Integrating salmon ocean research results into a management framework

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Managerial models that can be informed from ocean surveys

- *Stock assessment (i.e., forecast of abundance):*
- *Life-cycle modeling*
- *EBFM*

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Current ocean research application to management is currently limited in CA Current

Stock assessment

Table 4.3.1 "Stoplight" table of basin-scale and local/regional conditions for smolt years 2014-2017 and likely adult returns in 2018 for coho and Chinook salmon that inhabit coastal Oregon and Washington waters during their marine phase. Green/circles = "good," i.e., rank in the top third of all years examined. Yellow/squares = "intermediate," i.e., rank in the middle third of all years examined. Red/diamonds = "poor," i.e., rank in the bottom third of all years examined. Courtesy of Dr. Brian Burke (NOAA).

	Smolt year				Adult return outlook	
Scale of indicators	2014	2015	2016	2017	Coho, 2018	Chinook, 2018
Basin-scale						
PDO (May-Sept)	◆	◆	◆	■	■	◆
ONI (Jan-Jun)	■	◆	◆	■	■	◆
Local and regional						
SST anomalies	■	◆	◆	●	●	◆
Deep water temp	◆	◆	■	◆	◆	■
Deep water salinity	◆	◆	■	◆	■	◆
Copepod biodiversity	■	◆	◆	■	■	◆
Northern copepod anomaly	●	◆	◆	◆	◆	◆
Biological spring transition	■	◆	◆	◆	◆	◆
Winter ichthyoplankton biomass	◆	●	●	●	●	●
Winter ichthyoplankton community	■	■	◆	◆	◆	◆
Juvenile Chinook catch (Jun)	■	■	◆	◆	◆	◆
Juvenile coho catch (Jun)	■	■	■	◆	◆	■

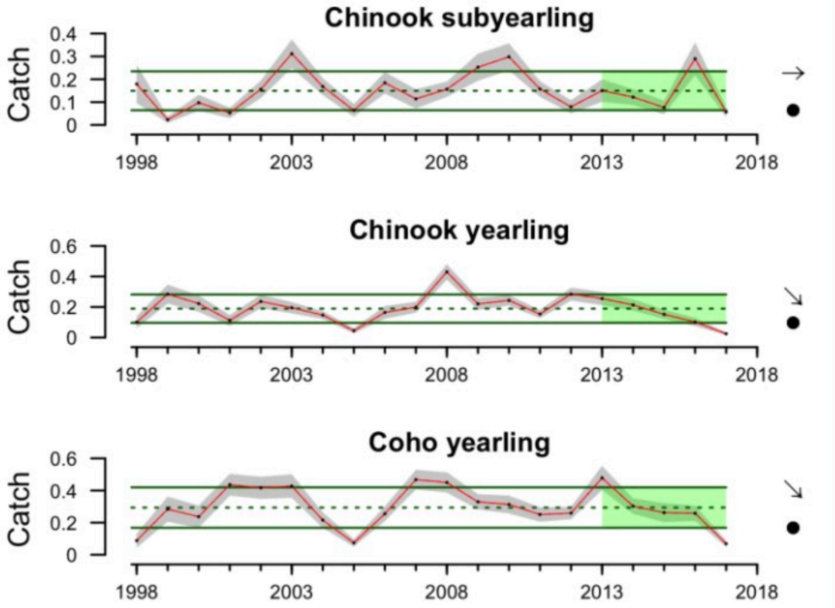


Figure 4.3.2 At-sea juvenile Chinook and coho salmon catches (Log_{10}(# km^{-1} + 1)) in June, 1998-2017 off Washington and Oregon. Lines, colors, and symbols as in Fig. 1.

https://www.integratedecosystemassessment.noaa.gov/sites/default/files/2019-03/CCIEA-status-report-2018.pdf

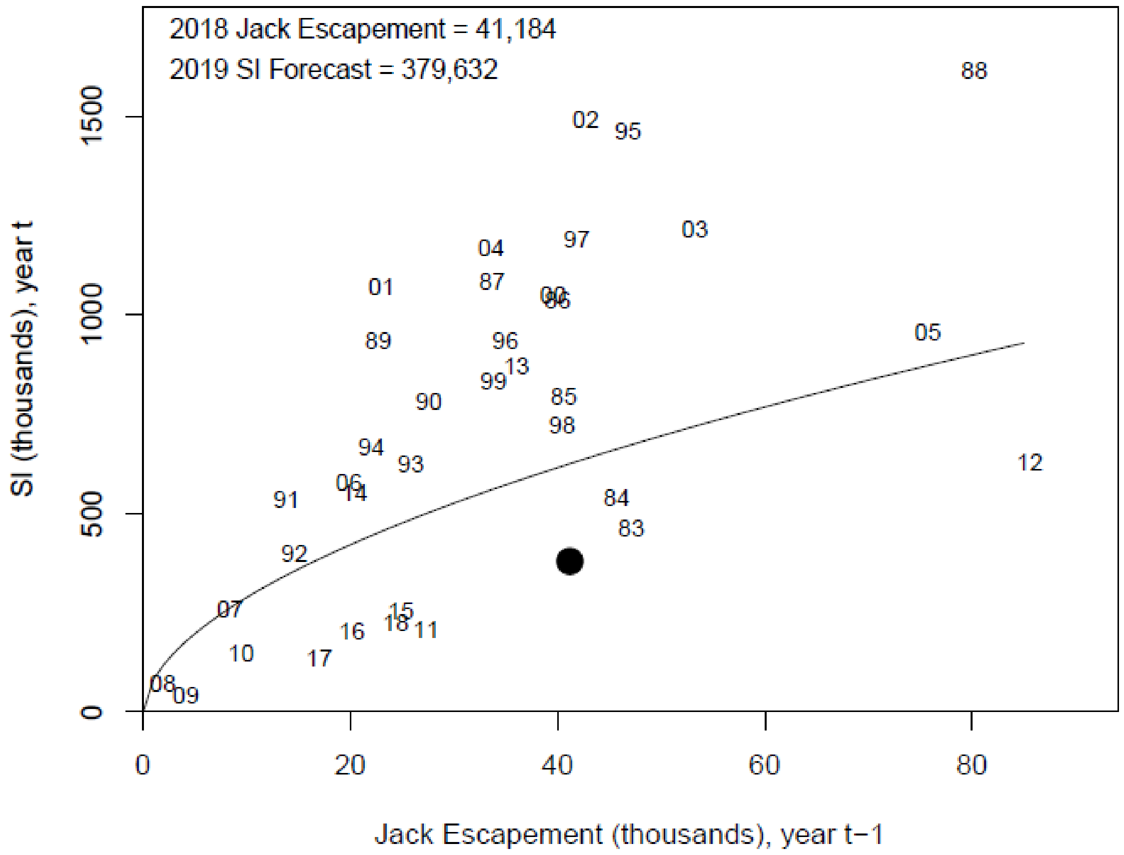
https://www.integratedecosystemassessment.noaa.gov/regions/california-current/cc-ecosystem-components

Sibling models to develop harvest rules

Harvestable adults at sea = # of jacks returning

This assumes ***constant maturation*** **and** ***natural mortality*** rates *– Solution: Ocean sampling of older fish*.

Stock assessment



Recently, ocean covariates have been brought forward for coho assessments

Stock assessment

The ensemble mean predictor used for the 2019 forecast was the geometric mean of the six GAM predictors:

Ensemble Mean of six forecasts based on environmental conditions and spawners.

Variables			Prediction	r^2	OCV[a/]
PDO	Spring Transition (Julian date; t-1)	Log Spawners (t-3)	67,525	0.65	0.56
PDO	Multivariate ENSO Index (Oct-Dec; t-1)	Upwelling (July-Sept; t-1)	67,001	0.68	0.59
PDO	Spring Transition (Julian date; t-1)	Multivariate ENSO Index (Oct-Dec; t-1)	63,031	0.68	0.60
PDO	Upwelling (July-Sept; t-1)	Sea Surface Temperature (May-Jul; t-1)	82,522	0.64	0.52
PDO	Sea Surface Height (Apr-June; t-1)	Upwelling (July-Sept; t-1)	95,194	0.68	0.55
PDO	Upwelling (Sept-Nov; t-1)	Sea Surface Temperature (Jan; t)	52,956	0.67	0.54
Ensemble Mean (90% prediction intervals)			70,097 (32,597-152,440)	0.74	0.61

PFMC 2019, Preseason Report

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PFMC 2019, Preseason Report

We need to consider including more process in this and previous examples

Pink salmon assessments are exploring ***inclusion of ocean processes***

Stock assessment

Pink salmon abundance is estimated from juvenile at-sea CPUE and at-sea abundance of predators.

Harvest = Ln(CPUE juvs) + Pred# + env2 +…env$_n$

Parameter	*r*	*P*-value
Juvenile pink salmon abundance		
$CPUE_{cal}$	**0.78**	**<0.001**
$CPUE_{ttd}$	**0.74**	**<0.001**
Seasonality	**-0.55**	**0.019**
Percentage of Juvenile Pinks	**0.55**	**0.010**
Juvenile pink salmon growth and condition		
Pink Salmon Size July 24	0.05	0.847
Condition Index	-0.05	0.856
Energy Content	-0.01	0.958
Percent Stomach Contents	-0.08	0.745
Predator Indexes		
Adult Coho Abundance	-0.27	0.273
Adult Coho Abundance/$CPUE_{cal}$	**-0.80**	**<0.001**
Zooplankton standing crop		
June/July Average Zooplankton Total Water Column	0.12	0.624
Local-scale physical conditions	-	
May 20-m Integrated Water Temperature	0.01	0.978
June 20-m Integrated Water Temperature	-0.24	0.343
Icy Strait Temperature Index (ISTI)	-0.18	0.488
June Mixed-layer Depth	-0.03	0.906
July 3-m Salinity	0.00	0.995
Basin-scale physical conditions		
Pacific Decadal Oscillation (PDO, y-1)	0.01	0.983
Northern Pacific Index (NPI, y)	**0.62**	**0.007**
ENSO Multivariate Index (MEI, Nov (*y-1*)-March (*y*))	0.25	0.326
North Pacific Gyre Oscillations	0.30	0.234
Ecosystem Indicators Rank Index (ERI)	**-0.83**	**<0.001**

Wertheimer et al 2017

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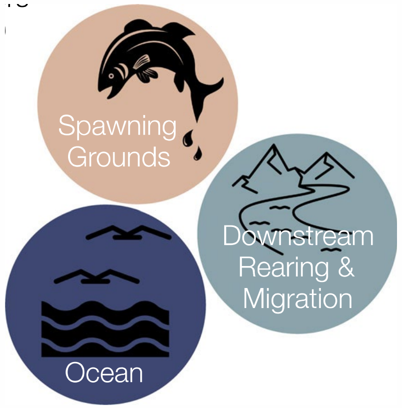
Aspects of salmon life-cycle discoverable from ocean research

Life-cycle modeling



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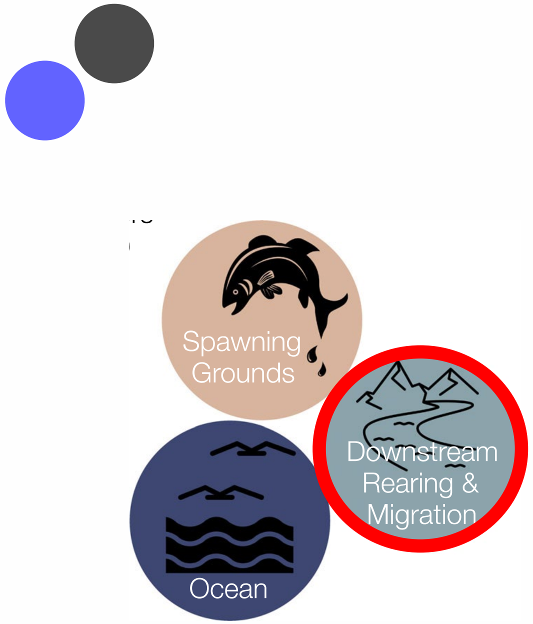

Carry-over effects (e.g., size at emigration, timing, diversity). *Can be studied with early sampling.*

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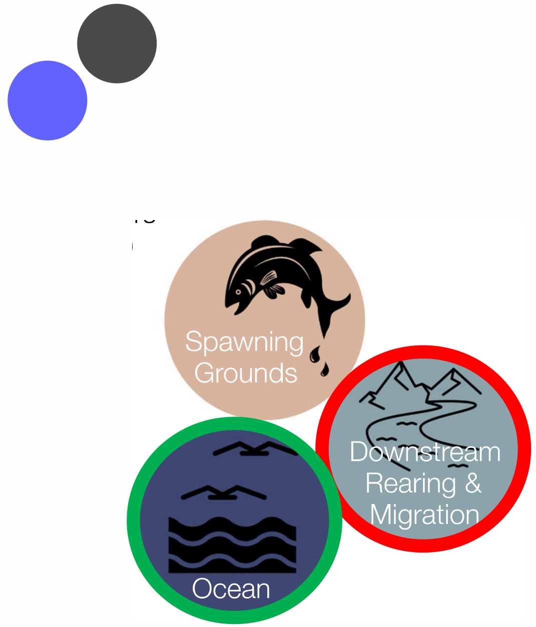

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Ocean life-history transitions.
Ocean surveys of older fish provide parameterization

Aspects of salmon life-cycle discoverable from ocean research

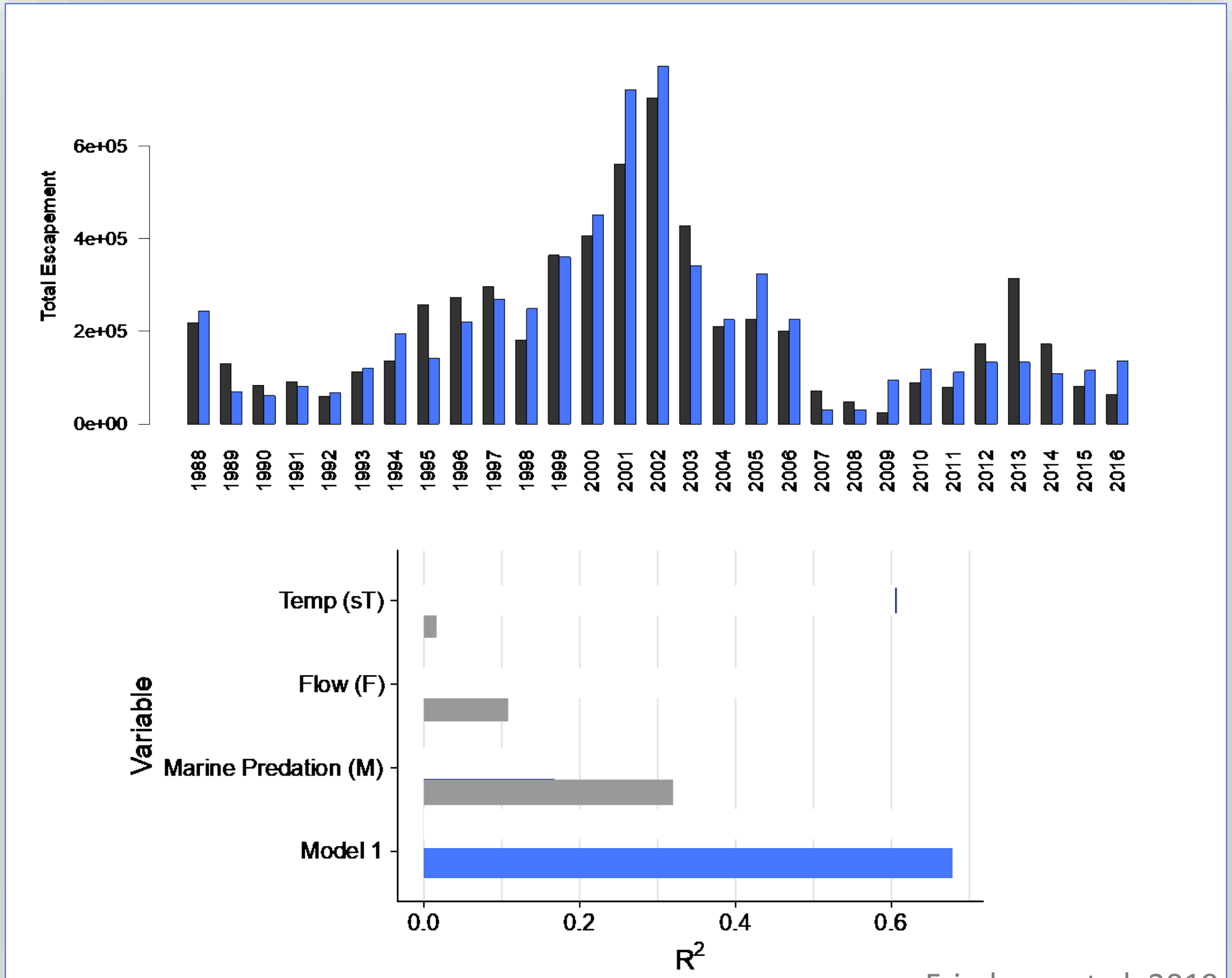
The ocean has influence on age and timing of spawning and can inform habitat management. *Sampling fish on return can be used here.*

Carry-over effects (e.g., size at emigration, timing, diversity). *Can be studied with early sampling.*

Ocean life-history transitions. *Ocean surveys of older fish provide parameterization*

Sensitivity analysis and management strategy evaluation

Life-cycle modeling



Friedman et al. 2019

The key is that ocean influences were parameterized in the context of the full life cycle. *Managerial decisions considered, such as flow-dependent emigration size or timing, can be evaluated properly in the context of predation at sea.*

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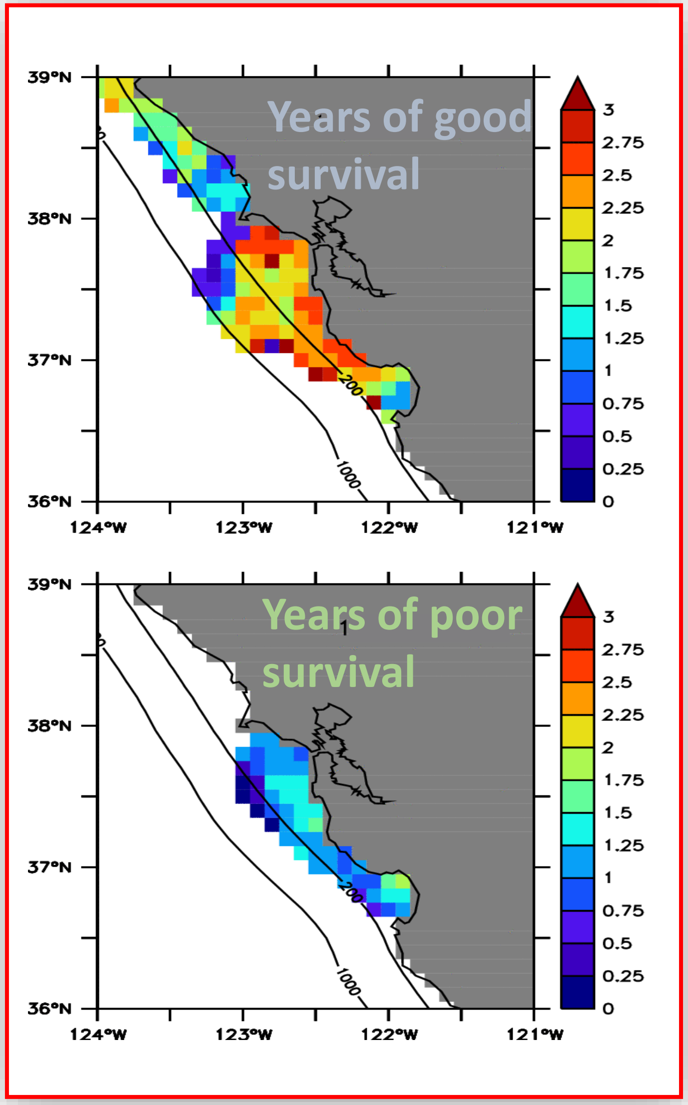
Agent-based models based on ocean survey results

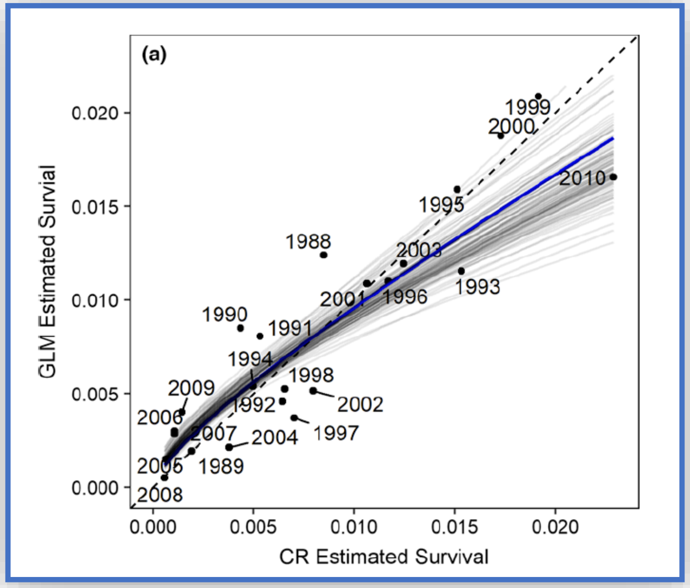
EBFM



Fiechter et al. 2015

Survey data is used to parameterize ecosystem-level models where there is need to incorporate ***behavior, distribution, prey dynamics and ocean state***.

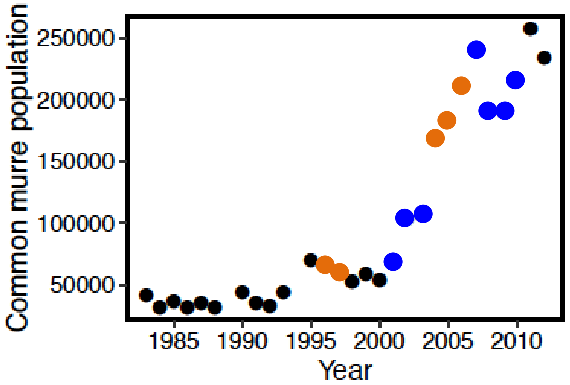
To the **left** is modeled growth of salmon at sea and to the **right** is modeled early survival related to growth.

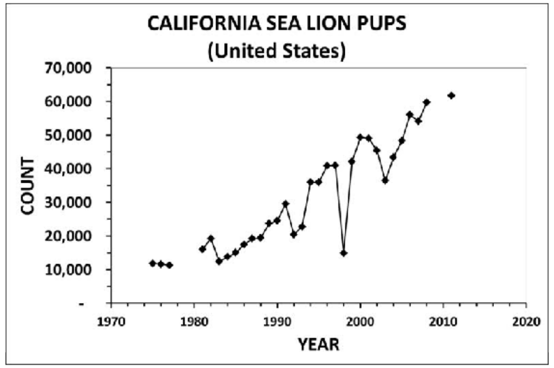


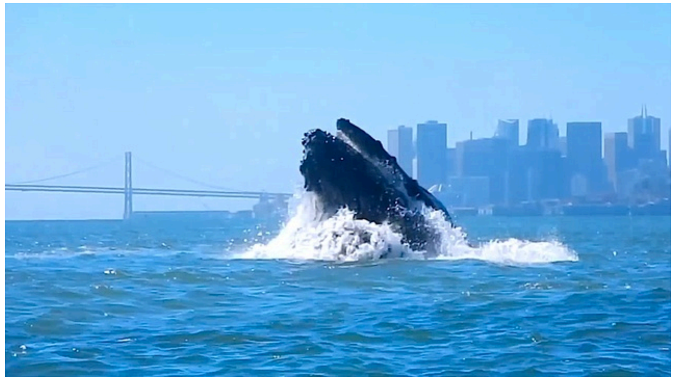
Henderson et al. 2018

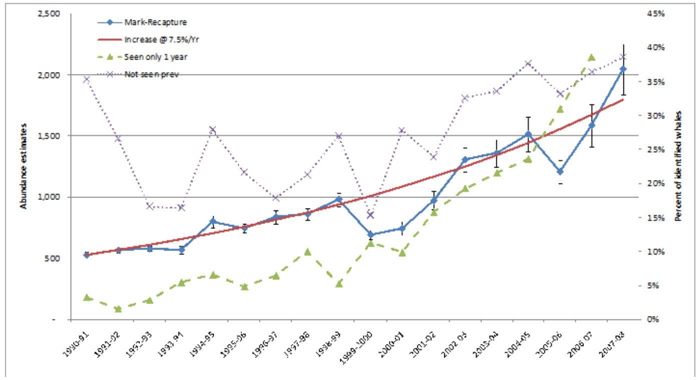
Much of morality at sea is due to predation

EBFM









More process studies need to be conducted to understand the role of predators on salmon mortality.

Conclusion: Managerial models that can be informed from ocean surveys

Stock assessment (i.e., forecast of abundance)

- Juvenile abundance and maturation

Life-cycle modeling

- Evaluation of carry-over effects on early, at-sea salmon dynamics.
- Sampling of older fish for estimation of transitional dynamics.

EBFM

- Behavioral studies to parameterize ecosystem models, including predators, salmon and prey.