NOAA's 2017 Southeast Pink Salmon Forecast from Ecosystem Monitoring in Southeast Alaska

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

NOAA FISHERIES
Alaska Fisheries Science Center

Southeast Alaska Purse Seine Task Force Meeting
Juneau, Alaska, 01 December 2016

Presentation outline

- Overview ABL's Southeast Coastal Monitoring (SECM) project: 1997-2016
- Introduce ecosystem metrics considered for use in forecasting pink salmon harvest
- Review past model performances (2004-16) & present the 2017 NOAA pink forecast
- Discuss implications of later ocean conditions and new ecosystem metrics on 2017 forecast

We acknowledge "real time" data sharing by:

- A. Piston, S. Heinl, & L. Shaul (ADFG) for Adult pink and coho salmon production metrics
- J. Hurrel & A. Phillips (Climate and Global Dynamics) for the North Pacific Index
- J. Joyce & S. Vulstek (NOAA, AFSC) for wild pink salmon fry production from Auke Creek
- E. Di Lorenzo (National Science Foundation, US GOBLEC) for the North Pacific Gyre Oscillation
- S. Hatch (Institute for Seabird Research & Monitoring) for GOA Kittiwake productivity
- K. Lefebvre (NOAA, NWFS) for preliminary harmful algal bloom data from Icy Strait

2016 Alaska pink salmon disaster

August 2016

Rep. Louise Stutes, R-Kodiak, asks the Walker administration to declare the pink salmon season a disaster, which would open up access to federal relief funds. *"This is the worst salmon year in nearly 40 years, and that's huge… It doesn't just affect the fishermen"*

September 2016

Gov. Bill Walker, in his letter to U.S. Commerce Secretary Penny Pritzker, said poor pink salmon returns in Kodiak, Prince William Sound, Lower Cook Inlet and Chignik are having a *"significant impact on those who depend on the fishery for their livelihood."*

October 2016

State Sen. Bert Stedman successfully appealed to Gov. Walker to *add Southeast Alaska to the pink salmon disaster declaration* related to the 2016 poor pink salmon run.

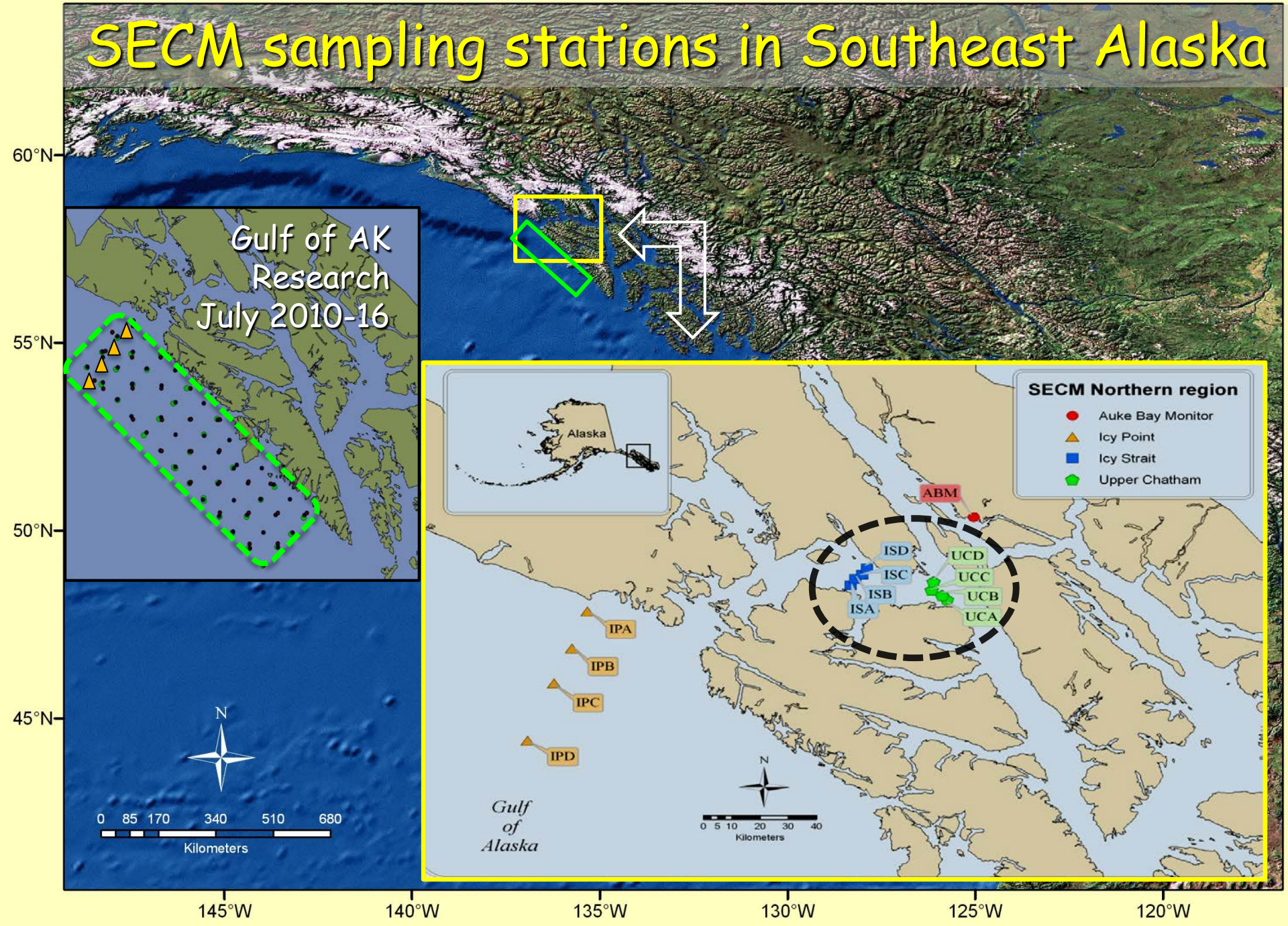
Petersburg Vessel Owners Assoc. Ex. Dir. Megan O'Neil: commented on the 2016 fishery in Southeast Alaska : *"wild pink salmon were off 47 percent from predictions…$14 M in lost revenue"*

November 2016…..Current Status

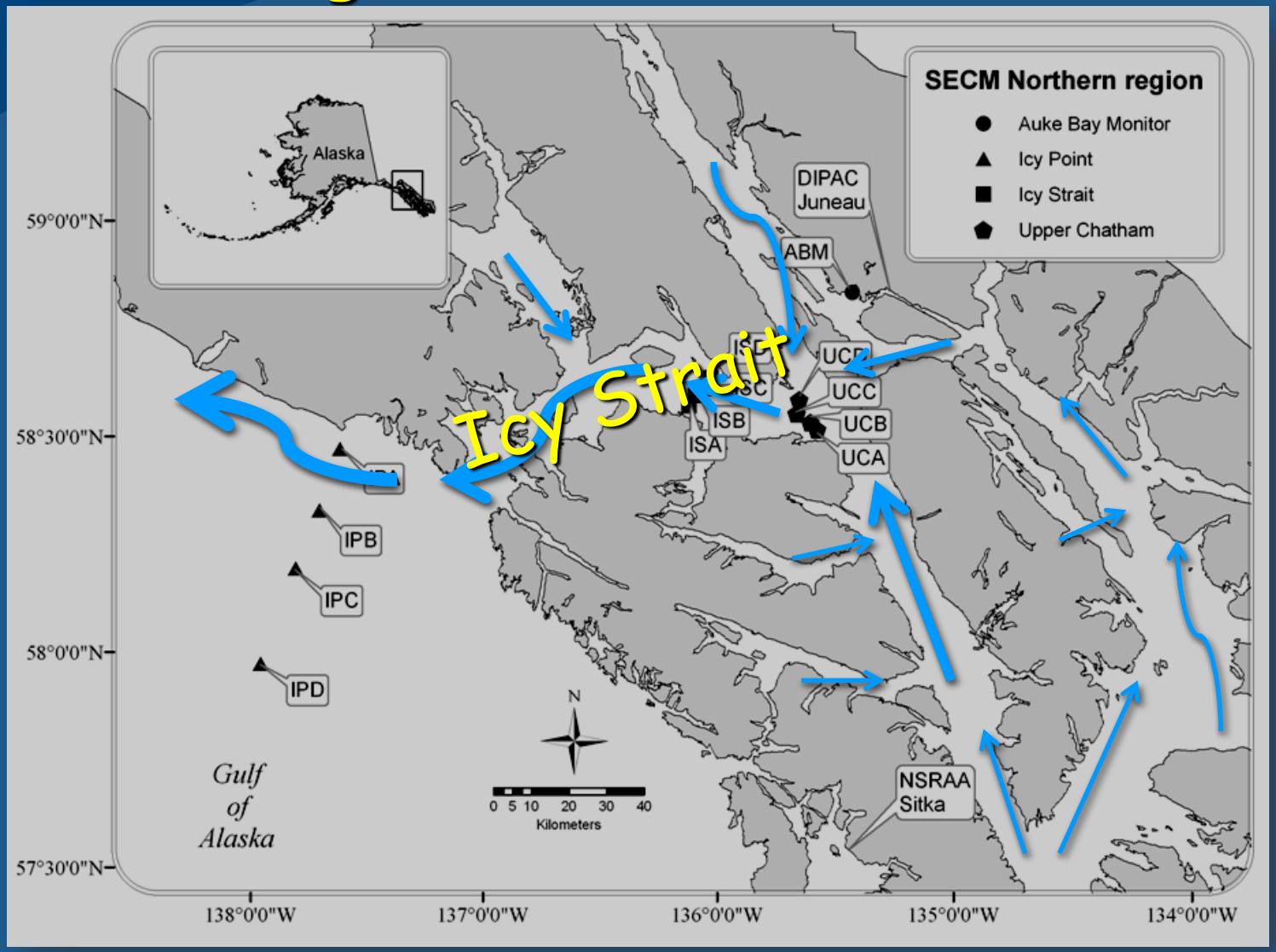
NOAA Gretchen Harrington indicated "NMFS AK Region works with the State and AFSC to determine if conditions for com. fish failure due to a fishery resource disaster exist. NMFS AK Reg makes recommendation to NOAA who then makes a recommendation to the Sec. of Comm., who then makes a determination and notifies the State and Congress… process can take over one year"

Southeast Alaska Coastal Monitoring (SECM) monthly sampling: May-Aug, 1997-2016

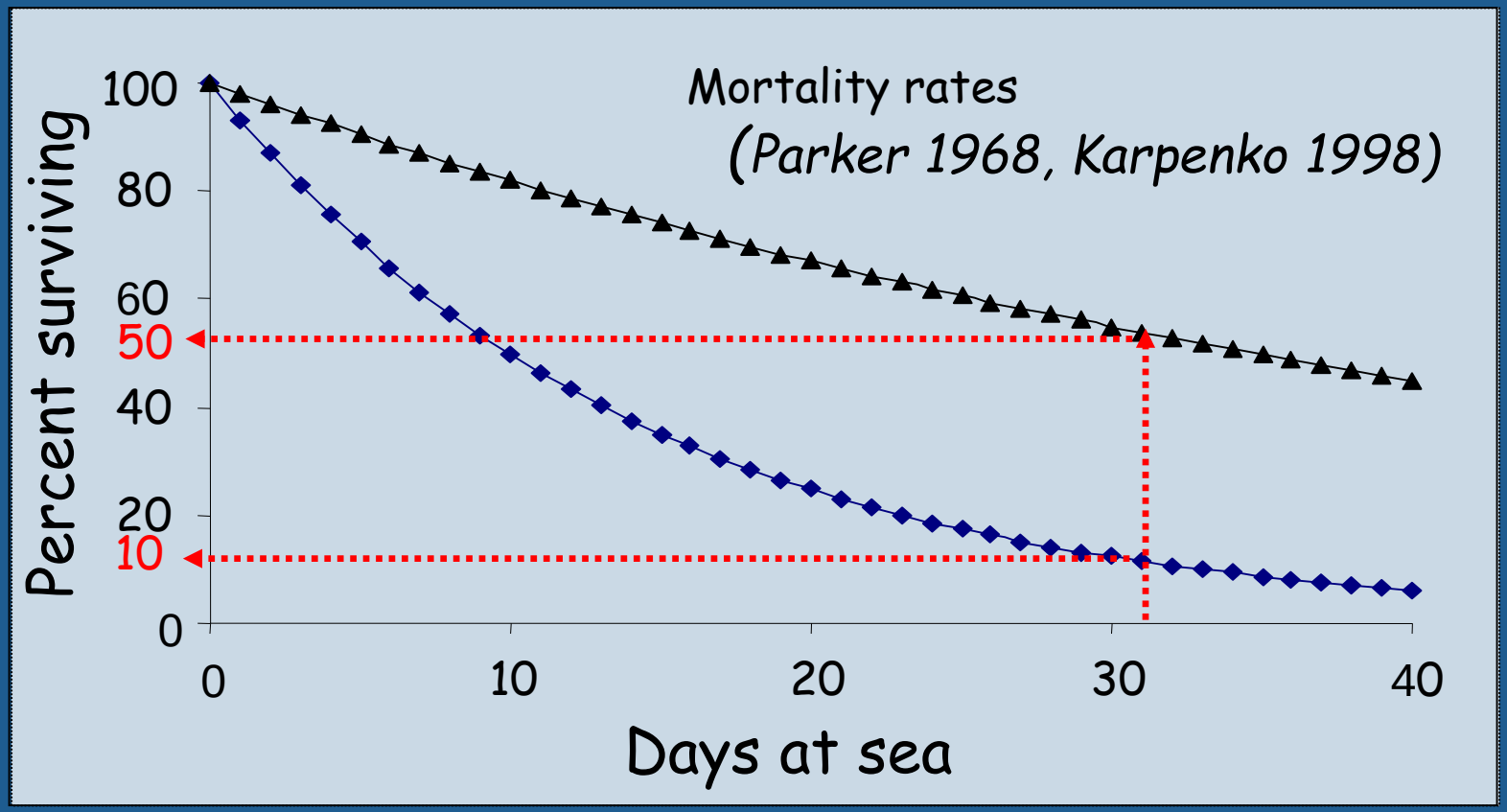
SECM sampling stations in Southeast Alaska



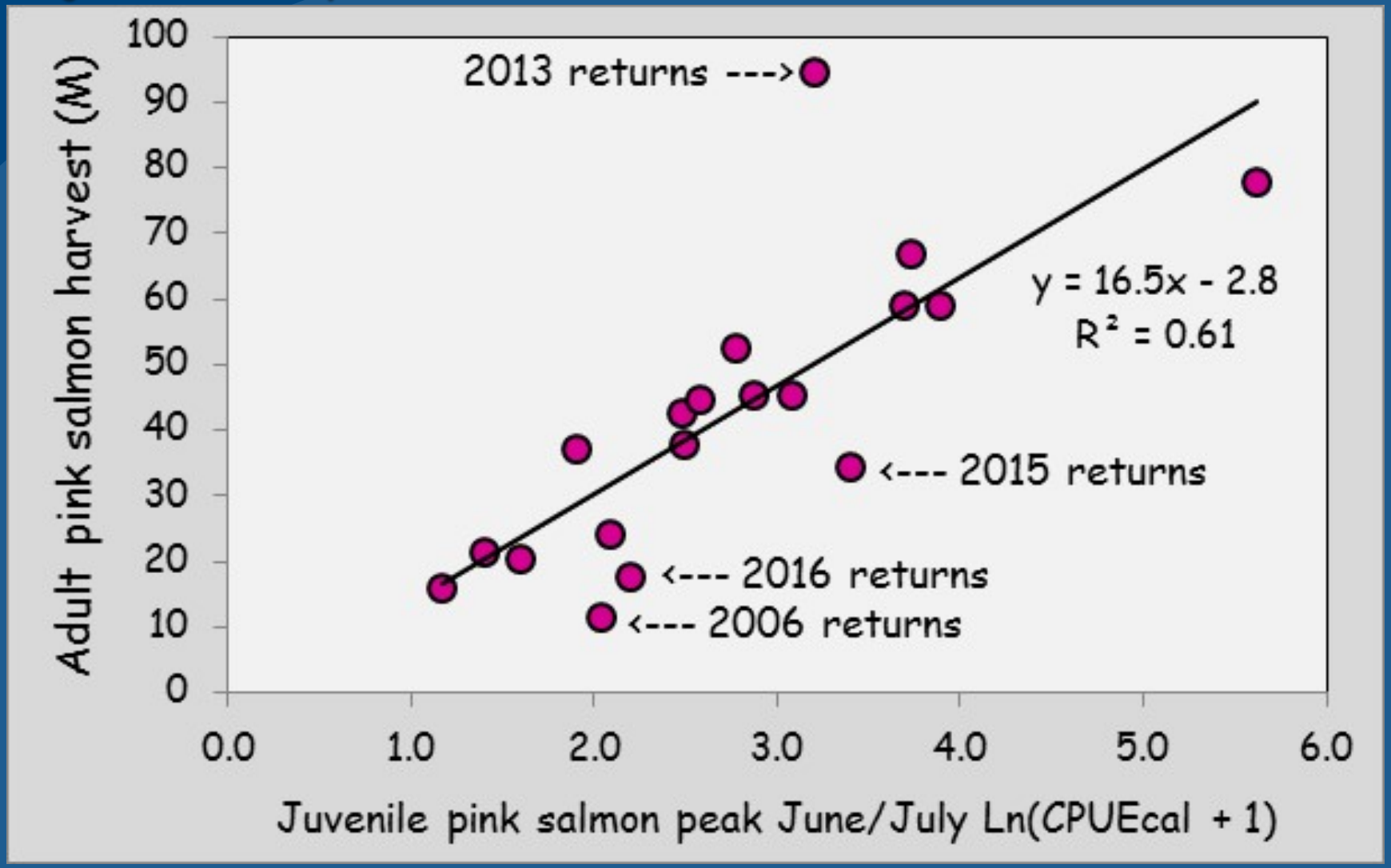
SECM project stations along a primary seaward migration corridor in Southeast



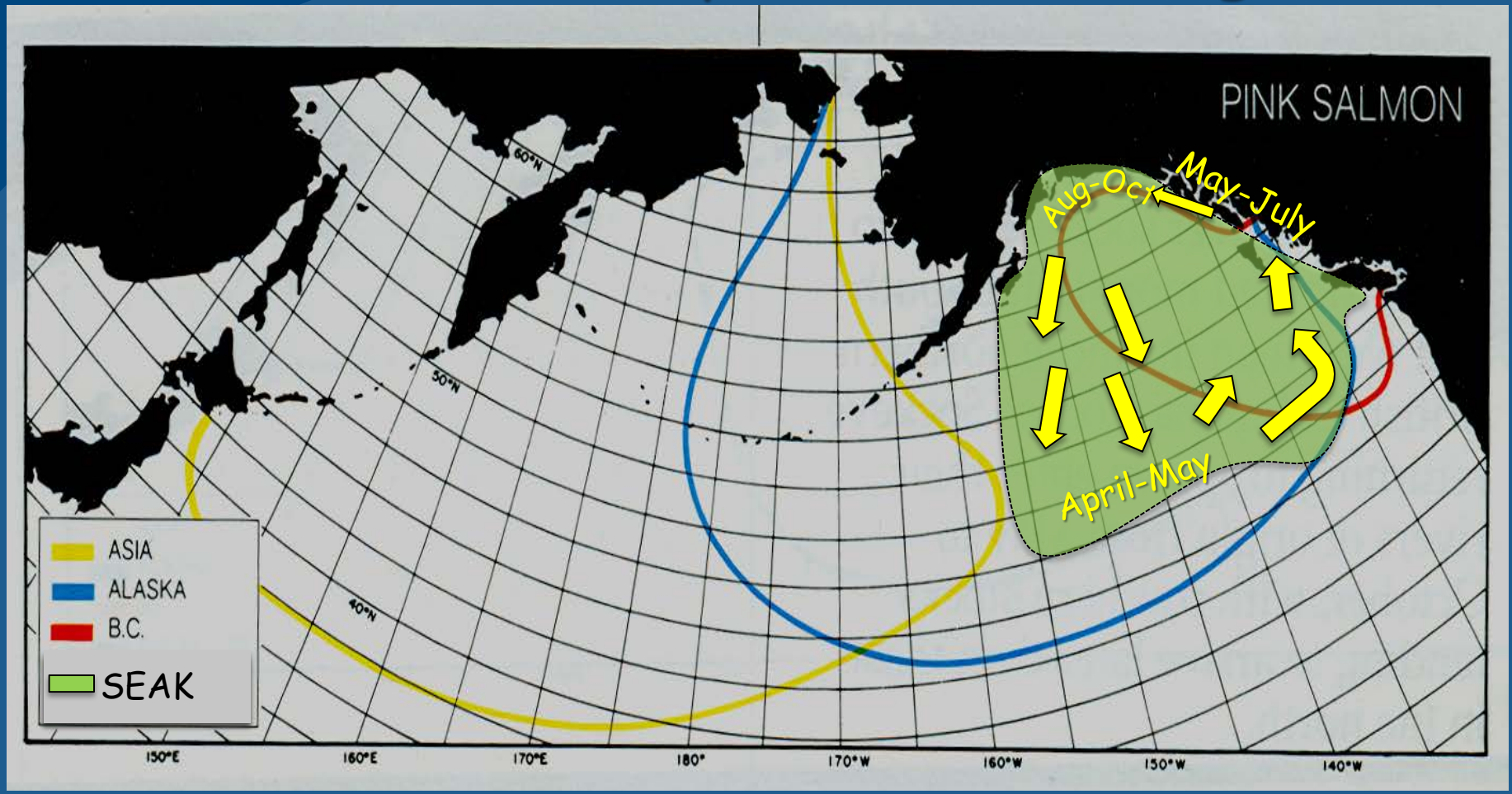
Paradigm of pink salmon biology:
Mortality during early marine life is high, variable, and impacts year class strength



Strong relationship most years with SECM juvenile pink catch & harvest 1997-2016



Generalized ocean distribution of pink salmon
Southeast Alaska pinks shaded in green



http://www.pac.dfo-mpo.gc.ca/fm-gp/species-especes/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

Temps ↑ ? ↑

Predators ↑ ?

Competitors ↑ ?

Prey QQ ↓ ?

Migration ← ? →

Toxins ↑ ?

Harvest

Optimal spawners, water flow, snow cover

Freshwater

Low predation, cool temps in fall/winter

N. Pacific Ocean

Warm Spring, good mixing, nutrients, light

Estuarine

Optimal entry time to continental shelf

Gulf of AK

Rapid offshore fry movement

Nearshore

SECM sampling

High juvenile abundance/distribution

Strait - Coastal

SECM ecosystem metrics considered

Physical data

Zooplankton biomass/diet

Catches (CPUE)

Size & growth

Stock comp

Predation

Selected biophysical factors considered for forecasting Southeast pink salmon harvest

Biological (region)

J-pink salmon: Peak $CPUE_{cal\ \&\ ttd}$, 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, $P < 0.05$

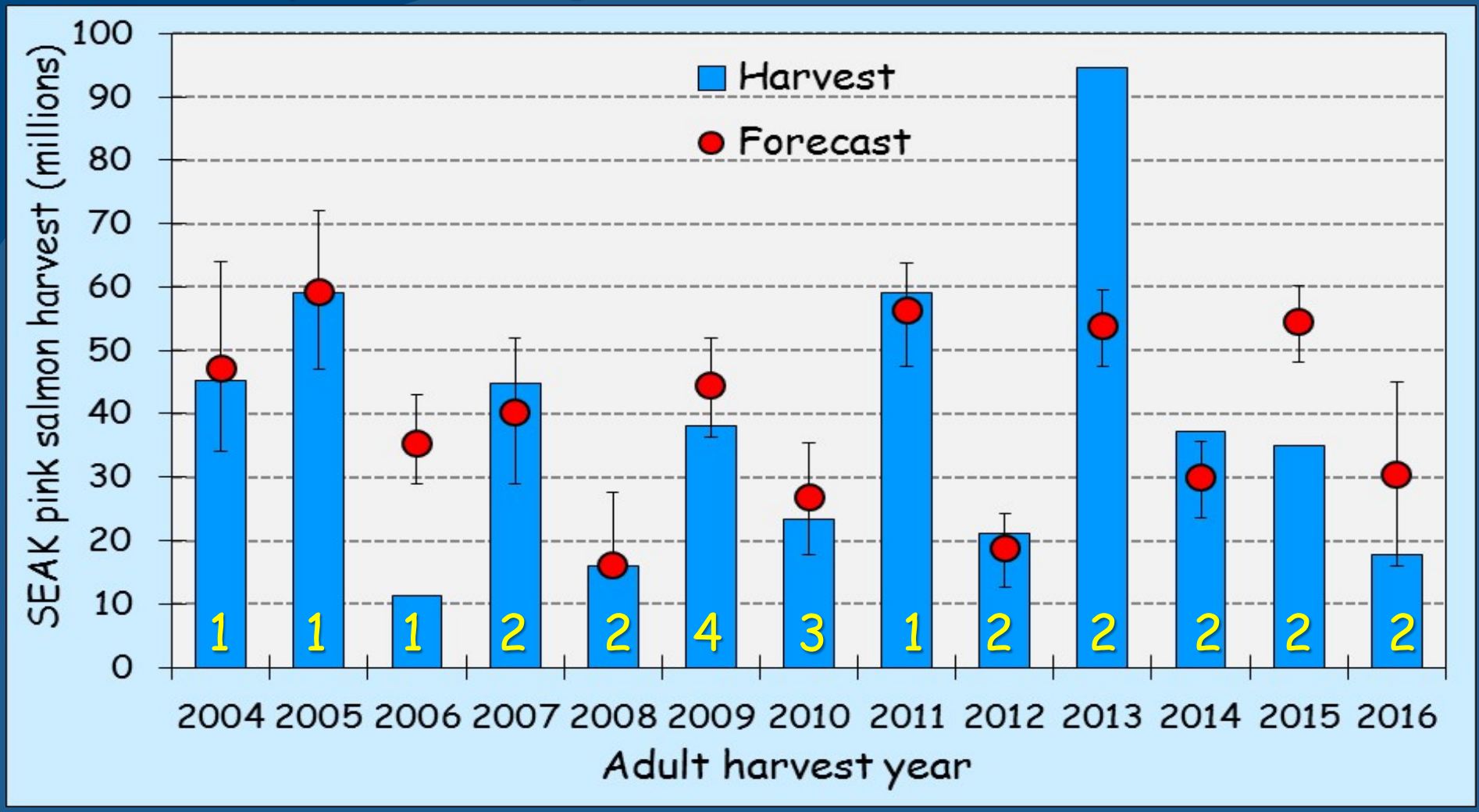
2) Use corrected Akiake Information Criteria (AIC_c) to check for "over parameterization"

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 2004-2016:

In 9 of 13 years, average forecast deviation <10% of harvest



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

SECM sampling results for 2016

All field work accomplished: Oceanographic sampling on RV *Sashin* in May, & trawl and oceanographic sampling conducted by the chartered FV *Northwest Explorer* in June, July, and August

FAVORABLE juvenile pink CPUE metrics & early seaward migration timing

FAVORABLE high proportion of pinks in catch & low coho predation index

BEST North Pacific Index over the 20 SECM years

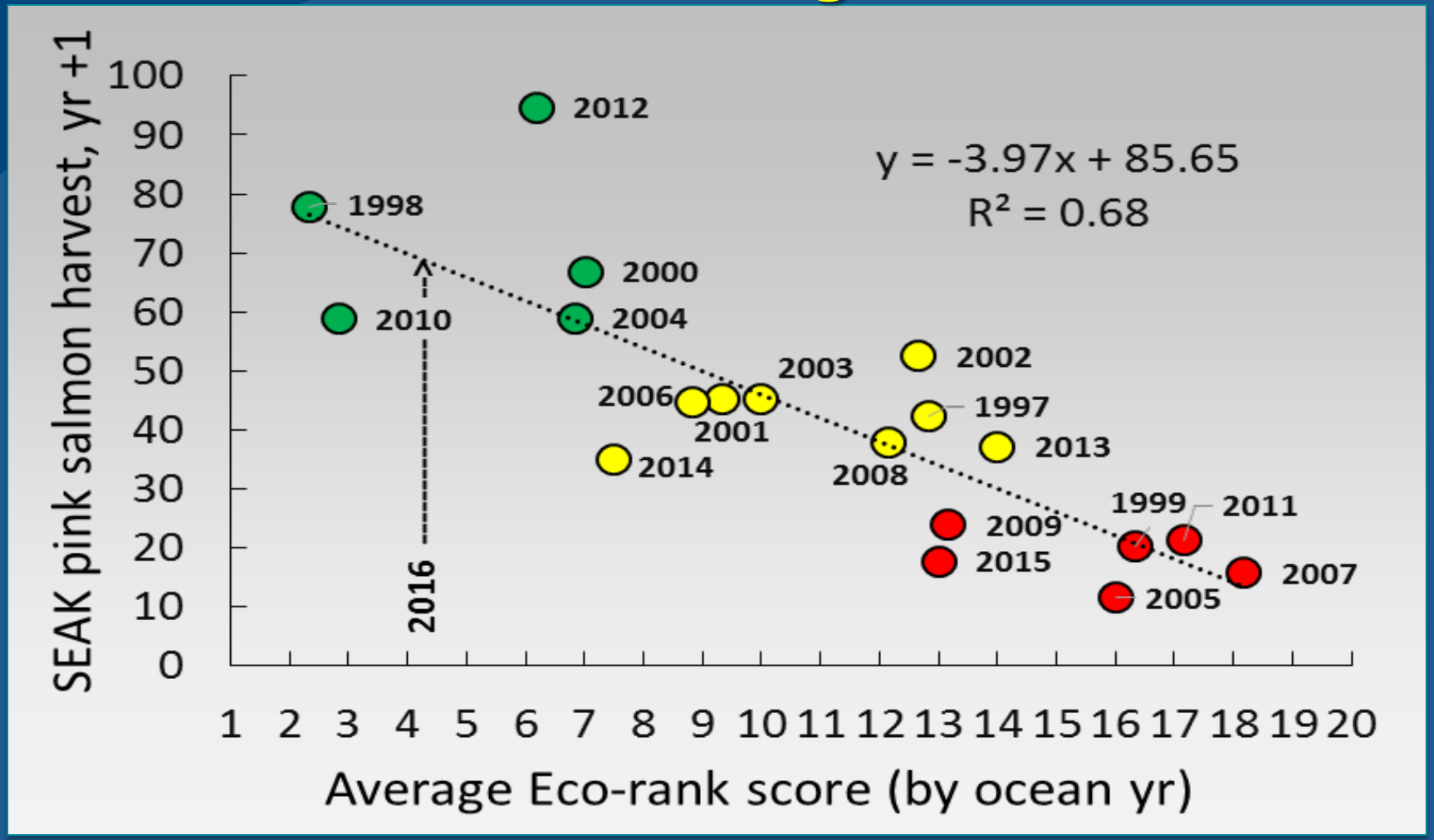
WARMEST Upper 20-m temps MJJA Icy Strait

Primary research data and ecosystem metrics used for NOAA pink salmon forecasts for Southeast Alaska. Details on column letter fields on next page.

PARENT pink salmon brood year					Chronological BIOLOGICAL and OCEAN ecosystem variables											FORECAST	ANNUAL RANK		HARVEST	
	ADULT BROOD YEAR					FRY	JUVENILE SECM DATA					STRAIT	OCEAN			ACCURACY	RANK of 6 sig. variables		pink salmon	
	A	B	C	D		E	F	G	H	I	J	K	L	M		N	O		P	
Brood year (BY)	SEAK pink salmon harvest (M)	(% northern in SEAK harvest)	SEAK pink salmon escapement index	(% northern in total SEAK index)	Ocean entry year (BY lagged 1 yr later)	Auke Creek fry outmigration (1,000s) Latitude 58°N, near Juneau	Juvenile peak pink (CAL) CPUE June or July	Juvenile peak pink (TTD) CPUE June or July	Peak seaward migration month	Proportion of pink in trail hauls in June-July-Aug	Adult coho predation impact Coho total #s/J-pink CPUE	Upper 1-20 m avg. Icy Strait temperature "ISTI" May, June, July and August	North Pacific Grye Ocillation (March, April, May)	North Pacific Index (- 1000) (June, July, Aug)	SeaBird productivity in the Gulf of Alaska kittiwake chicks/nest on Middletone Is.	NOAA forcast deviations from harvest in millions (-red=forecast too high, +greeen= forecast too low)	*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)
Year 0	Harvest		Escapement		Year 1	Fry	Juvenile					Temps	Ocean basin			Year 2			Production	
Data source	$ADFG_1$	$ADFG_1$	$ADFG_2$	ADFG		$NOAA_1$	$NOAA_2$	$NOAA_2$	$NOAA_2$	$NOAA_2$	$NOAA_2$ $ADFG_3$	$NOAA_2$	$NPGO_4$	CGD_5	$ISRC_5$	$NOAA_2$	↓	↓		$ADFG_1$
1996	64.6	34%	18.1	17%	1997	31.1	2.5	2.2	July	17%	1.5	9.5	-0.7	15.6	0.32	na	*12.8*	13	1998	42.4
1997	28.9	60%	14.8	47%	1998	60.8	**5.6**	**5.3**	June	42%	**0.8**	9.7	0.6	18.1	0.36	na	*2.3*	1	1999	77.8
1998	42.4	51%	14.3	44%	1999	53.5	1.6	1.4	July	**10%**	3.9	9.0	1.7	15.8	0.21	na	*16.3*	18	2000	20.2
1999	77.8	59%	**27.3**	50%	2000	132.1	3.7	3.3	July	25%	1.0	9.0	**2.2**	16.9	0.99	na	*7.0*	6	2001	67.0
2000	20.2	50%	10.8	39%	2001	61.5	2.9	2.6	July	28%	2.0	9.5	2.2	16.8	1.03	na	*9.3*	9	2002	45.3
2001	67.0	41%	18.6	22%	2002	150.1	2.8	2.5	July	26%	2.5	8.6	1.3	15.6	0.97	na	*12.7*	12	2003	52.5
2002	45.3	47%	16.6	49%	2003	95.1	3.1	2.7	July	22%	1.8	9.8	1.2	16.1	0.50	-2	*10.0*	10	2004	45.3
2003	52.5	51%	20.0	44%	2004	**169.6**	3.9	3.4	June	31%	1.4	9.7	0.2	15.1	0.18	0	*6.8*	5	2005	59.1
2004	45.3	47%	15.7	54%	2005	87.9	2.0	1.7	Aug	26%	3.3	10.2	**-1.3**	15.5	0.37	-24	*16.0*	17	2006	11.6
2005	59.1	53%	19.9	51%	2006	65.9	2.6	2.3	June	26%	1.9	8.9	-0.5	17.0	0.47	+5	*8.8*	8	2007	44.8
2006	**11.6**	58%	10.2	72%	2007	81.9	**1.2**	**1.0**	Aug	15%	3.7	9.3	0.1	15.7	0.42	0	*18.2*	20	2008	15.9
2007	44.8	40%	17.6	29%	2008	117.6	2.5	2.2	Aug	29%	2.1	**8.2**	1.5	16.1	0.78	-6	*12.2*	11	2009	38.0
2008	15.9	34%	**9.5**	14%	2009	34.8	2.1	2.7	Aug	27%	1.7	9.5	0.4	**15.1**	0.20	-3	*13.2*	15	2010	24.0
2009	38.0	43%	12.7	31%	2010	121.6	3.7	5.0	June	**61%**	0.9	9.6	1.6	17.6	0.78	+3	*2.8*	2	2011	58.9
2010	24.0	47%	11.2	43%	2011	30.9	1.3	1.6	Aug	25%	**4.1**	8.9	1.1	15.7	0.50	+3	*17.2*	19	2012	21.3
2011	58.9	61%	14.3	**81%**	2012	61.8	3.2	4.3	July	48%	1.1	8.7	1.6	16.7	0.87	+41	*6.2*	4	2013	94.7
2012	21.3	41%	11.0	13%	2013	51.2	1.9	2.6	July	13%	2.9	9.2	0.7	16.0	1.00	+7	*14.0*	16	2014	37.2
2013	**94.7**	43%	25.2	44%	2014	47.4	3.4	4.6	July	53%	2.0	9.4	-0.3	15.8	0.45	-19	*7.5*	7	2015	35.1
2014	37.2	**30%**	13.8	**11%**	2015	**14.2**	2.2	1.8	June	19%	2.6	9.9	-1.2	15.7	0.21	-13	*13.0*	14	2016	17.8
2015	35.1	**64%**	11.2	64%	**2016**	100.1	3.9	3.1	June	50%	1.6	**10.3**	0.0	**18.9**	**0.08**	?	*4.2*	3	2017	?
				Bivariate 2017 harv. predictions			*61 M*	*47 M*	*57 M*	*62 M*	*53 M*		*37 M*	*88 M*	*27 M*	→	*65 M*			
Harvest correlations	0.34	0.30	0.31	0.50		0.37	**0.78**	**0.76**	**-0.50**	**0.56**	**-0.80**	-0.24	0.45	**0.62**	0.44	→	**-0.86**	Pearson correlation "r"		
Probability value=	0.15	0.20	0.19	0.03*		0.12	**0.00***	**0.00***	**0.03***	**0.01***	**0.00***	0.32	0.05	**0.01***	0.06	→	**0.00***	(* = significant @ p<0.05)		

Data sources: ADFG (S. Heinl$_1$, A. Piston$_2$, and L. Shaul$_3$); NPGO=North Pacific Gyre Ocillation (E. Di Lorenzo, http://www.o3d.org/npgo/); CGD = Climate & Global Dynamics (J. Hurrell, http://www.cgd.ucar.edu/cas/jhurrell/indices.data.html), & NOAA Auke Bay Laboratories (J. Joyce$_1$ - Auke Creek research station & E. Fergusson/J. Orsi$_2$ - Southeast Coastal Monitoring project); ISRC = Institute for Seabird Research and Conservation (S. Hatch$_6$).

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



2016 ocean conditions = 69 M harvest in 2017

2017 pink salmon forecast models

Models considered	Regre. *P* value	Adj. R^2	AIC_c	Jack-knife % [error] avg/median	Prediction for 2017 (80% CI)
Eco-rank (6 variables)	< 0.001	67%	150.0	29/20	69 M
$CPUE_{cal}$	< 0.001	59%	156.0	31/14	61.4
Eco-rank + May temp	< 0.001	**79%**	**150.0**	28/26	55.9 M (40-72)
$CPUE_{cal}$ + ISTI	< 0.001	71%	156.0	**22/18**	**46.2 M (28-64)**

Implications of later ocean conditions and new ecosystem metrics on forecast

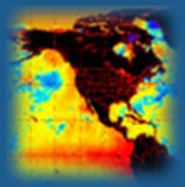
egg → fry → juvenile → adult → egg

Juvenile CPUE & growth?

Later ocean conditions?

Adult production?

Climate?



Prey?

Competitors?

Predators?

Later ocean conditions in 2016?

- North Pacific Index -
- North Pacific Gyre Oscillation -
- Juvenile pink salmon GOA abundance -
- Seabird productivity in the GOA -
- Post-BLOB ocean temps –
- Harmful algal blooms -

Later ocean conditions in 2016?

- North Pacific Index - positive conditions in the North Pacific Ocean in summer

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Later ocean conditions in 2016?

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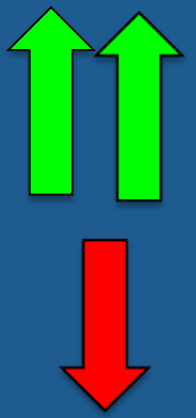
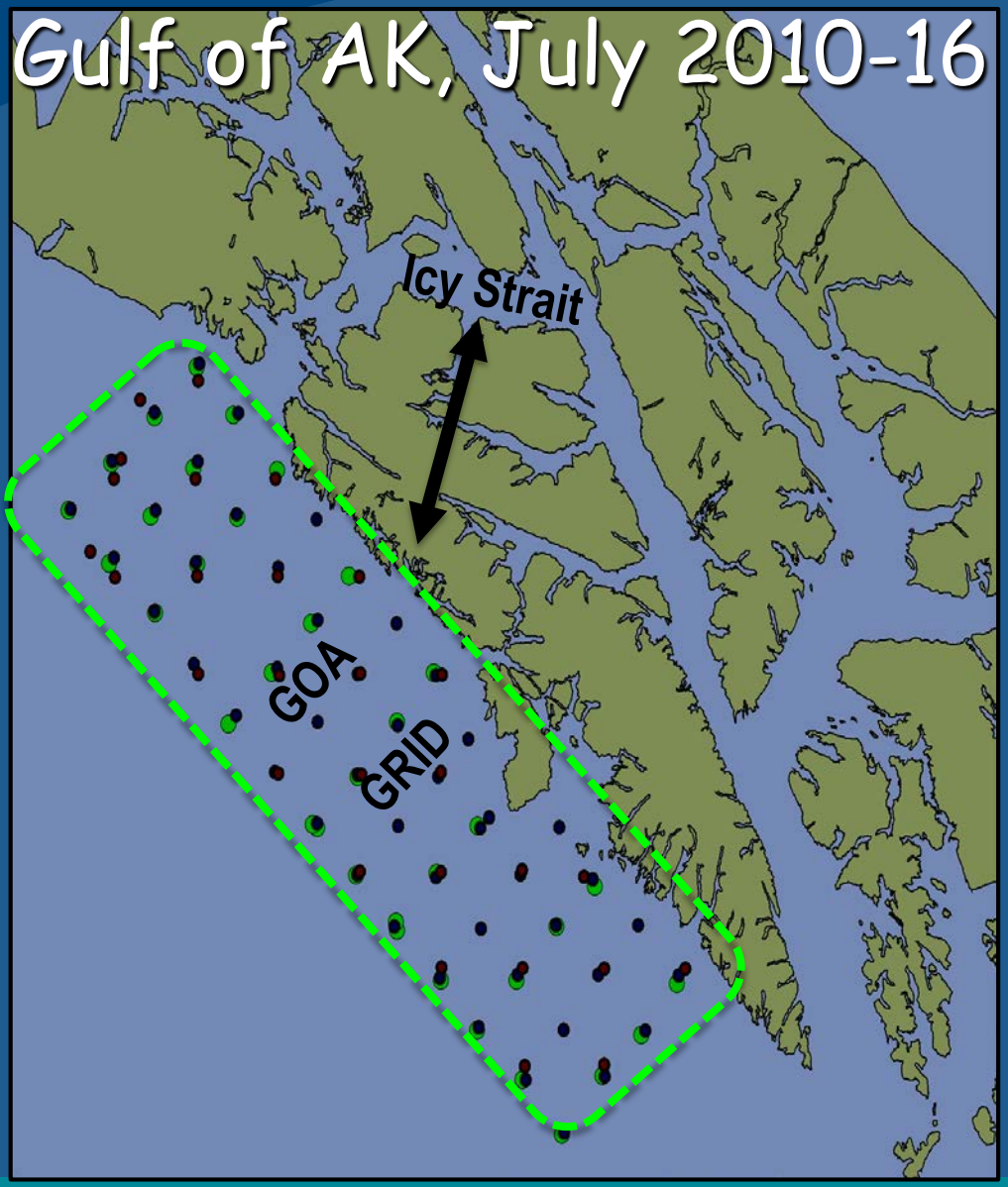
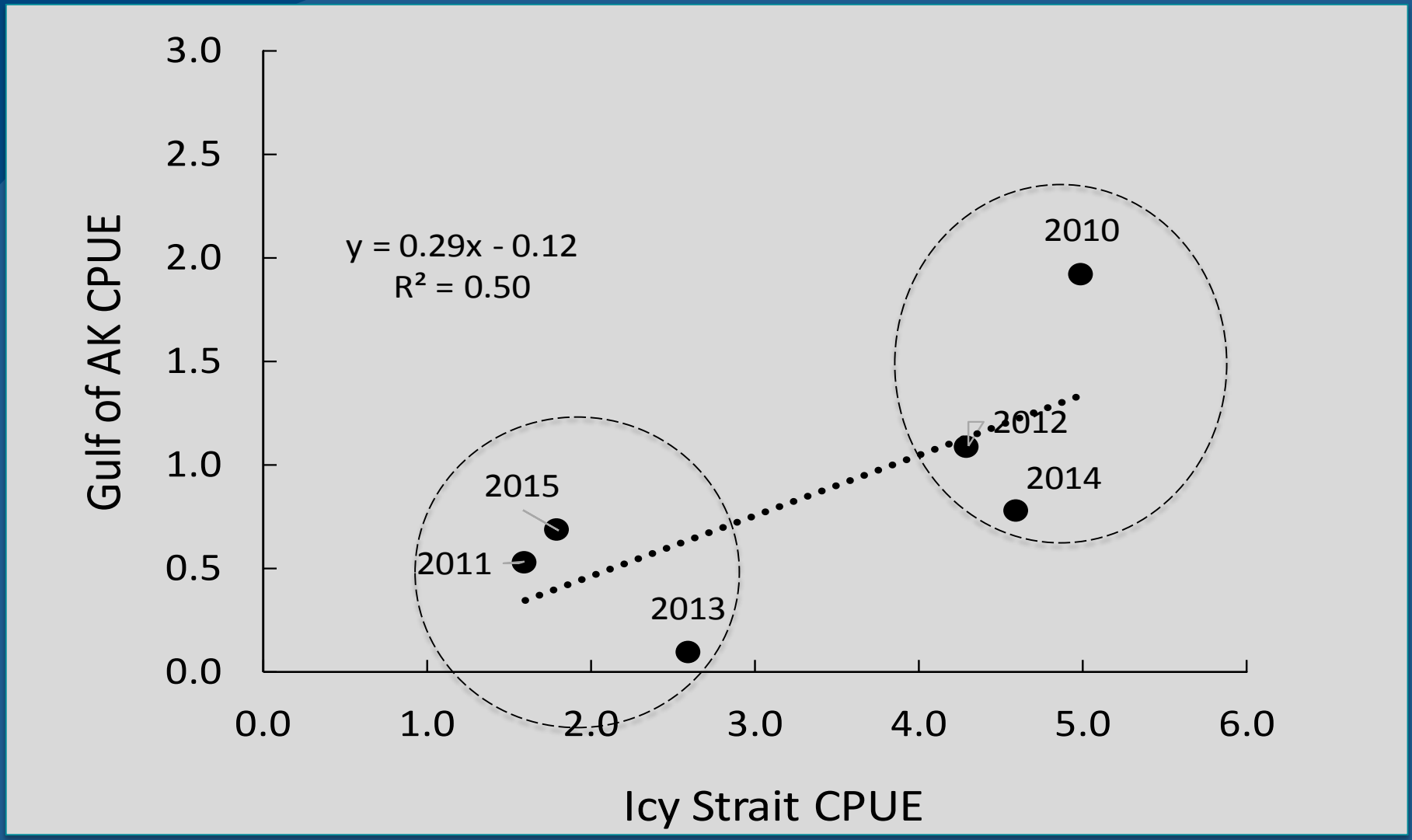


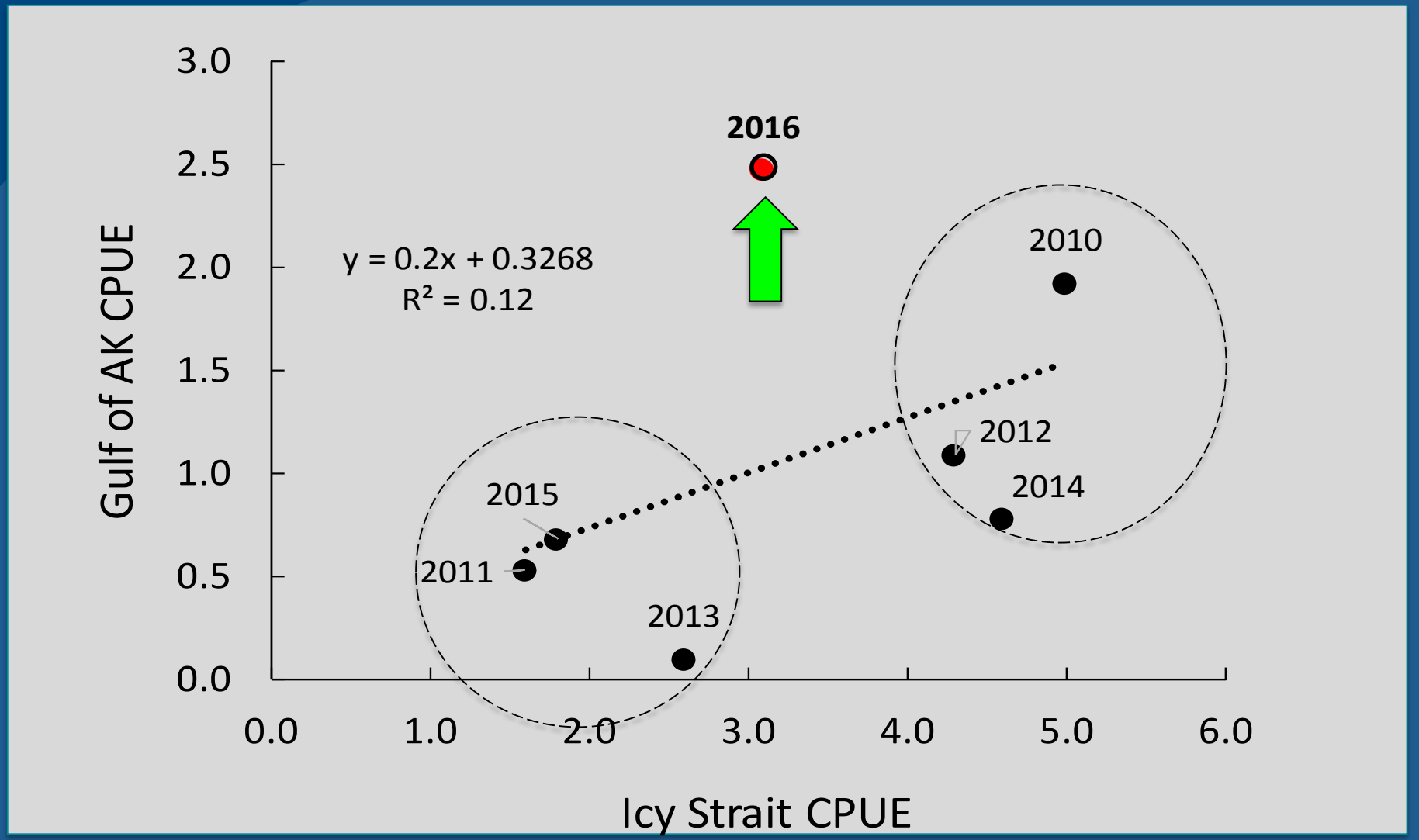
Juv. pink CPUE: Icy Strait vs. Gulf of AK



Icy Strait vs. Gulf of AK juv. pink catches 2010-2015 (Per. Cor. value 0.73, P-value 0.10)



Icy Strait vs. Gulf of AK juv. pink catches 2010-2016 (Per. Cor. value 0.44, P-value 0.33)



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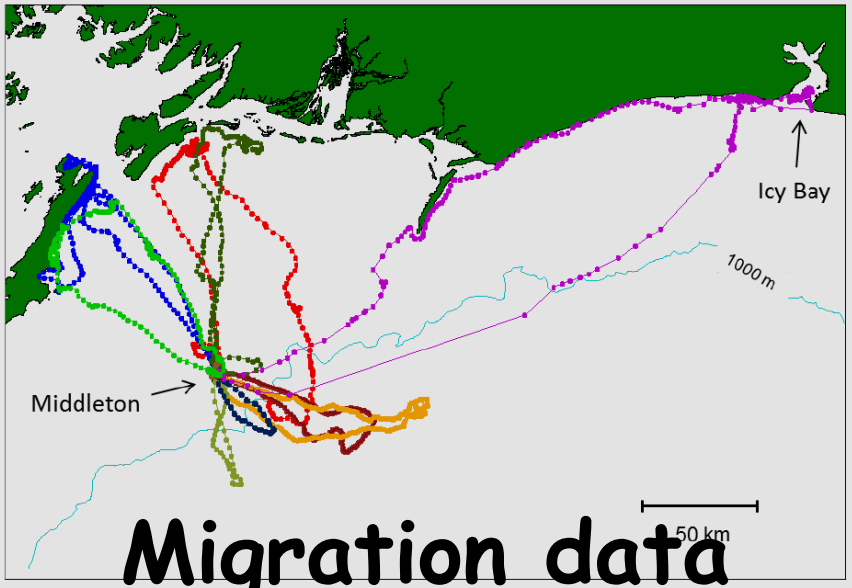
- Seabird productivity in the GOA -
- Post-BLOB ocean temps –
- Harmful algal blooms -

Middleton Island kittiwake productivity data 1997-2016, courtesy of Scott Hatch, Institute for Seabird Res. & Conservation

Institute for Seabird Research and Conservation

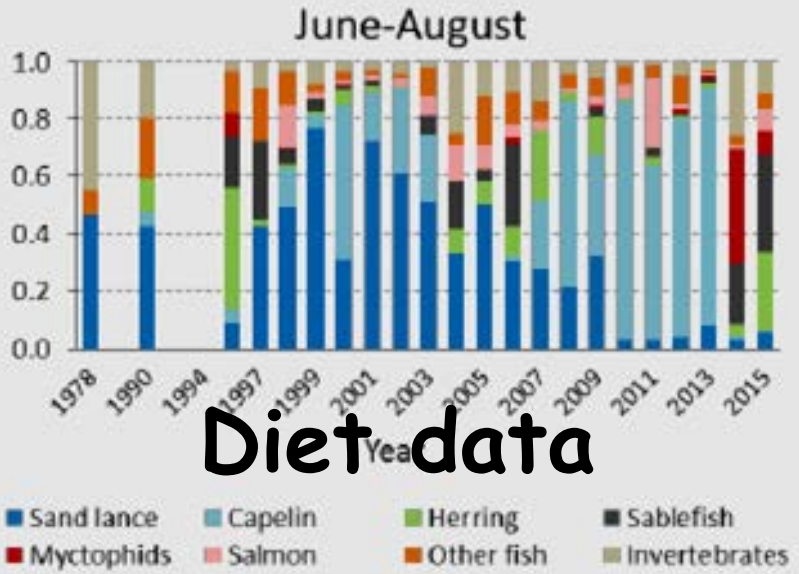
Middleton Island Seabird Research and Monitoring

2015 Field Report



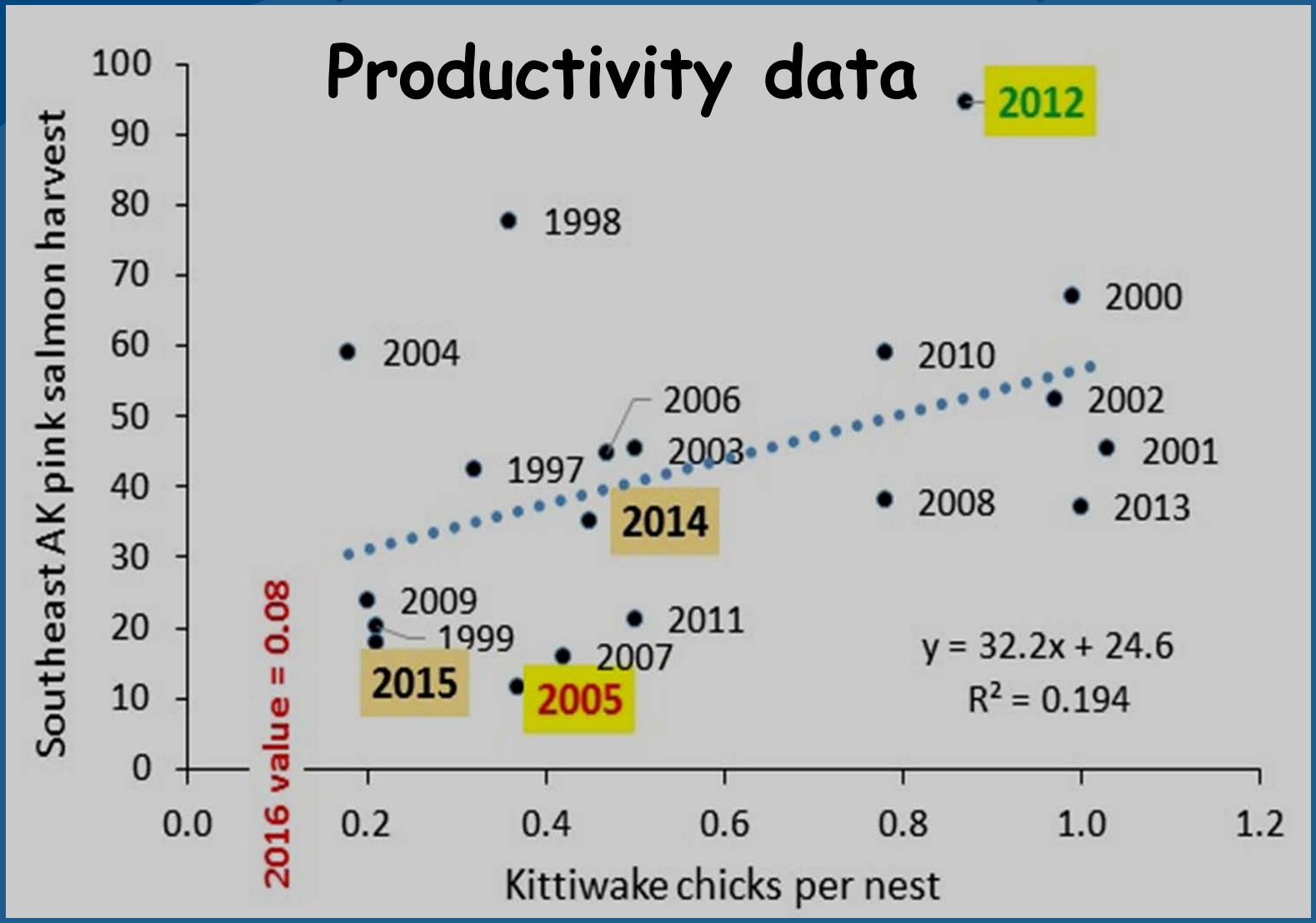
Migration data

Fig 5. Routes taken during 9 foraging trips by black-legged kittiwakes fitted with GPS tracking devices at the Middleton tower colony during July 2015. All birds were unfed breeders with chicks concurrently in the nest.



Diet data

Kittiwake chicks per nest (y) vs. Southeast Alaska pink salmon harvest (y + 1)



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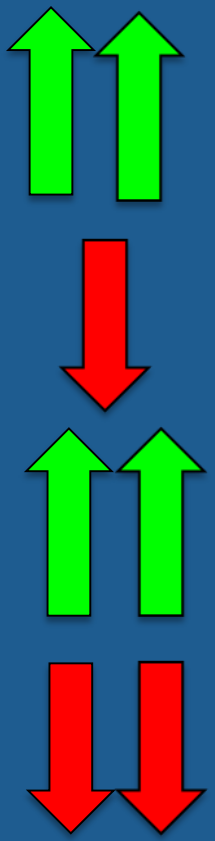
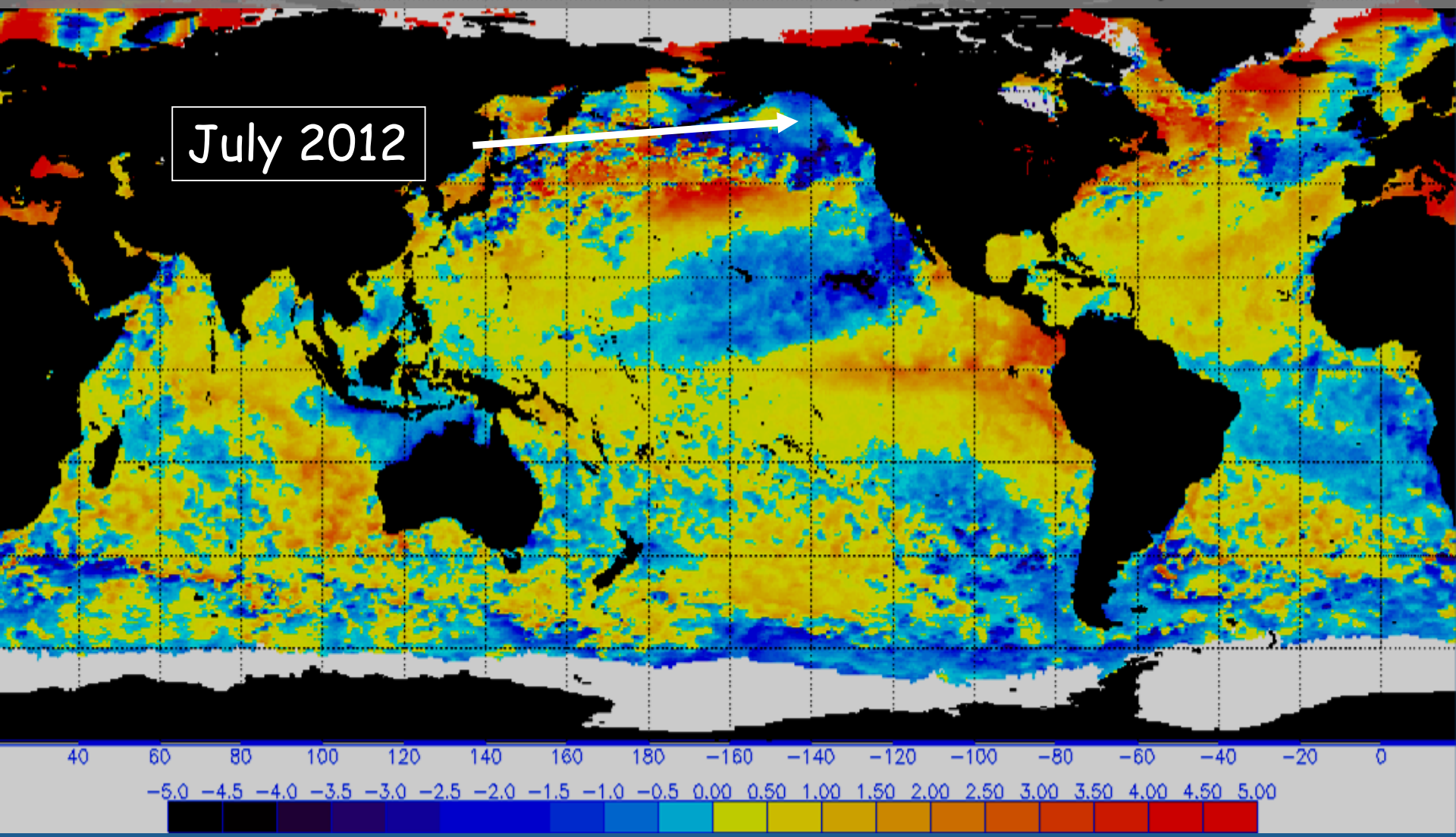


Anomalously warm summer conditions in eastern GOA in 2005 (12 M in 2006)

−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

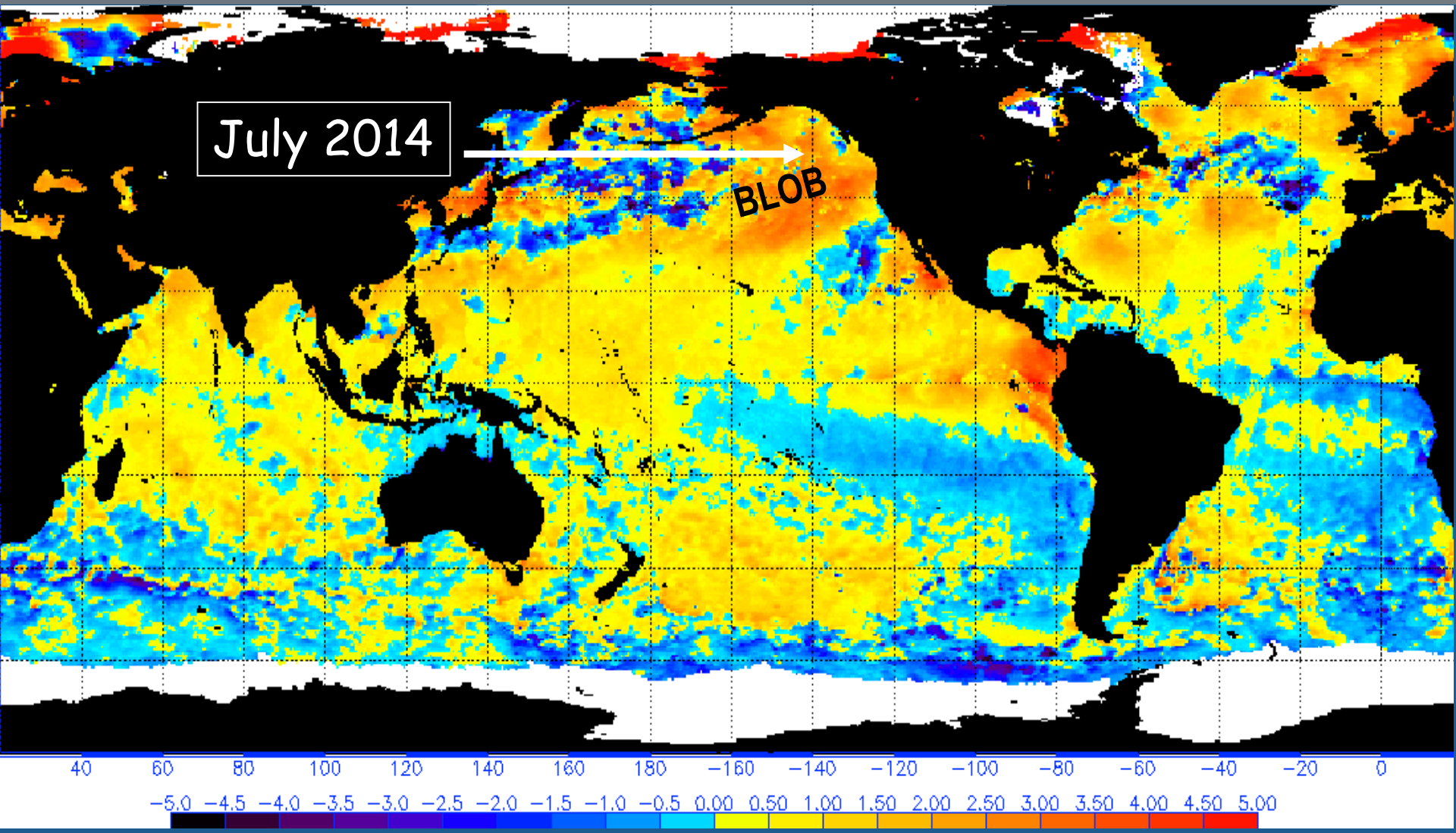
http://www.osdpd.noaa.gov/PSB/EPS/SST/data/anomnight.7.12.2005.gif

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



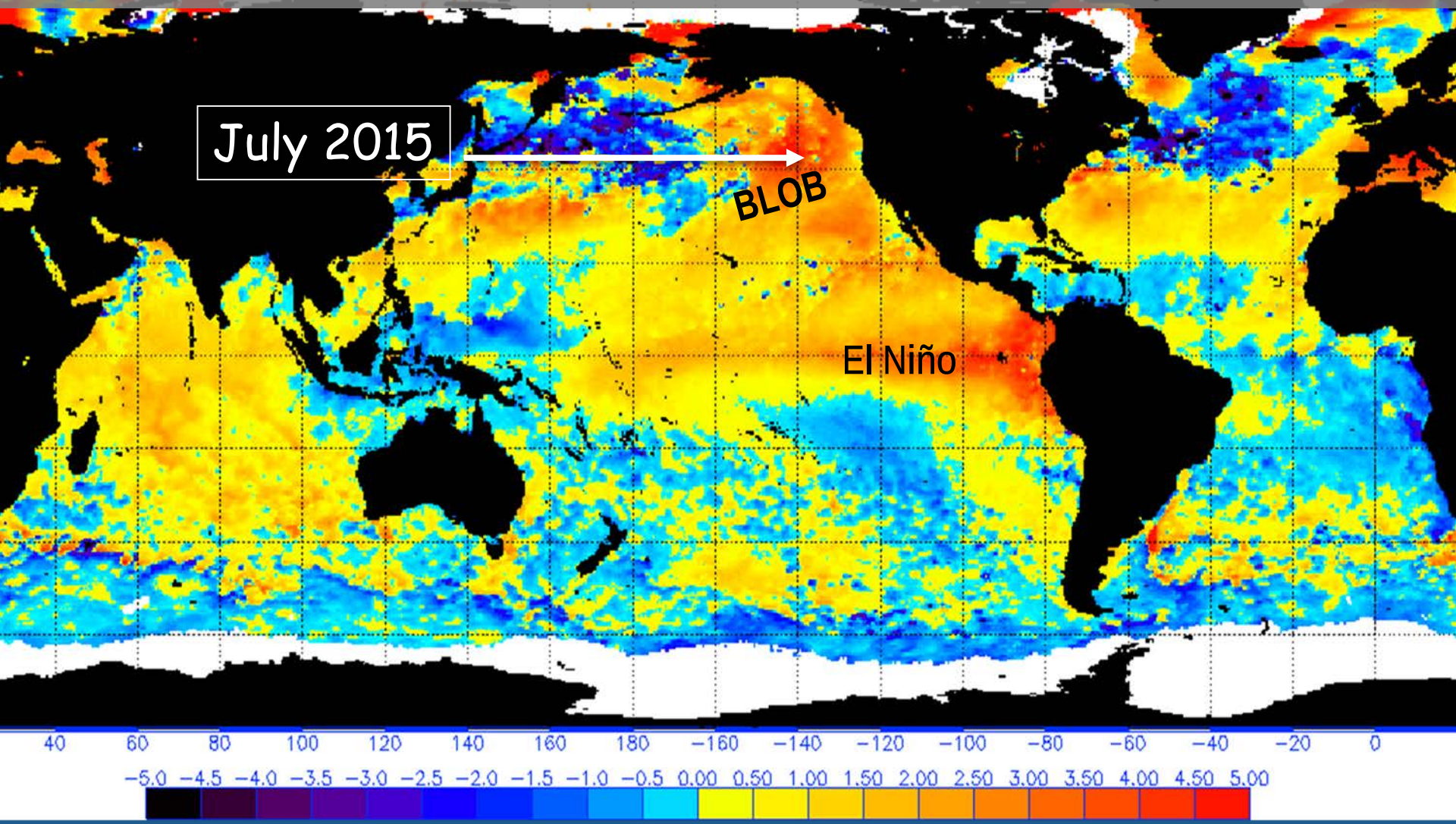
http://www.osdpd.noaa.gov/PSB/EPS/SST/data/anomnight.7.12.2012.gif

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



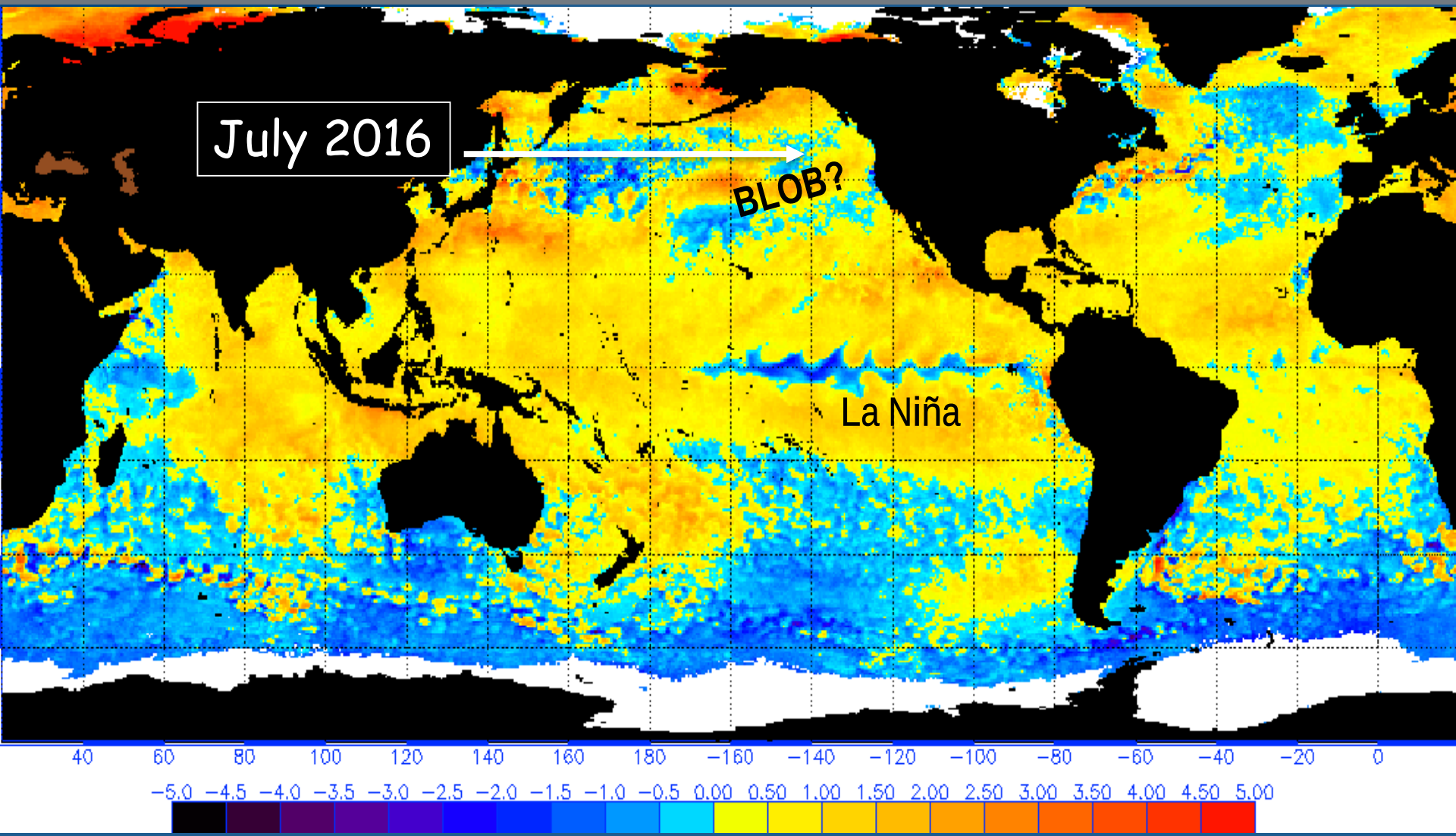
http://www.ospo.noaa.gov/data/sst/anomaly/2014/anomnight.7.10.2014.gif

"Warm blob" summer conditions in eastern GOA in 2015 (18 M in 2016)



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

"Warm blob" summer conditions in eastern GOA in 2016 (46 M? in 2017)



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Later ocean conditions in 2016?

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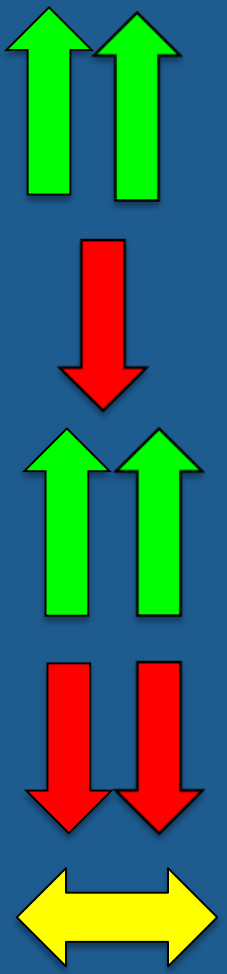
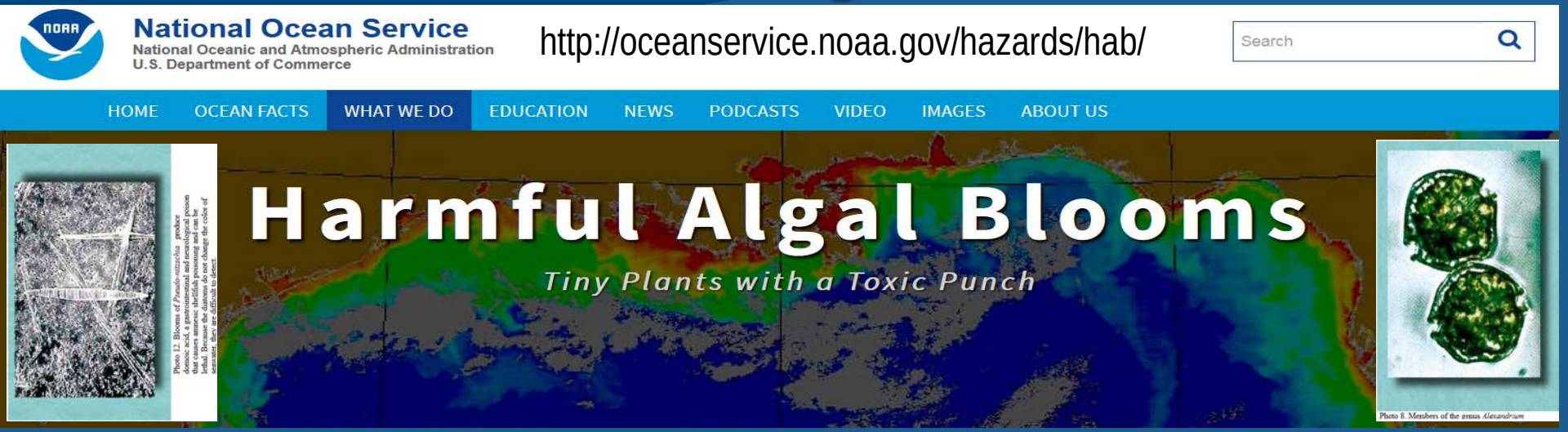
- Juvenile pink salmon GOA abundance - Catch ratio Icy Strait : GOA
- Seabird productivity in the GOA - kittiwake chicks/nest, Middleton Is./Sum
- Post-BLOB ocean temps – July SSTs plots comparing 2005, 2012, 2014 to 2016
- Harmful algal blooms-



What about harmful algal blooms (HABs)?



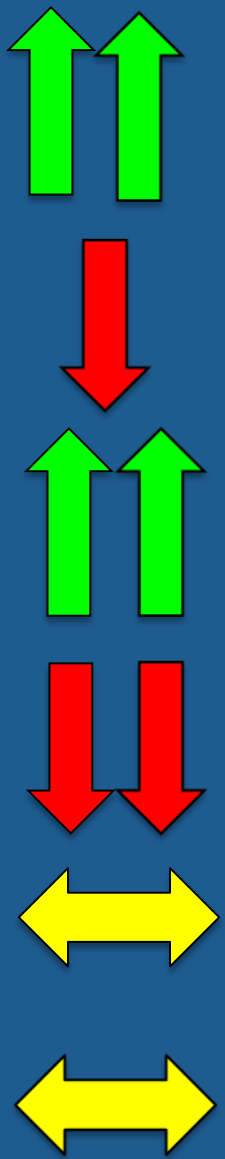
Pseudo-nitzschia: this diatom group produces the deadly neurotoxin domoic acid the toxin responsible for amnesic shellfish poisoning (ASP).

Alexandrium is a genus of dinoflagellates, with many species producing saxitoxin that can lead to paralytic shellfish poisoning. (PSP).

Kathi Lefebvre of the NWFC examined juvenile pink salmon samples from Icy Strait in July of the years 1997 to 2016: preliminary results show the presence of low levels of both Domoic acid and Saxitoxin each year, with some spike years noted; however the 2016 ocean year did not appear to be a high HAB level year.

Later ocean conditions in 2016?

- North Pacific Index - positive conditions in the North Pacific Ocean in summer
- North Pacific Gyre Oscillation - moderate impacts in the southern GOA in spring
- Juvenile pink salmon GOA abundance - Catch ratio Icy Strait : GOA
- Seabird productivity in the GOA - kittiwake chicks/nest, Middleton Is./Sum
- Post-BLOB ocean temps – July SSTs plots comparing 2005, 2012, 2014 to 2016
- Harmful algal blooms - low detectable amounts in juv. pink salmon Icy Str./July



Conclusions:

- 46.2 M pink salmon harvest forecast SEAK 2017
- Juvenile pink salmon in Icy Strait in 2016 were abundant, early, widespread in Icy Strait/GOA
- Unclear what impacts sustained warm conditions will have in the Gulf of Alaska in terms of salmon ocean survival – record Icy Strait temps in 2016
- Continue to evaluate later ocean indicators to help improve future salmon forecasts for SEAK: GOA seabird productivity, harmful algal blooms, NPGO
- If the impacts of later ocean conditions have indeed moderated, then the 2017 SEAK pink harvest may likely surpass ADFG/NOAA forecasts

For financial & collaborative support we thank:

NOAA AK Fisheries Science Center

Northern Fund of the Pacific Salmon Commission

Alaska Department of Fish & Game

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.

2016 NOAA Forecast
30.4 million pink salmon
16-45 M prediction interval

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.

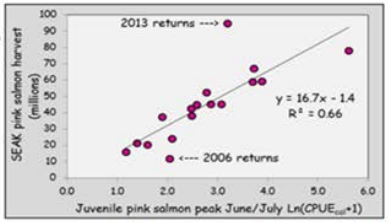
Fortunately, direct measures of juvenile pink salmon abundance at sea from SECM sampling have provided a powerful tool to improve forecasts. Juvenile salmon marine mortality is reported to be high and variable during their initial spring nearshore residency. The SECM sampling of juveniles, which occurs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

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

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.



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

SECM Forecasting Reports:
(NPAFC documents)
2004-2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014

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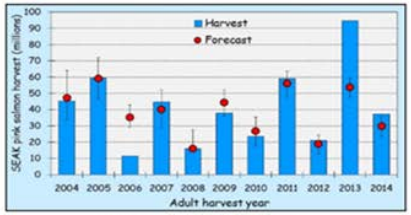

Previous forecast model predictions (with 80% confidence intervals) and actual harvests

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Chukchi Sea Ecosystem Assessment
Salmon Ocean Ecology & Bycatch Analysis:
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.

Measuring water properties with a conductivity-temperature-depth profiler

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

Sampling zooplankton with a tandem Bongo net in Icy Strait

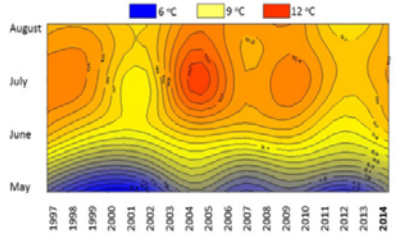
SECM research was initiated in the spring of 1997, just prior to the onset of a strong El Niño event, and has continued annually. SECM sampling occurs around Icy Strait (58°N, 136°W) in the northern region and have been sustained for 18 years. This is a principal migration corridor for salmon that transit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

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

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.



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

SECM Introductory video: "What we do"

Videos on salmon ID and "what we do"!

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Taking the retirement plunge…

Jan 2017

It's been a privilege to participate at the PSTFMs the past 12 years!