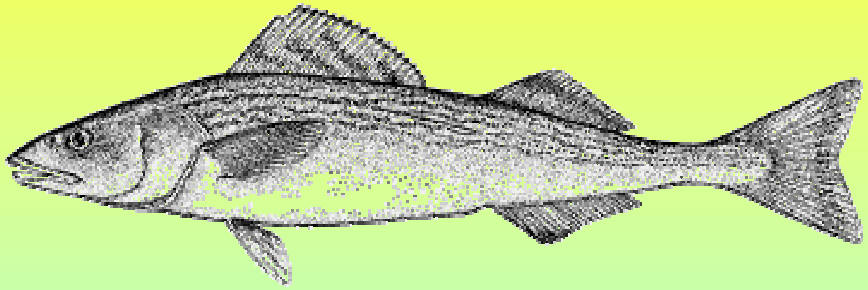
Changes in Sablefish Recruitment in Response to Oceanographic Conditions



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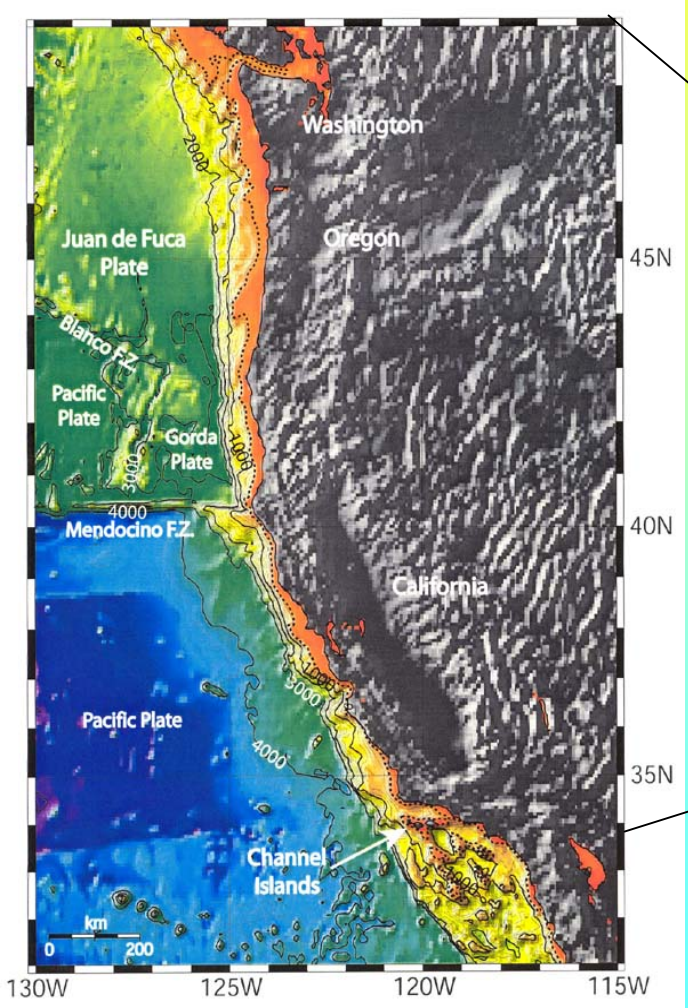
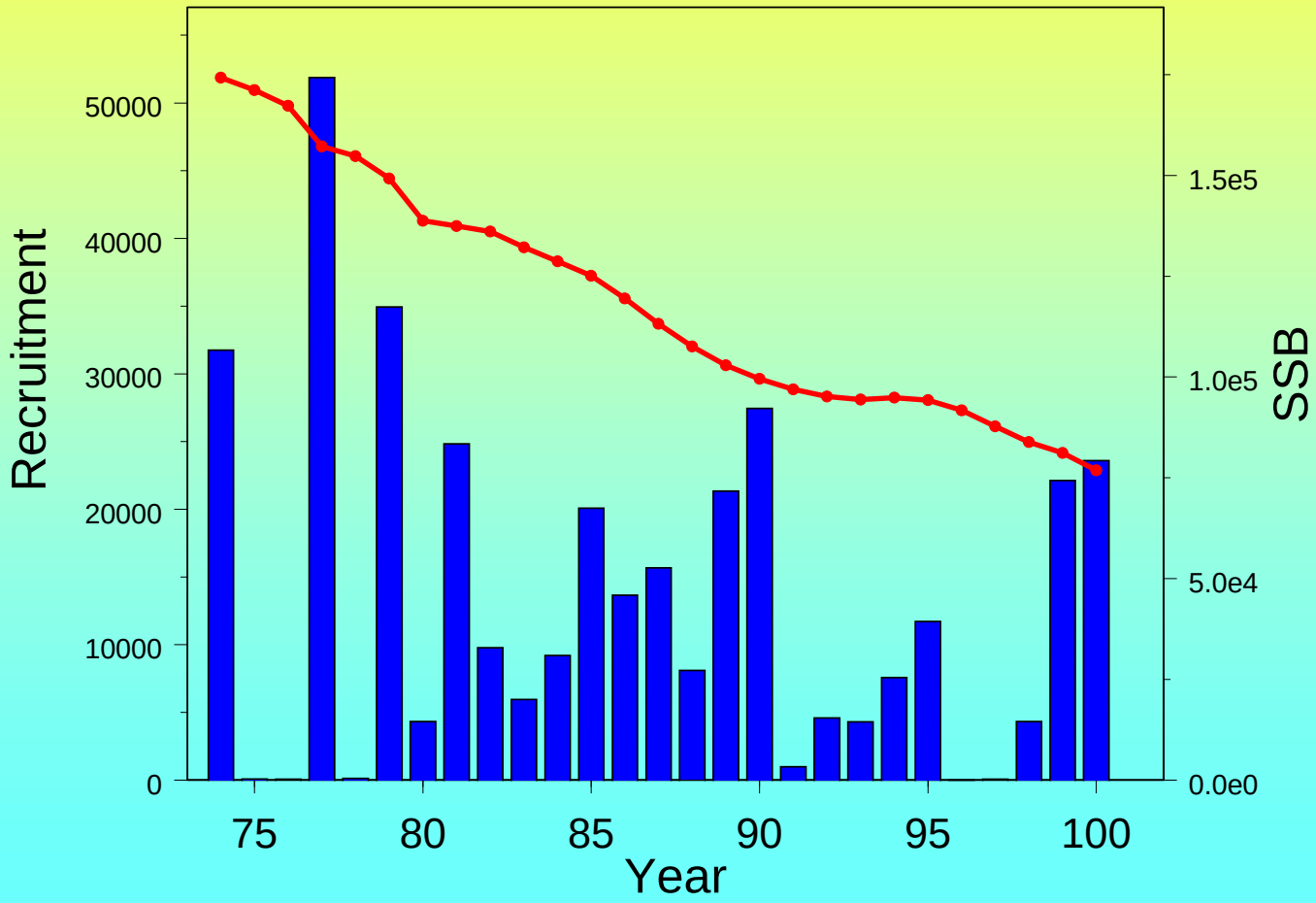
Overview

- Sablefish stock-recruitment and its problems
- Early life history characteristics of sablefish
- Use of the General Additive Model (GAM)
- Seasonal behavior of the predictive oceanographic variables (north and east Ekman transport, sea level) and GAM fits to these variables
- Resampling via bootstrap to quantify bias and error around estimates of coefficient
- Incorporation of environmental parameters into the stock assessment model

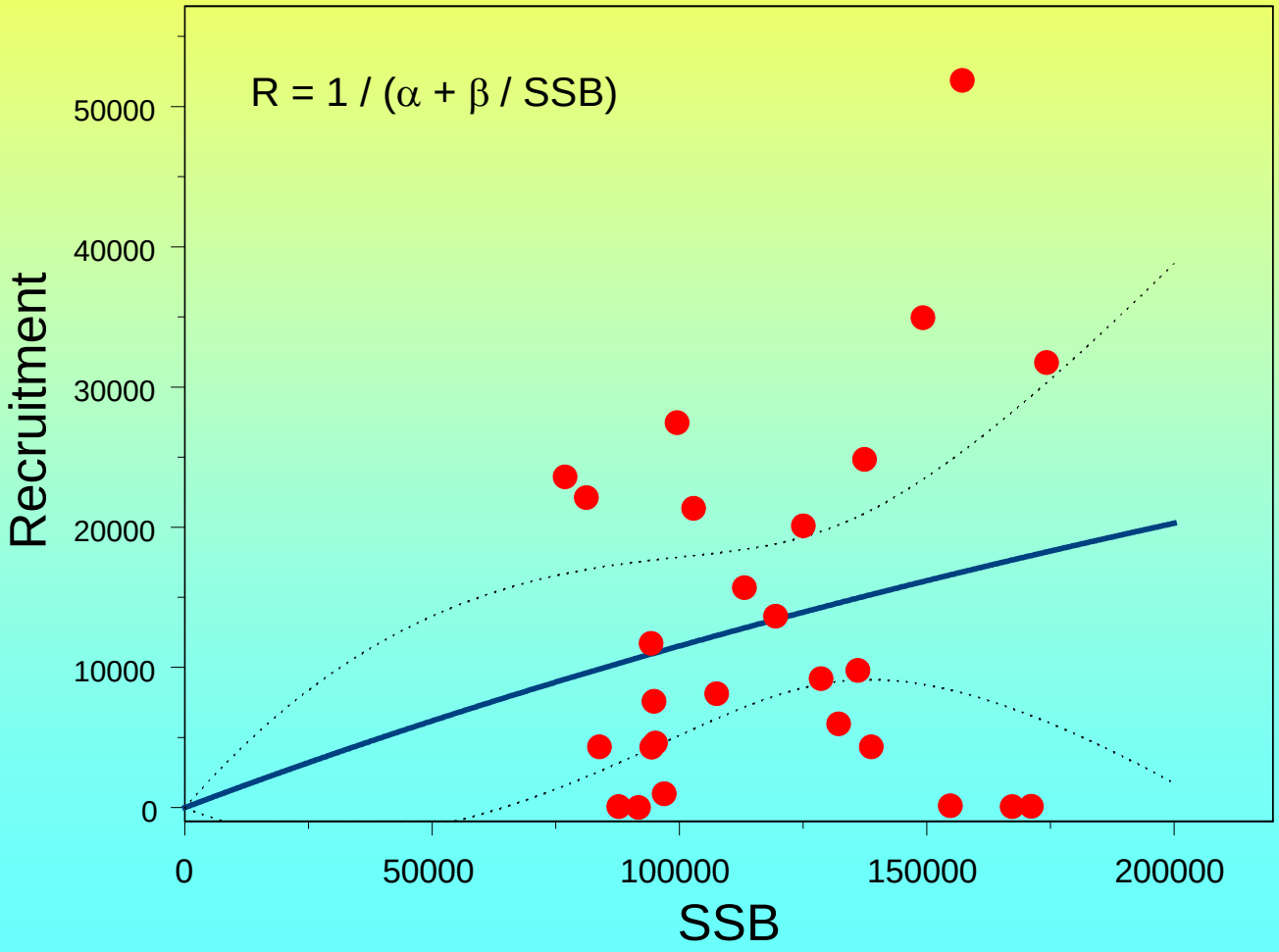
The US west coast sablefish assessment covers from the US/Canadian border in the north to the US/Mexico border in the south



According to the last sablefish assessment (2002), estimated spawning stock biomass (SSB) has steadily declined during 1972-2001



Stock-Recruit data does not fit traditional Ricker or Beverton-Holt models well



Sablefish egg/larvae abundance at surface peaks from February to April

(CalCOFI data, reproduced from Moser et al. 1994)

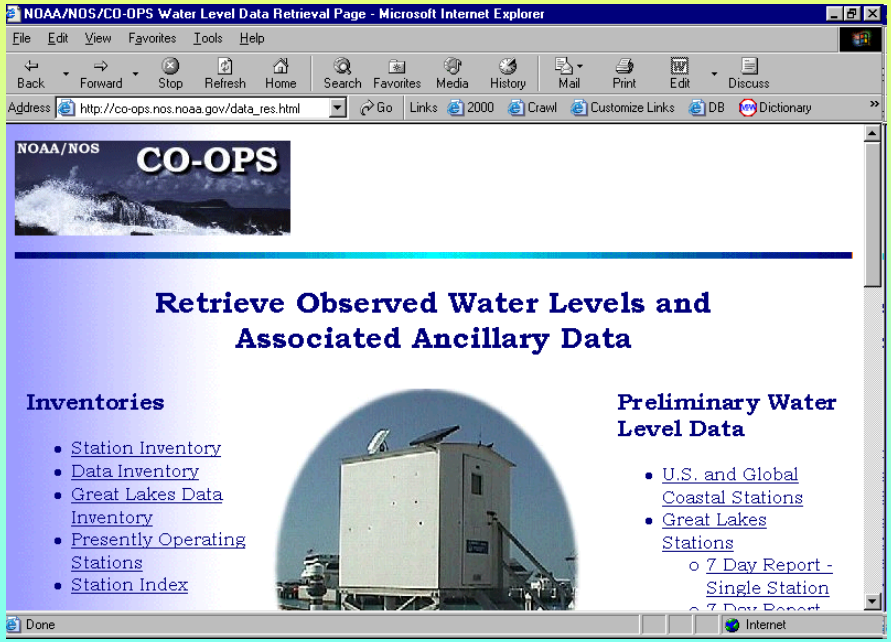
REGION	JAN	FEB	MAR	APR	MAY
Washington	0	-	37.8	158.1	16.4
Northern Oregon	0	-	25.4	87.9	20.9
Southern Oregon	0	-	45.2	22.4	17.8
Northern Calif.	0	-	21.9	11.4	2.1
Central Calif.	0	5.2	1.4	1.1	0

The General Linear Model (GLM)
vs.
The General Additive Model (GAM)

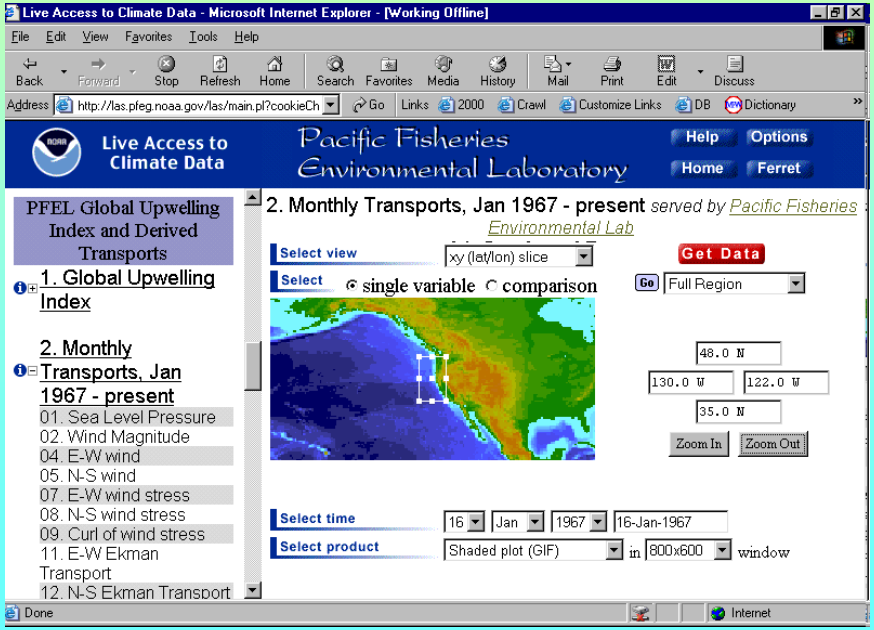
- The GAM does not necessarily impose a rigid parametric dependence of recruitment on the environment
- A GAM lets the data show us the appropriate functional form through the use of scatterplot smoothers while at the same time maintains the predictive power of a more rigid model.
- Terms can be modeled non-parametrically or parametrically or both forms combined into a semi-parametric model

Oceanographic data was obtained from the NOAA CO-OPS web site and the NOAA Pacific Fisheries Environmental Lab "Live Access Server"

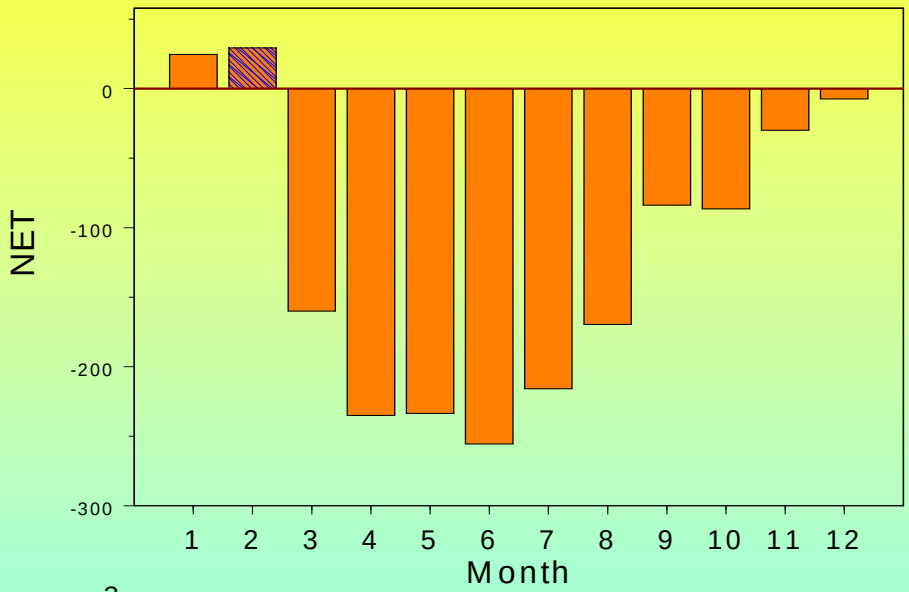
http://co-ops.nos.noaa.gov/data_res.html

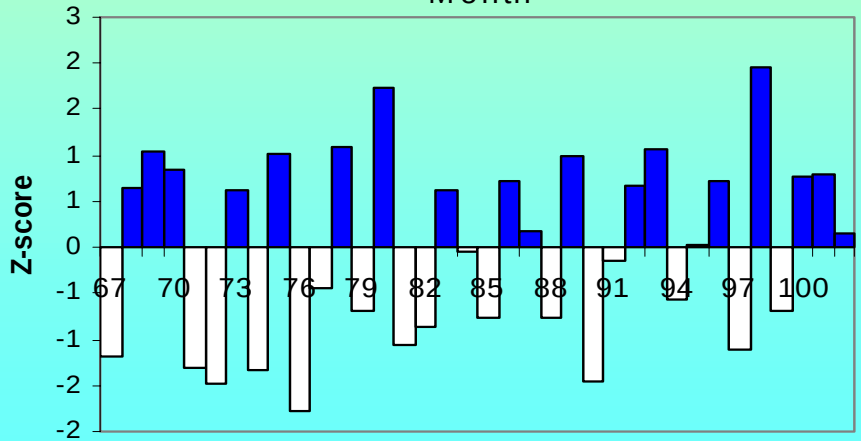


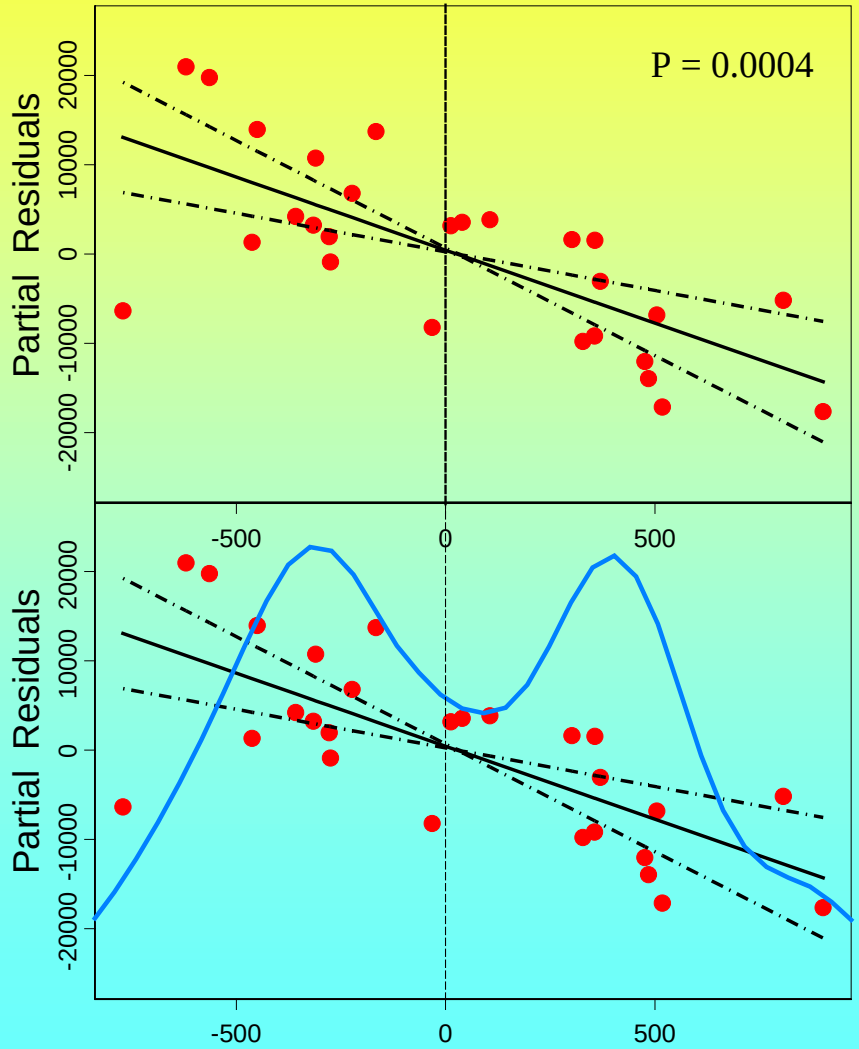
http://las.pfeg.noaa.gov/las/



Northward Ekman Transport (NET) at 48 ° Lat in February alternates between north(+) and south(-)

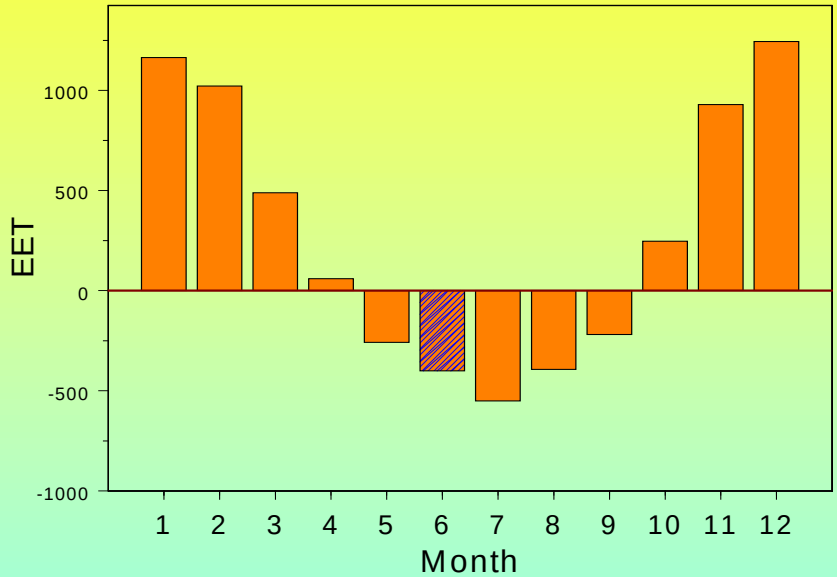


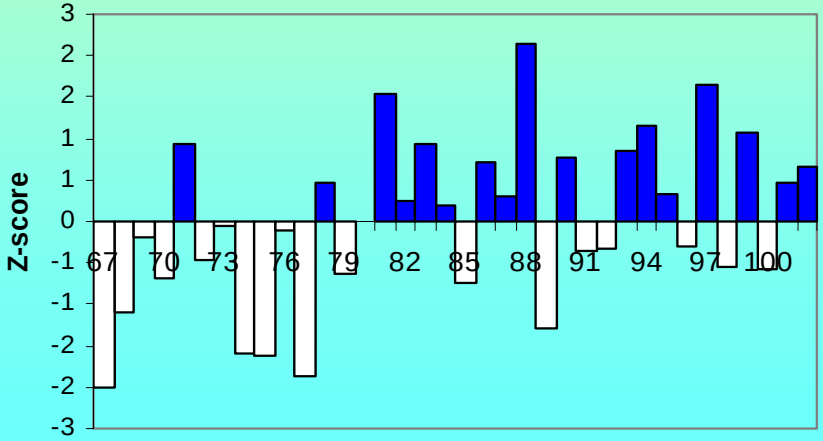


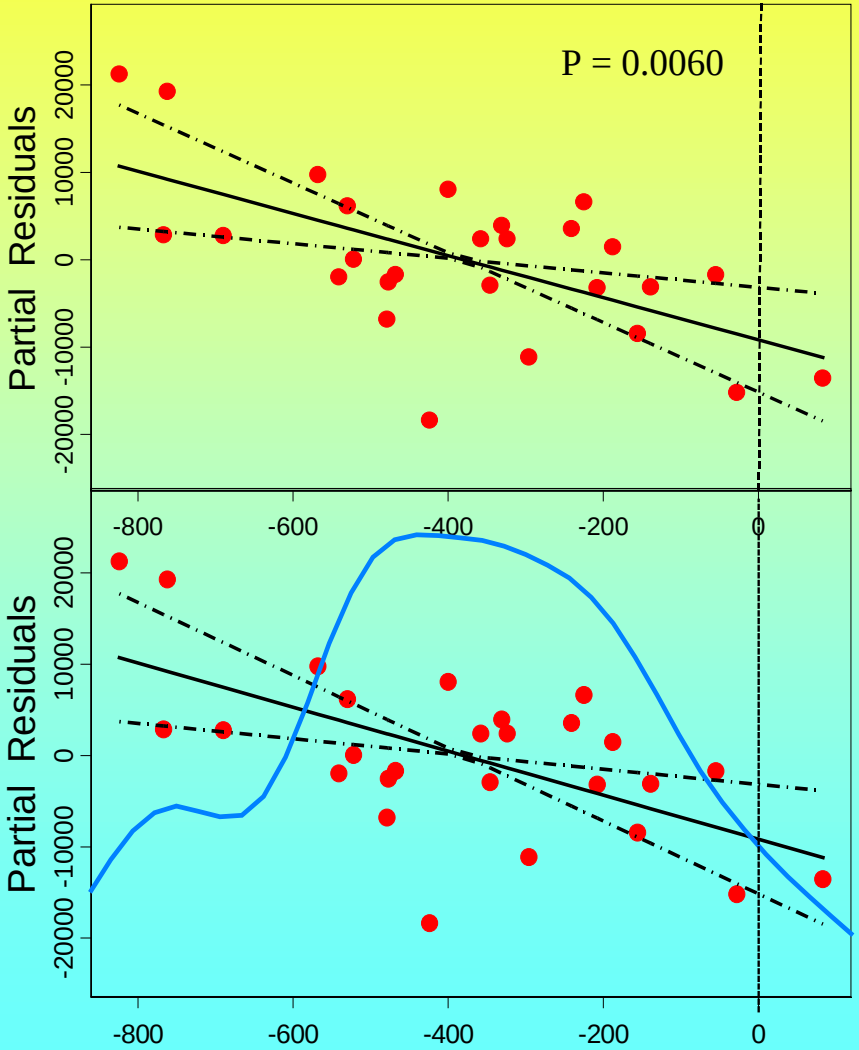


N Ekman Trans - 48 - Feb

Eastward Ekman Transport (EET) at 45º in June is an index of summer upwelling and is generally west(-)

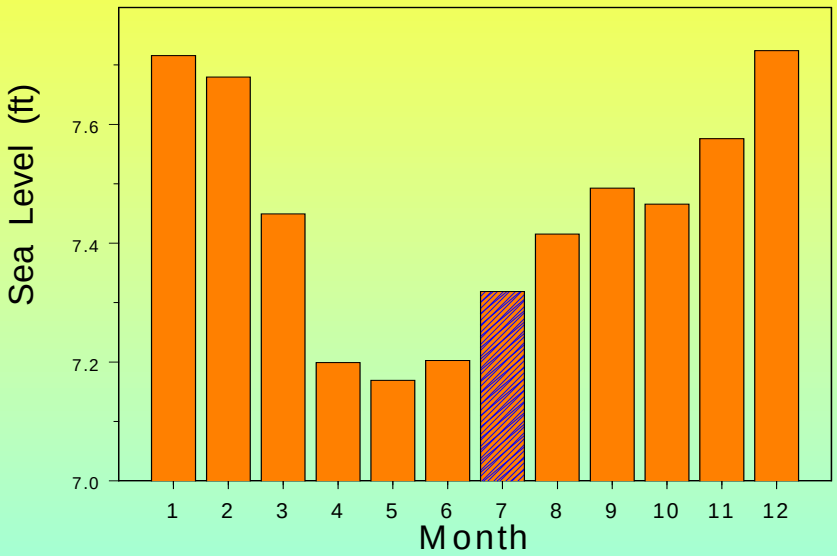


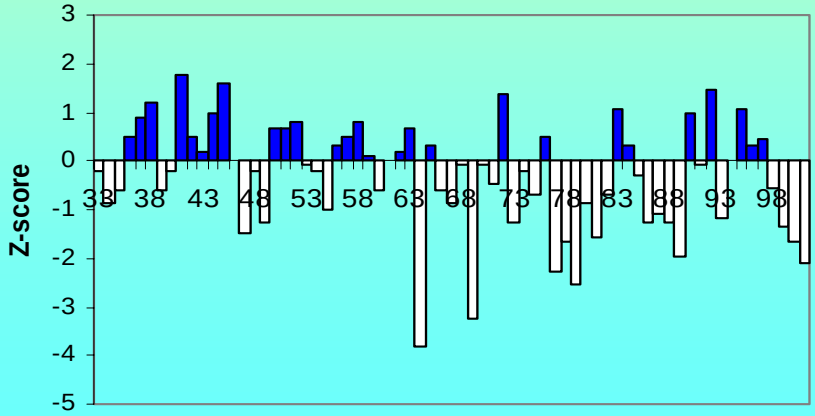




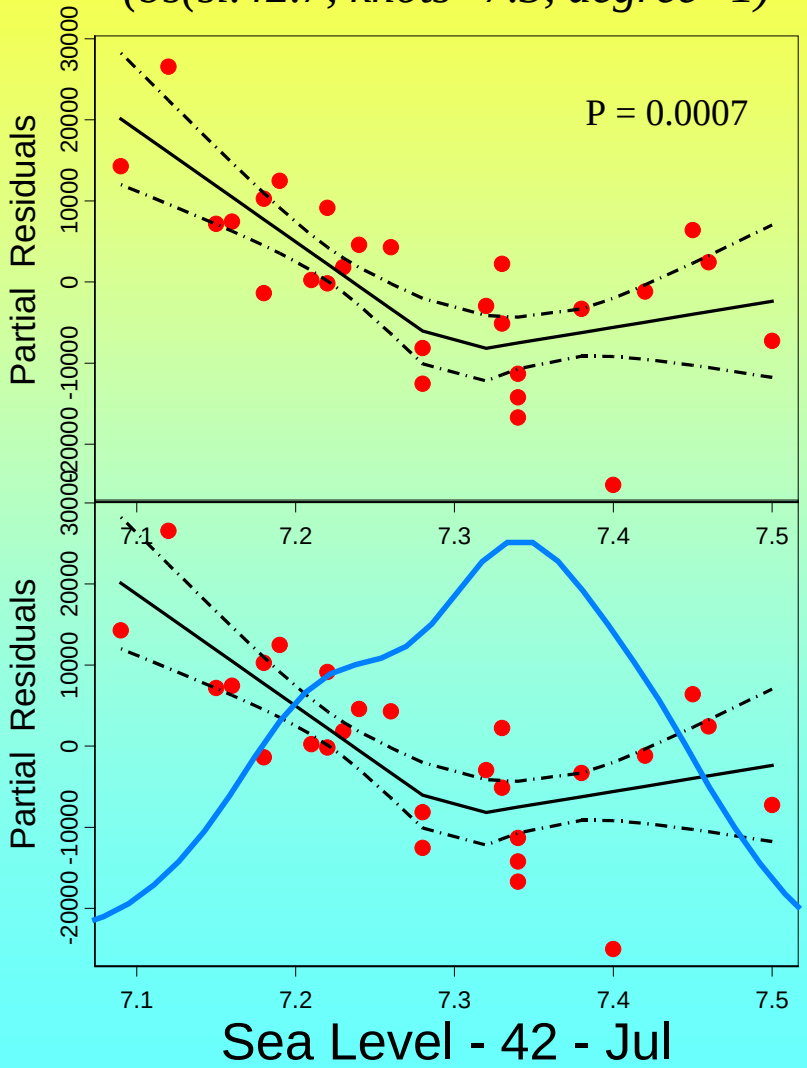
E Ekman Trans - 45 - June

Sea Level (SL) at 42º in July is an indicator of Along Shore Transport (< sea level = > transport)





(bs(sl.42.7, knots=7.3, degree=1)



The most parsimonious model was chosen using stepwise selection and Akaike's Information Criteria (AIC)

$$AIC = -2 * \ln(likelihood) + 2*\boldsymbol{K}$$

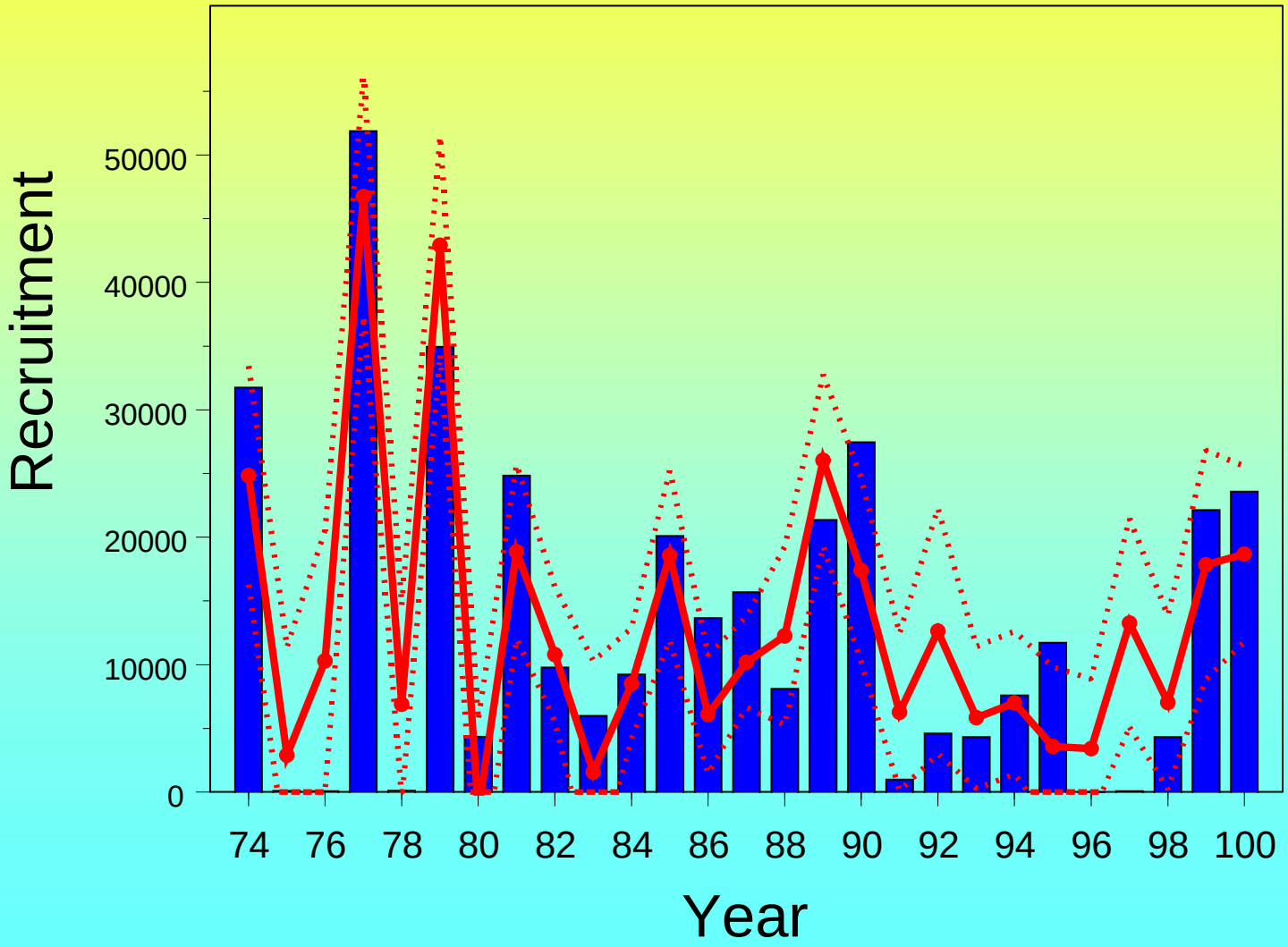
Where ***K*** is the number of parameters in the model. The AIC statistic accounts simultaneously for the degrees of freedom used and the goodness of fit: more parsimonious models have a lower AIC.

Resulting Model

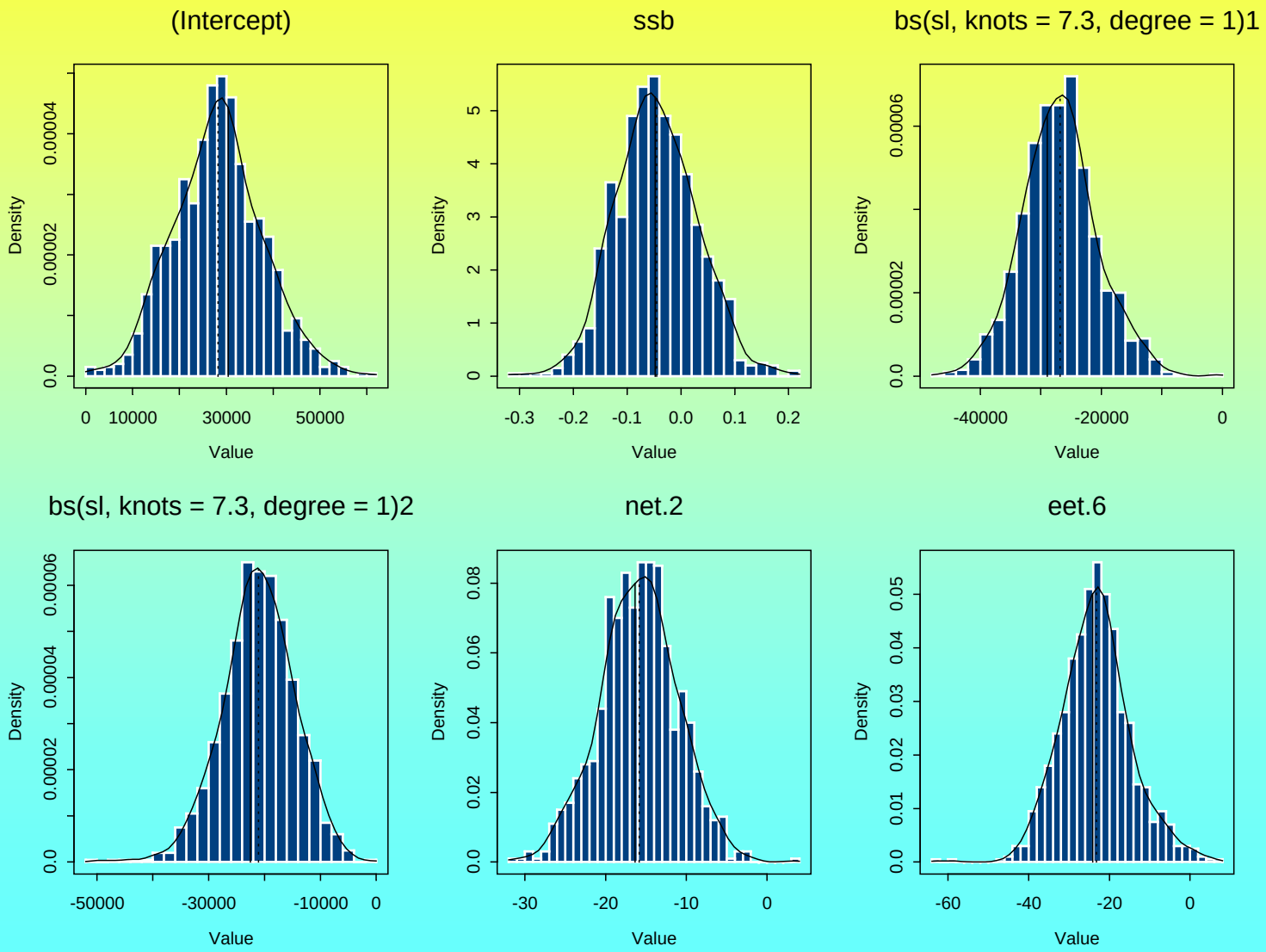
$$R = SSB + SL.42°.7 + NET.48°.2 + EET.45º.6$$

Model	Res SE	AIC	F	Pr(F)	R^2
SSB	13010	4.91E+9	1.107	0.3010	0.0420
SSB + SL	10830	4.06E+9	4.881	0.0090	0.3890
SSB + SL + NET	9412	3.65E+9	6.696	0.0009	0.5589
SSB + SL + NET + EET	8014	3.39E+9	9.559	<0.0001	0.6948

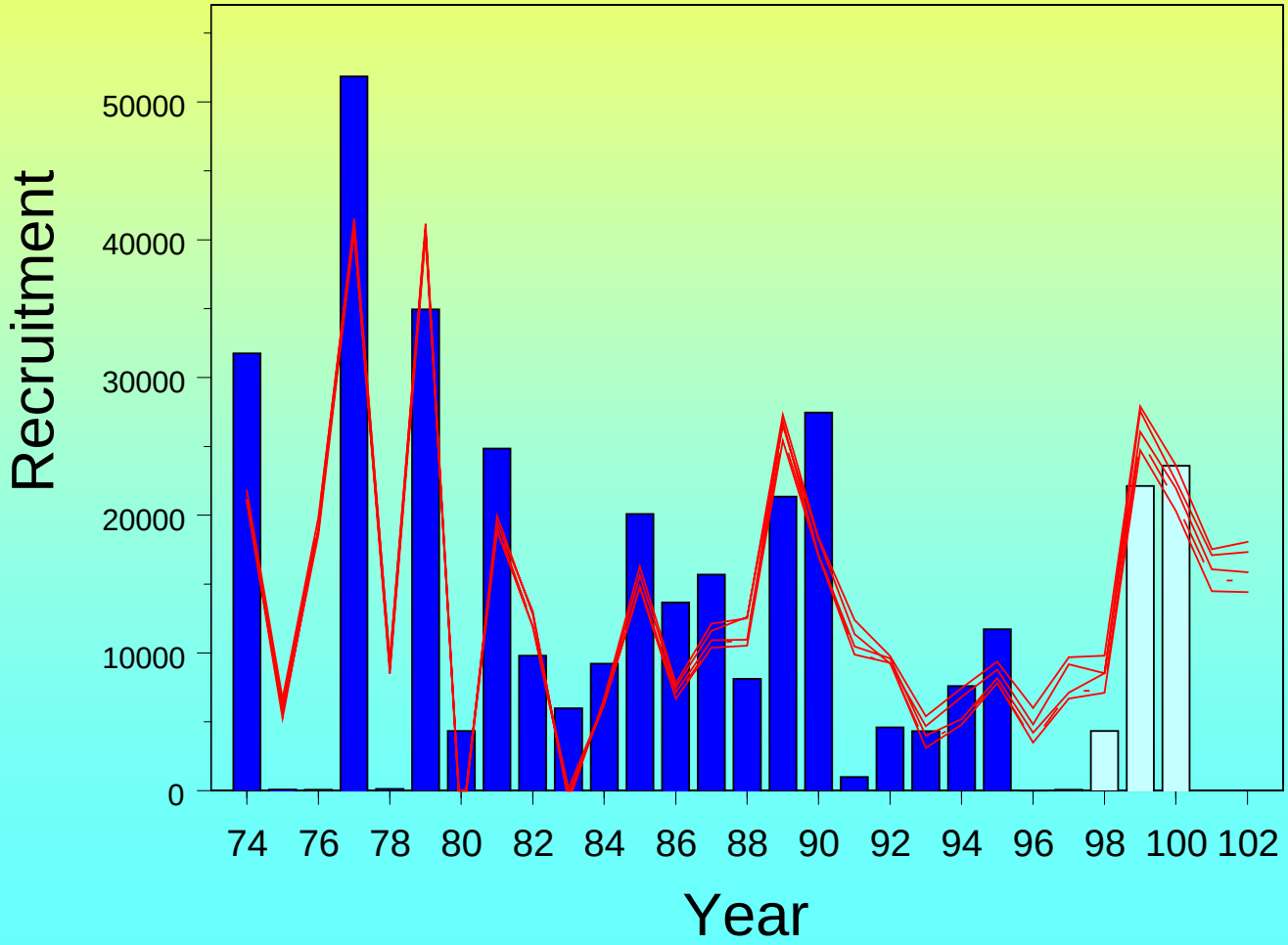
The GAM with environmental covariates explained 69% of the variation in recruitment



Bootstrap analysis strongly suggests normality in the distribution of error around the estimated means of the coefficients



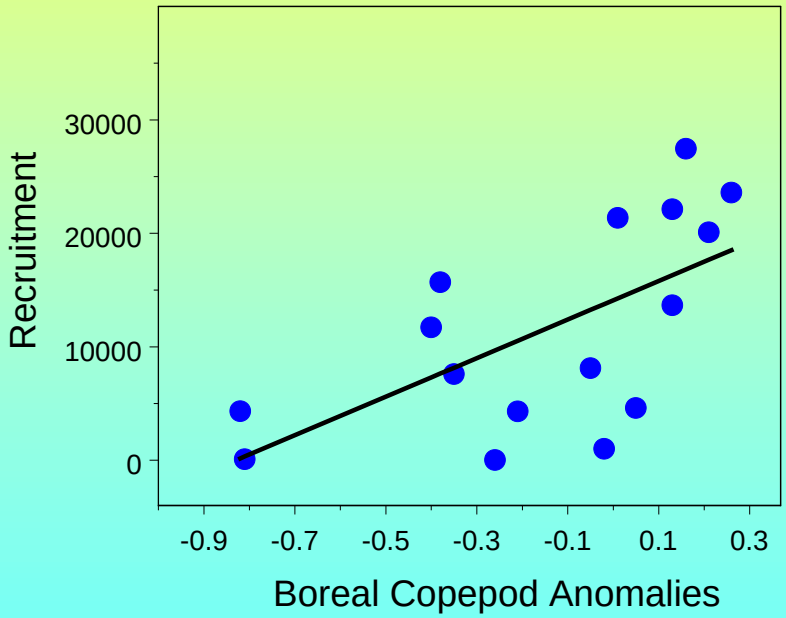
Stability was tested by successively deleting one year of data for the last five years (1996-2000), refitting the model, and predicting deleted years as well as 2001 and 2002

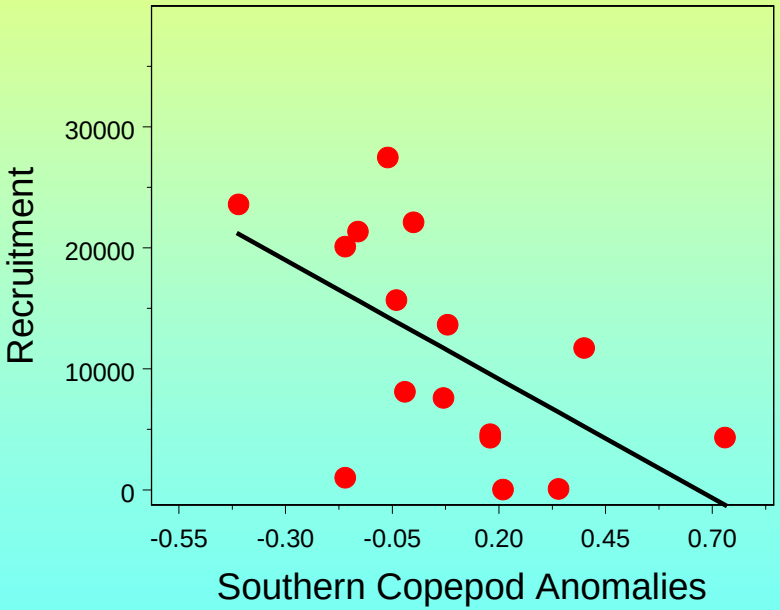


Possible Explanations for Observations

- Increased negative northern Ekman transport in February may transport eggs/larvae from more northern areas (Vancouver Island area)
- Increased negative eastern Ekman transport in June is associated with increased spring upwelling which is a generally better condition for juvenile sablefish
- Increased along shore transport may work with spring upwelling to bring more nutrients into the system

Recruitment may be related to Northern vs. Southern copepod anomalies





Data from Mackas et al. 2001

Current Direction of the Work

Recruitment is fit internal to the stock-assessment model by using a log-likelihood function and modeling the deviates Re from Rs with the equation below

$$\boldsymbol{Re = Rs * exp(mx)}$$

where:

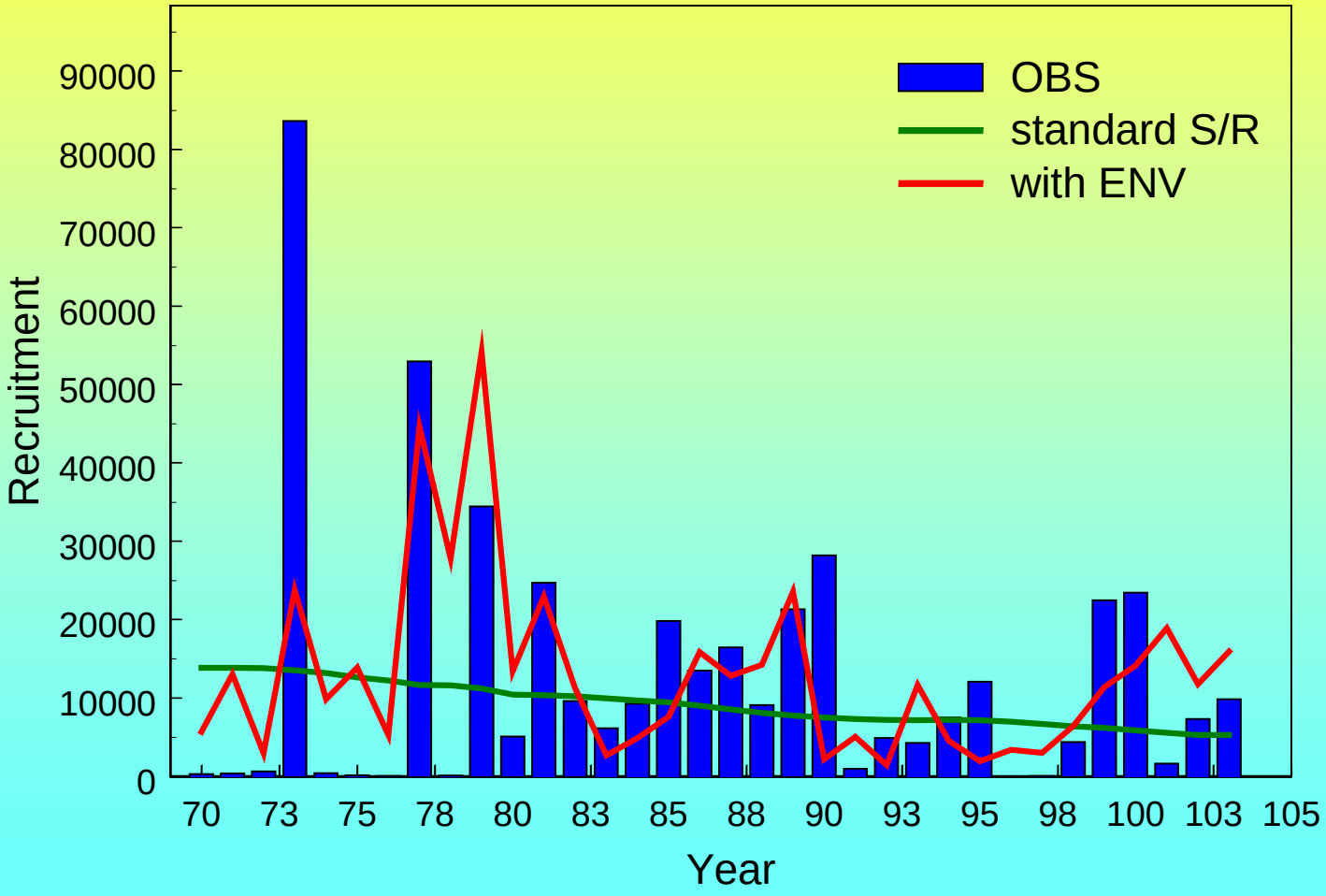
Re = recruits from the environmental model

Rs = recruits from the stock/recruit model

m_i *= fitted parameter*

x_i *= environmental effect anomaly (centered at 0)*

Much more of the variance is accounted for when using the stock-environmental-recruit model



Advantages to fitting within the stock assessment model

- Keeps the fitting process and parameter estimates internally consistent
- Allows for each years recruitment to be treated individually with regard to standard error
- Allows for gaps in the data
- Allows improvements to the stock assessment fit to be quantified

Conclusions

- Estimates of recruitment for a given year may be possible by August via oceanographic variables
- Estimates of historical (pre-survey) recruitment may be possible, which could lead to inferences with regard to “virgin” state (*B0*)
- Fitting the recruitment relationship internal to the stock assessment model will allow for fitting, hind casting, and forecasting to be done simultaneously