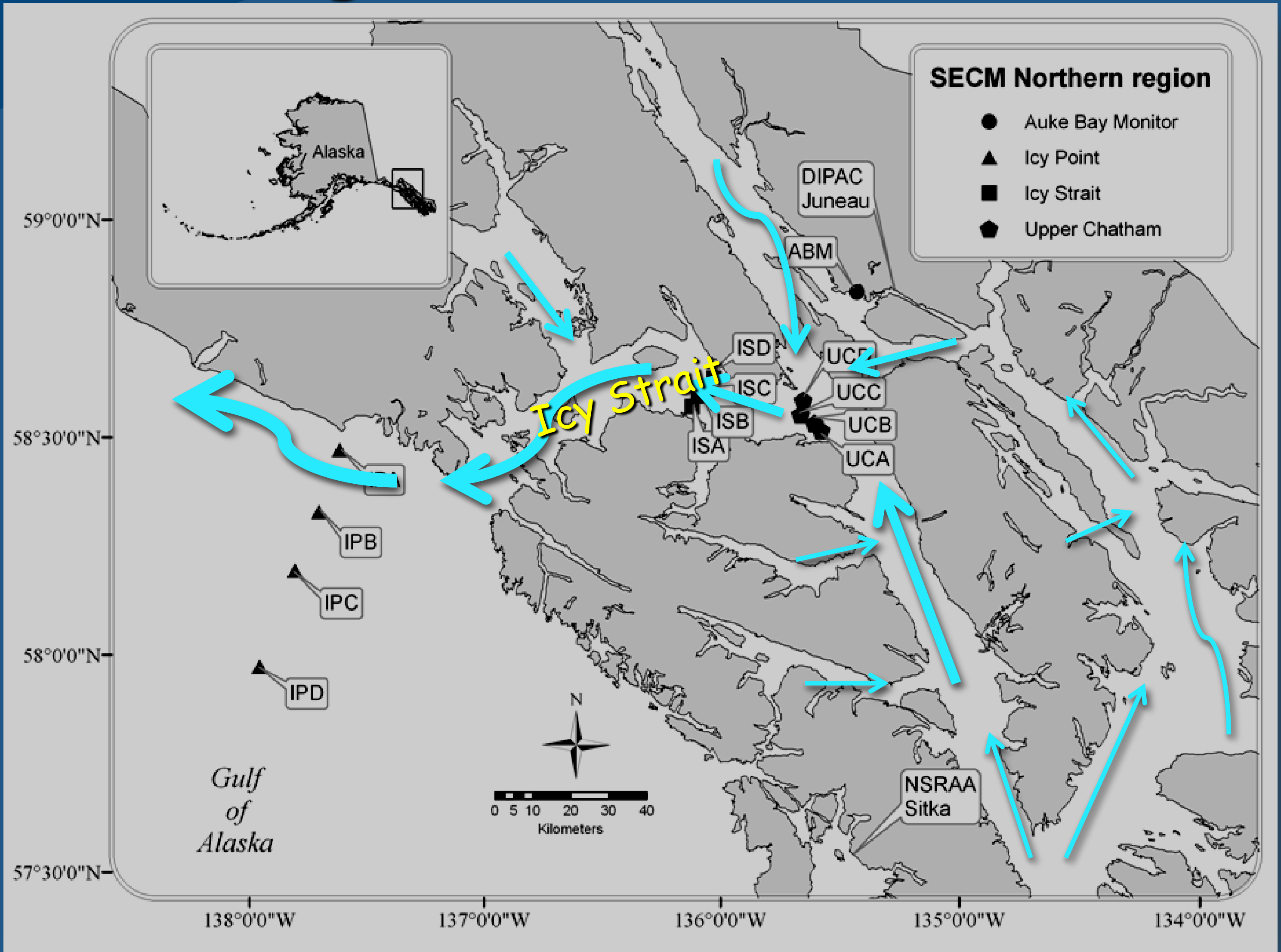
However…Ocean state suitability can also impact fish during annual ocean residence

Southeast Alaska Coastal Monitoring (SECM) monthly sampling: May-Aug, 1997-2013

SECM pre-season pink salmon harvest forecasts to SEAK: past 10 years

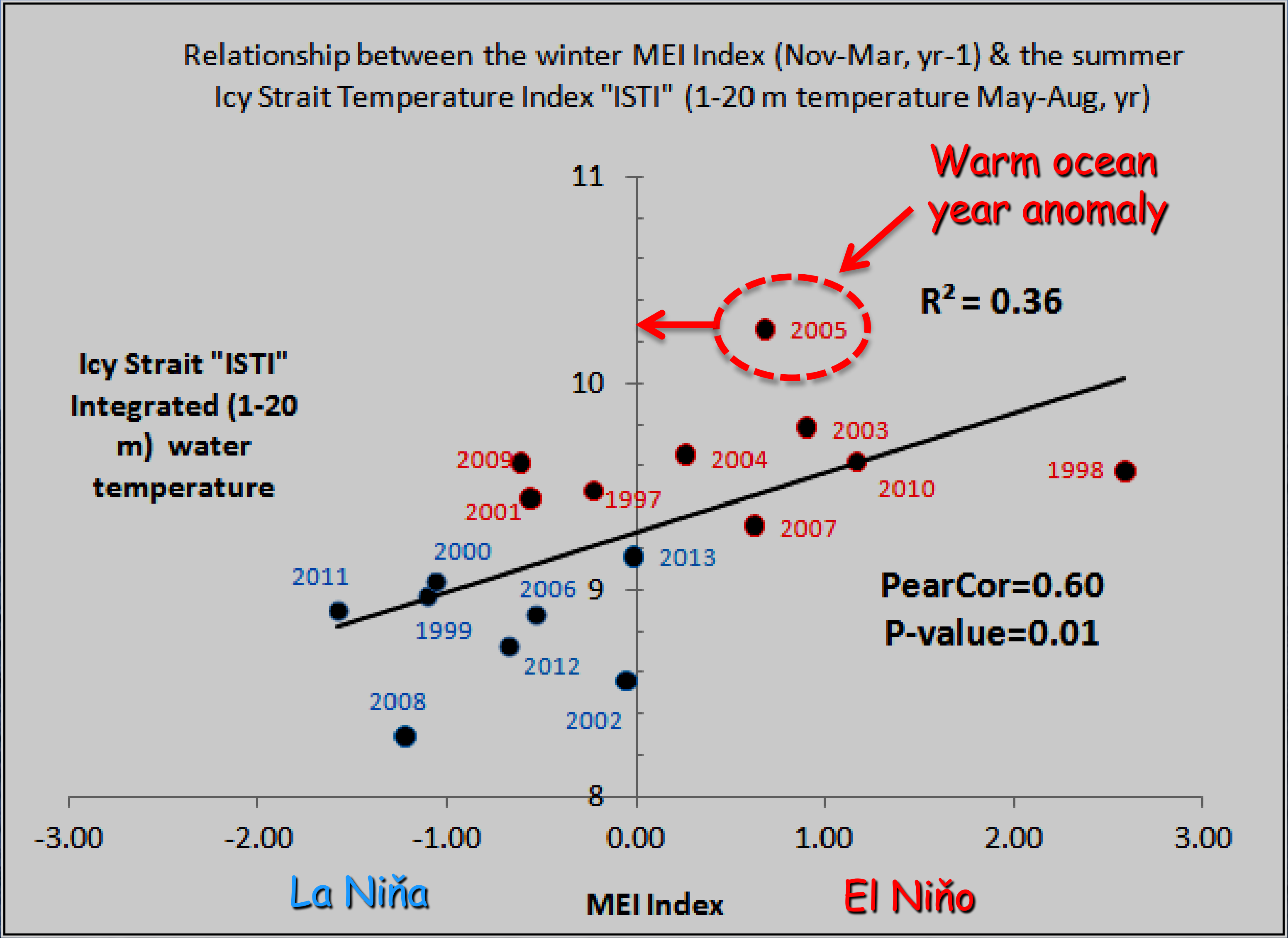


SECM monitoring stations along the primary seaward migration corridor in Southeast

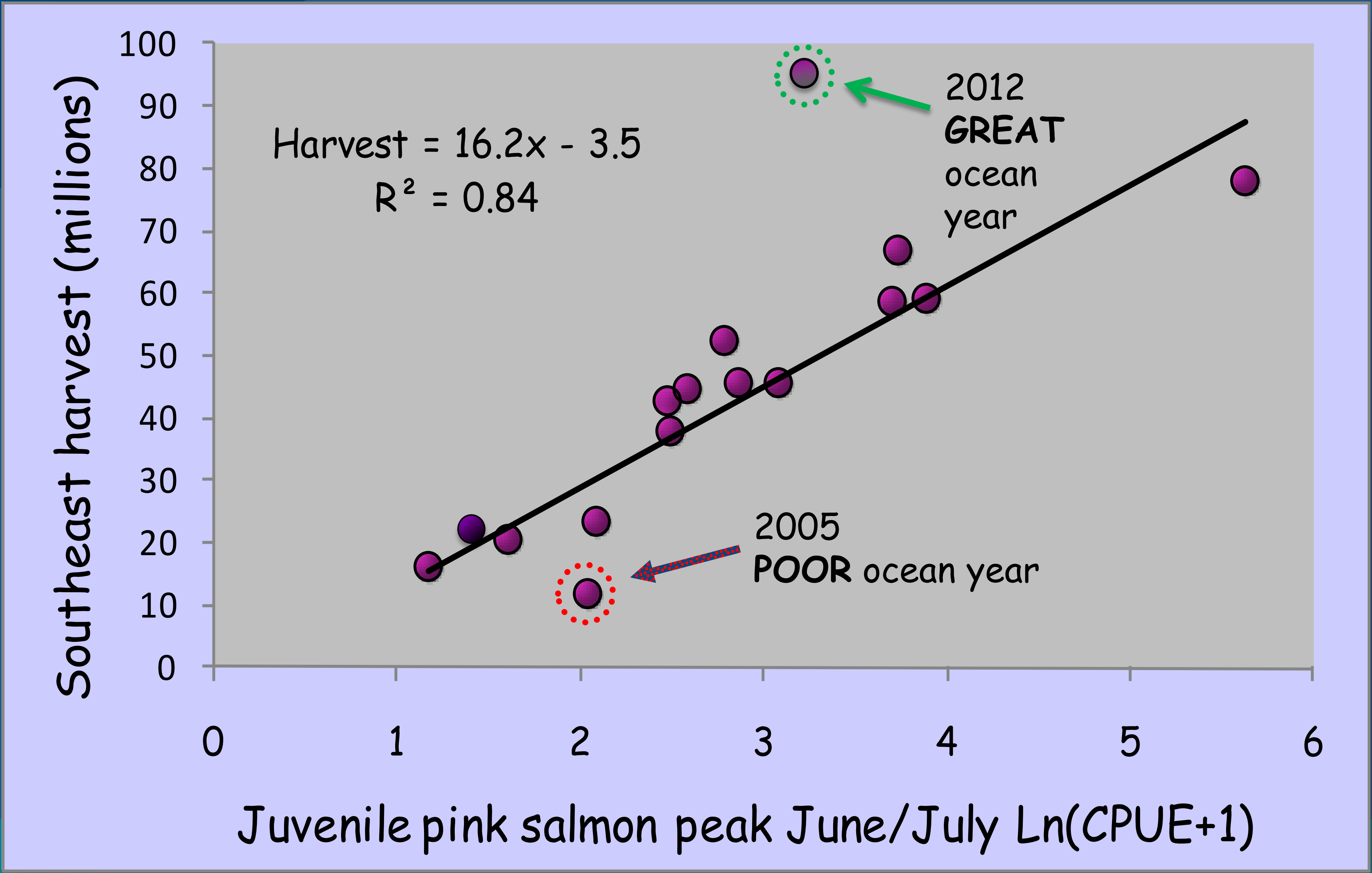


Pink salmon have simple ocean life history, spend only one winter

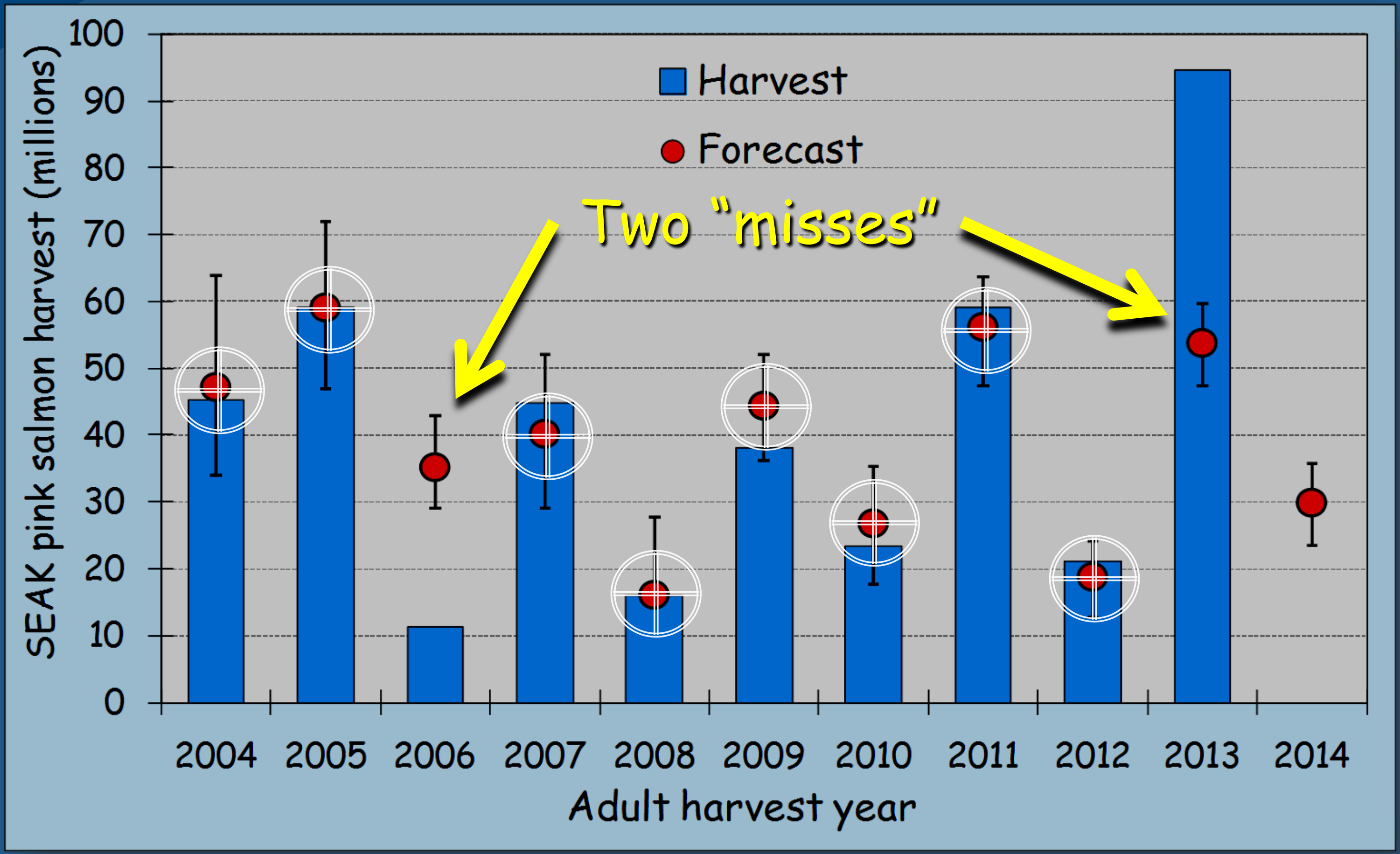
Climate connection between the MEI (winter) and Icy Strait 20-m integrated °C (summer)



Significant relationship: SECM juvenile pink catch and next years harvest of adults 98-13



Step 3. Developing research products based on the relationships



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)

Ocean entry year (BY lagged 1 yr later)	Juvenile peak pink (CAL) CPUE June or July	Juvenile peak pink (TTD) CPUE June or July	Peak seaward migration month	Proportion of pink in trawl hauls in June-July-Aug	Adult coho predation impact Coho total #s/J-pink CPUE	North Pacific Index (June, July, Aug)
	NOAA[2]	NOAA[2]	NOAA[2]	NOAA[2]	NOAA[2] ADFG[3]	CGD
1997	2.5	2.2	July	12%	1.4	15.6
1998	5.6	5.3	June	57%	0.8	18.1
1999	1.6	1.4	July	8%	3.4	15.8
2000	3.7	3.3	July	18%	0.9	16.9
2001	2.9	2.6	July	19%	1.8	16.8
2002	2.8	2.5	July	14%	2.2	15.6
2003	3.1	2.7	July	24%	1.6	16.1
2004	3.9	3.4	June	29%	1.2	15.1
2005	2.0	1.7	Aug	19%	2.8	15.5
2006	2.6	2.3	June	30%	1.7	17.0
2007	1.2	1.0	Aug	9%	3.0	15.7
2008	2.5	2.2	Aug	14%	1.9	16.1
2009	2.1	2.7	Aug	22%	2.2	15.1
2010	3.7	5.0	June	66%	1.3	17.6
2011	1.4	1.6	Aug	21%	4.6	15.7
2012	3.2	4.3	July	40%	1.5	16.7
2013	1.9	2.7	July	9%	3.7	16.0

3) Ranked scores were averaged across each year:

---→

"traffic light"

High harvest

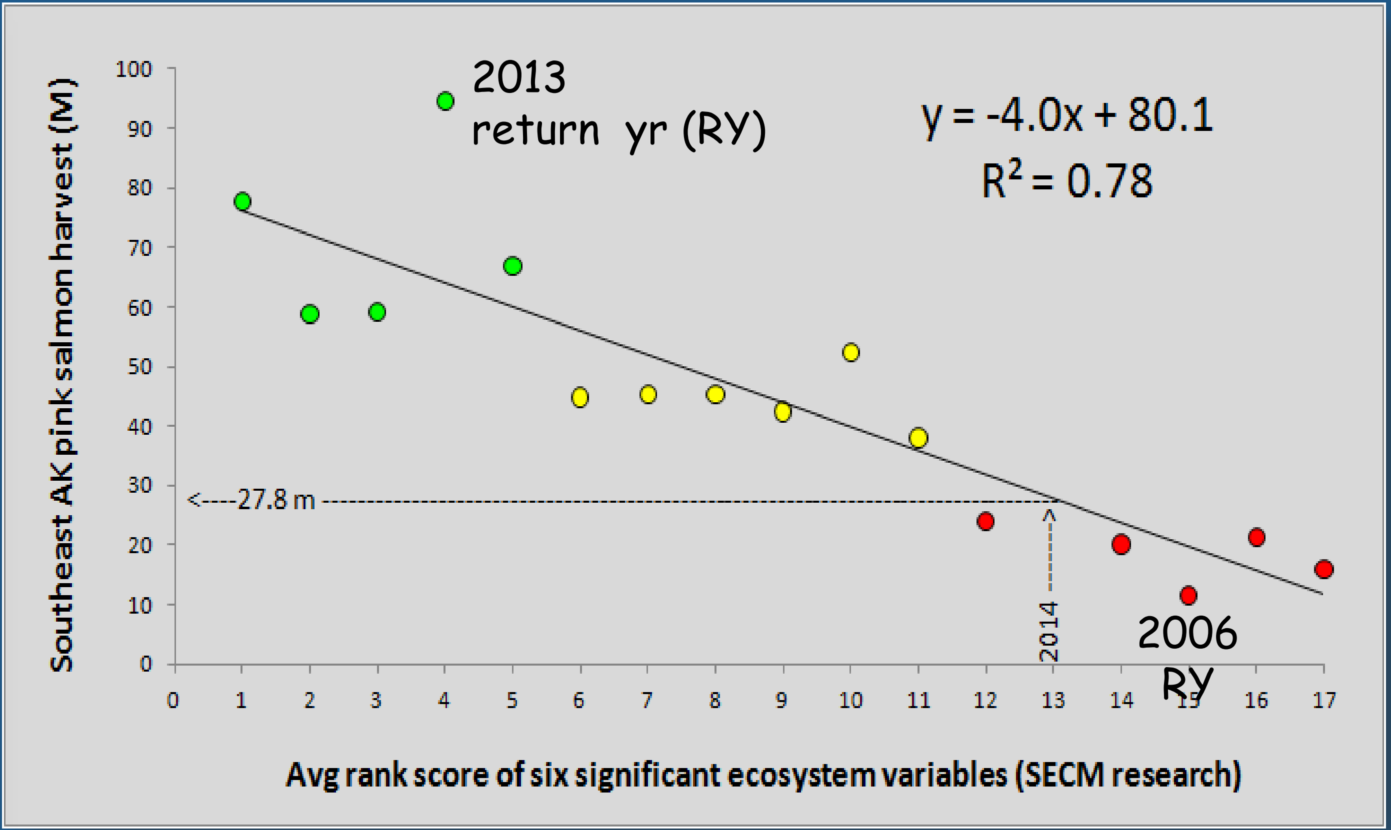
Average harvest

Low harvest

Rank score of averages of the six significant variables	SEAK pink harvest (M) (BY lagged 2 yrs later)
9	1998
1	1999
14	2000
5	2001
8	2002
10	2003
7	2004
3	2005
15	2006
6	2007
17	2008
11	2009
12	2010
2	2011
16	2012
4	2013
13	2014

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

Year	Ave. rank	Harvest
1998	9	42.4
1999	1	77.8
2000	14	20.2
2001	5	67.0
2002	8	45.3
2003	10	52.5
2004	7	45.3
2005	3	59.1
2006	15	11.6
2007	6	44.8
2008	17	15.9
2009	11	38.0
2010	12	24.0
2011	2	58.9
2012	16	21.3
2013	4	94.7
2014	13	?



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

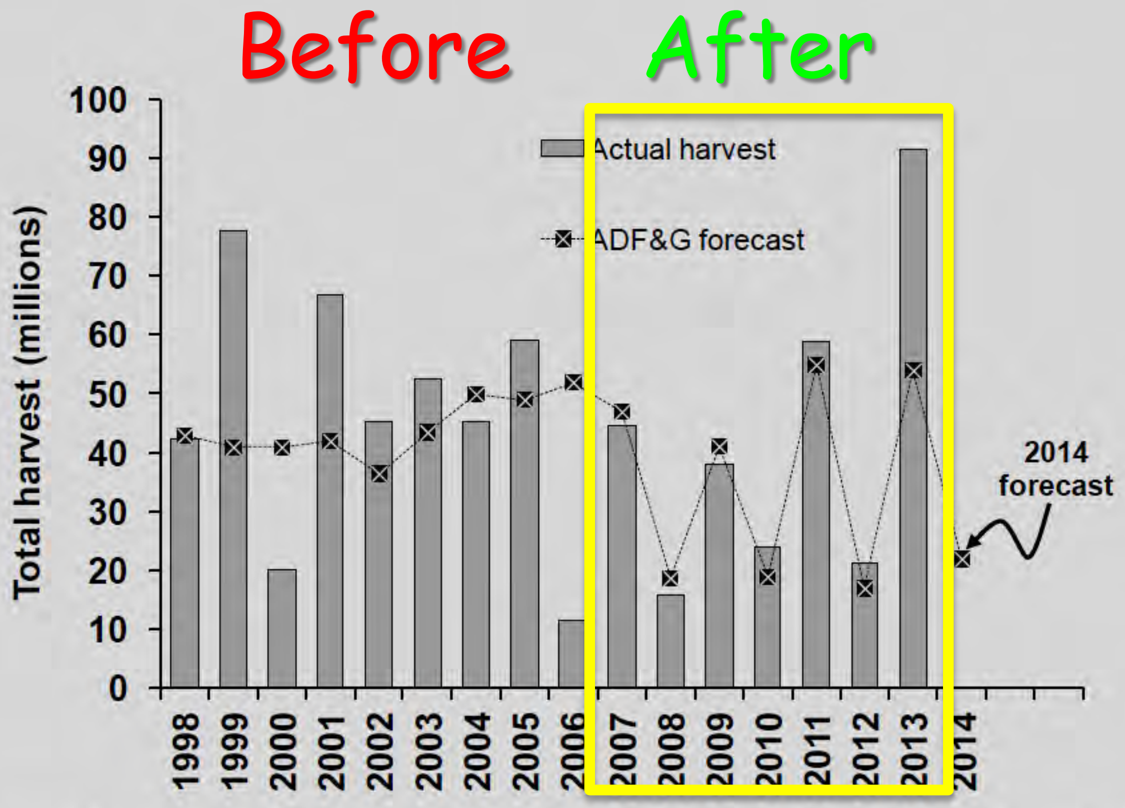


Figure 4. Annual harvest of pink salmon in Southeast Alaska compared to the ADF&G pre-season harvest forecast, 1998–2013. The 2007–2014 ADF&G harvest forecasts were adjusted using NOAA's juvenile pink salmon data.

NOAA pink salmon forecast AFSC web page

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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.

2014 NOAA Forecast
29.9 million pink salmon
with an 80% bootstrap confidence interval of 26-38 M

Juvenile and adult pink salmon captured during SECM sampling

Purse seiners harvest pink salmon worth upwards of $125 million annually in SEAK.

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 peak average catch per unit effort (CPUE) of juvenile pink

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  - Southeast Alaska Coastal Monitoring
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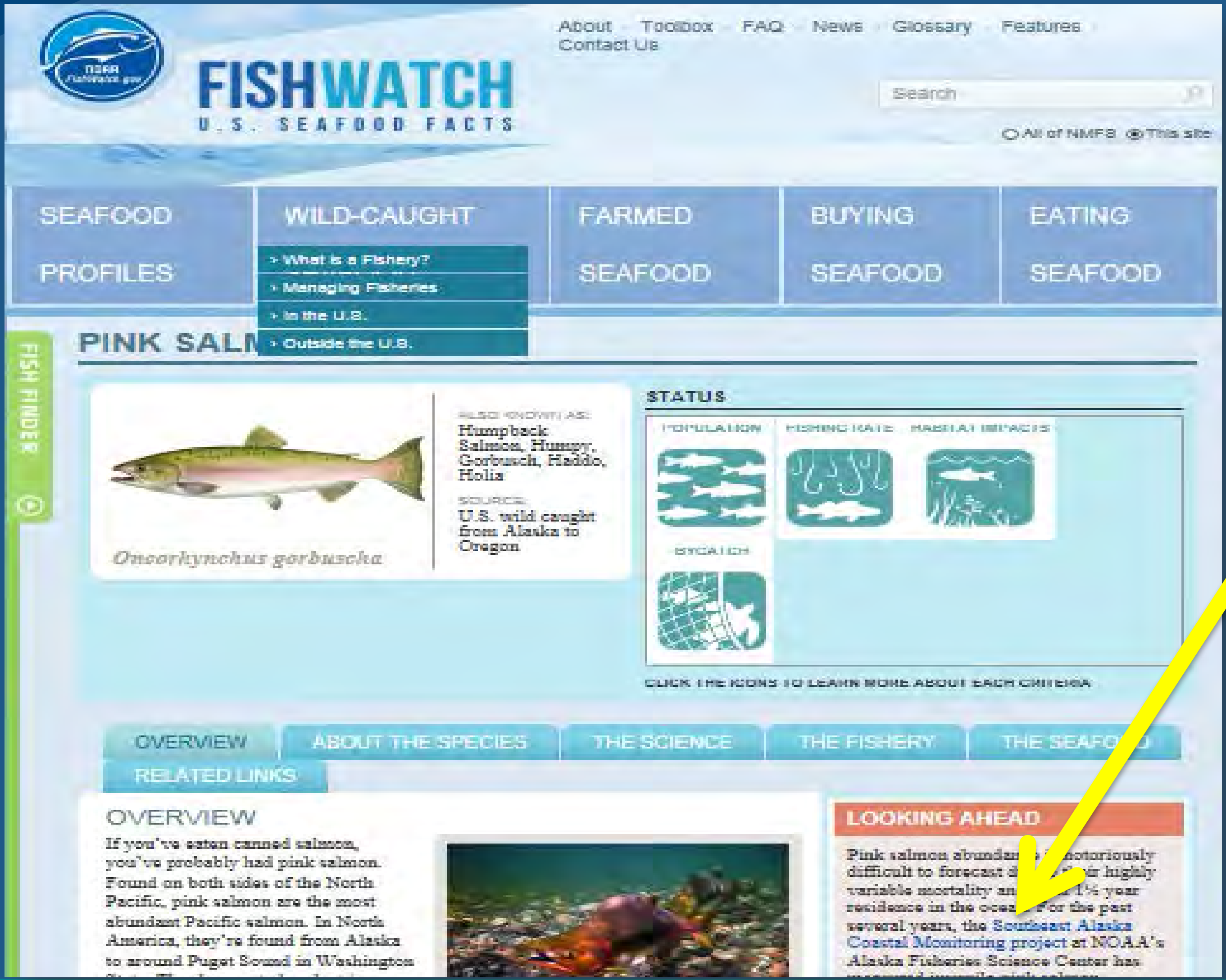
Forecast linked to NOAA FishWatch.gov




Arctic Ocean
Chukchi Sea
Beaufort Sea
Yukon
River
Bering Sea
Gulf of Alaska
Southeast
Alaska
North Pacific Ocean
Alaska
Hawaii

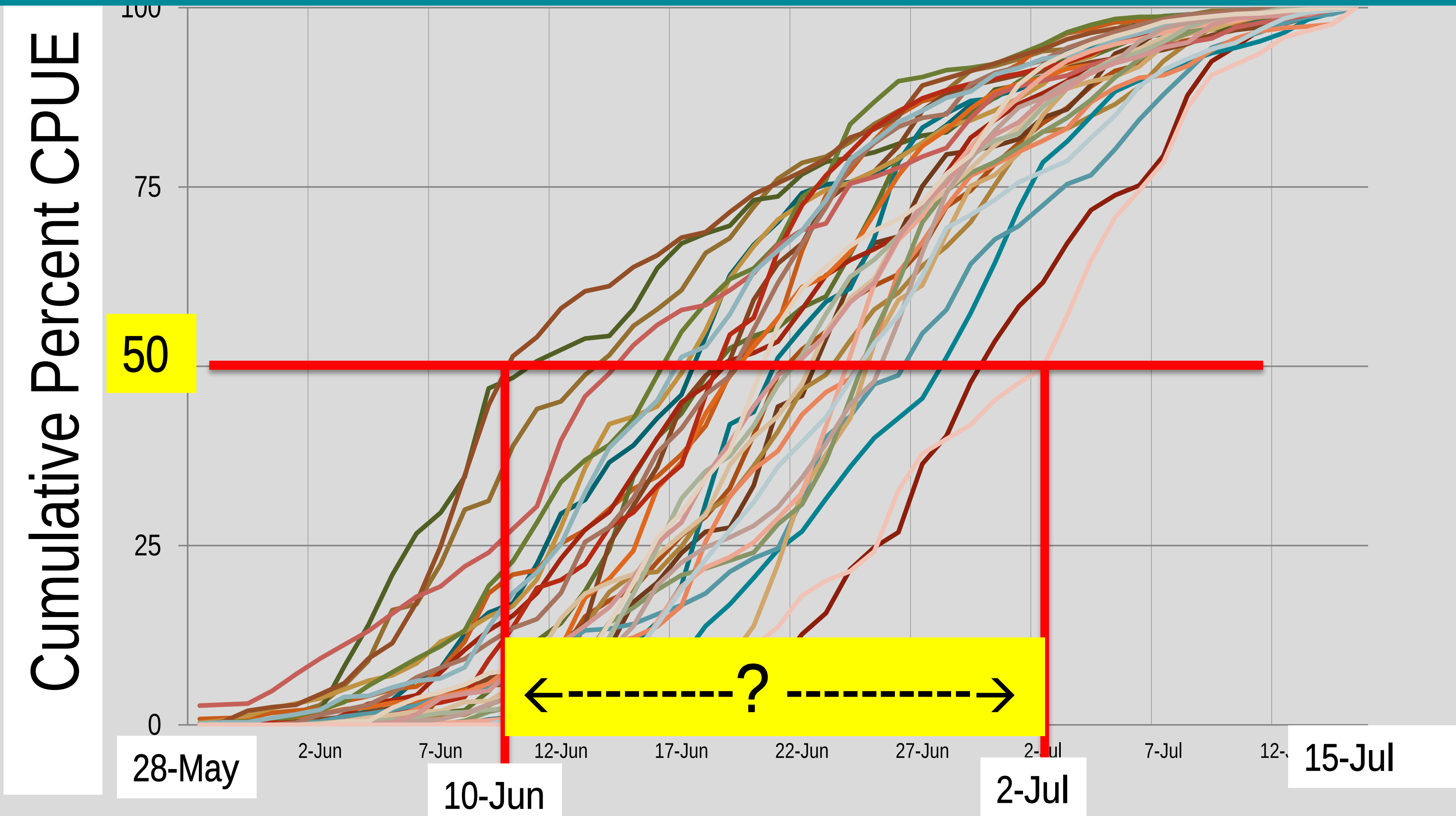
Yukon River: Commercial gillnet & subsistence

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

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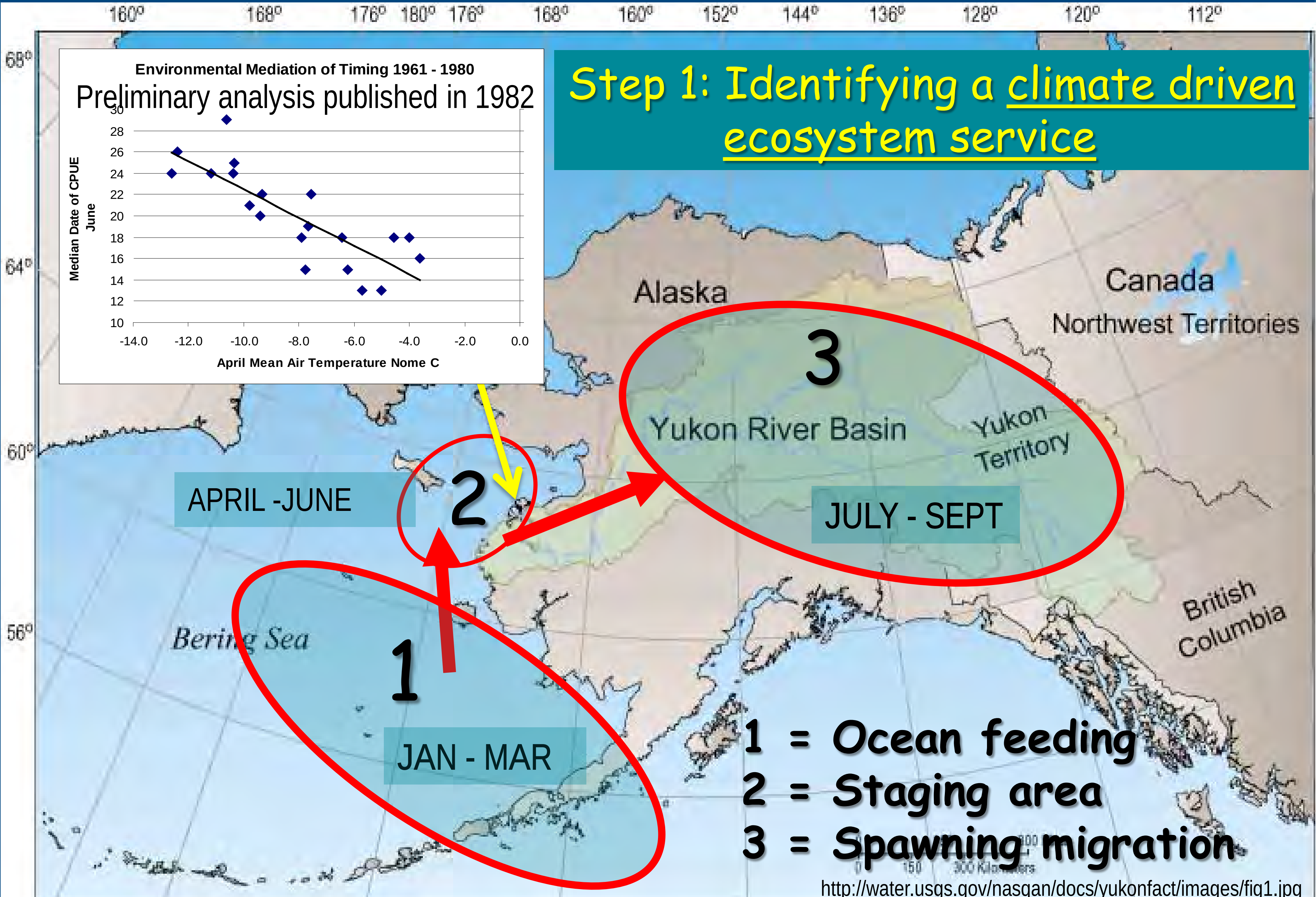
Step 1: Identifying a climate driven ecosystem service



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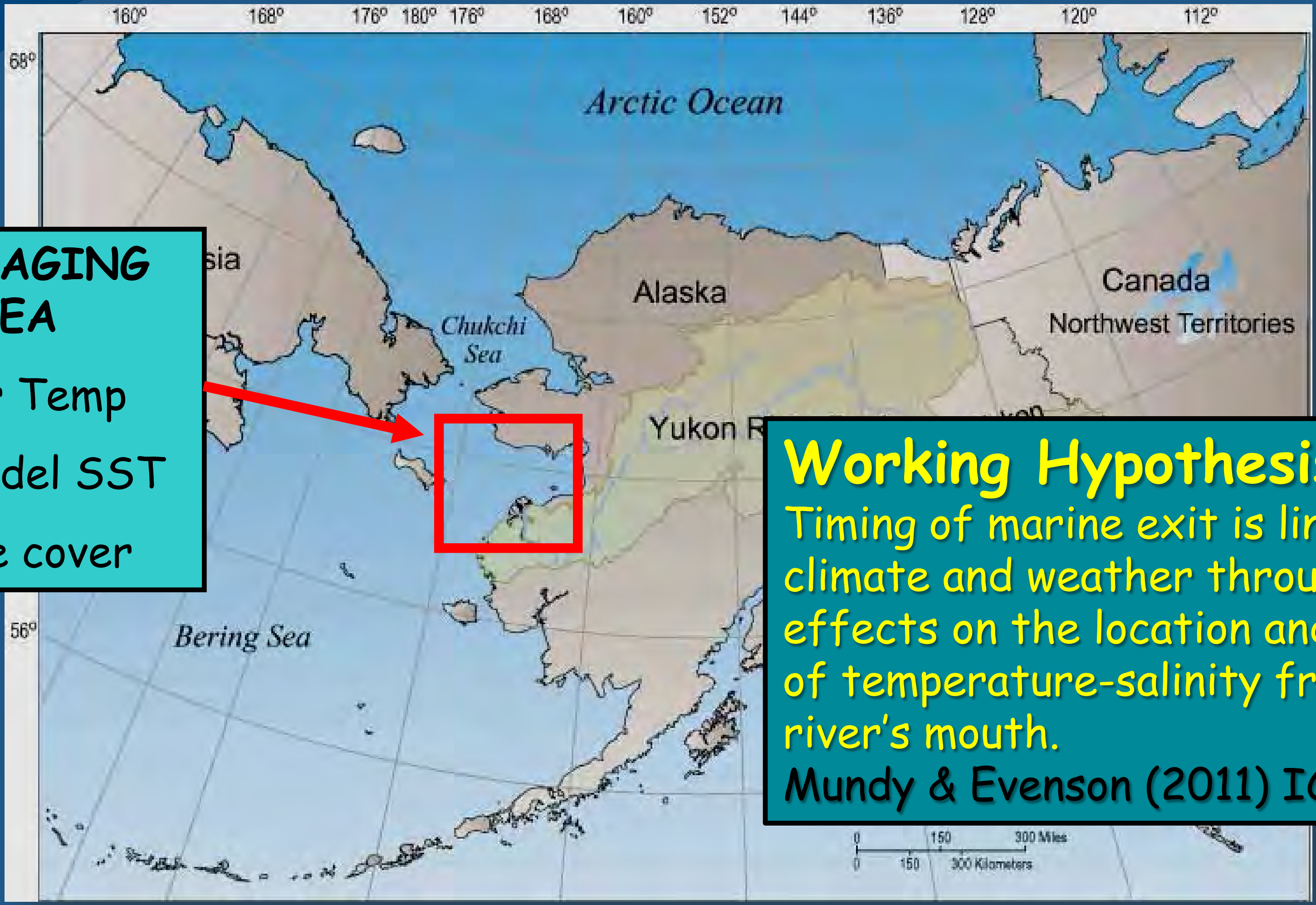
Step 2. Understanding and defining processes and relationships between climate, fish behavior and fishery performance



STAGING AREA

Air Temp

Model SST

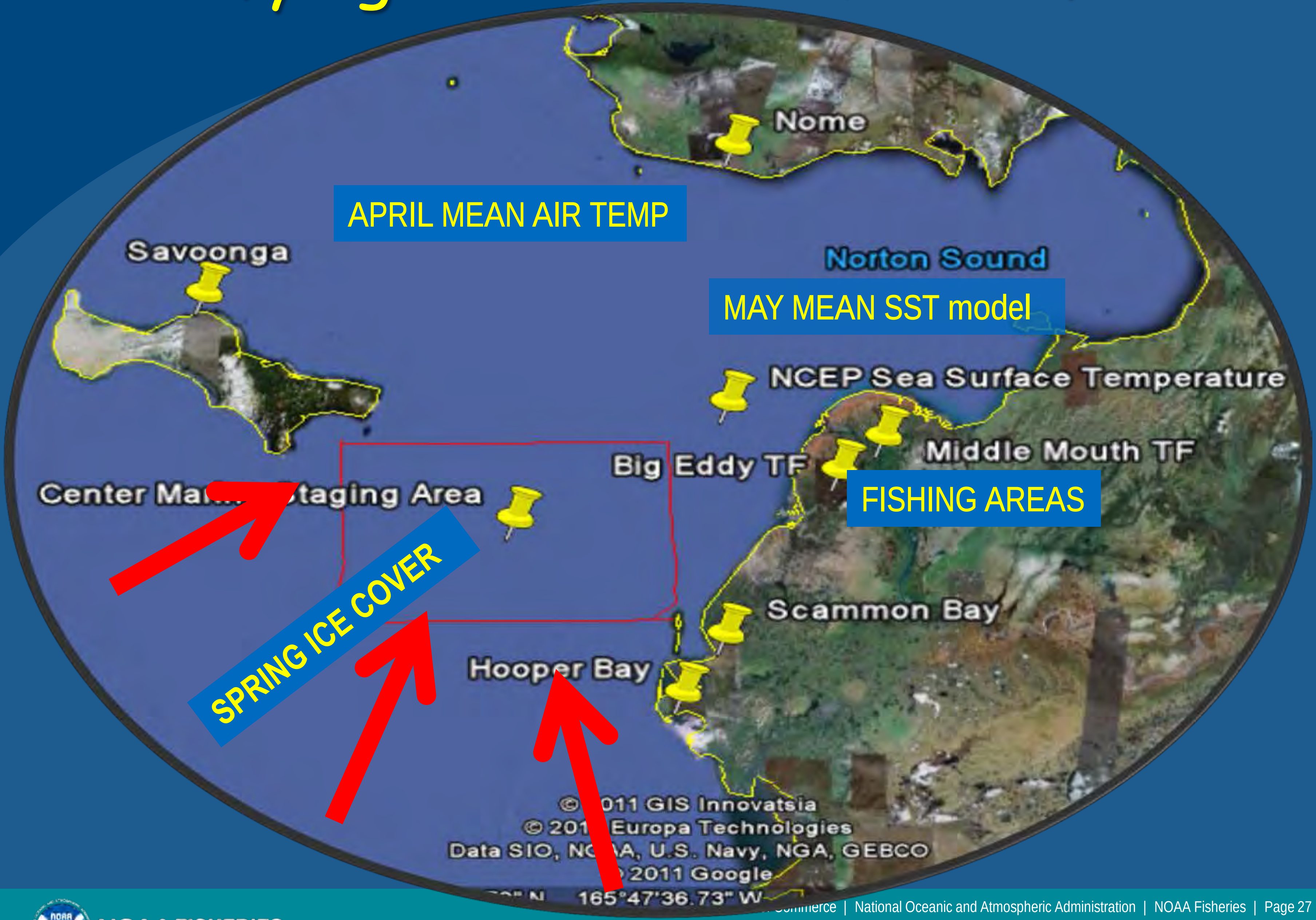
Ice cover

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



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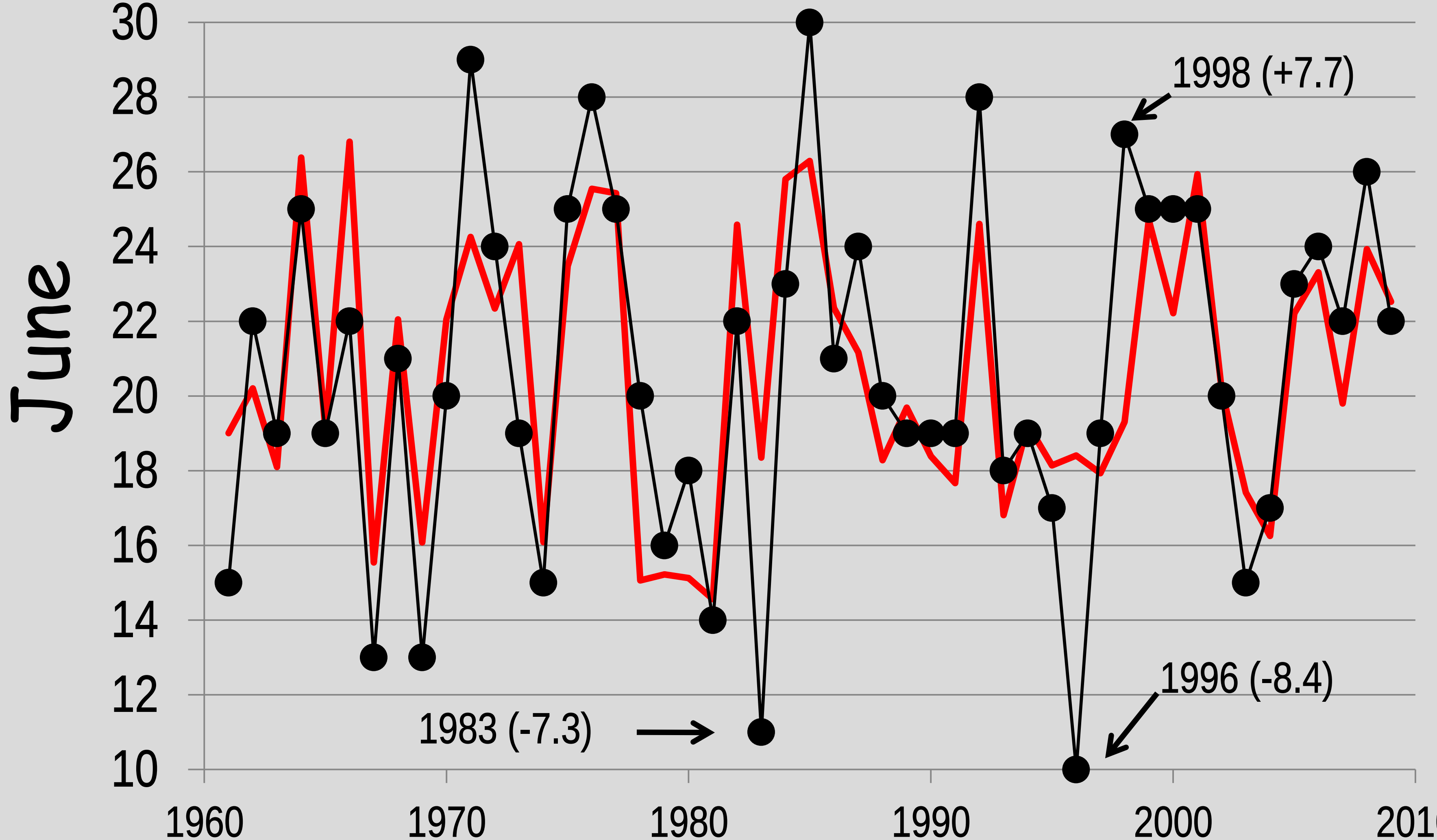
Model Timing = (-0.410)AIRT + (-1.638)SST + 17.357

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

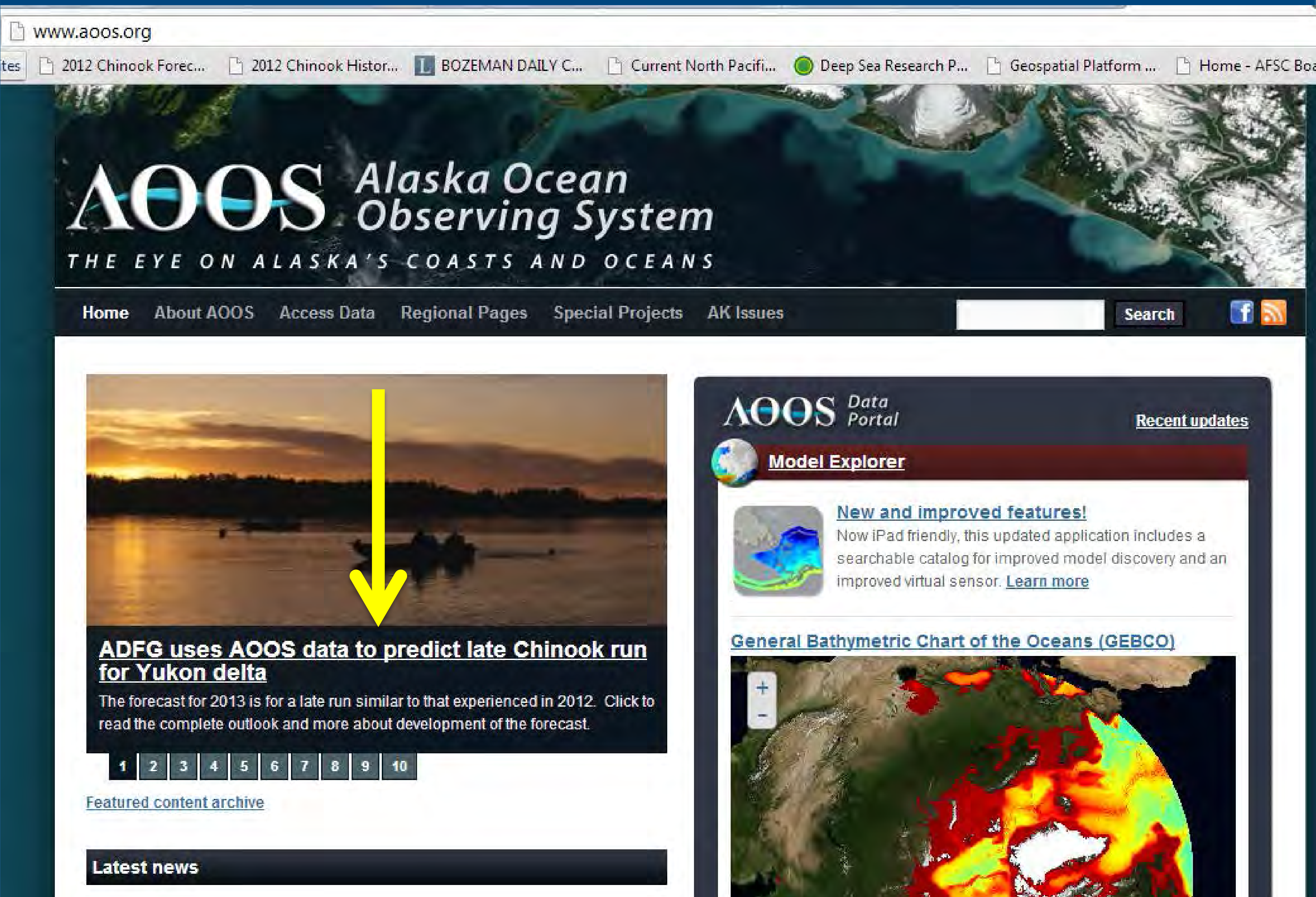
Year	Percentile	Date observed	Date forecasted	Error (days)
2010	15	June 17	June 17	0
2011	15	June 15	June 16	1
2012*	15	June 22	June 17	5
2013	15	June 21	June 21	0
2010	50	June 25	June 24	1
2011	50	June 21	June 24	3
2012*	50	July 2	June 25	7
2013	50	June 28	June 28	0

*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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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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General Bathymetric Chart of the Oceans (GEBCO)

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