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# The NOAA 2016 Southeast Pink Salmon Forecast from Ecosystem Monitoring in Southeast Alaska

Joe Orsi\*, Emily Fergusson, &  
Alex Wertheimer

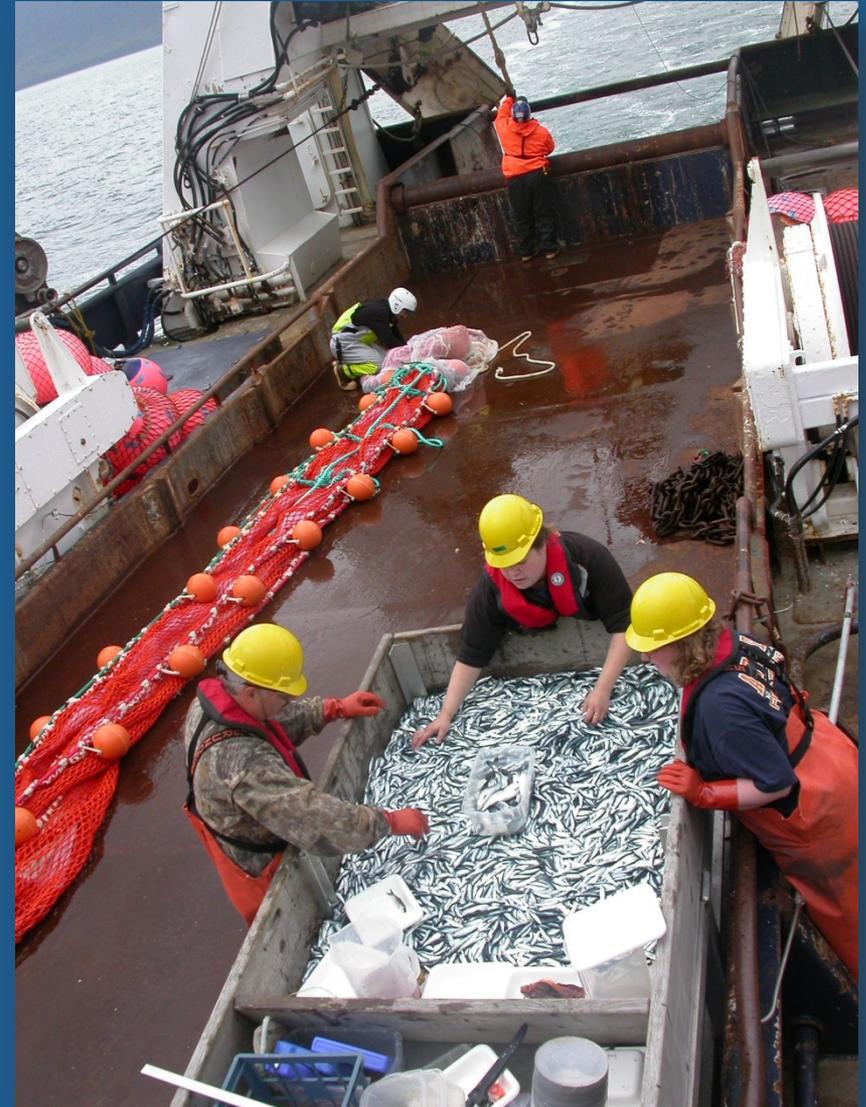
*\*The views expressed are those of the author and do not necessarily represent those of NOAA*

Southeast Alaska Purse Seine Task Force Meeting  
Sitka, Alaska, 01 December 2015

# Presentation outline

- ❖ Overview ABL's Southeast Coastal Monitoring (SECM) project: 1997-2015
- ❖ Introduce ecosystem metrics considered for use in forecasting pink salmon harvest
- ❖ Review past model performances (2004-15) & present the 2016 NOAA pink forecast
- ❖ Discuss forecast model "nuts & bolts" and the implications of 2015 ocean conditions

# Southeast Alaska Coastal Monitoring (SECM) monthly sampling: May-Aug, 1997-2015



# SECM sampling stations in Southeast Alaska

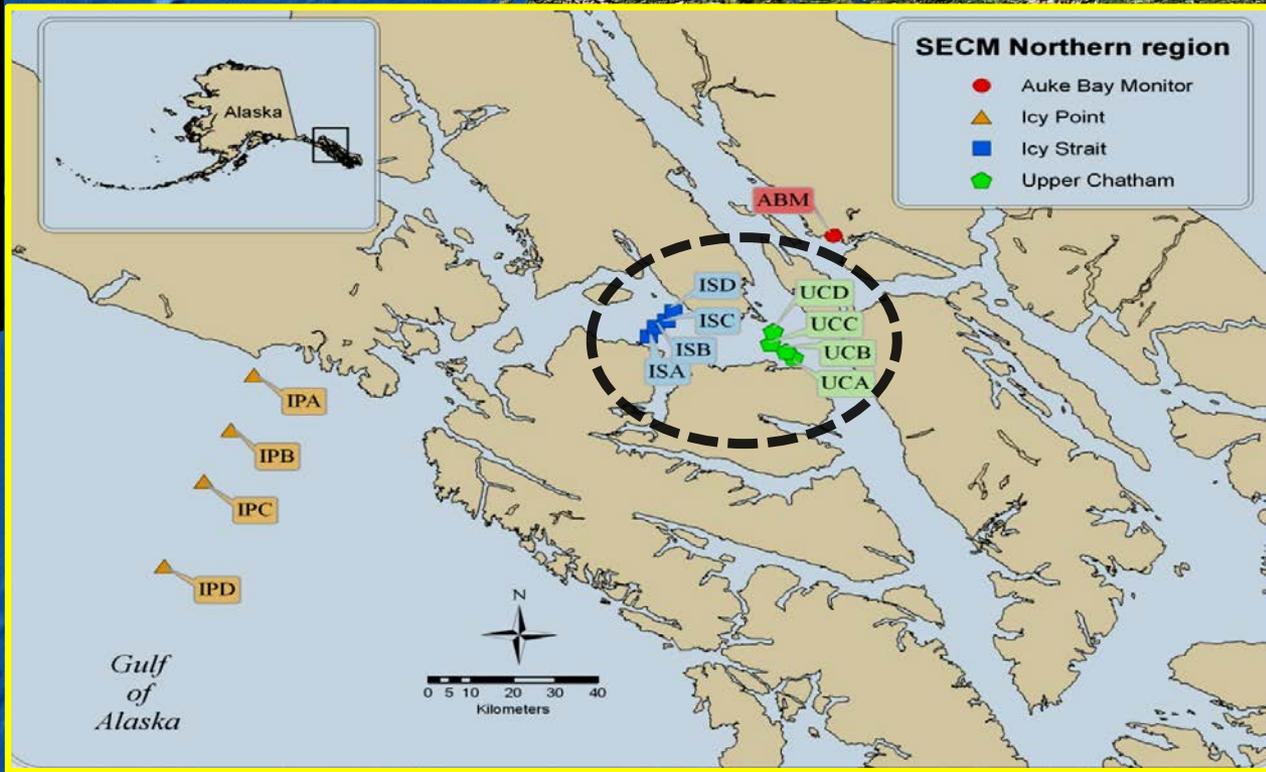
60°N

55°N

50°N

45°N

Gulf of AK Integrated  
Research Project  
July 2010-15



- SECM Northern region**
- Auke Bay Monitor
  - ▲ Icy Point
  - Icy Strait
  - ◆ Upper Chatham



145°W

140°W

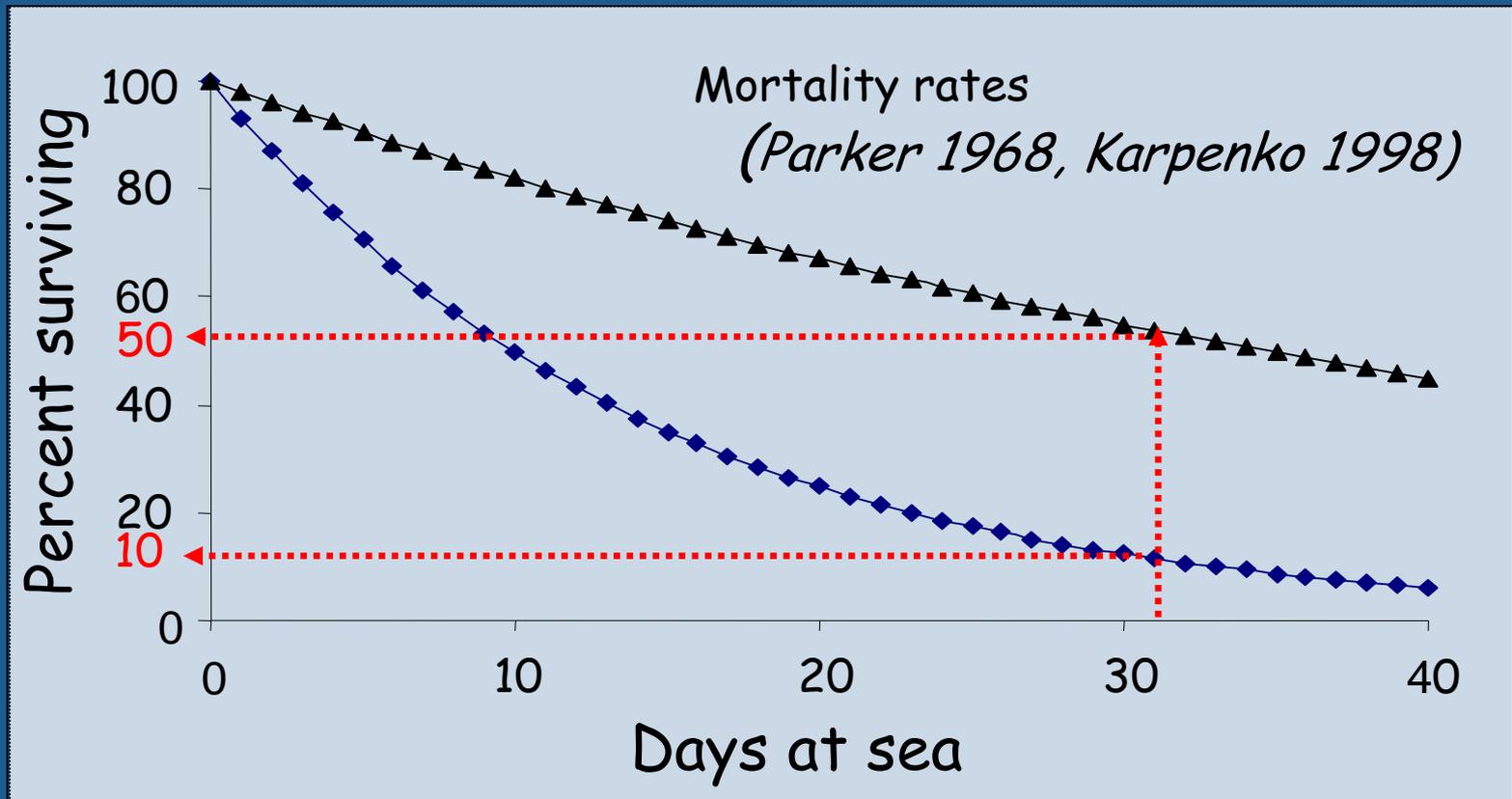
135°W

130°W

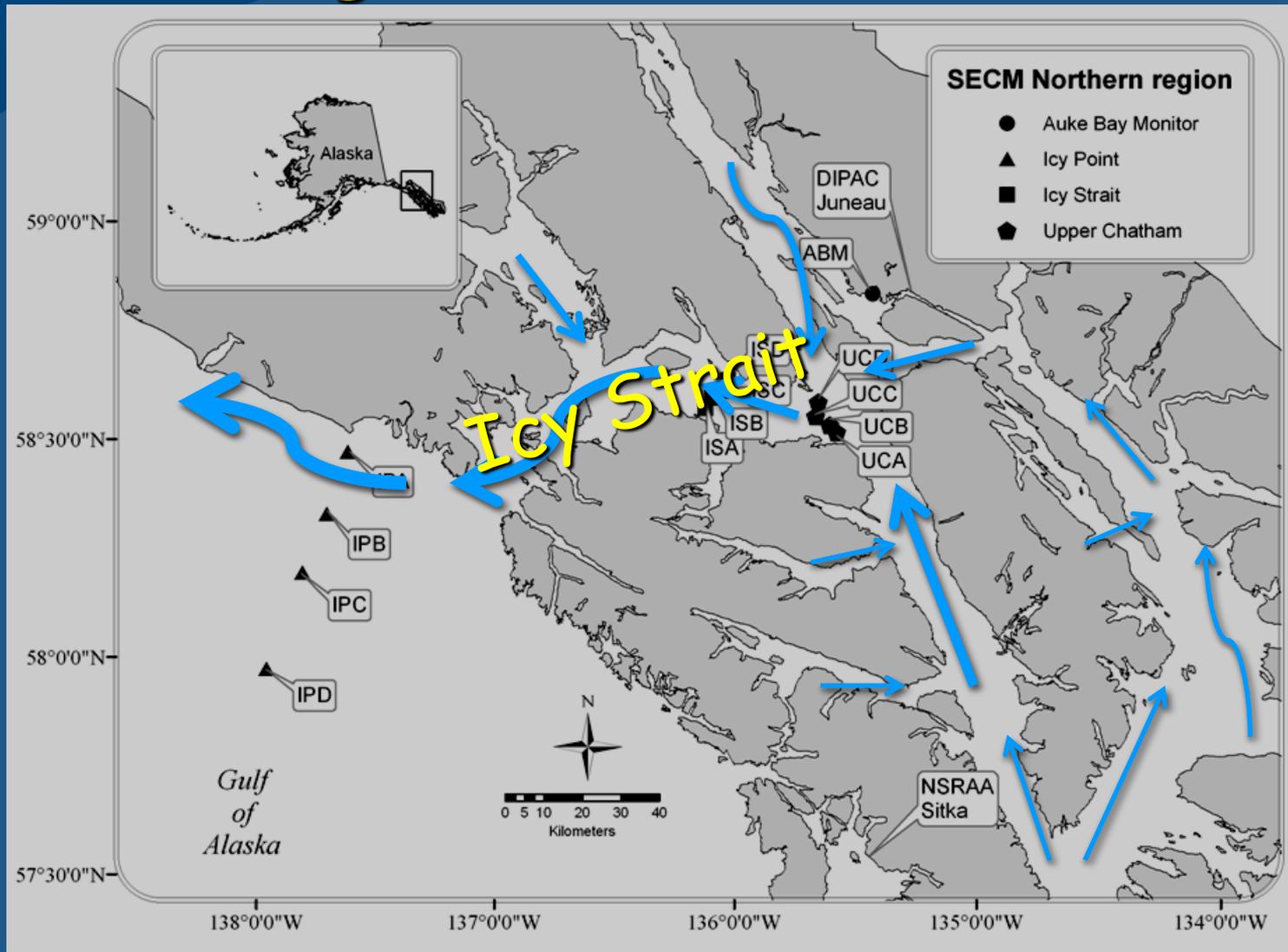
125°W

120°W

# Paradigm of pink salmon biology: Mortality during early marine life is high, variable, and impacts year class strength

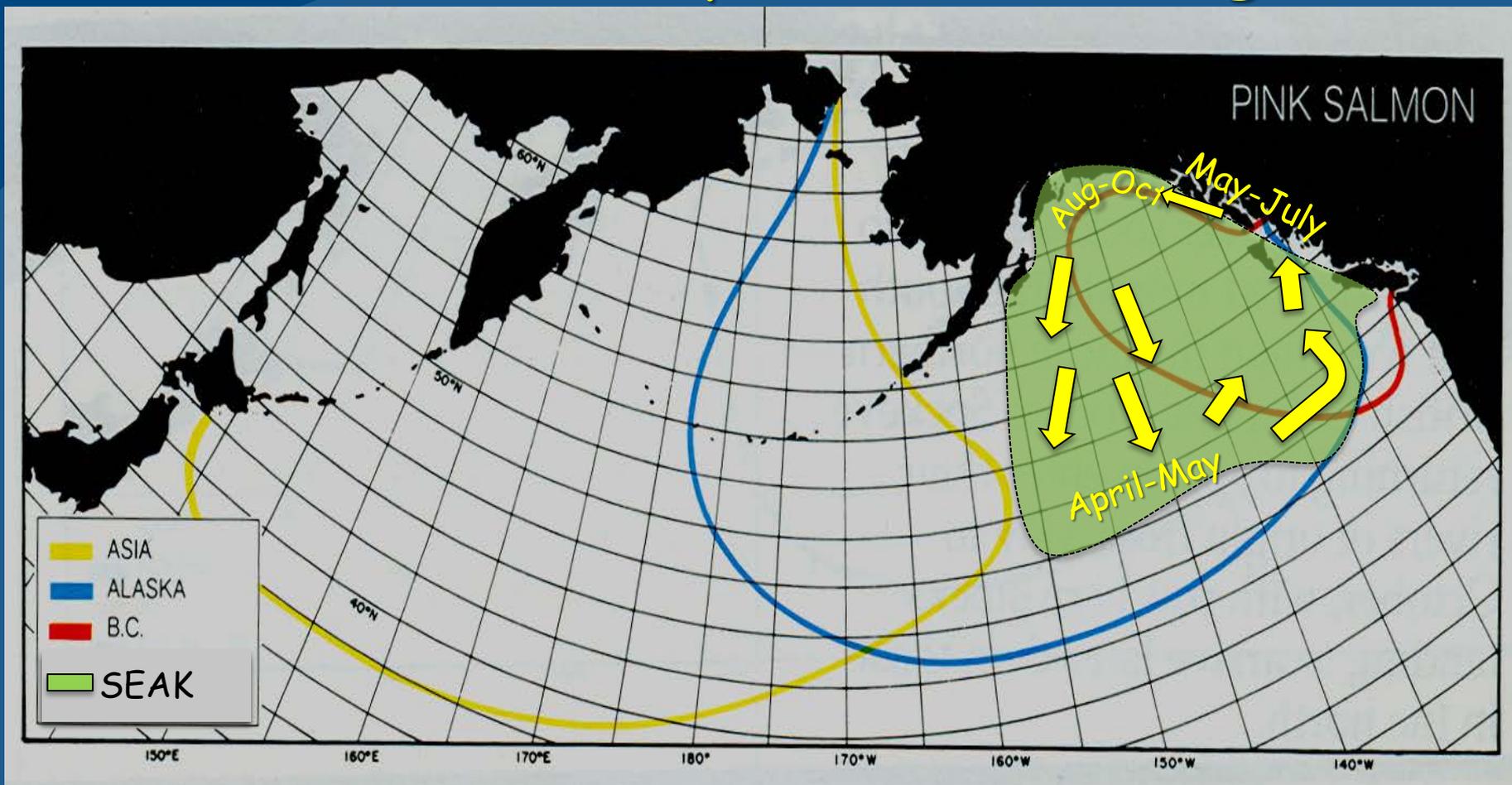


# SECM project stations along a primary seaward migration corridor in Southeast



# Generalized ocean distribution of pink salmon

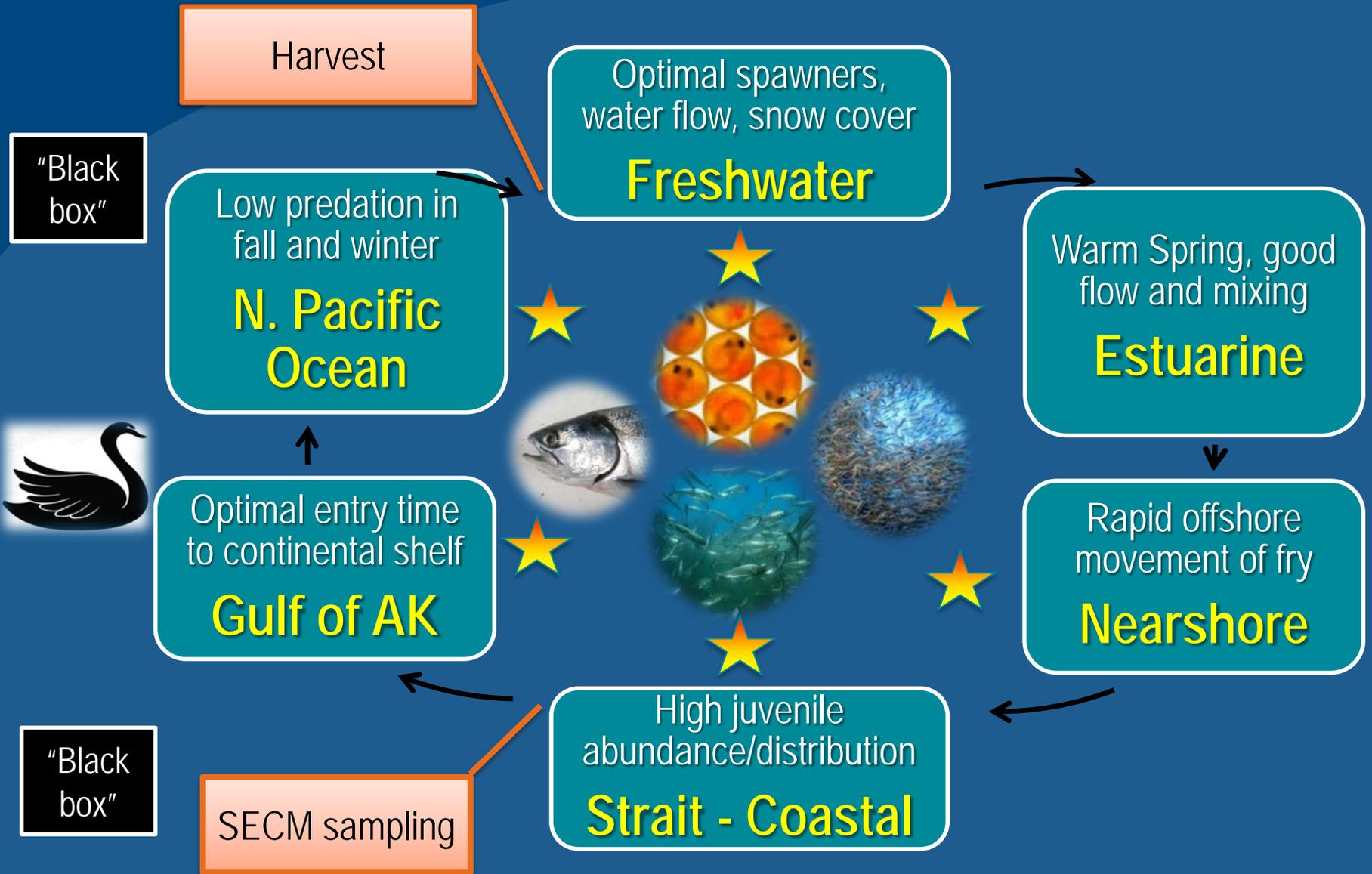
## Southeast Alaska pinks shaded in green



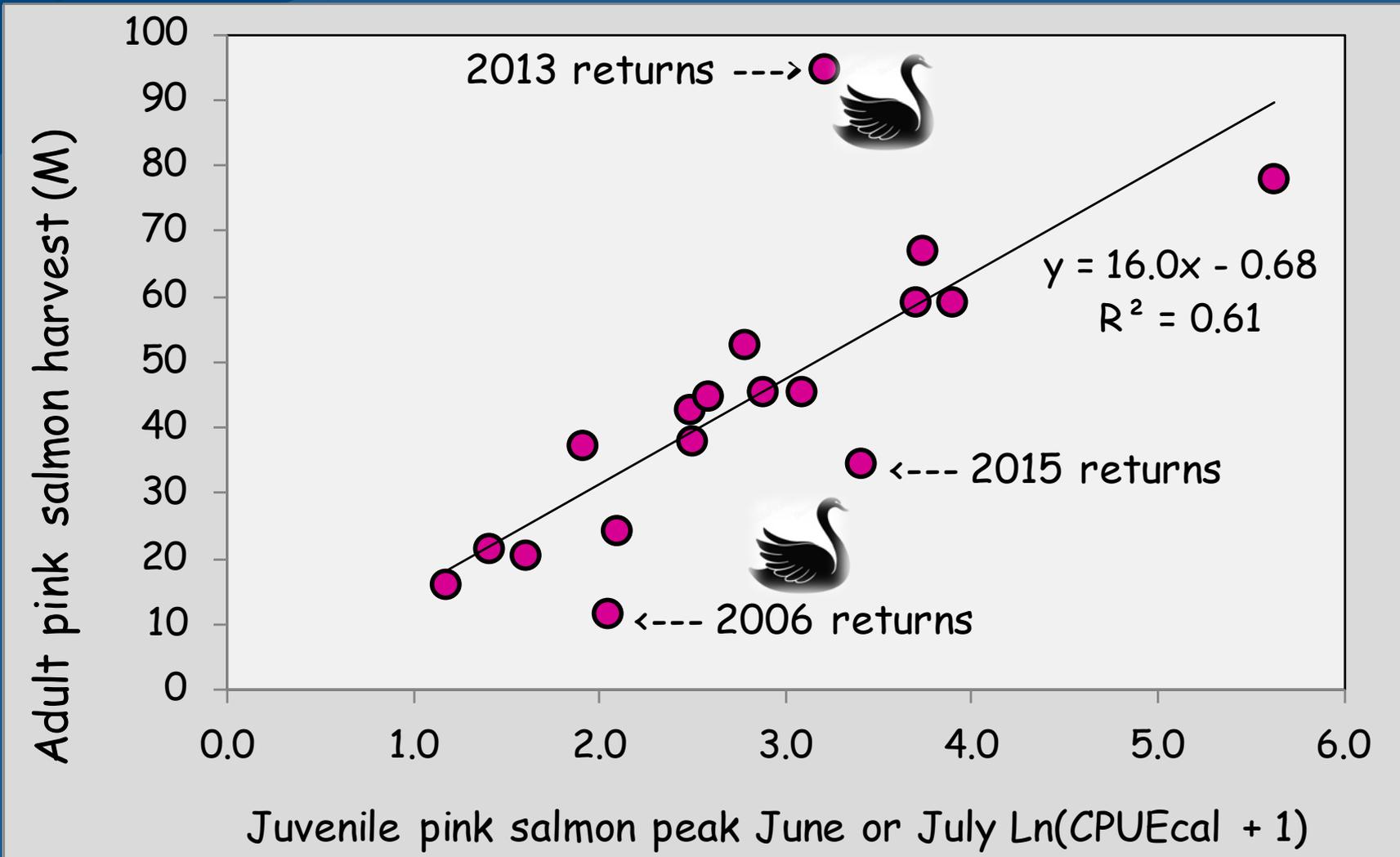
<http://www.pac.dfo-mpo.gc.ca/fm-gp/species-especies/salmon-saumon/facts-infos/pink-rose-eng.html>

Takagi et al. 1981, INPFC Bulletin 40, Distribution and origin of pink salmon....

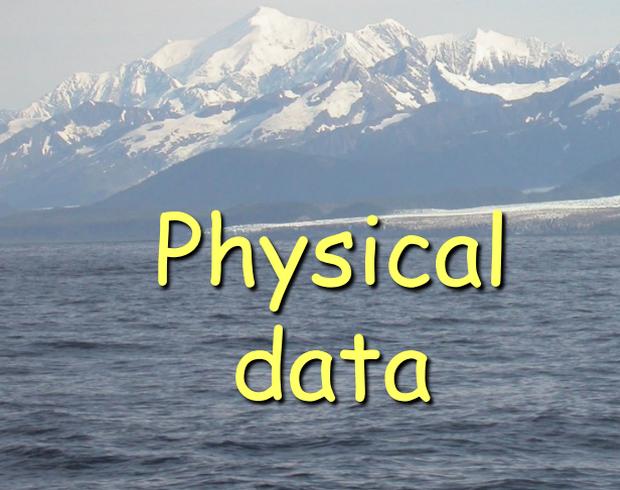
# Key pink salmon life history phases



# Strong relationship most years with SECM juvenile pink catch & harvest 1997-2015



# SECM ecosystem metrics considered



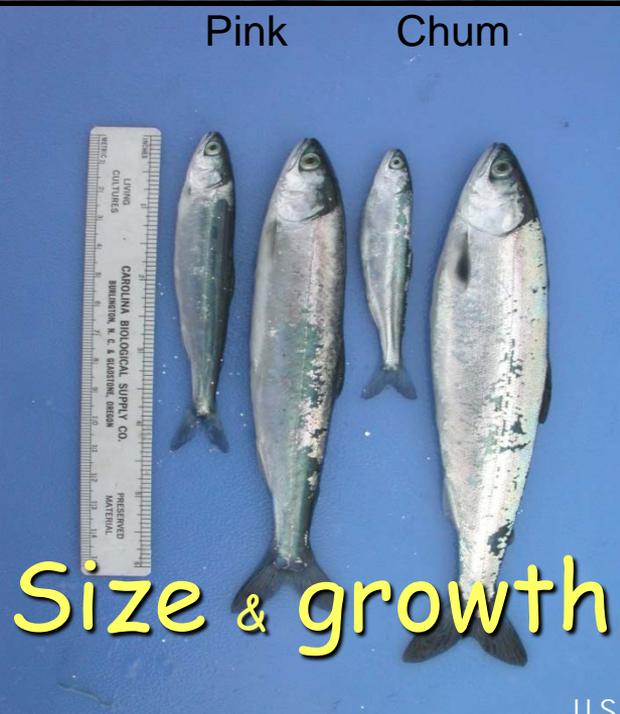
Physical data



Zooplankton biomass/diet



Catches (CPUE)



Pink Chum

Size & growth



Stock comp



Predation

# Selected biophysical factors considered for forecasting Southeast pink salmon harvest

## Biological (region)

J-pink salmon: Peak CPUE<sub>cal & ttd</sub>, peak migration month, catch composition, growth, size at time, condition

Trophic: Surface and integrated measures of zooplankton, and predation (adult coho)

## Physical (region & ocean basin)

Region: Temperature (surface + integrated-"ISTI"), salinity, & mixed layer depth

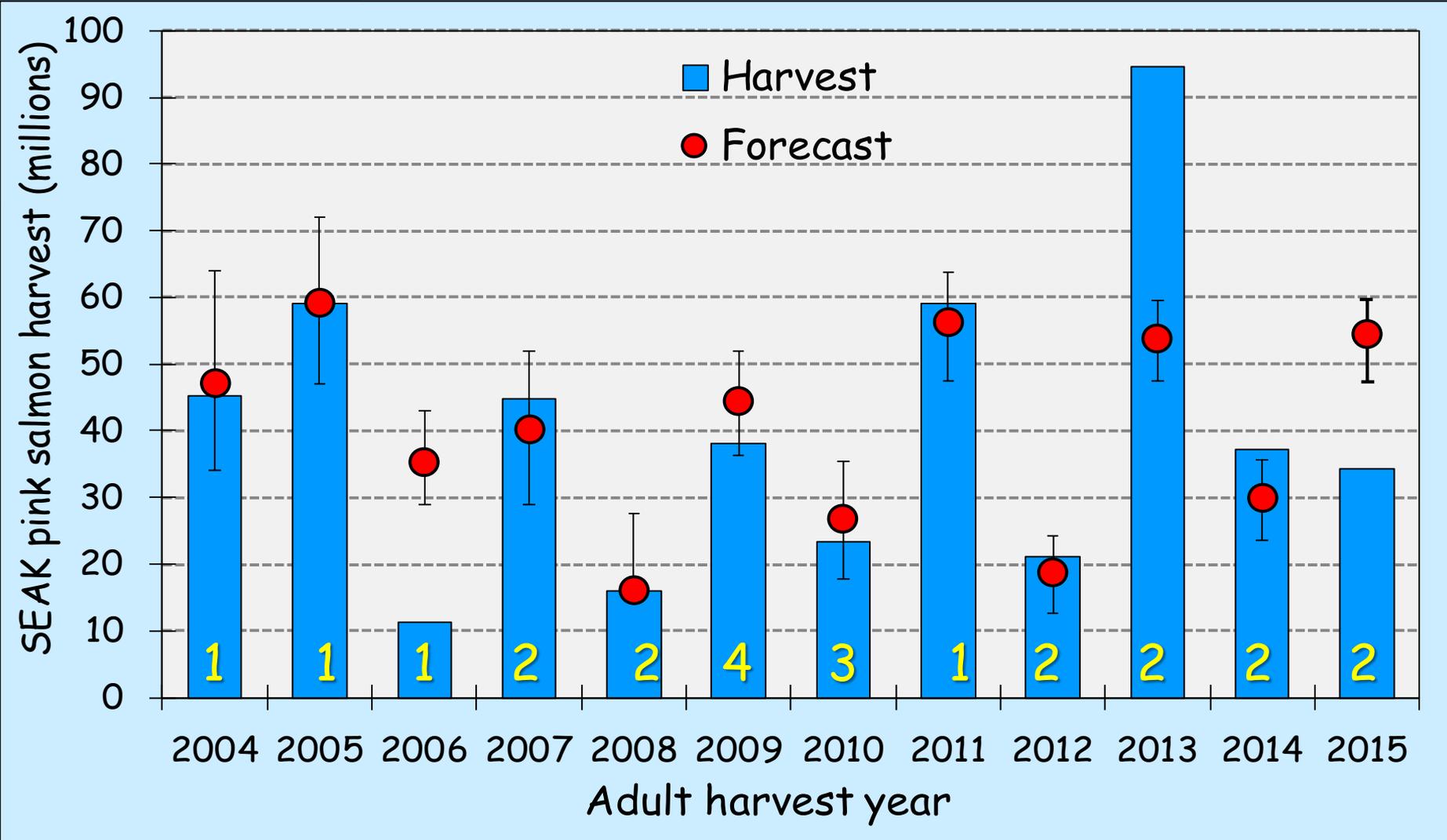
Ocean basin: ENSO (El Niño Southern Oscillation Index), PDO (Pacific Decadal Oscillation Index), & NPI (North Pacific Index)

# Forecasting procedures using a general linear model

- 1) Forward-Backward Stepwise Regression considering all variables,  $P < 0.05$
- 2) Use corrected Akaike Information Criteria ( $AIC_c$ ) to check for "over parameterization"
- 3) "Jackknife" procedure to evaluate models over time series (hindcasting + remove 1 yr.)
- 4) Bootstrap "best" model to generate forecast confidence intervals by re-sampling CPUE data to account for measurement error

# SECM pink salmon forecast models 2004-2015:

In 9 of 12 years, forecasts 0-20% of harvest,  $\bar{x}$  deviation 9%



Number of parameters in each model (1=CPUE only)

# 2015 SECM sampling results

May oceanographic sampling completed w/ RV *Sashin*

June, July, and August trawl and oceanographic sampling conducted with chartered FV *Northwest Explorer* (used past five years)

Low-moderate juvenile pink CPUEs but a favorable early seaward migration timing

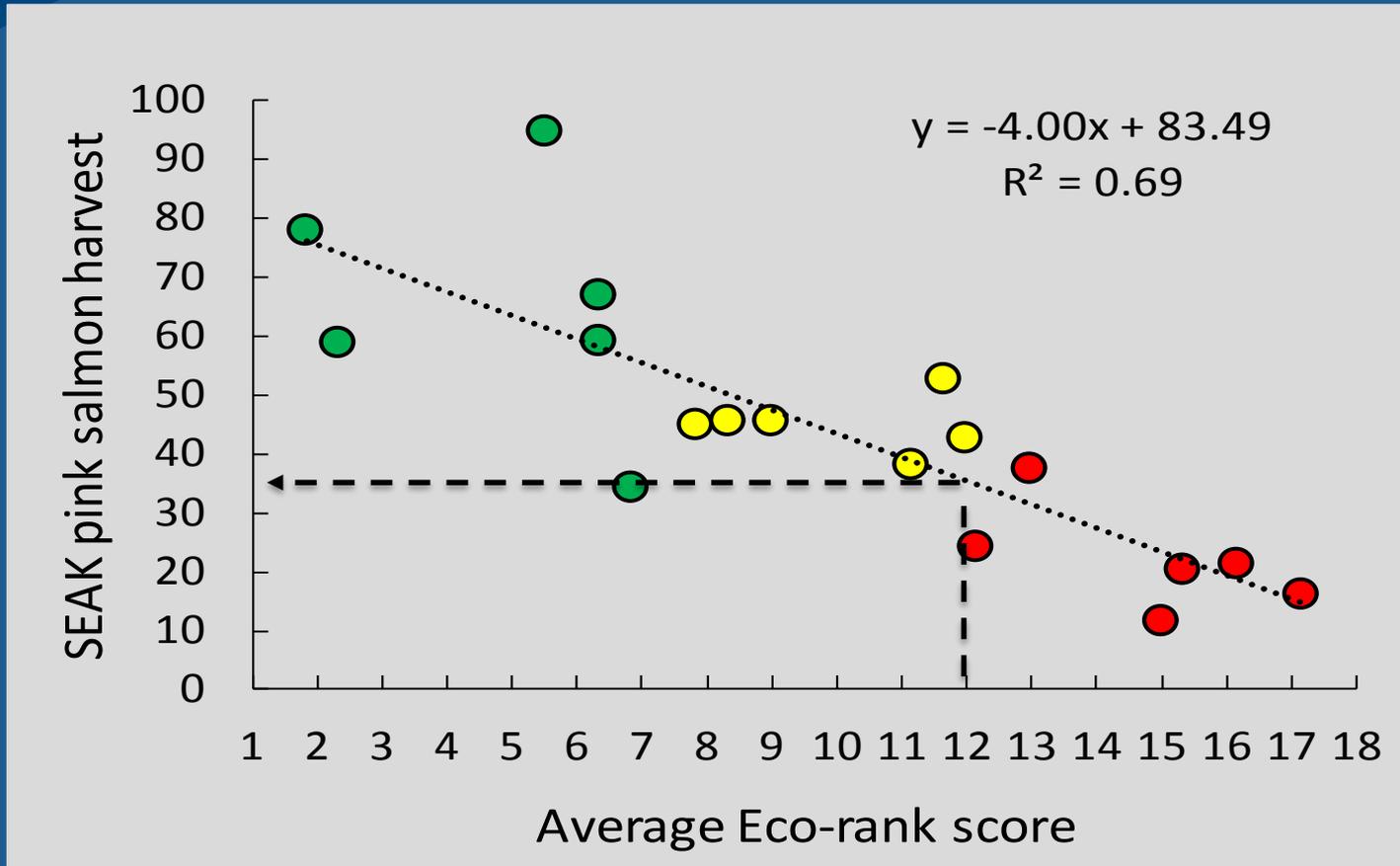
Unfavorable proportion of pinks in catch and a high coho predation index

North Pacific Index was average

Upper 20-m water temp MJJA, 2<sup>nd</sup> warmest ISTI

Brood year (BY)	SEAK pink salmon harvest (M)	Pink regional proportionality (% Northern harvest: Green= 40-60%, Yellow= >20<40% or >60<80%; and Red = <20% or >80%)	Pink salmon escapement index for SEAK		Ocean entry year (BY lagged 1 yr later)	Auke Creek fry outmigration (1,000s) Latitude 58°N, near Juneau	Upper 1-20 m avg. lcy Strait temperature "ISTT" May, June, July and August		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 #sJ-pink CPUe	North Pacific Index (June, July, Aug)		Average rank score of the six variables	Ranking of the average rank scores		SEAK pink salmon harvest year (BY lagged 2 yrs. later)	SEAK pink salmon harvest (M) (response variable)
Data source	ADFG <sub>1</sub>	ADFG	ADFG <sub>2</sub>			NOAA <sub>1</sub>	NOAA <sub>2</sub>		NOAA <sub>2</sub>	NOAA <sub>2</sub>	NOAA <sub>2</sub>	NOAA <sub>2</sub>	NOAA <sub>2</sub> ADFG <sub>3</sub>	CGD		↓	↓			ADFG <sub>1</sub>
1996	64.6	17%	18.1		1997	31.1	9.5		2.5	2.2	July	17%	1.5	15.6		12.0	12		1998	42.4
1997	28.9	47%	14.8		1998	60.8	9.7		5.6	5.3	June	42%	0.8	18.1		1.8	1		1999	77.8
1998	42.4	44%	14.3		1999	53.5	9.0		1.6	1.4	July	10%	3.9	15.8		15.3	17		2000	20.2
1999	77.8	50%	27.3		2000	132.1	9.0		3.7	3.3	July	25%	1.0	16.9		6.3	4		2001	67.0
2000	20.2	39%	10.8		2001	61.5	9.5		2.9	2.6	July	28%	2.0	16.8		8.3	8		2002	45.3
2001	67.0	22%	18.6		2002	150.1	8.6		2.8	2.5	July	26%	2.5	15.6		11.7	11		2003	52.5
2002	45.3	49%	16.6		2003	95.1	9.8		3.1	2.7	July	22%	1.8	16.1		9.0	9		2004	45.3
2003	52.5	44%	20.0		2004	169.6	9.7		3.9	3.4	June	31%	1.4	15.1		6.3	5		2005	59.1
2004	45.3	54%	15.7		2005	87.9	10.2		2.0	1.7	Aug	26%	3.3	15.5		15.0	16		2006	11.6
2005	59.1	51%	19.9		2006	65.9	8.9		2.6	2.3	June	26%	1.9	17.0		7.8	7		2007	44.8
2006	11.6	72%	10.2		2007	81.9	9.3		1.2	1.0	Aug	15%	3.7	15.7		17.2	19		2008	15.9
2007	44.8	29%	17.6		2008	117.6	8.2		2.5	2.2	Aug	29%	2.1	16.1		11.2	10		2009	38.0
2008	15.9	14%	9.5		2009	34.8	9.5		2.1	2.7	Aug	27%	1.7	15.1		12.2	14		2010	24.0
2009	38.0	31%	12.7		2010	121.6	9.6		3.7	5.0	June	61%	0.9	17.6		2.3	2		2011	58.9
2010	24.0	43%	11.2		2011	30.9	8.9		1.3	1.6	Aug	25%	4.1	15.7		16.2	18		2012	21.3
2011	58.9	81%	14.3		2012	61.8	8.7		3.2	4.3	July	48%	1.1	16.7		5.5	3		2013	94.7
2012	21.3	13%	11.0		2013	51.2	9.2		1.9	2.6	July	13%	2.9	16.0		13.0	15		2014	37.2
2013	94.7	44%	25.2		2014	47.4	9.4		3.4	4.6	July	53%	2.0	15.8		6.8	6		2015	34.4
2014	37.2	11%	13.8		2015	14.2	9.9		2.2	1.8	June	19%	2.6	15.7		12.0	13		2016	?
Harvest correlations	0.33	0.23	0.29			0.31	-0.17		0.78	0.75	-0.67	0.54	-0.80	0.61		Pearson correlation "r"				
Probability value=	0.18	0.36	0.24			0.21	0.49		0.00*	0.00*	0.00*	0.02*	0.00*	0.01*		(* = significant @ p<0.05)				

# Eco-rank model: SEAK harvest vs. avg rank score of the six significant variables



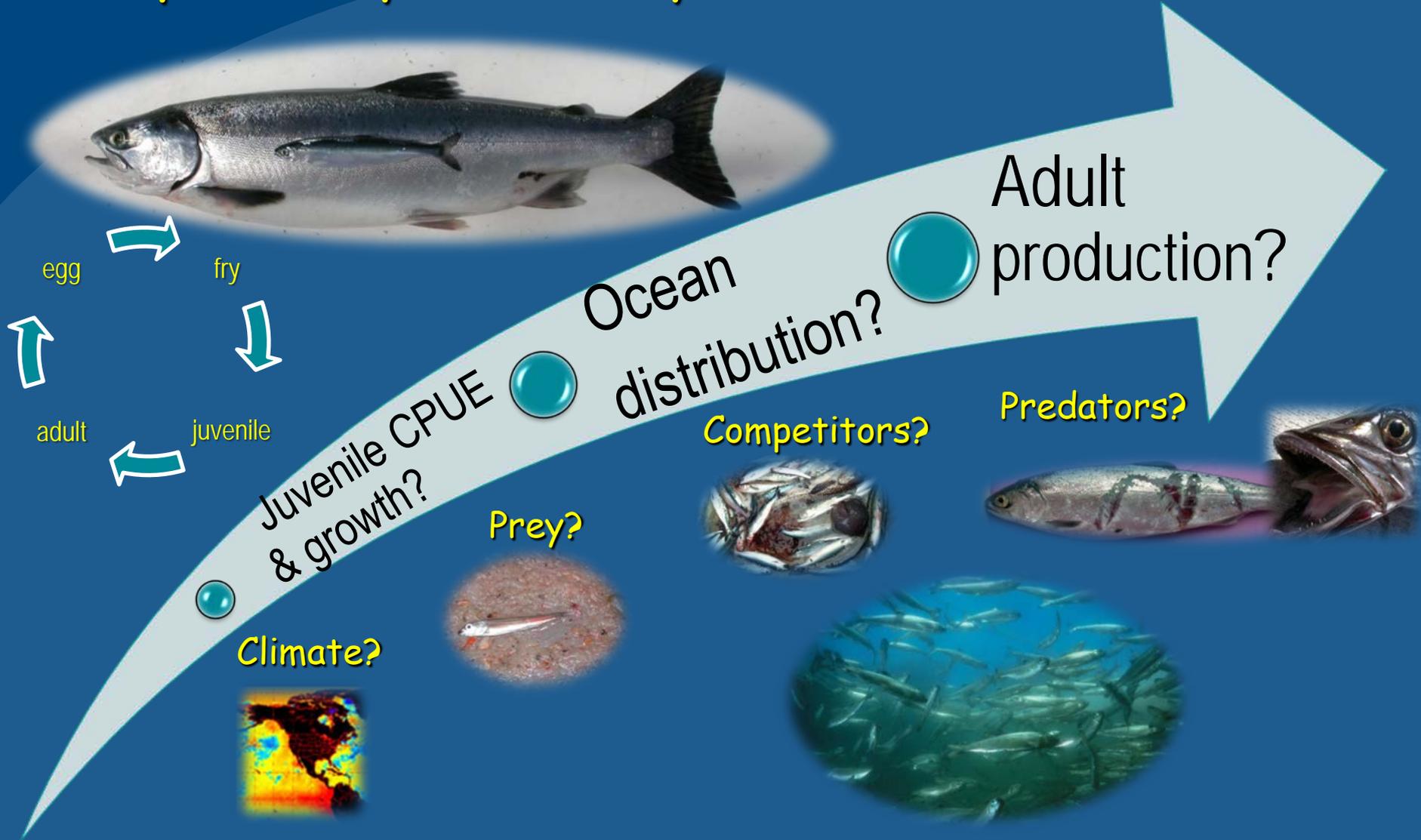
Rank 12 (2015 ocean conditions) = ~37 M harvest in 2016

# 2016 pink salmon forecast models

Models considered	Regre. $P$ value	Adj. $R^2$	$AIC_c$	Jack-knife % [error] avg/median	Prediction for 2016 (80% CI)
$CPUE_{cal}$	< 0.001	59%	153.2	29/15	34.6 M (-)
$CPUE_{cal} +$ ISTI	< 0.001	70%	149.4	<b>22/13</b>	24.2 M (-)
Eco-rank (6 variables)	< 0.001	68%	148.8	26/15	37.1 M (-)
<b>Eco-rank + May temp</b>	< 0.001	<b>78%</b>	<b>143.8</b>	26/23	<b>30.4 M</b> <b>(16-45)</b>

# Potential pink salmon productivity drivers

## Simple two year life cycle - one ocean winter -

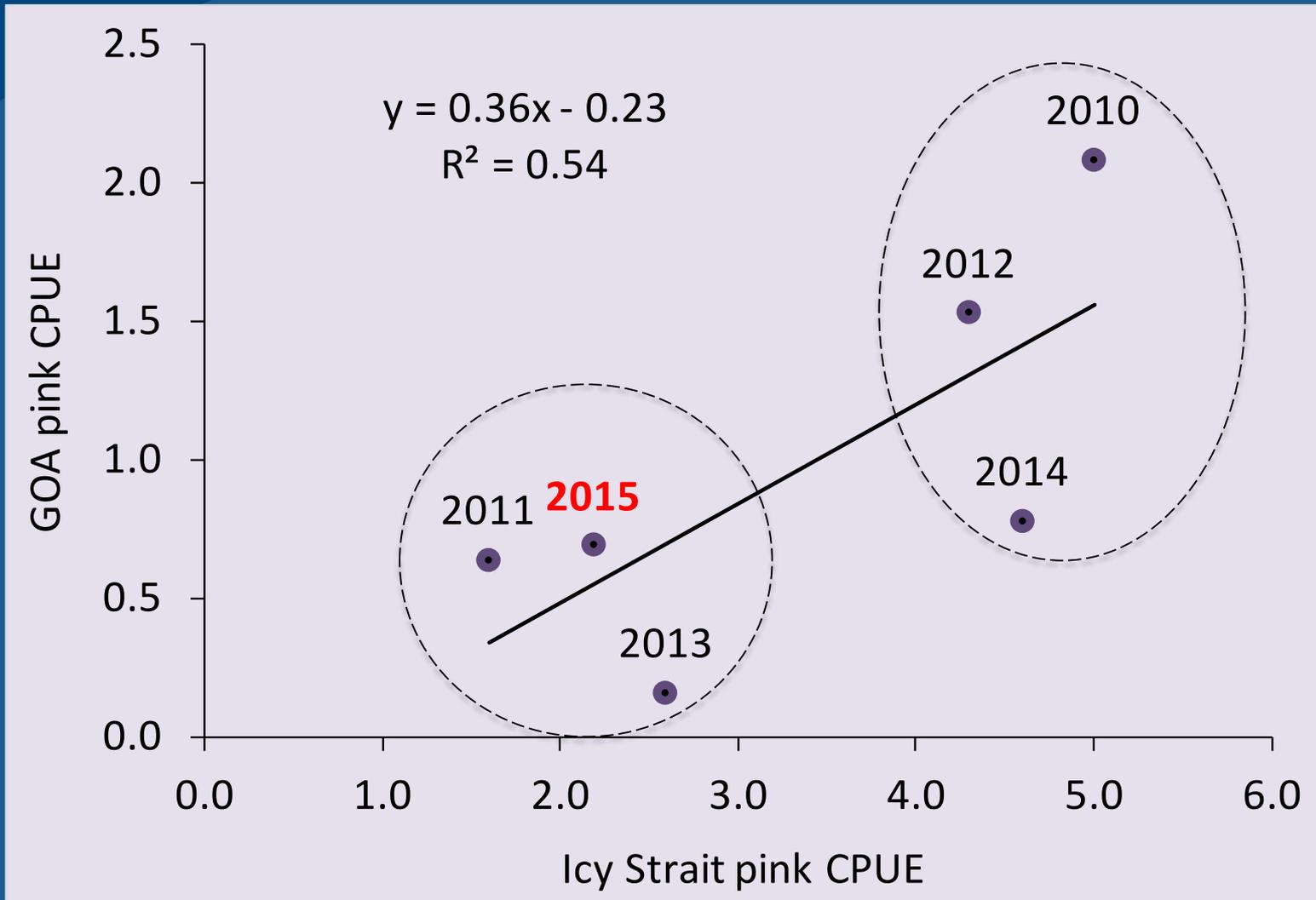


# Gulf of Alaska juvenile pink distribution?



# Icy Strait vs. Gulf of AK juv. pink catches

Pear. Cor. value 0.73, P-value 0.098



# Implications of climate, 2015 ocean conditions on pink salmon production?

Ocean sunfish ~900 lbs.



Pacific saury



Market squid

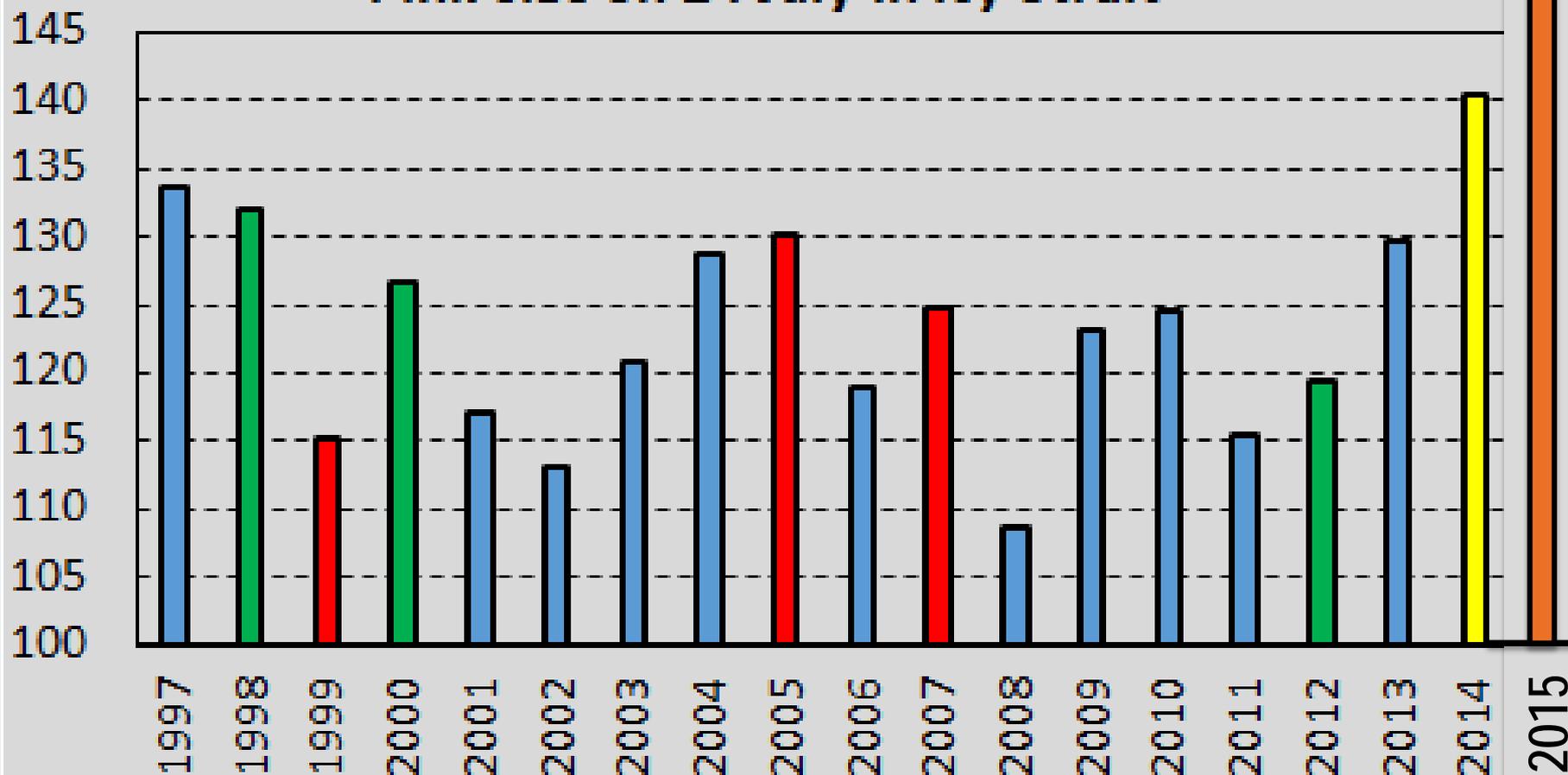


Pacific pomfret

# How well did juvenile pinks grow in 2015?

Note 3 best (green) and worst (red) return years

## Pink size on 24 July in Icy Strait



# Predators of juvenile/immature salmon?



# Predators of juvenile/immature salmon?



# Are spiny dogfish trending upwards?





# Anomalously warm summer conditions in eastern GOA in 2005 (12 M in 2006)

July 2005

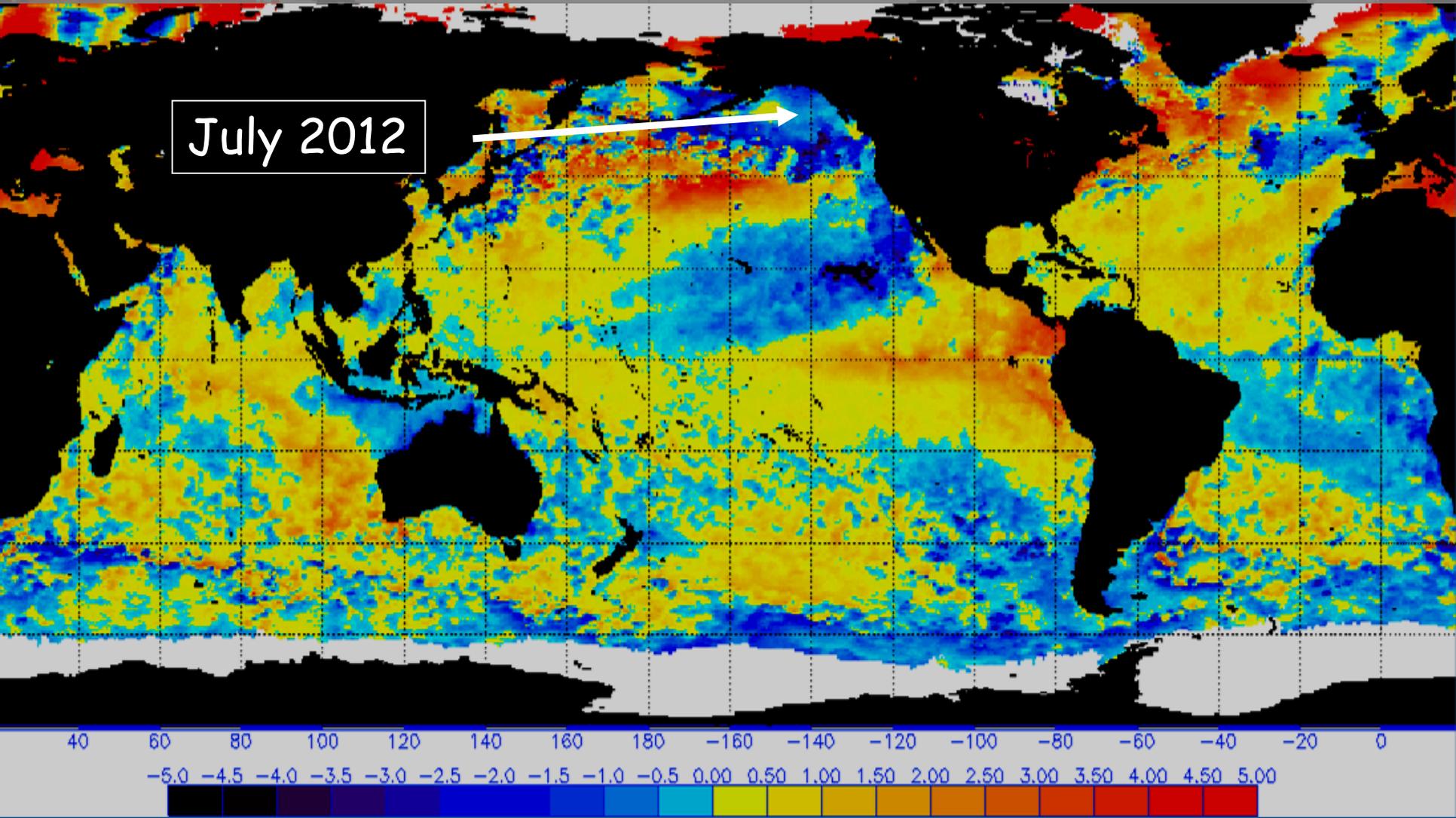


-5.0 -4.5 -4.0 -3.5 -3.0 -2.5 -2.0 -1.5 -1.0 -0.5 0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00

<http://www.osdpd.noaa.gov/PSB/EPS/SST/data/anomnight.7.12.2005.gif>



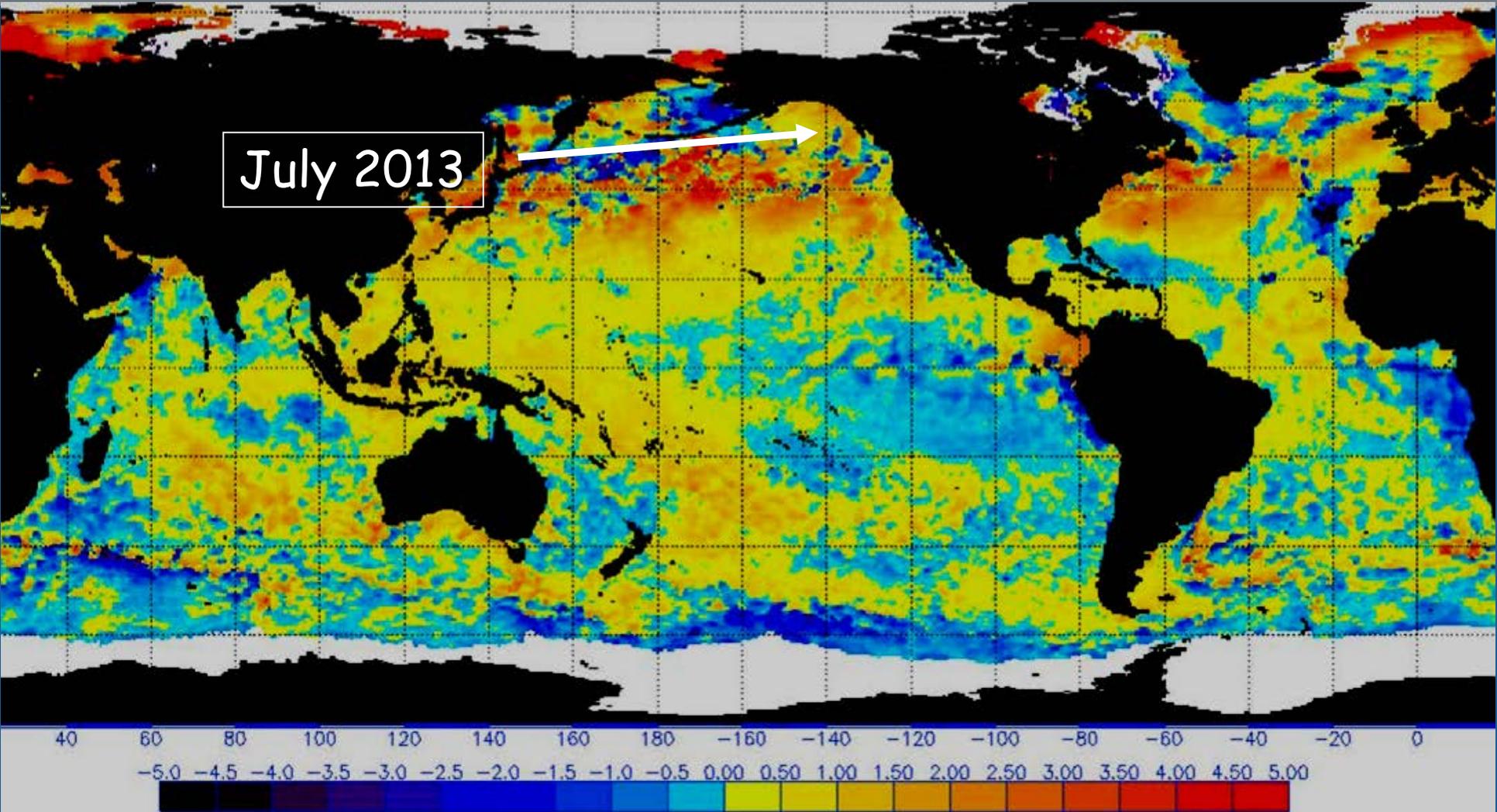
# Anomalously cold summer conditions in eastern GOA in 2012 (95 M in 2013)



<http://www.osdpd.noaa.gov/PSB/EPS/SST/data/anomnight.7.12.2012.gif>

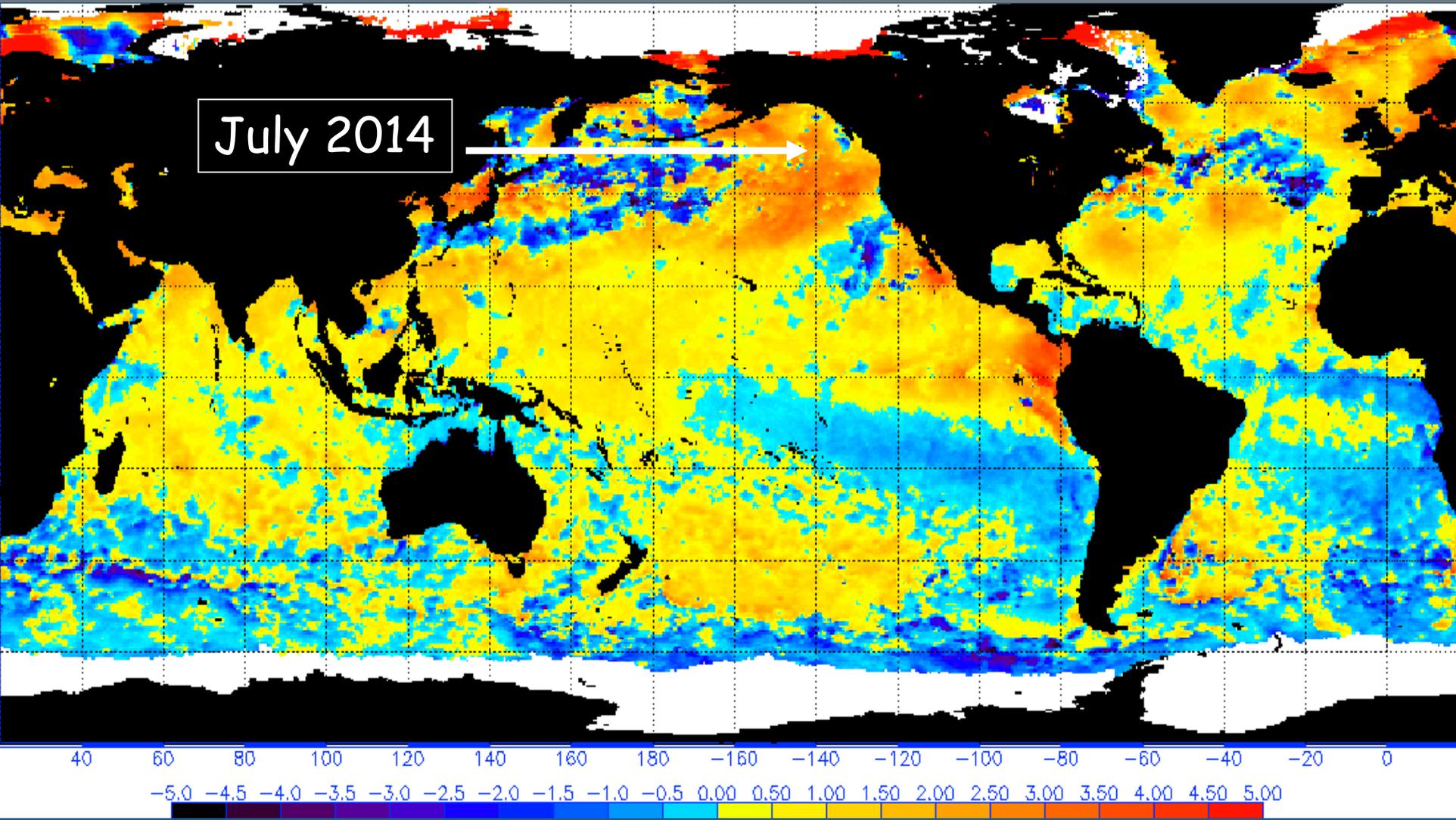


# Intermediate summer conditions in eastern GOA in 2013 (37 M in 2014)



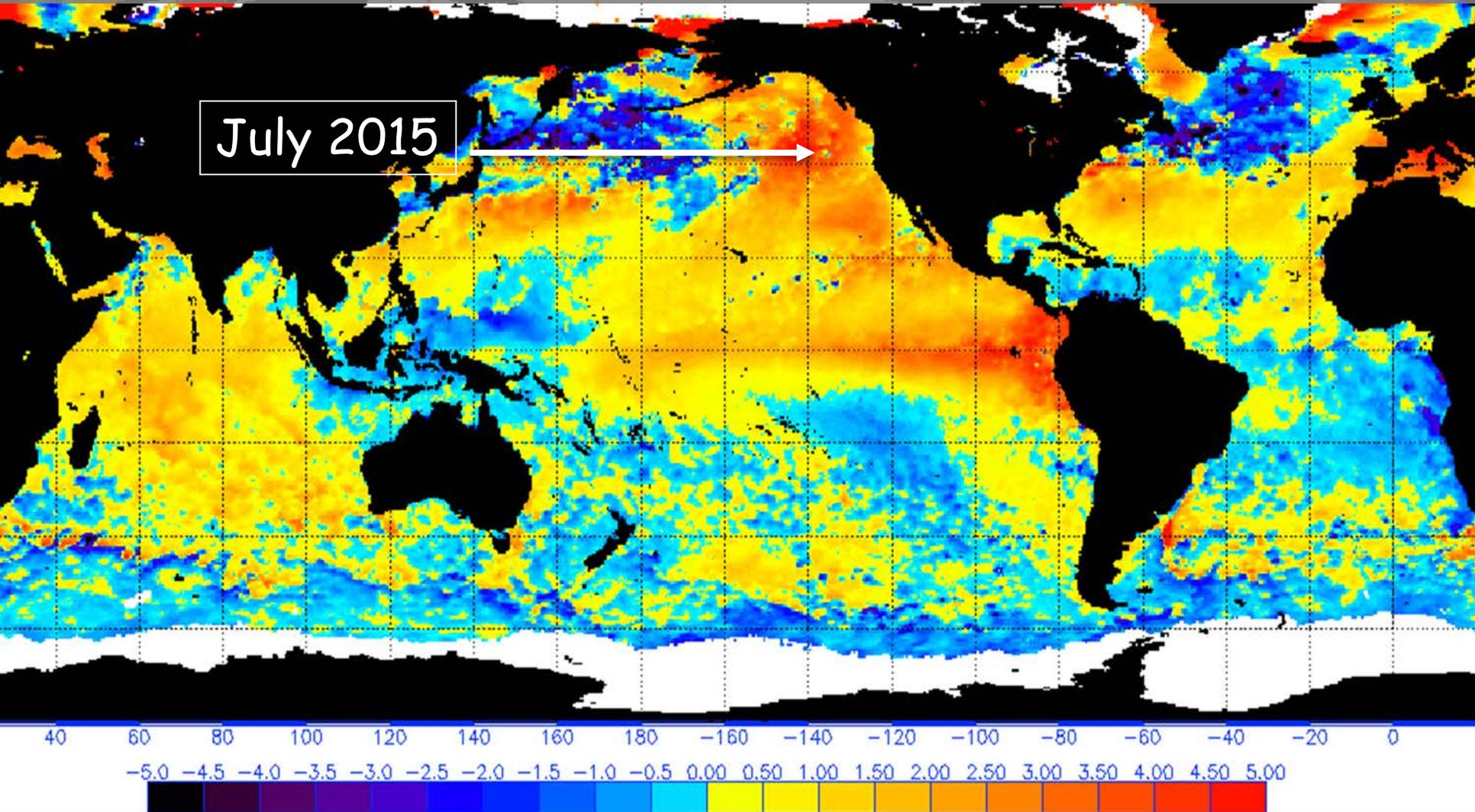
<http://www.ospo.noaa.gov/data/sst/anomaly/2013/anomnight.7.11.2013.gif>

# "Warm blob" summer conditions in eastern GOA in 2014 (34 M in 2015)



<http://www.ospo.noaa.gov/data/sst/anomaly/2014/anomnight.7.10.2014.gif>

# "Warm blob" summer conditions in eastern GOA in 2015 (?30 M? in 2016)



<http://www.ospo.noaa.gov/data/sst/anomaly/2015/anomnight.7.9.2015.gif>



# Conclusions:

- ❖ 30.4 M pink salmon harvest forecast SEAK 2016
- ❖ Juvenile pink salmon in Icy Strait in 2015 were "huge", early, and present in low-moderate #s
- ❖ Unclear what impacts El Niño conditions will have on an already warm Gulf of Alaska in term of salmon ocean survival - mixed history of returns
- ❖ Unknown ecological impacts of subtropical fish species (tuna, ocean sunfish, thresher sharks) in the GOA on pink salmon (competition/predation)
- ❖ After record harvest/escapements regionally in 2013, southern pink returns failed in 2015, suggesting negative impacts in the southern GOA

# We will update our NOAA pink salmon web pages soon...



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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.

**2015 NOAA Forecast**  
**54.5 million pink salmon**  
 with an 80% bootstrap  
 confidence interval of 48-58 M



**Juvenile and adult pink salmon captured during SECM sampling**

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.

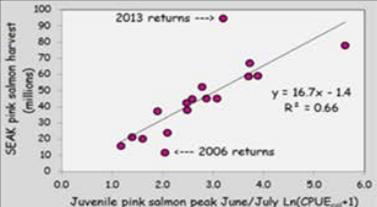
Fortunately, direct measures of juvenile pink salmon abundance at sea from SECM sampling have provided a powerful tool to improve forecasts. Juvenile salmon mortality is reported to be high and variable during their initial spring nearshore residency. Juvenile salmon mortality, which occurs later in 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 salmon in Icy Strait in June or July. Thus, summer juvenile pink salmon abundance in Icy Strait usually reflects the ensuing harvest of pink salmon to the region.

The SECM forecast models have performed well in 8 of the past 10 harvest years, giving estimates that averaged within 9% of actual harvests. However, the 2006 harvest was well below the forecast and the 2013 harvest was well above the forecast. Step-wise multiple regression models have been developed that include additional environmental parameters beyond CPUE if they significantly improve model fit and help to explain later ocean conditions that affect year class strength. The SECM preferred forecast for 2015 is based on a two parameter model with CPUE and a temperature index.



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



**Correlation of juvenile pink peak June or July CPUE and SEAK adult pink**

2013 returns -->

2006 returns <--

$y = 16.7x - 1.4$   
 $R^2 = 0.66$



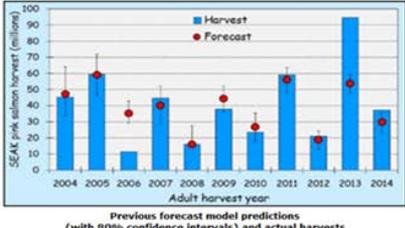
**SECM Forecasting Reports:**  
(NPAFC documents)

[2004-2007](#), [2008](#), [2009](#), [2010](#), [2011](#), [2012](#), [2013](#), [2014](#)



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**SEAK pink salmon harvest (millions)**

■ Harvest  
 ● Forecast

**Adult harvest year**

Previous forecast model predictions (with 80% confidence intervals) and actual harvests

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**Anadromous Fish**

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### EMA: Southeast Alaska Coastal Monitoring

Research conducted by EMA's Southeast Alaska Coastal Monitoring (SECM) project focuses on the study of juvenile salmon in the coastal waters of the Gulf of Alaska ecosystem. (Watch the streaming "What we do" video below.) This Auke Bay Laboratories project addresses key objectives of the [NOAA Fisheries Strategic Plan](#) and international science programs including the North Pacific Anadromous Fish Commission (NPAFC) and the North Pacific Research Board ([Gulf of Alaska Integrated Ecosystem Project](#)). Ecosystem metrics from SECM research are used to develop indexes and stock assessments for NOAA's annual [Ecosystem Consideration Report](#).

Primary SECM goals are to:

- Understand the early marine ecology and distribution of juvenile salmon and associated species
- Build time series of oceanographic and ecological indices for the coastal waters of Southeast Alaska
- Identify factors affecting salmon productivity (e.g., climate change, prey, abundance, and predators)
- Produce data sets to evaluate hatchery and wild stock interactions, and forecast regional adult salmon returns

SECM research was initiated in the spring of 1997, just prior to the onset of a strong El Niño event, and has continued annually. SECM sampling occurs around Icy Strait (58°N, 136°W) in the northern region and have been sustained for 18 years. This is a principal migration corridor for salmon that transit dynamic tidal and oceanographic features to offshore waters as juveniles and return in subsequent years as adults.

SECM researchers have compiled a multi-year time series of biophysical data associated with juvenile salmon culled from monthly sampling intervals in May, June, July, and August. Juvenile salmon and ecologically related species are sampled with a surface trawl and:

- Temperature and salinity profiles
- Surface nutrients and chlorophyll
- Zooplankton (upper 20-m and integrated)
- Size, abundance, and origin of salmon
- Potential predators of juvenile salmon

Some of these biophysical data are being used to [forecast pink salmon](#) returns to Southeast Alaska and to evaluate recent trends in commercial salmon harvest and ocean survival within the region. These analyses also explore the impact of large-scale, climate-driven processes on salmon year-class strength.



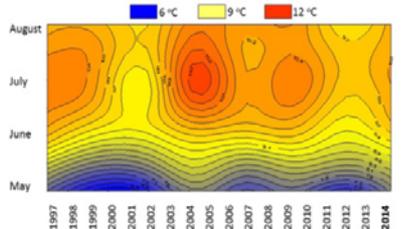
**Measuring water properties with a conductivity temperature-depth profiler**



**Sampling zooplankton with a tandem Bongo net in Icy Strait**



**Processing a fish catch after a surface trawl haul onboard a chartered vessel**



**Interannual variability of late spring and summer temperatures in the upper 20 m water column of Icy Strait, 1997-2014.**

Legend: 6°C (blue), 9°C (yellow), 12°C (red)

**SECM Introductory video: "What we do"**

## Videos on salmon ID and "what we do"!

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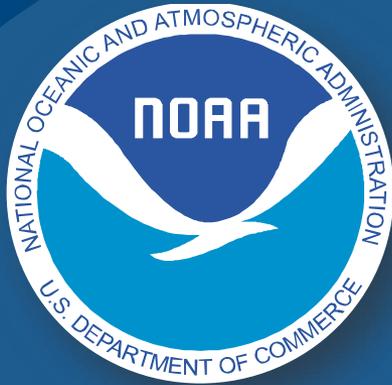
**Data Sets**



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MERRY CHRISTMAS!



17th Salmon Ocean Ecology Meeting  
Baranof Hotel, Juneau, Alaska 29-31 March 2016

