Primary productivity contribution to climate-catch models of Pacific sardine

Small Pelagics Symposium
March 6-11, 2017
Victoria, BC, Canada

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[1]S. Lluch-Cota, [1]D. Lluch-Cota, C.[1,3]Salvadeo y [4]G. Ponce-Díaz.

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Multidimensional hábitat

Quick response

Challenging Management

Modelling approaches

Climate-Catch

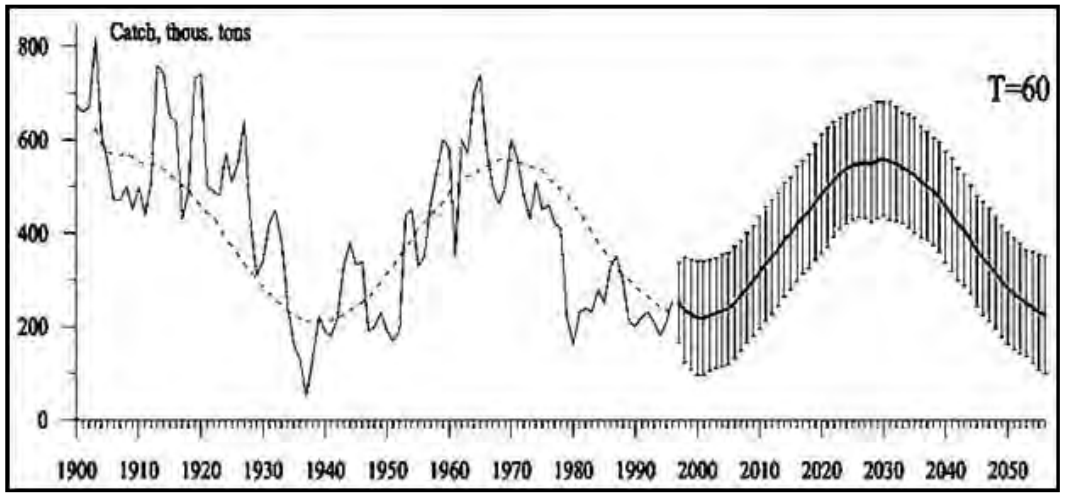
Checkeley *et al*., 2017; Koenigstein *et al*., 2016; Zwolinski 2014; Lluch-Cota 2013; Bakun *et al*., 2010; Lluch-Belda *et al*., 2003.

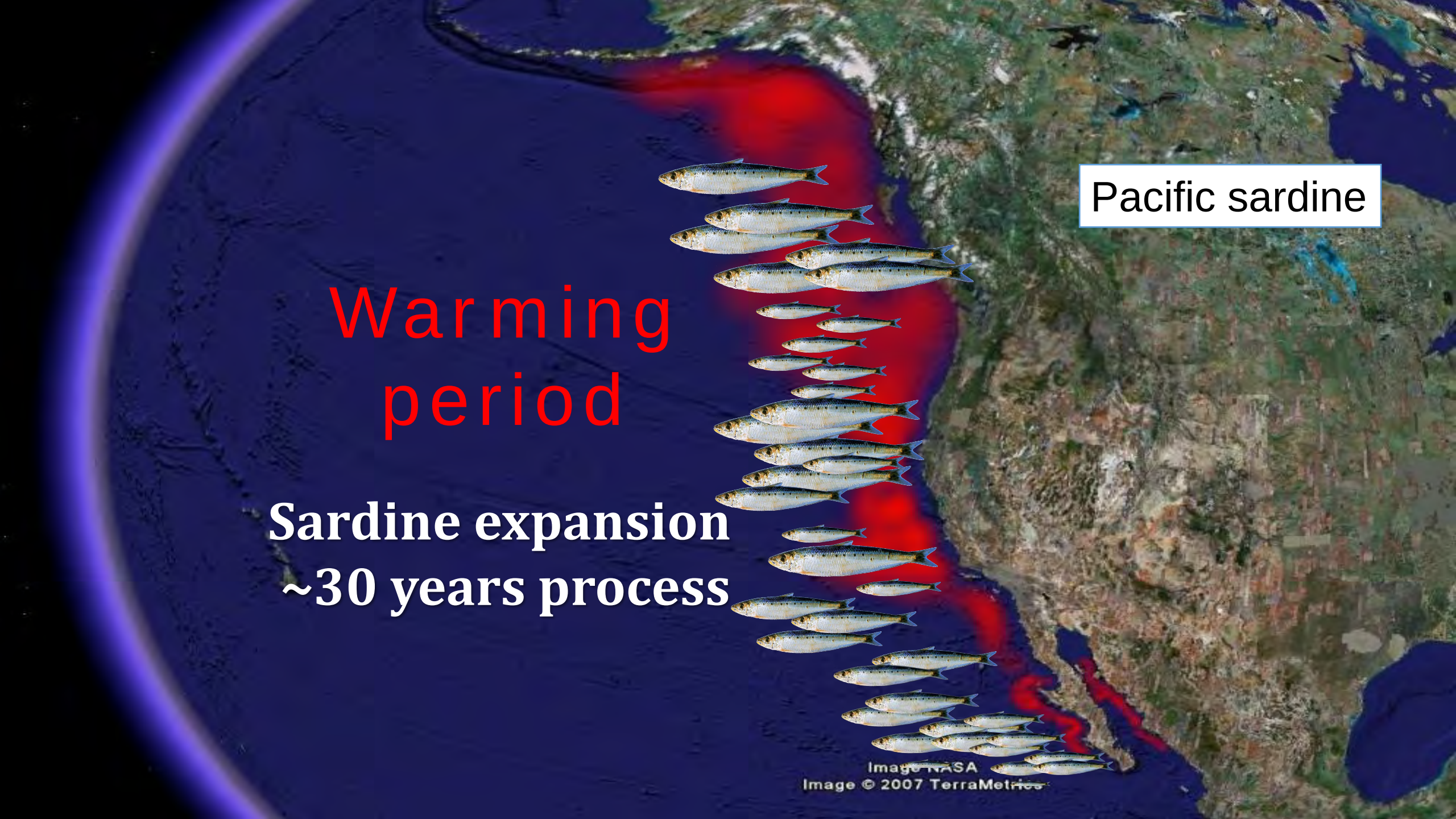
Small-pelagics fishing, registers the **highest catches** than any other fishery in the **world**.

They are also **important to** worldwide **aquaculture** as a source of food for farmed species.

FAO, 2016; Isaac, 2016

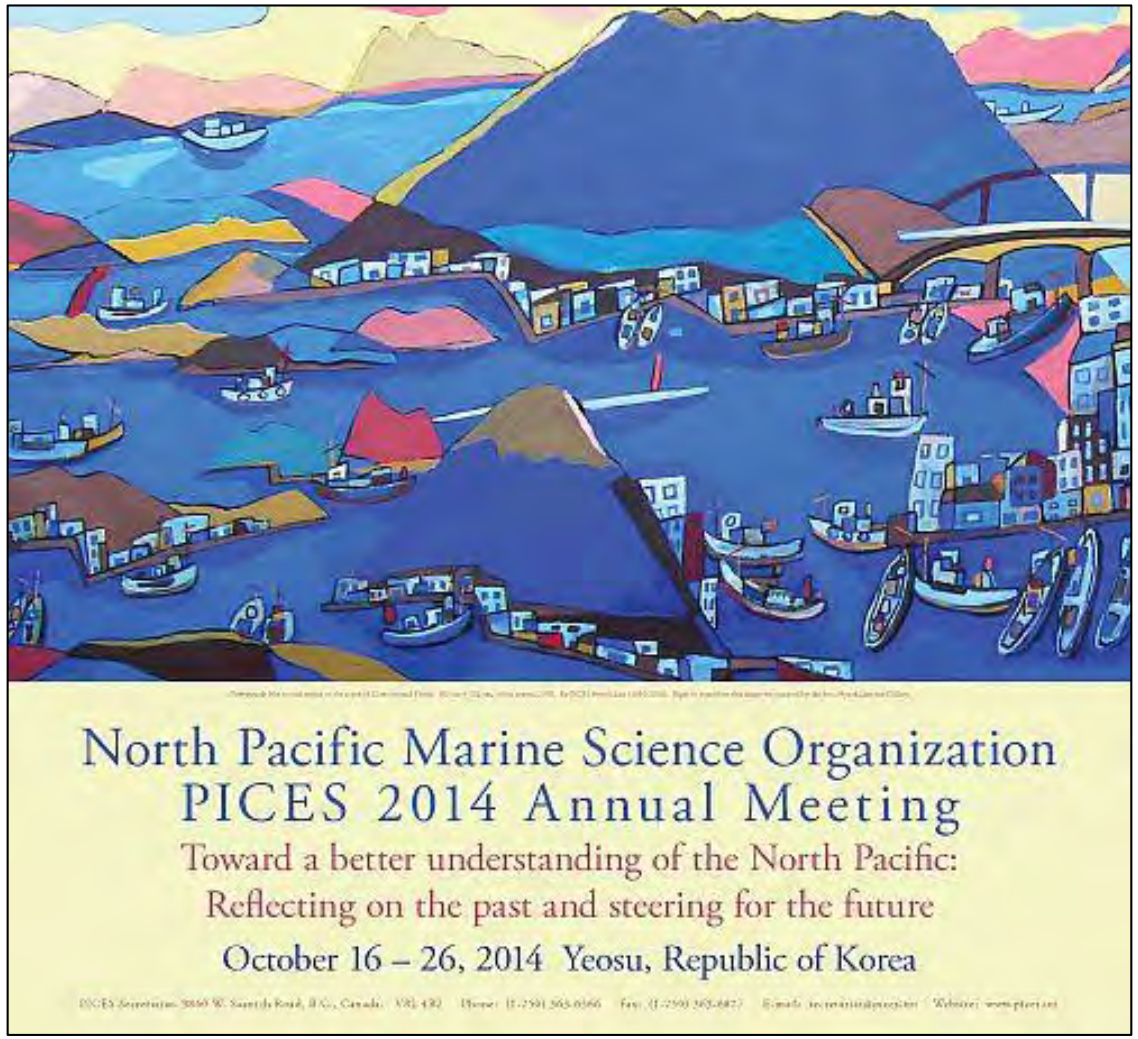
→ Fish stocks have strong low−frequency changes

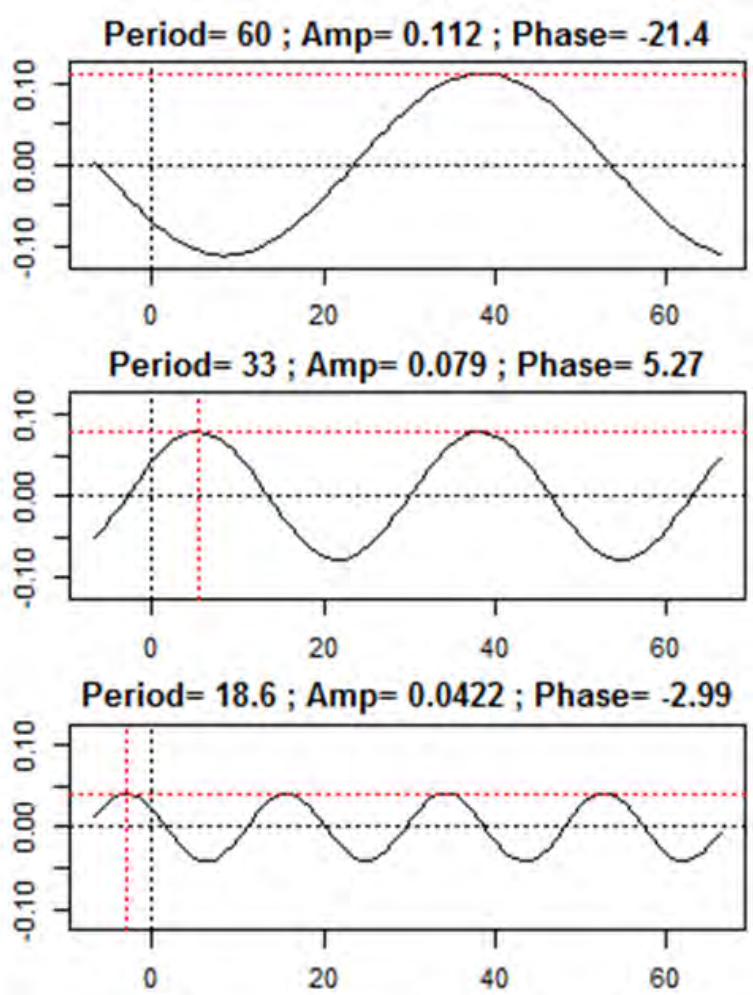



Pacific sardine
Warming
period
Sardine expansion
~30 years process
Image NASA
Image © 2007 TerraMetrics

Cooling period

Sardine contraction
~30 years process


North Pacific Marine Science Organization
PICES 2014 Annual Meeting
Toward a better understanding of the North Pacific:
Reflecting on the past and steering for the future
October 16 – 26, 2014 Yeosu, Republic of Korea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Period= 33 ; Amp= 0.079 ; Phase= 5.27
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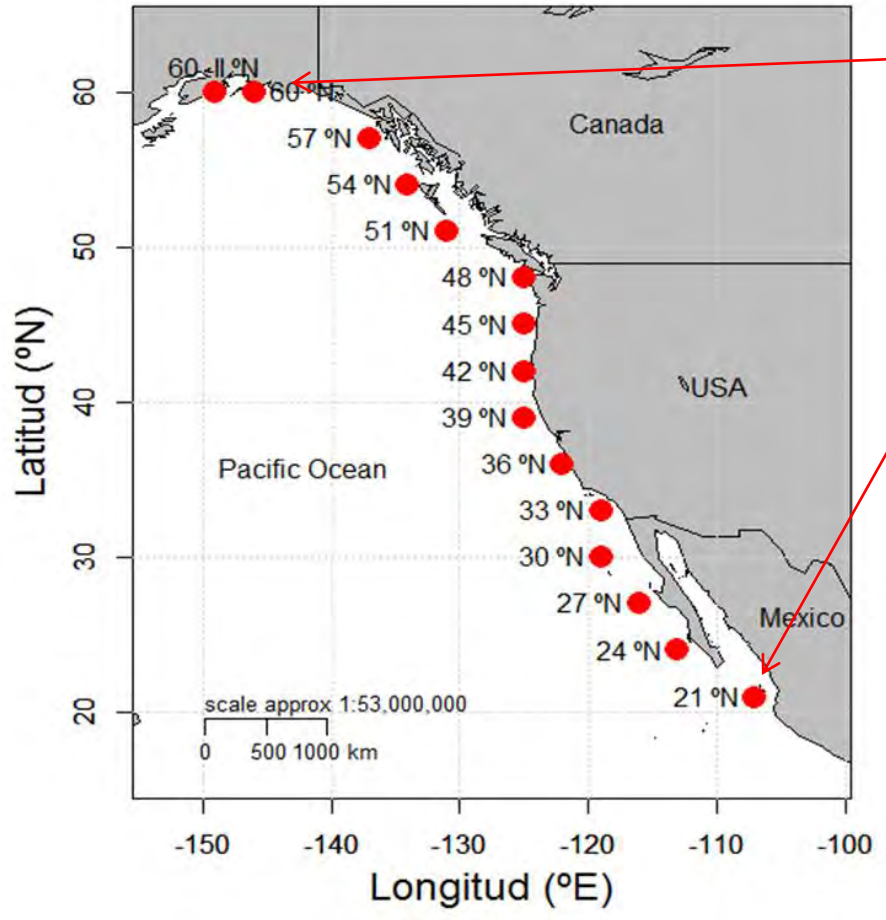
0.10
0.00
-0.10
0
20
40
60



15 Stations

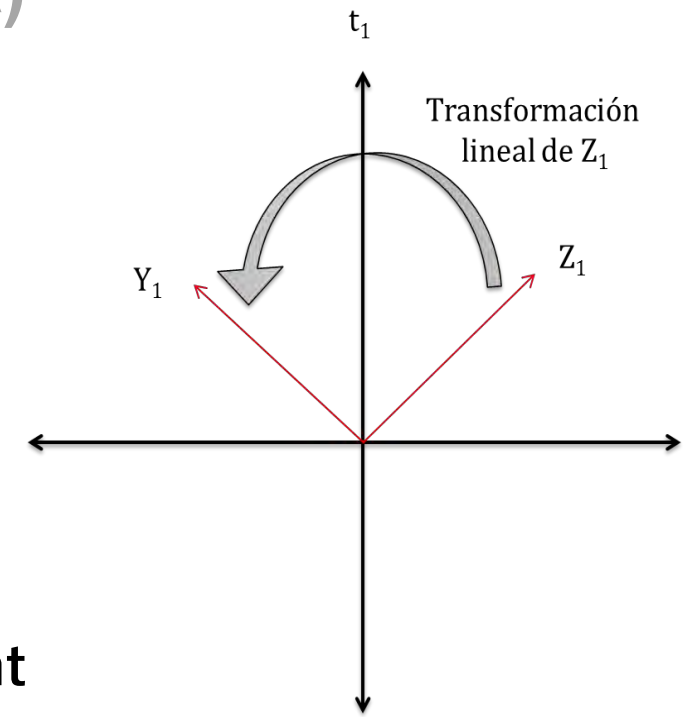
21 – 60° N

1946 – 2012 . . .

fish stock nowcast/forecast models using climate and upwelling information

MAXIMUM AUTOCORRELATION FACTOR ANALYSIS (MAFA)

≈ PRINCIPAL COMPONENTS ANALYSIS

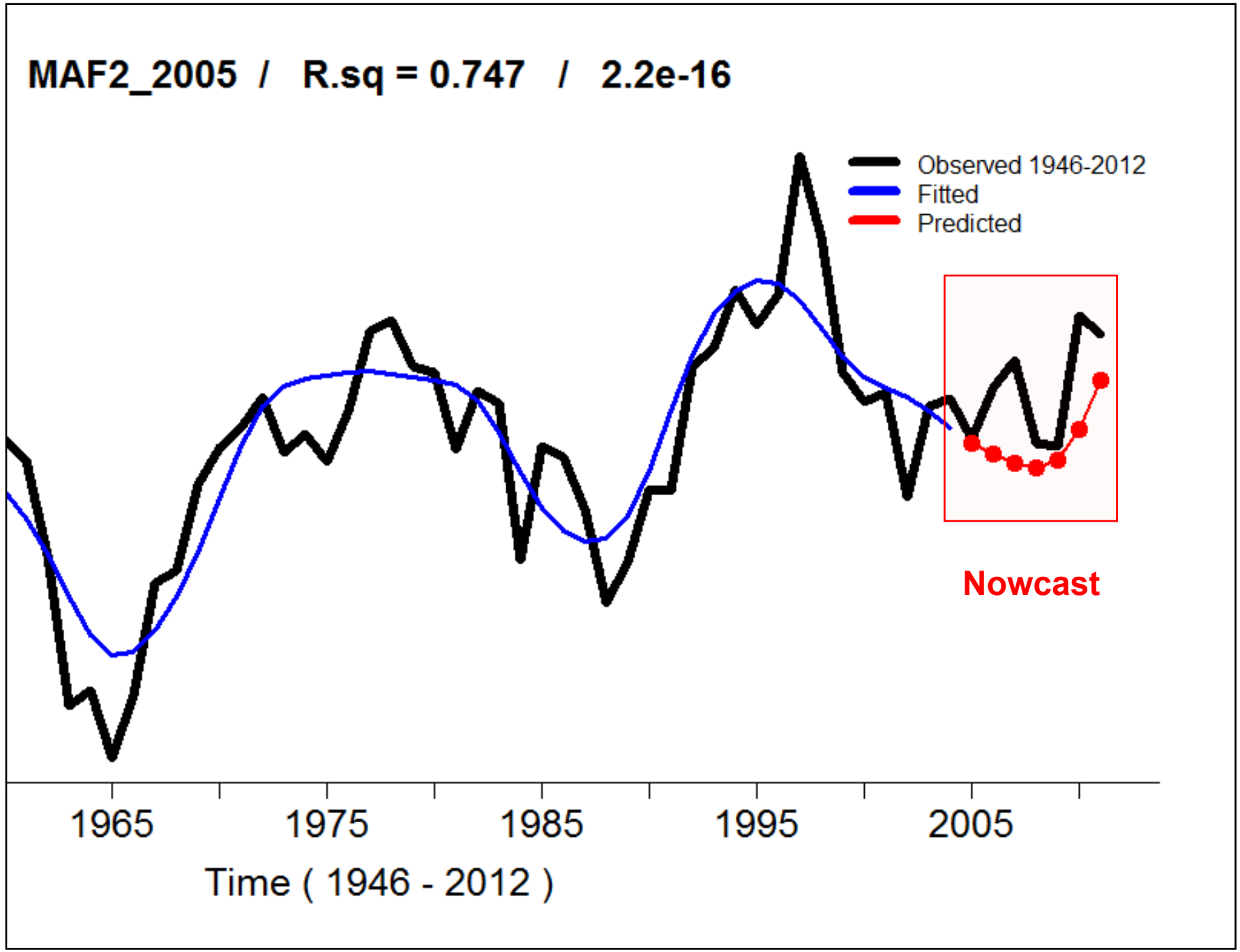


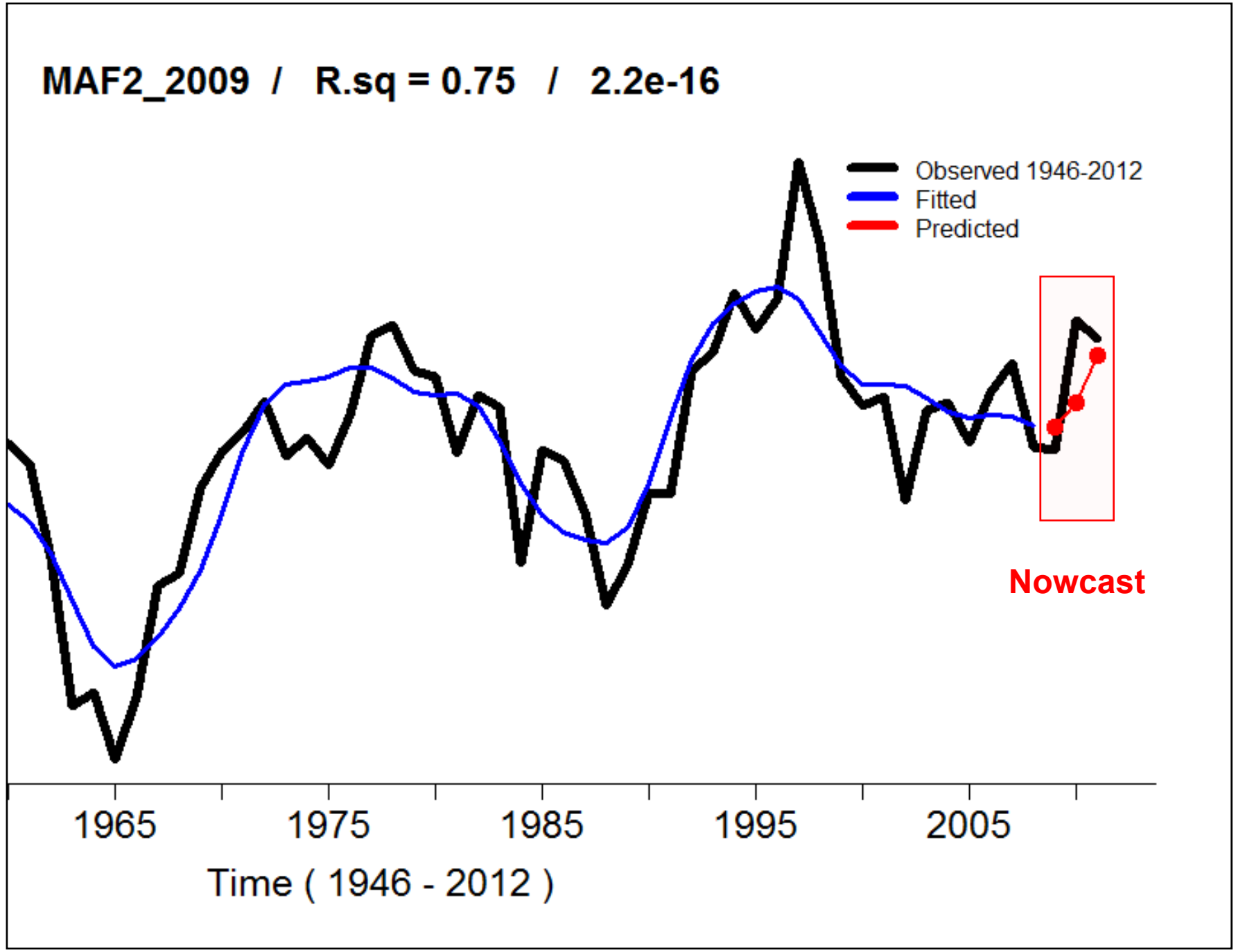
AUTOCORRELATION

VARIANCE

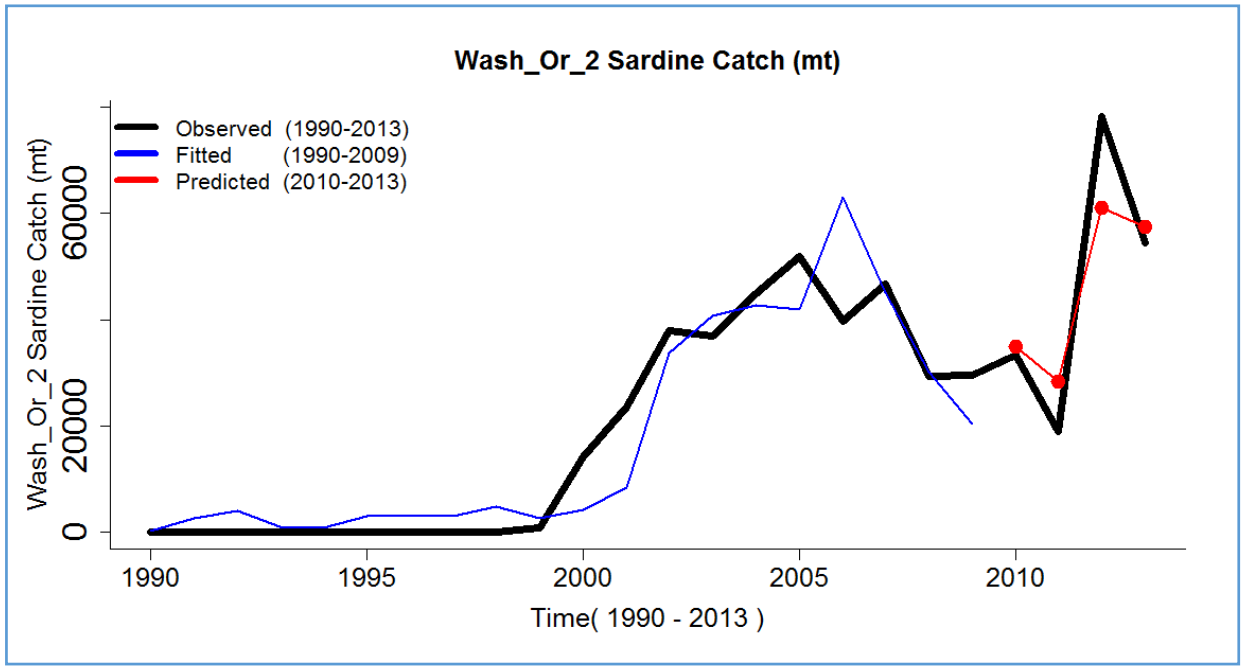
Priority to the dominant structure in time

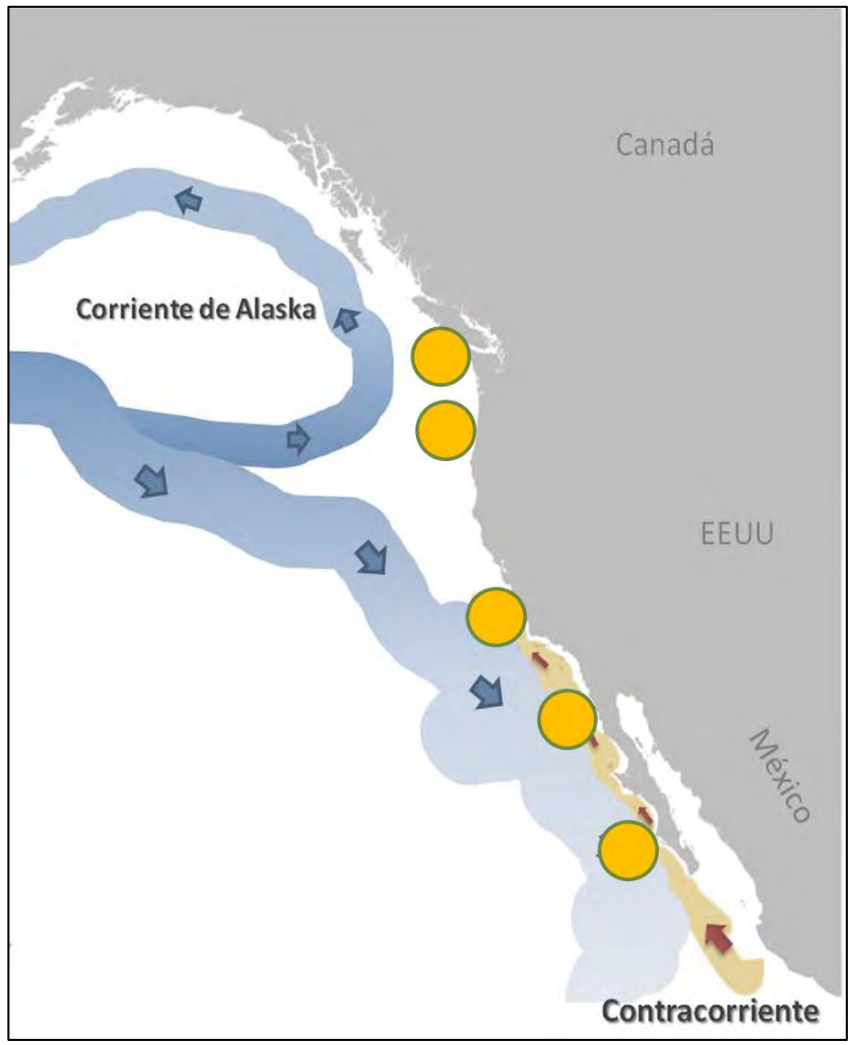
Switzer y Green, 1984; Shapiro y Switzer, 1989

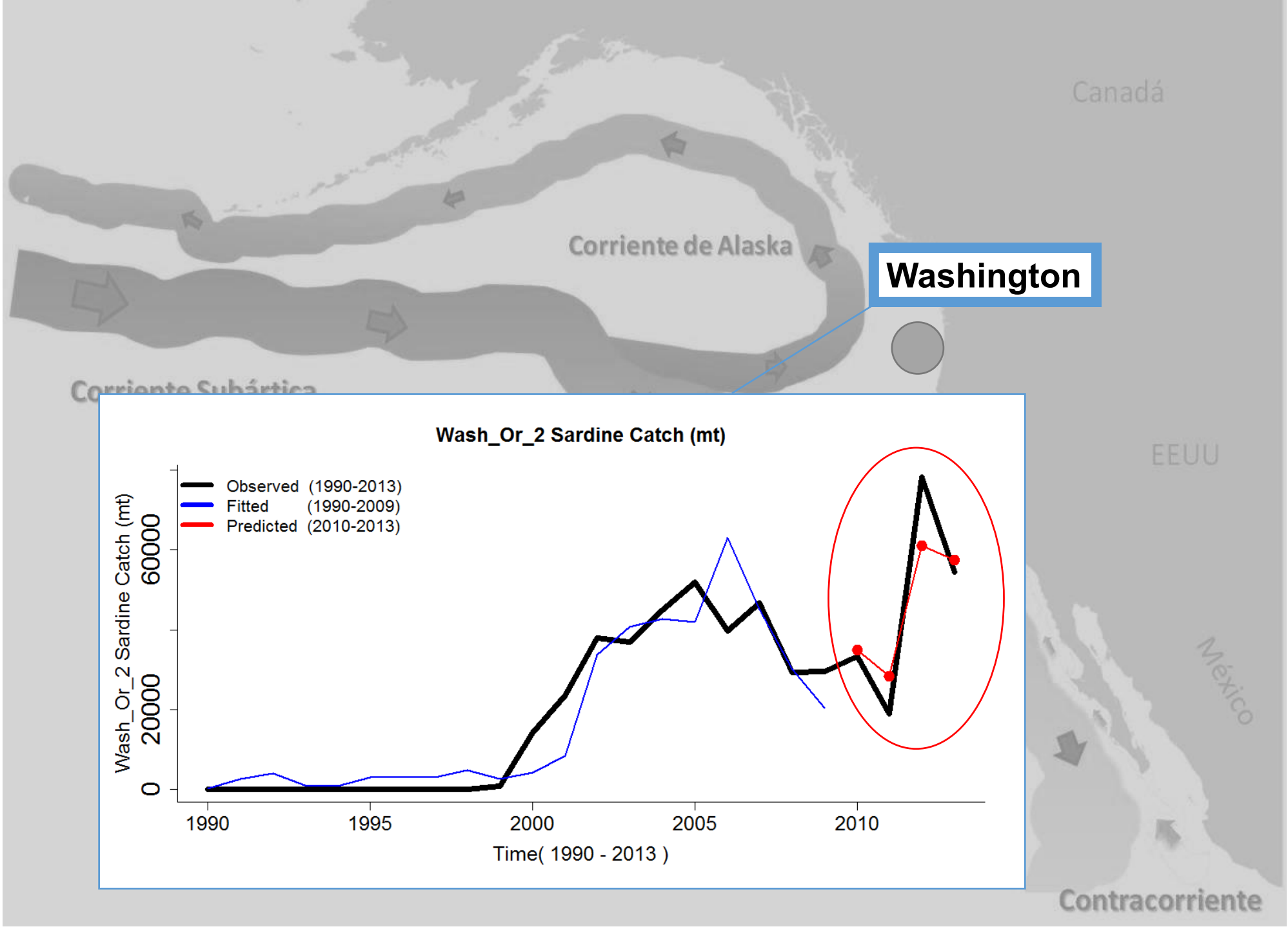

MAF2_2005 / R.sq = 0.747 / 2.2e-16
Observed 1946-2012
Fitted
Predicted
Nowcast
1965
1975
1985
1995
2005
Time (1946 - 2012)

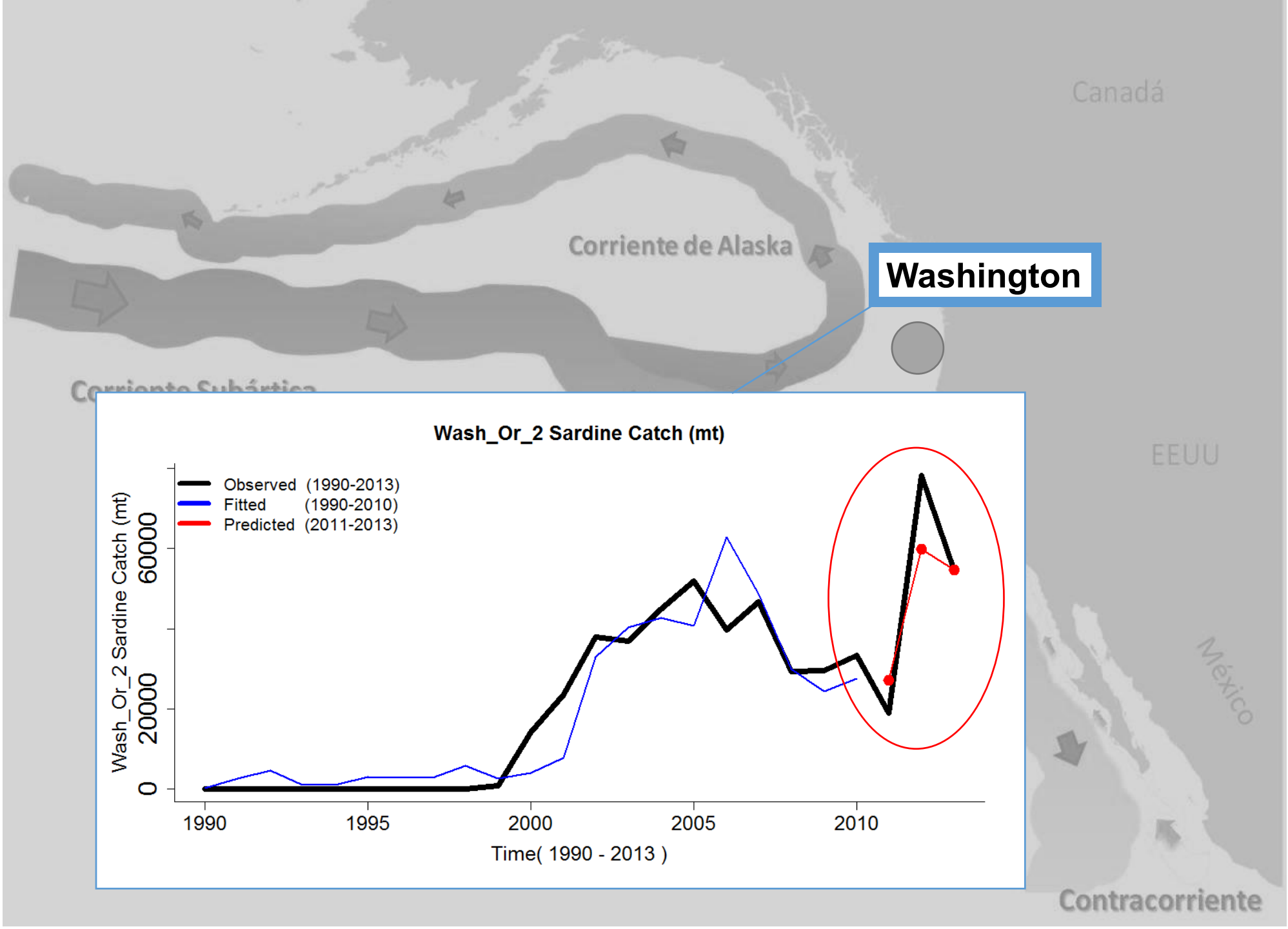

MAF2_2009 / R.sq = 0.75 / 2.2e-16
Observed 1946-2012
Fitted
Predicted
Nowcast
1965
1975
1985
1995
2005
Time (1946 - 2012)

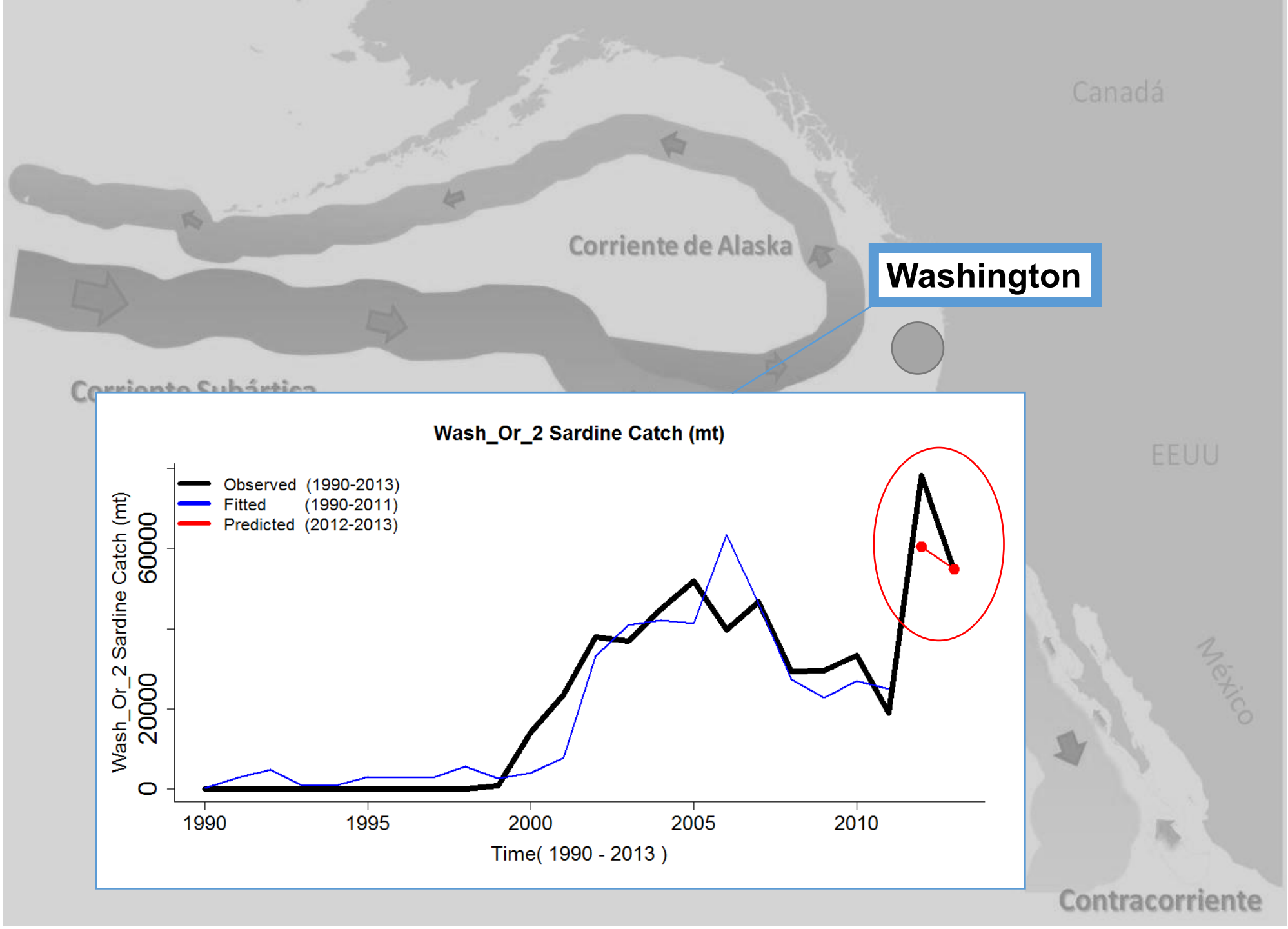
Climate-Catch Models

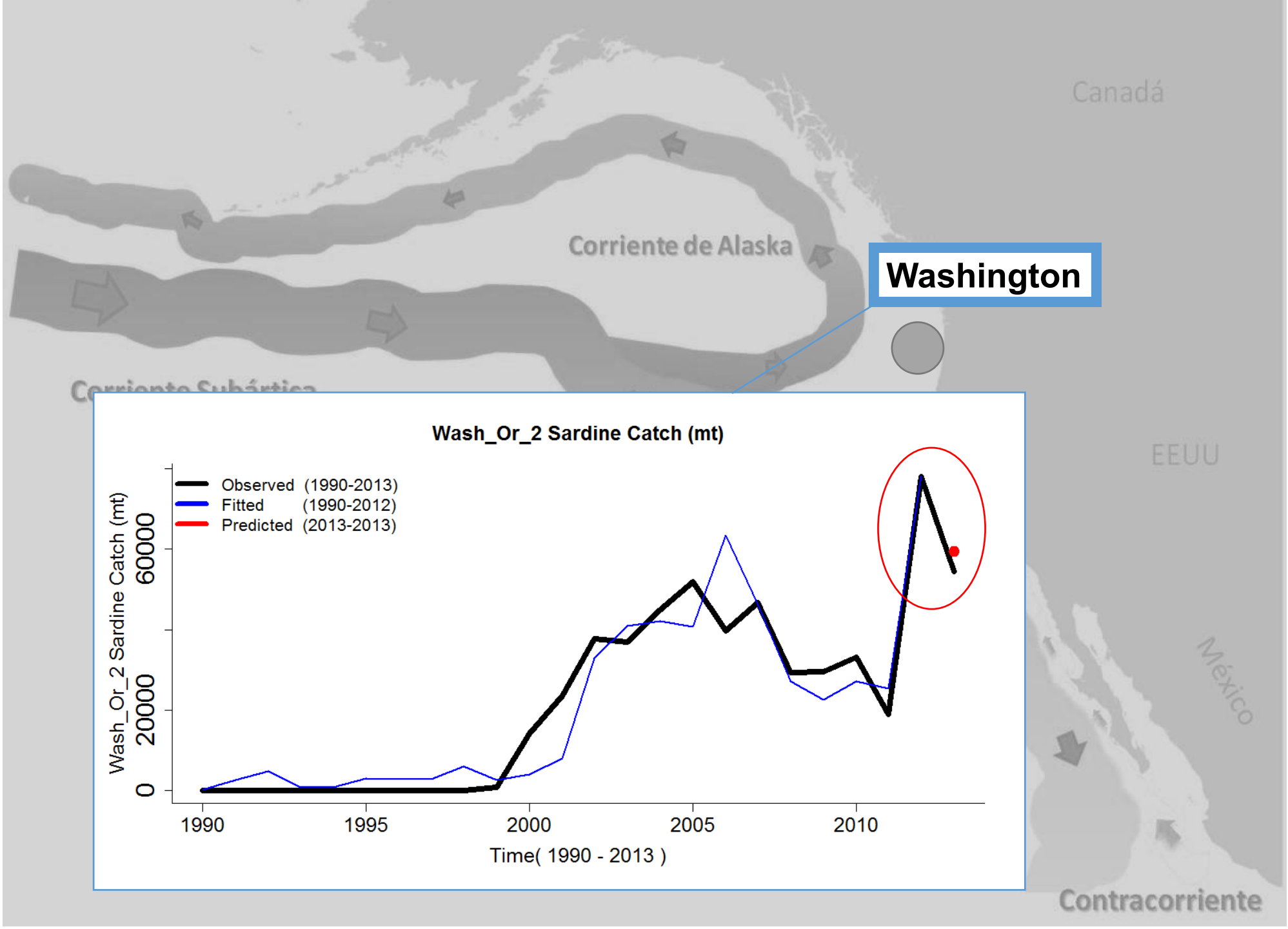





Canadá
Corriente de Alaska
Washington
Corriente Subártica
EEUU
México
Contracorriente
Wash_Or_2 Sardine Catch (mt)
Observed (1990-2013)
Fitted (1990-2009)
Predicted (2010-2013)
Wash_Or_2 Sardine Catch (mt)
0
20000
60000
1990
1995
2000
2005
2010
Time(1990 - 2013)


Canadá
Corriente de Alaska
Washington
Corriente Subártica
EEUU
México
Contracorriente
Wash_Or_2 Sardine Catch (mt)
Observed (1990-2013)
Fitted (1990-2010)
Predicted (2011-2013)
Wash_Or_2 Sardine Catch (mt)
0
20000
60000
1990
1995
2000
2005
2010
Time(1990 - 2013)


Canadá
Corriente de Alaska
Washington
Corriente Subártica
EEUU
México
Contracorriente
Wash_Or_2 Sardine Catch (mt)
Observed (1990-2013)
Fitted (1990-2011)
Predicted (2012-2013)
Wash_Or_2 Sardine Catch (mt)
0
20000
60000
1990
1995
2000
2005
2010
Time(1990 - 2013)


Canadá
Corriente de Alaska
Washington
Corriente Subártica
EEUU
México
Contracorriente
Wash_Or_2 Sardine Catch (mt)
Observed (1990-2013)
Fitted (1990-2012)
Predicted (2013-2013)
Wash_Or_2 Sardine Catch (mt)
0
20000
60000
1990
1995
2000
2005
2010
Time(1990 - 2013)

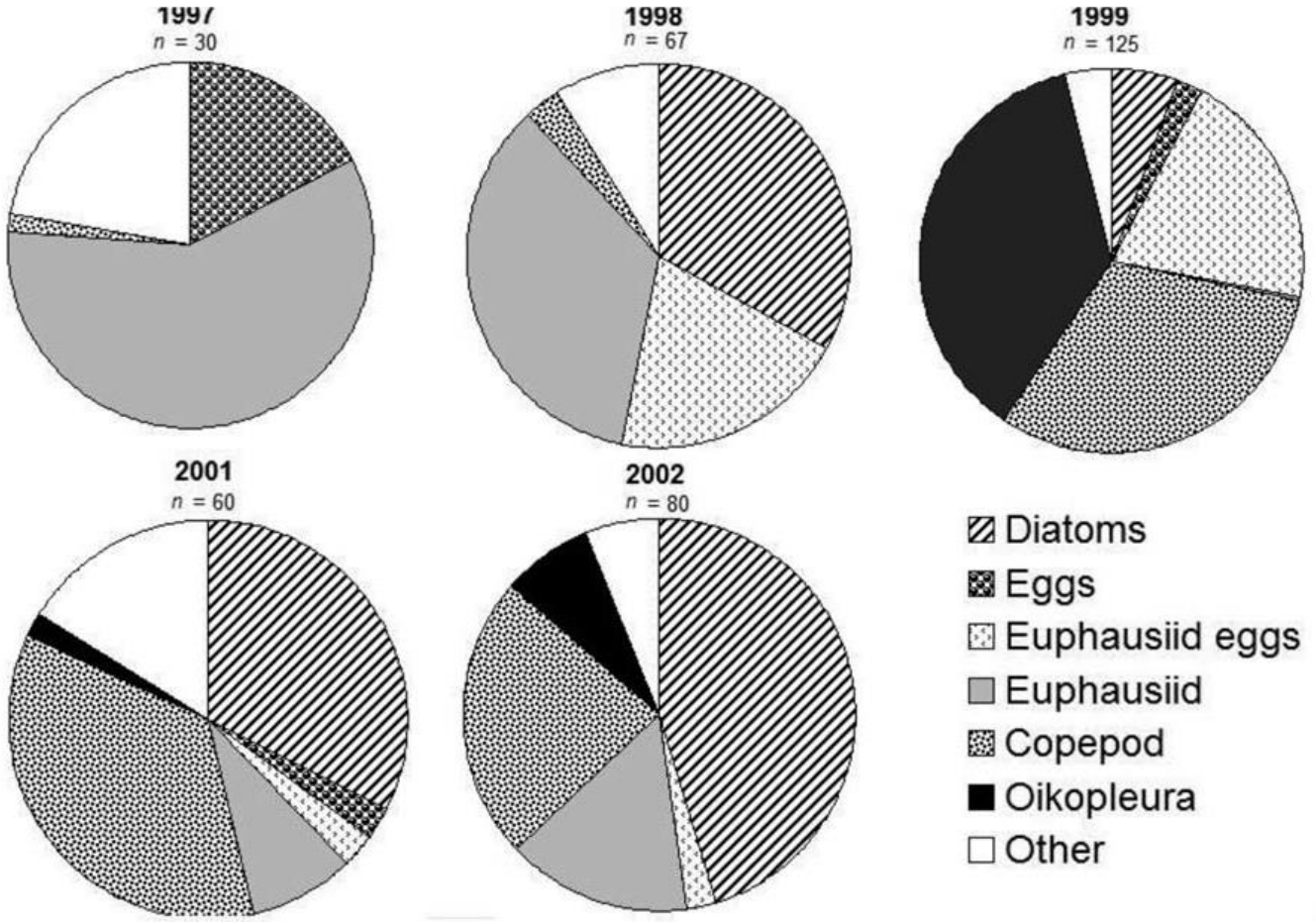
However . . .

…is a big jump!

Primary Productivity

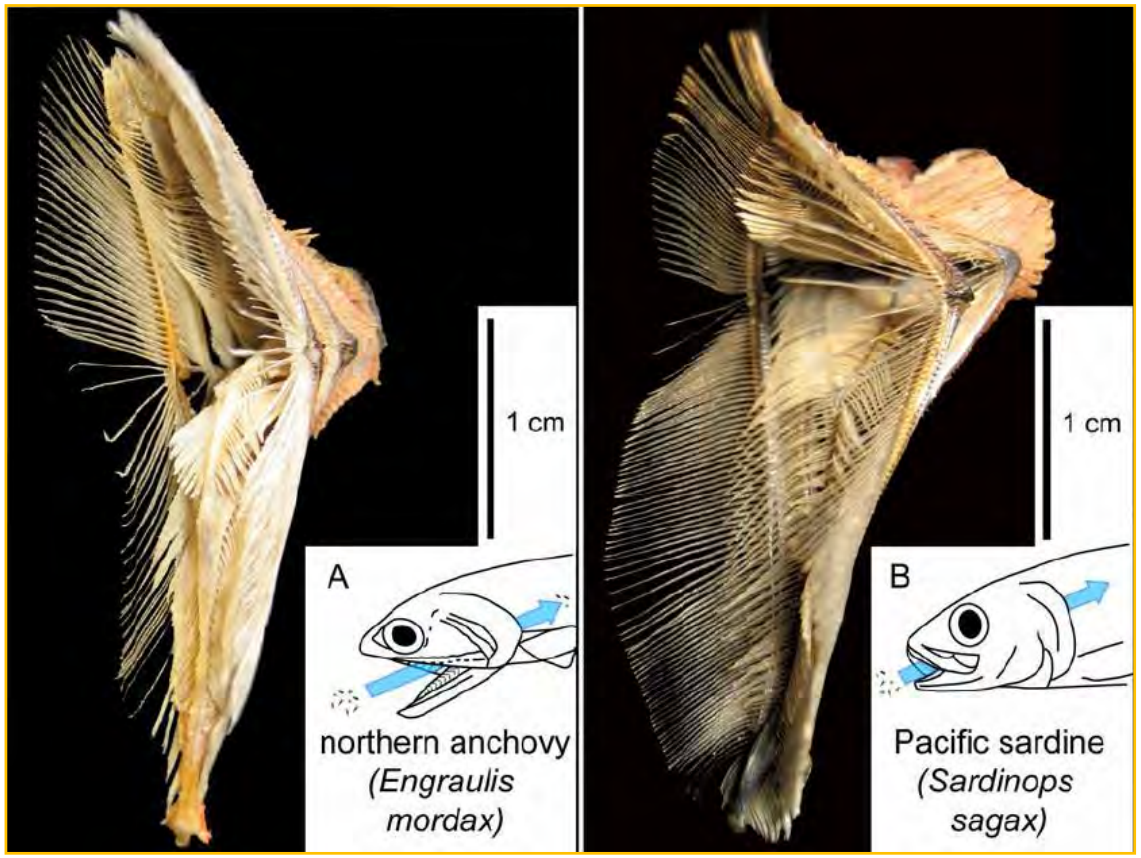
Diet Variability

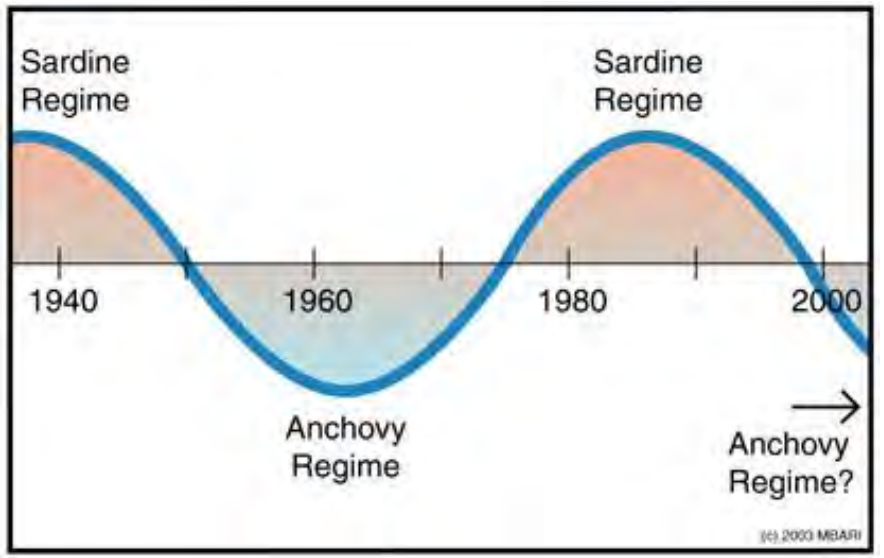
Distribution & abundance



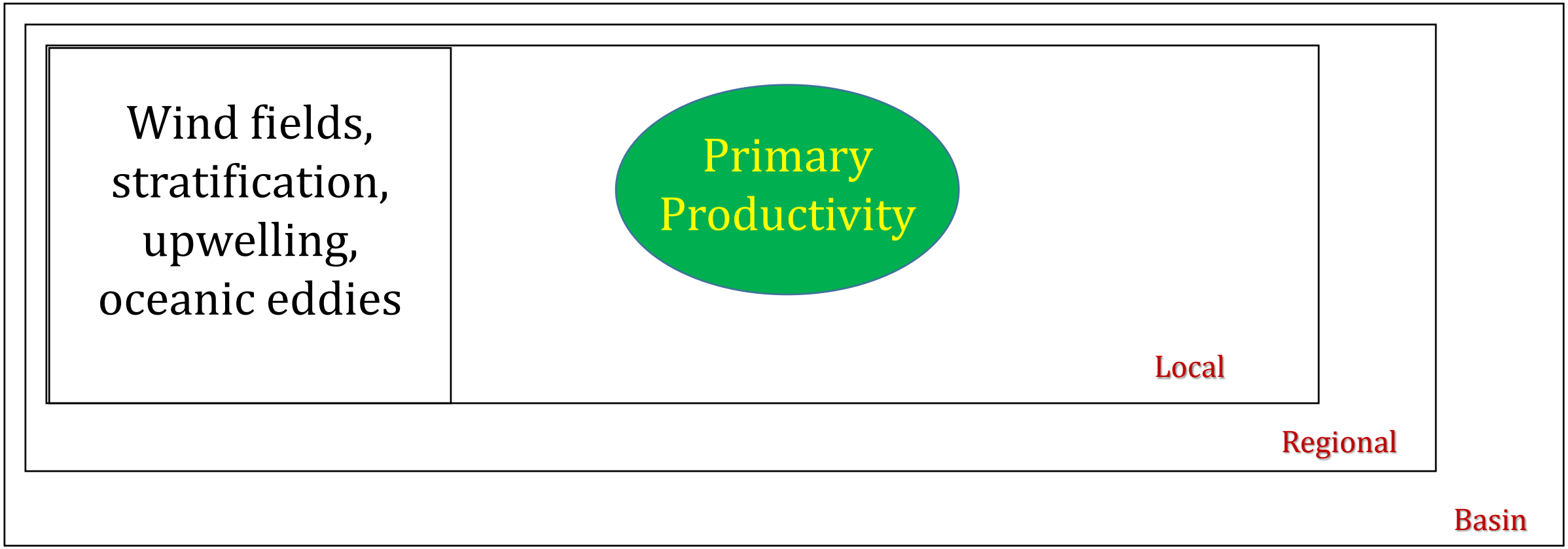
McFarlane *et al.*, 2005. CalCOFI Rep.

Some authors have suggested the relevance of (sardine/anchovies) feeding apparatus sizes to capture different portions of plankton species.





Rykaczewski, 2009; Bakun 2004



Macias *et al*., 2012; Di Lorenzo *et al*., 2008; Rykaczewski and Checkley, 2008; Mantua *et al*., 1997

PICES, 2014 +

Revista de Biología Marina y Oceanografía
Vol. 50, Nº2: 331-345, agosto 2015

ARTÍCULO

Patrones históricos y escenarios térmicos futuros en mares mexicanos

Historical patterns and predicted thermal scenarios in Mexican seas

Romeo Saldívar-Lucio[1], Christian Salvadeo[2], Pablo Del Monte-Luna[1], Francisco Arreguín-Sánchez[1], Héctor Villalobos[1], Daniel Lluch-Belda†[1], Germán Ponce-Díaz[1], José Luis Castro-Ortiz[1], José Alberto Zepeda-Domínguez[1], Fernando Aranceta-Garza[1] y Luis César Almendarez-Hernández[1]

PLOS ONE

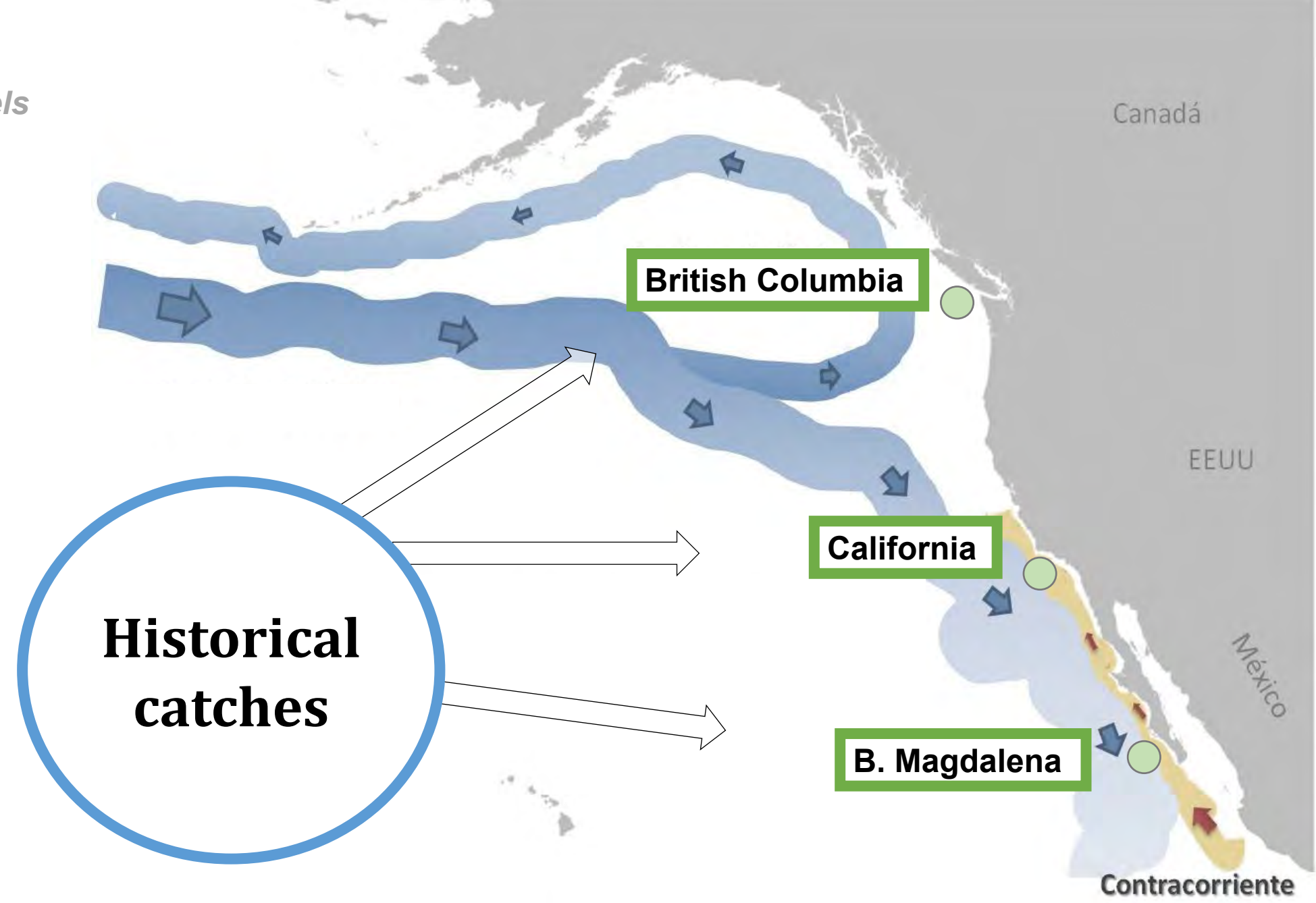
RESEARCH ARTICLE

Macro-Scale Patterns in Upwelling/ Downwelling Activity at North American West Coast

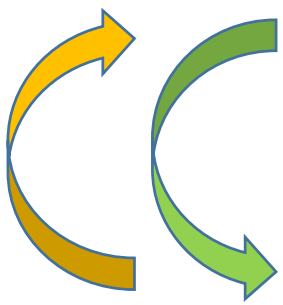
Romeo Saldívar-Lucio[1,4]*, Emanuele Di Lorenzo[2], Miguel Nakamura[3], Héctor Villalobos[1], Daniel Lluch-Cota[4], Pablo Del Monte-Luna[1]*

This work was aimed to test the contribution of (multi-scale) PP and closely related oceanic processes, (e.g. upwelling, eddies) in climate-catch models of the pacific sardine at three fishing ports of the eastern margin of the North Pacific basin.

Climate-Catch Models

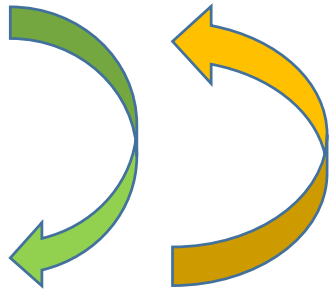


DOUBLE CLIMATIC CONTROL



Adults Condition Factor

Reproductive Success



Zowolinski and Demer, 2014

RECRUITMENT

Parental stock size → Subsequent recruitment

Parental stock size → Year class strength

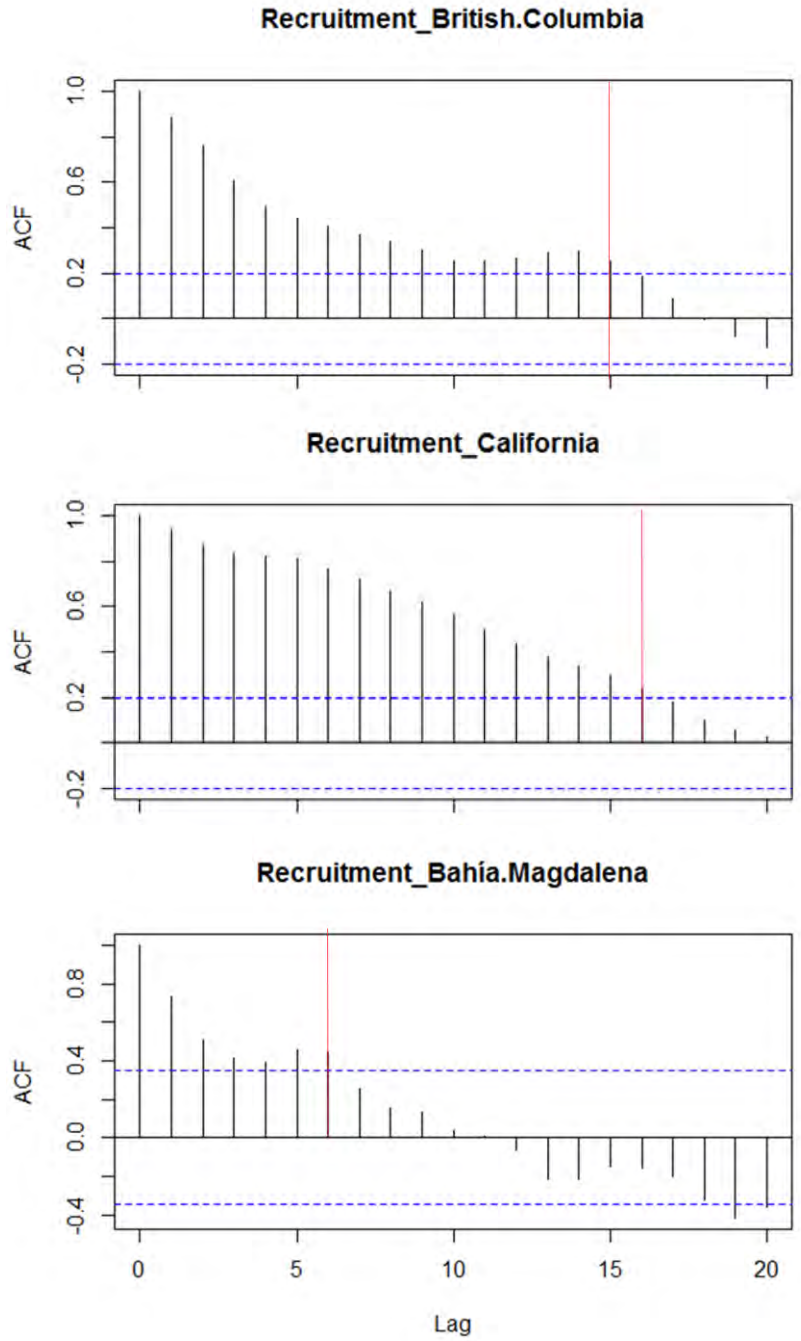
α = density-dependent parameter

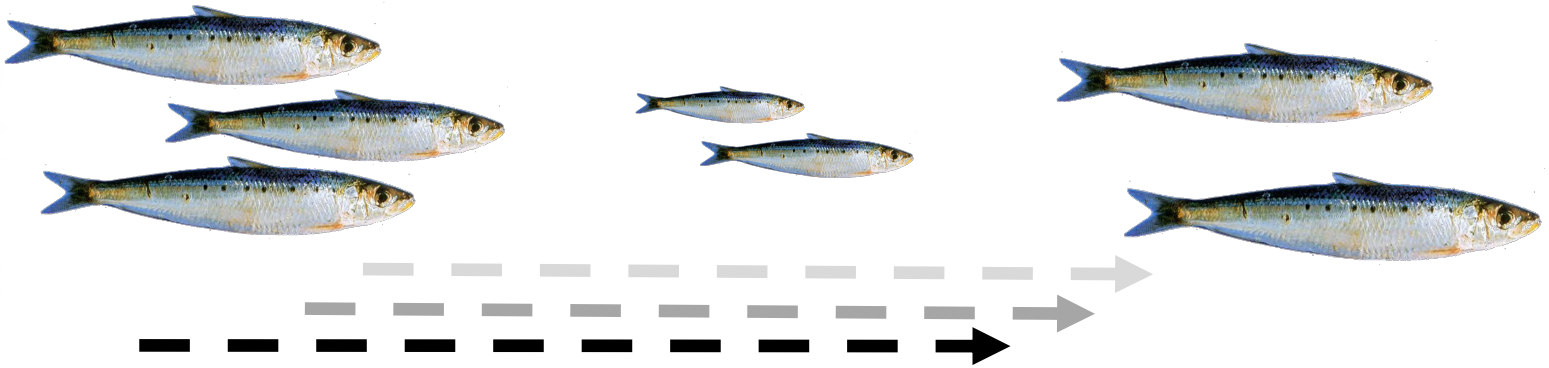
β = level of density dependence

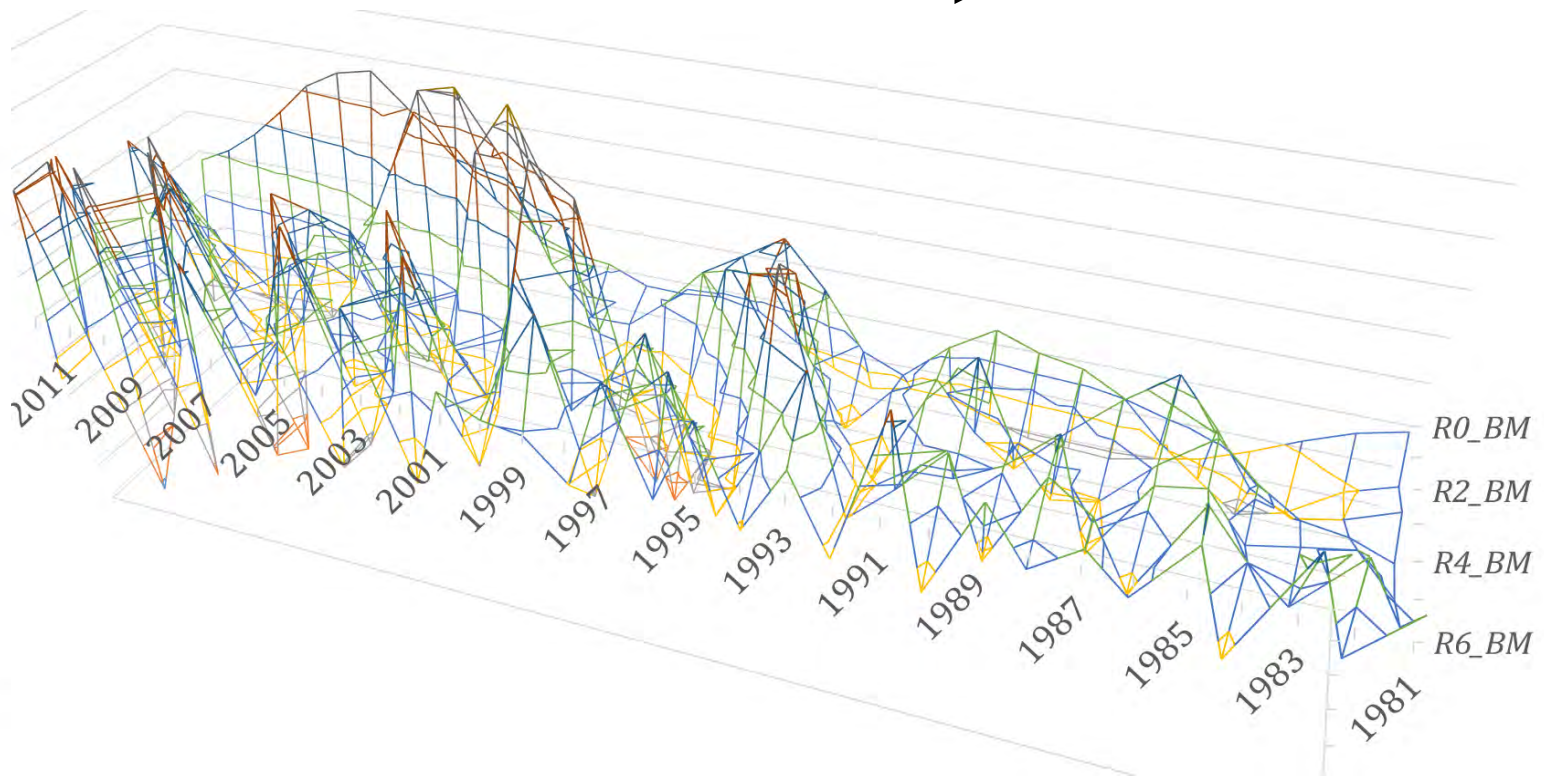
$$R = \frac{\alpha S}{\beta + S}$$

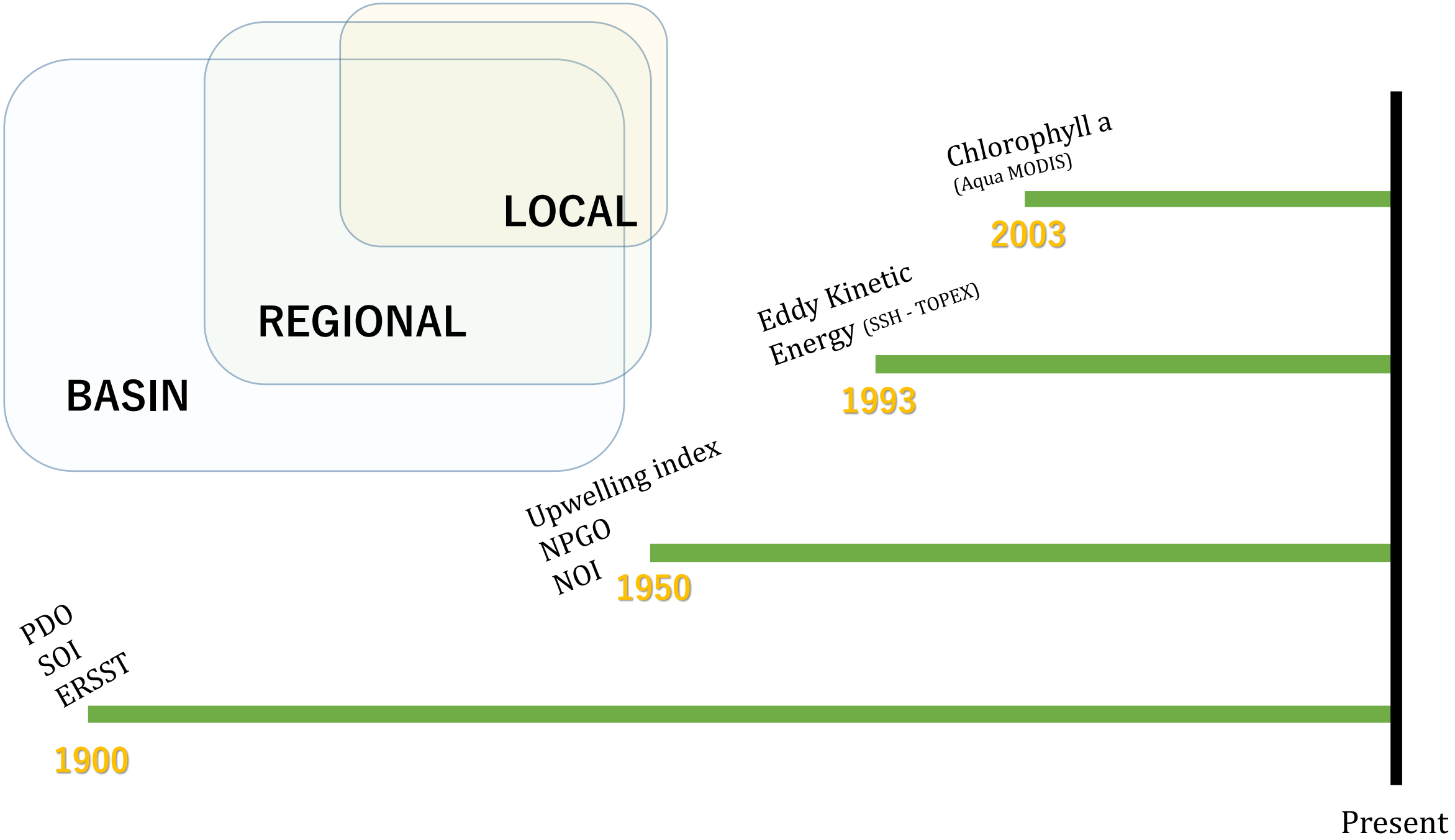
Galindo-Cortes *et al.*, 2009; Sparre and Venema, 1998

Climate-Catch Models







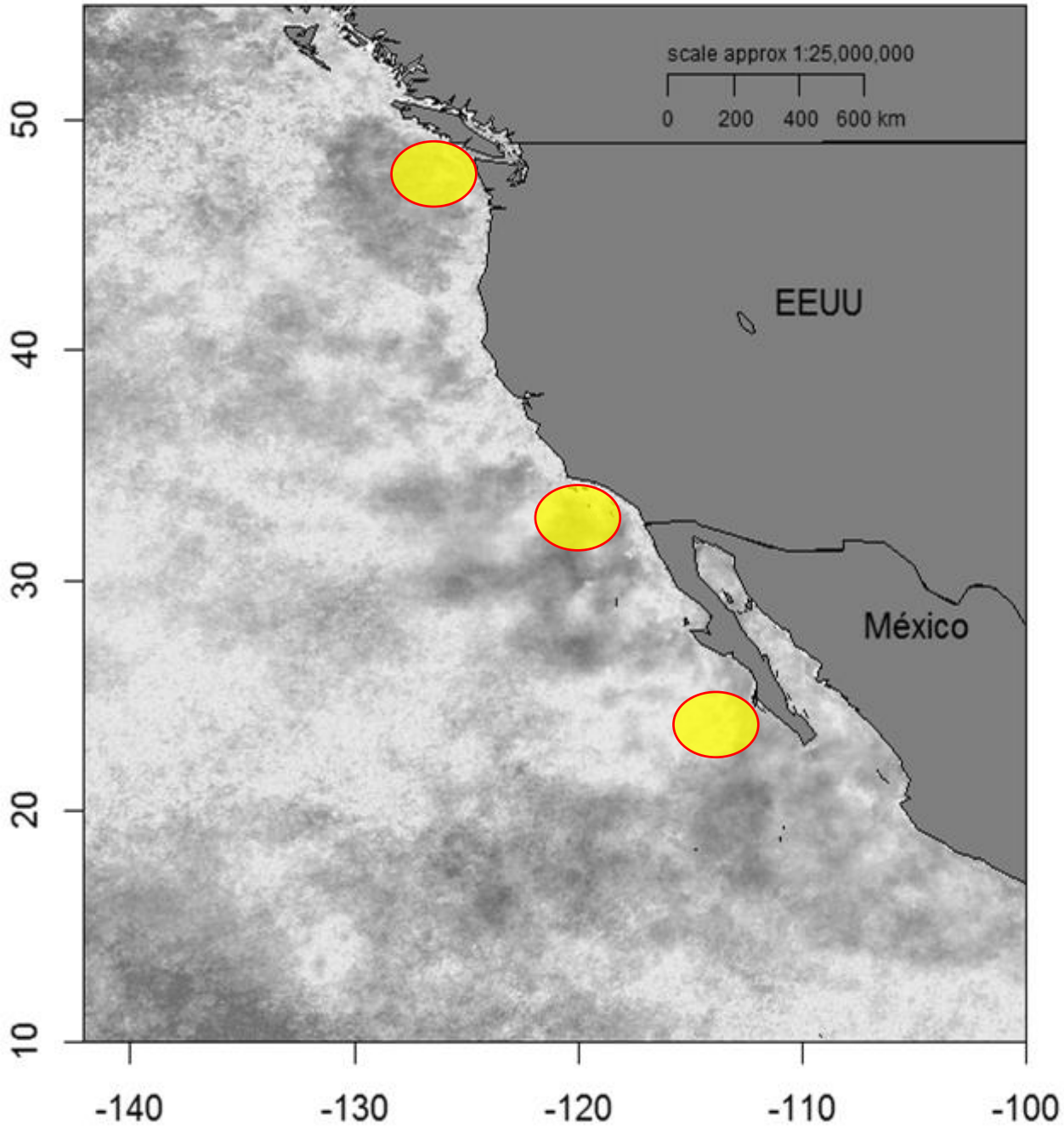

LOCAL
REGIONAL
BASIN
Chlorophyll a
(Aqua MODIS)
2003
Eddy Kinetic
Energy (SSH - TOPEX)
1993
Upwelling index
NPGO
NOI
1950
PDO
SOI
ERSST
1900
Present

Environmental Data

British Columbia, Can:
Lat: 48 – 50 ° N
Lon: 124 – 128 ° W

California, US:
Lat: 32 – 34 ° N
Lon: 118 – 122 ° W

Bahía Magdalena, Mex:
Lat: 22 – 24 ° N
Lon: 110 – 114 ° W



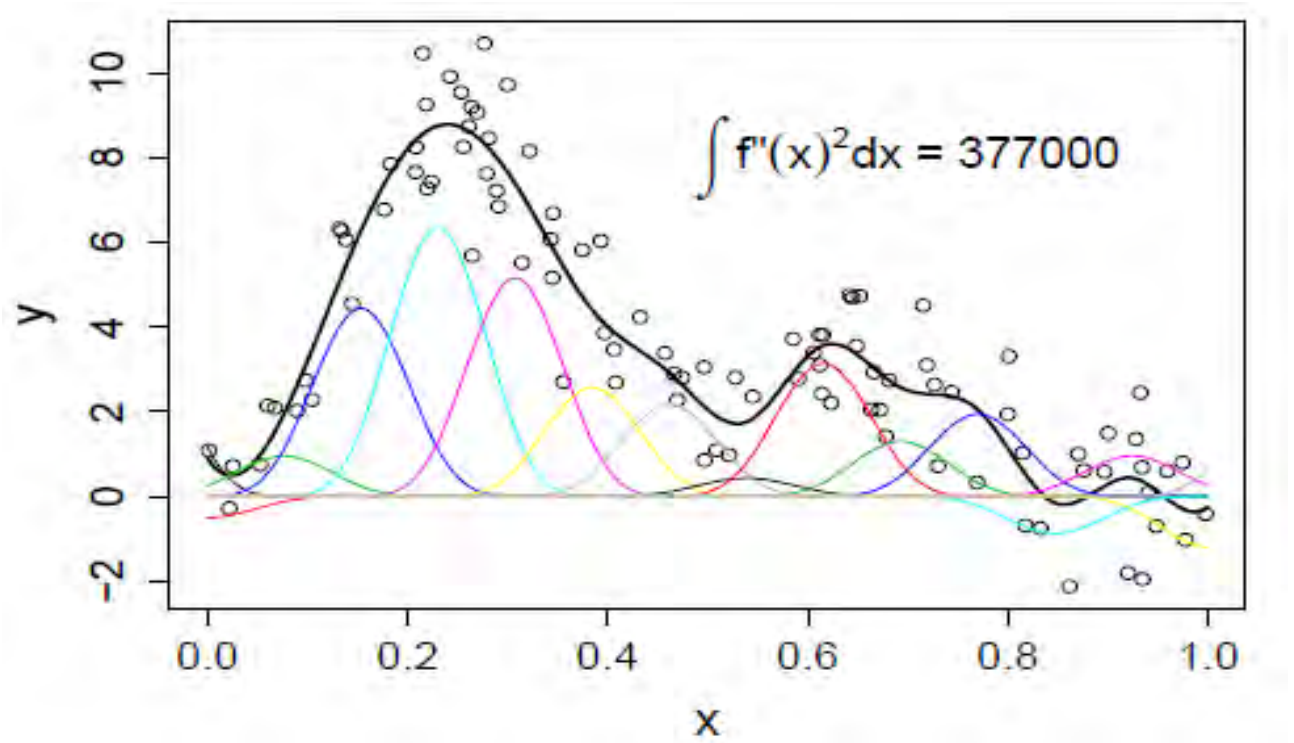
RECRUITMENT

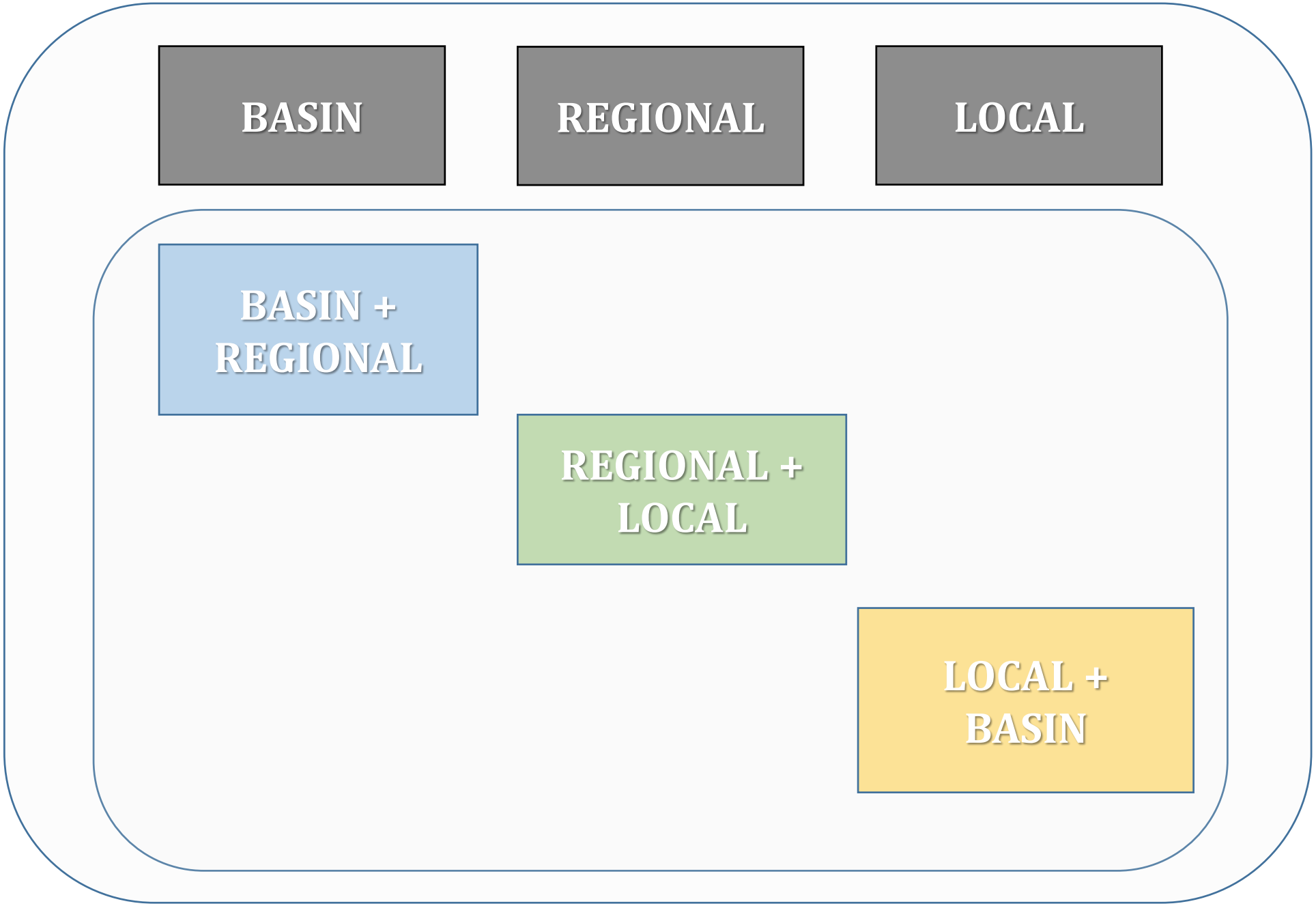
CATCH

ENVIR-1

ENVIR-2

$$g(\mu_i) = \mathbf{X}_i^* \boldsymbol{\theta} + f_1(x_{1i}) + f_2(x_{2i}) + f_3(x_{3i}, x_{4i}) + \ldots$$




BASIN
REGIONAL
LOCAL
BASIN + REGIONAL
REGIONAL + LOCAL
LOCAL + BASIN

BASIN

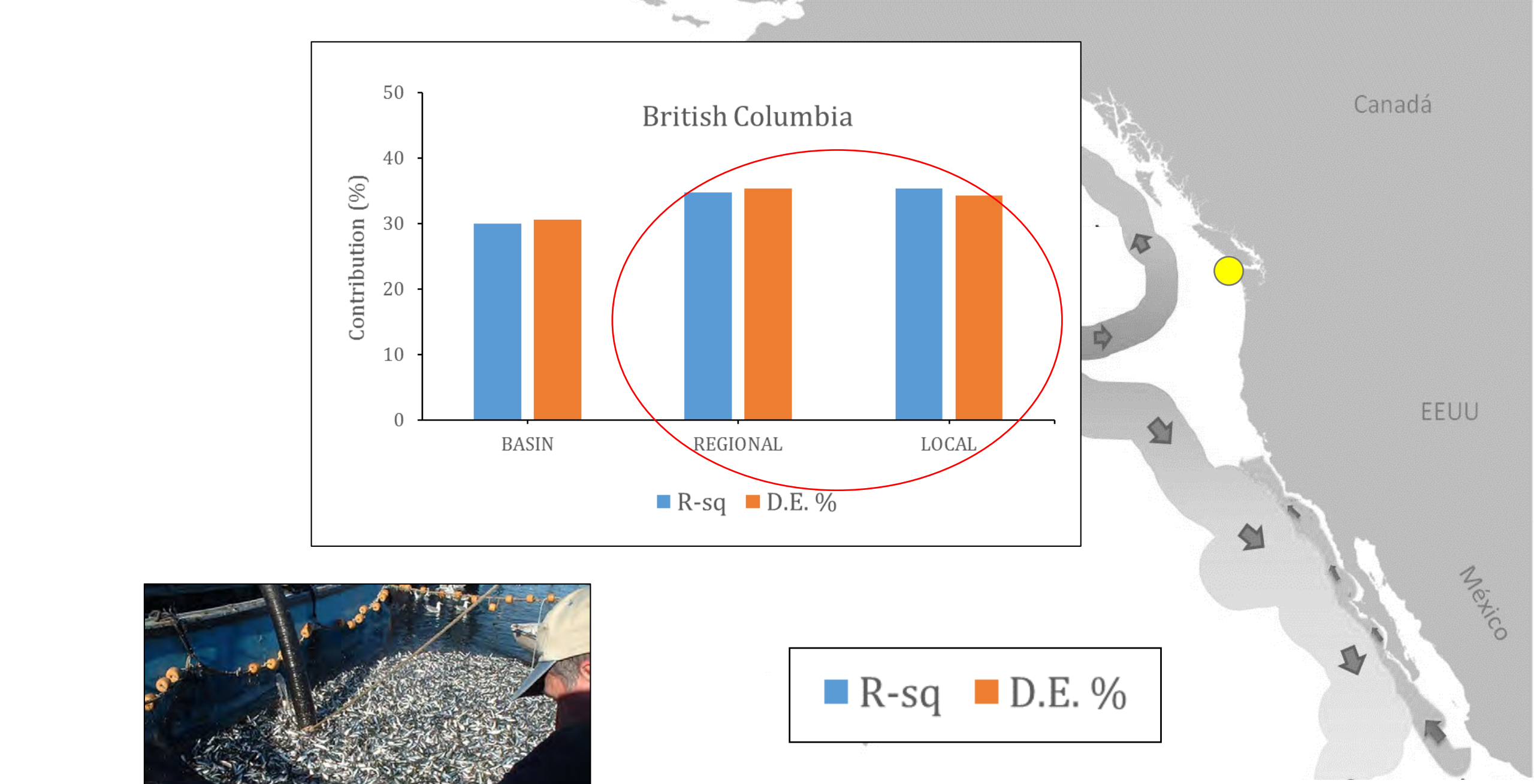
REGIONAL

LOCAL

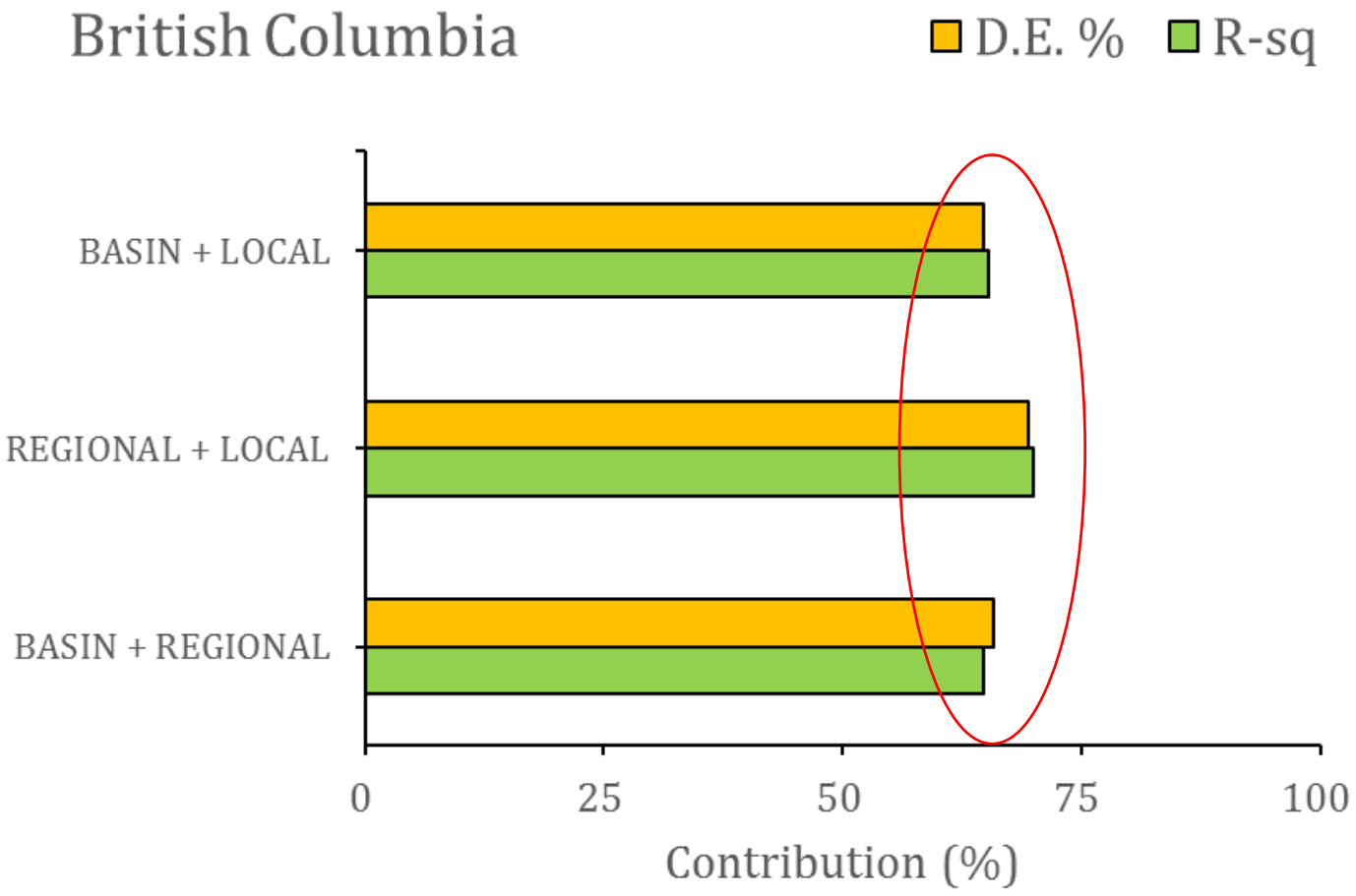
R^2 %D.E. *Residuals*

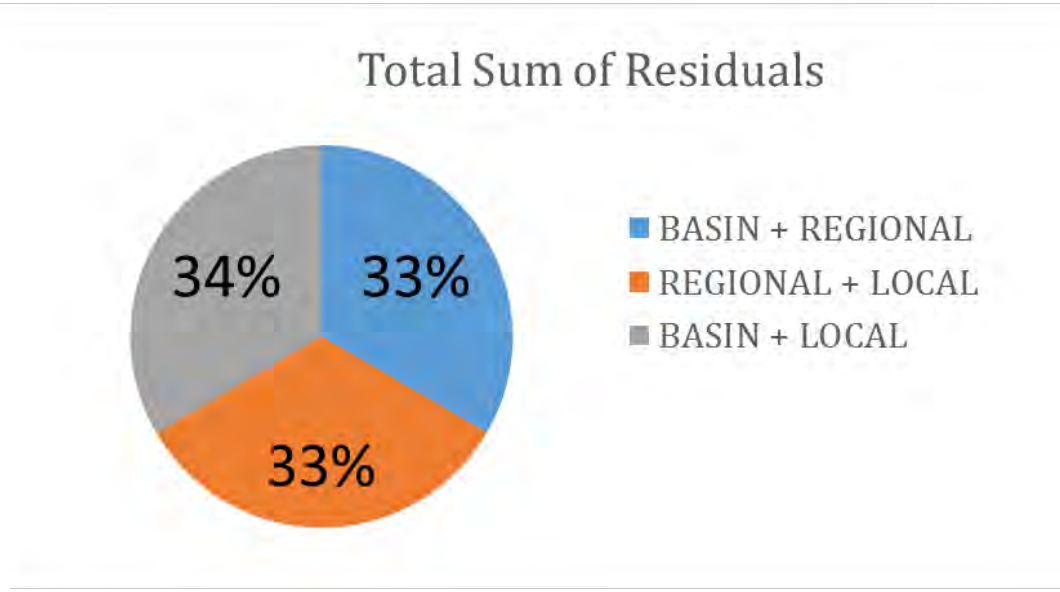
* Selection criteria (statistics)
* Three variables (PP)

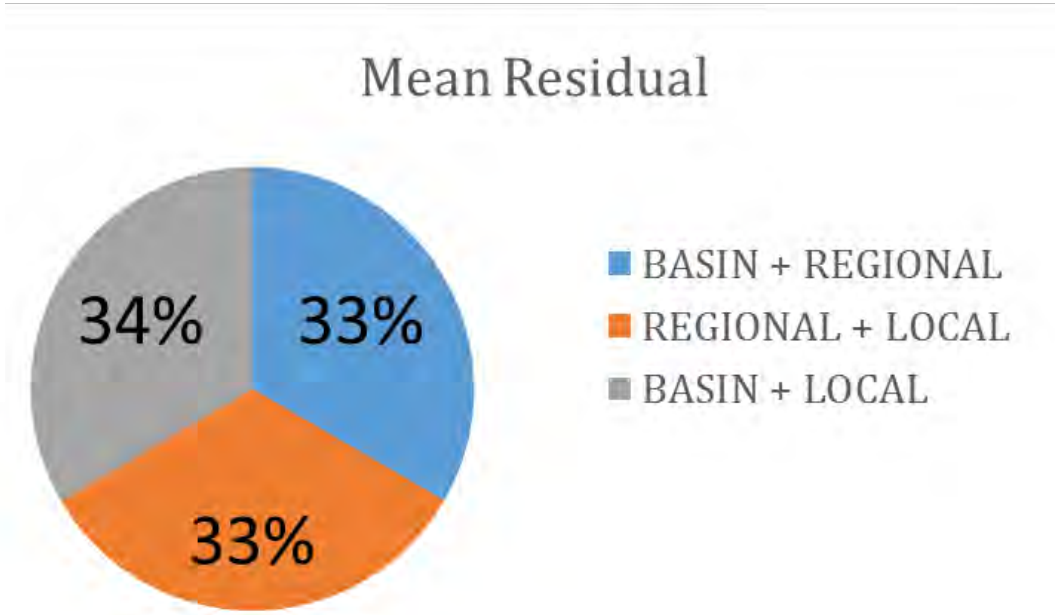
Relative contributions (%)

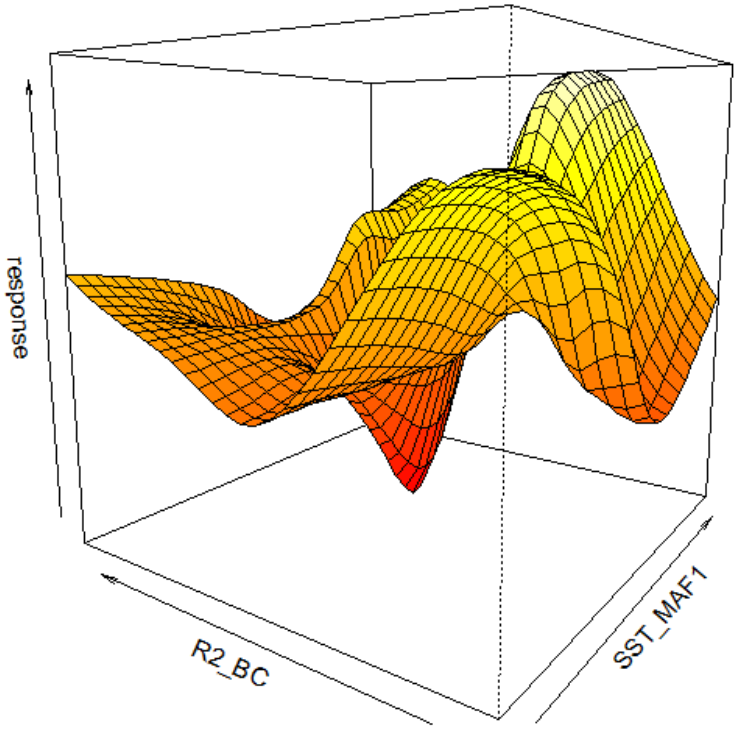

British Columbia
Contribution (%)
50
40
30
20
10
0
BASIN
REGIONAL
LOCAL
R-sq
D.E. %
Canadá
EEUU
México

R-sq D.E. %

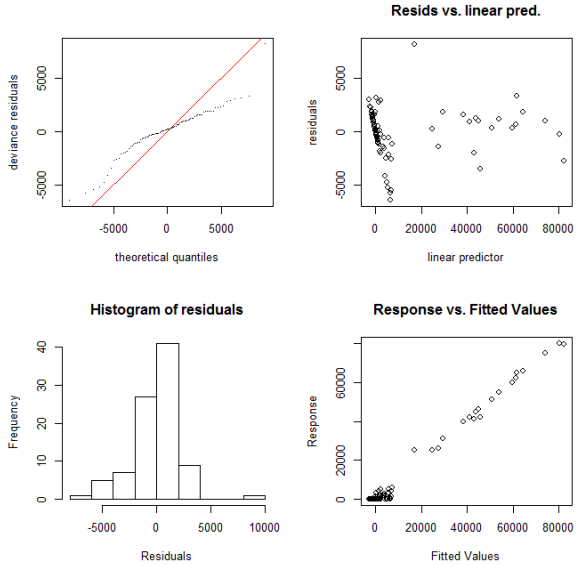

British Columbia
D.E. %
R-sq
BASIN + LOCAL
REGIONAL + LOCAL
BASIN + REGIONAL
0
25
50
75
100
Contribution (%)

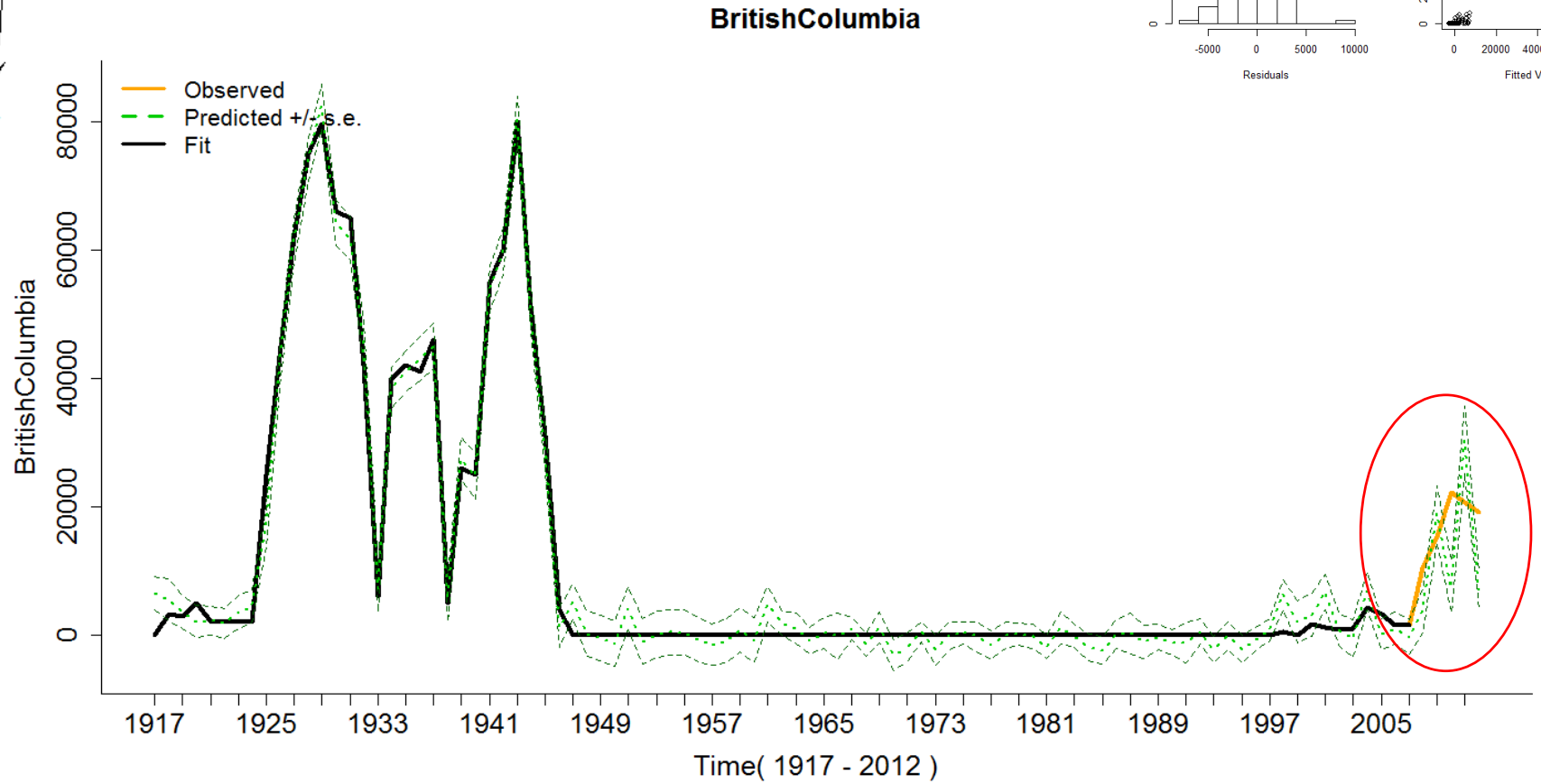

Total Sum of Residuals
34%
33%
33%
BASIN + REGIONAL
REGIONAL + LOCAL
BASIN + LOCAL


Mean Residual
34%
33%
33%
BASIN + REGIONAL
REGIONAL + LOCAL
BASIN + LOCAL

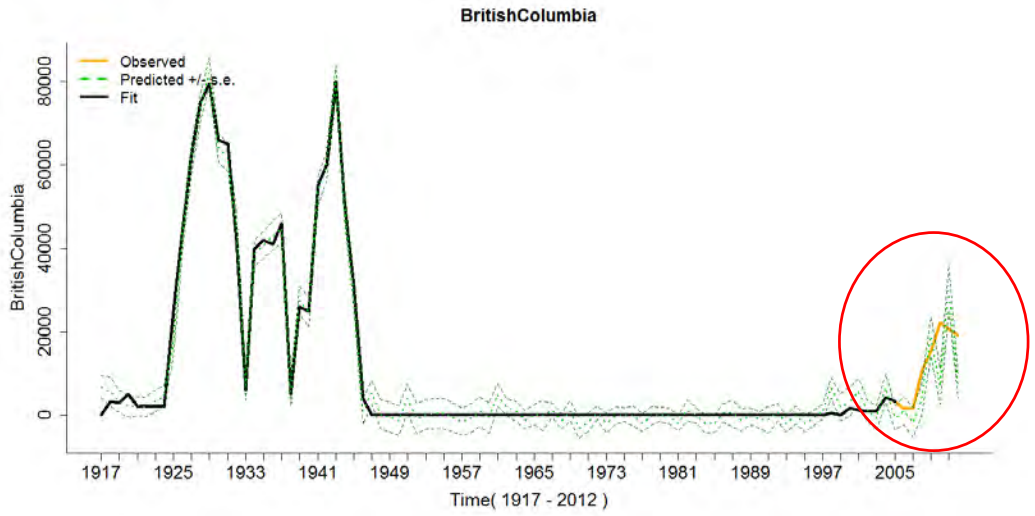


REGIONAL 1917-2007

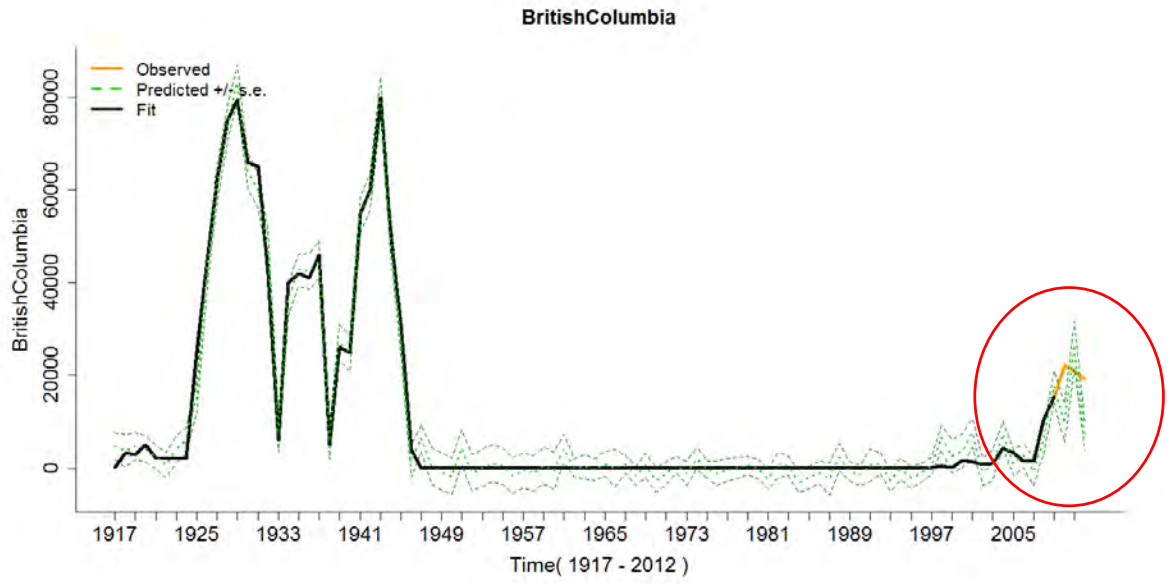




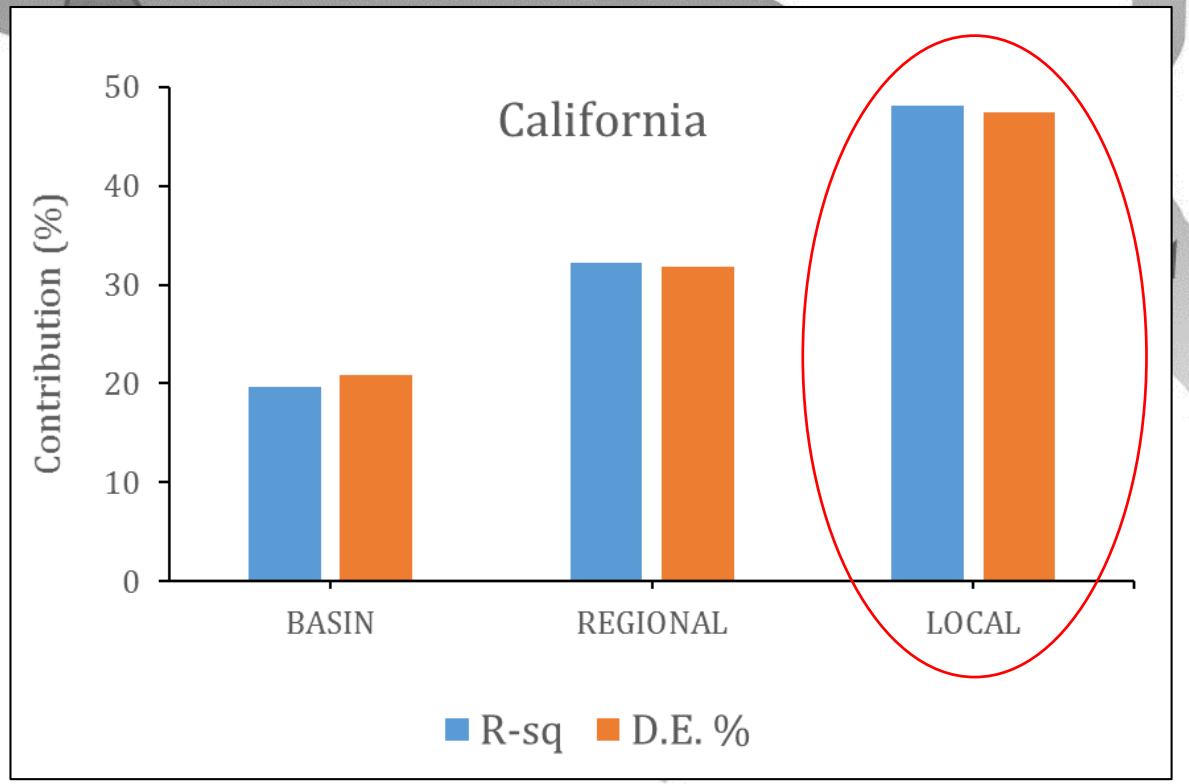
REGIONAL
1917-**2005**



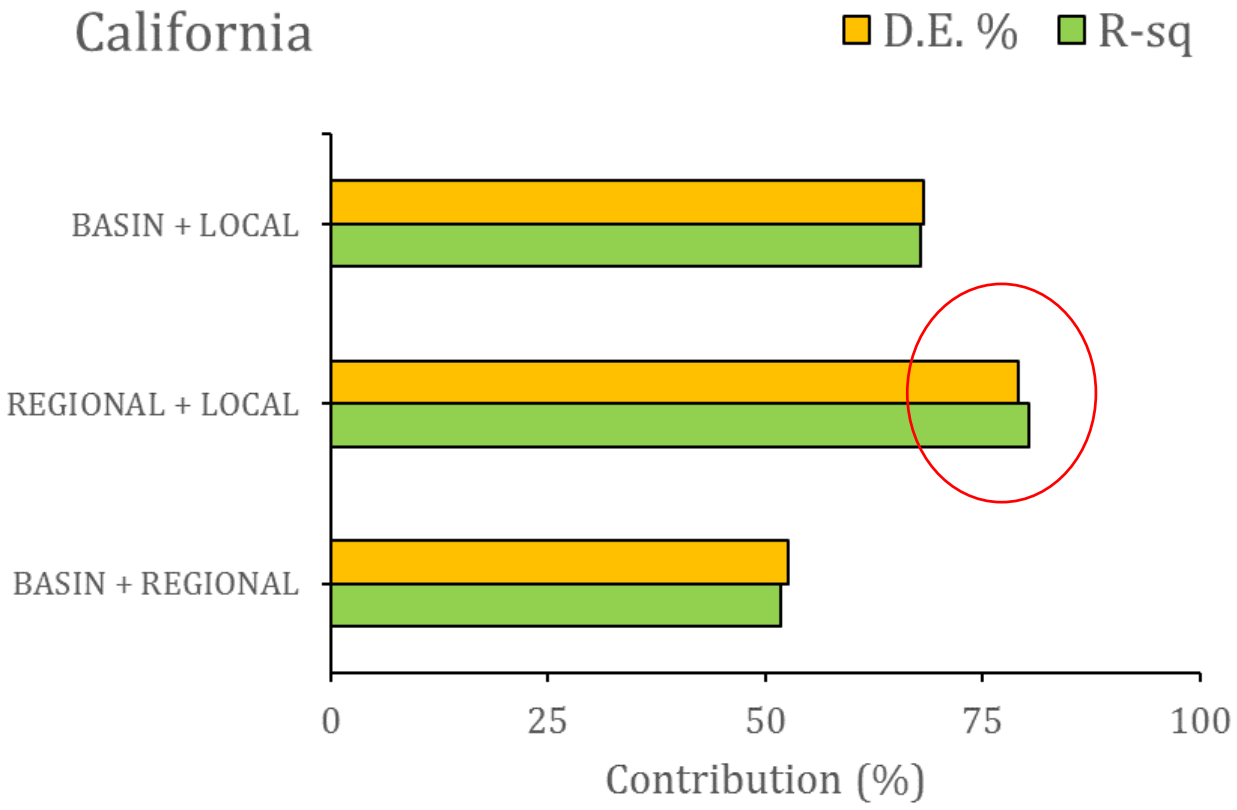
REGIONAL
1917-**2009**

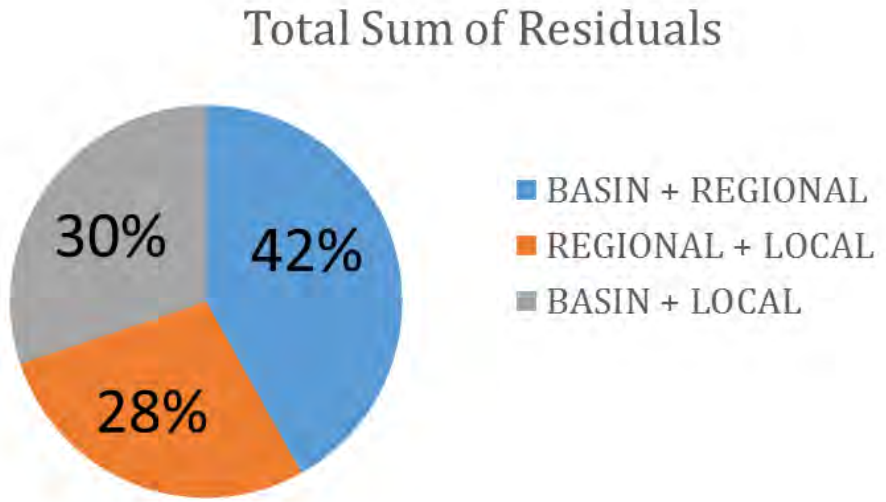


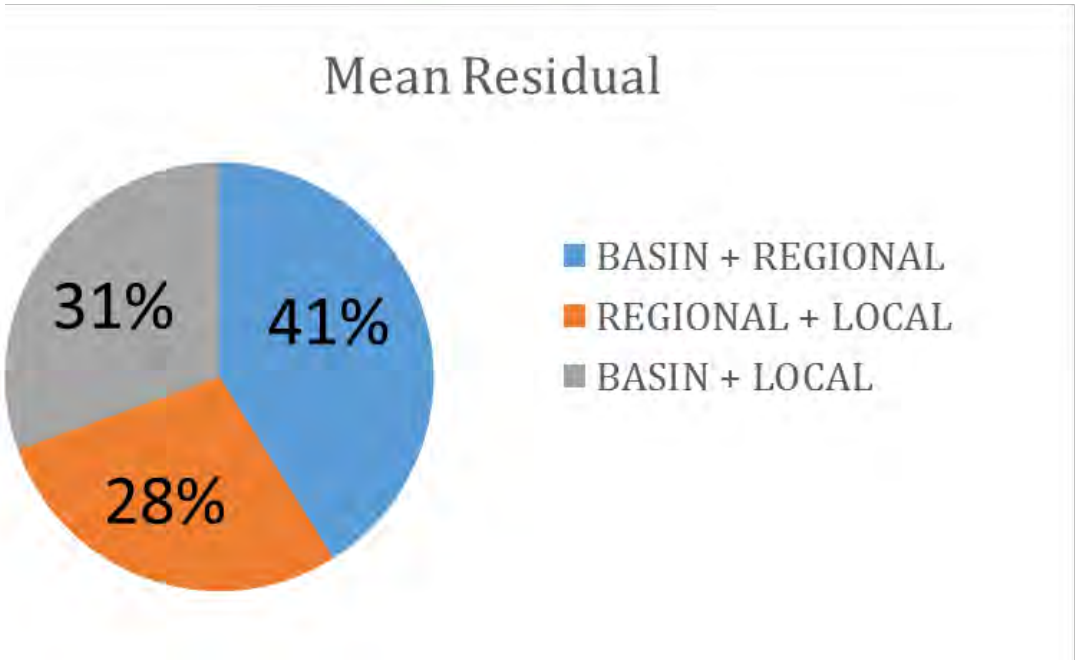
R-sq D.E. %


California
Contribution (%)
50
40
30
20
10
0
BASIN
REGIONAL
LOCAL
R-sq
D.E. %

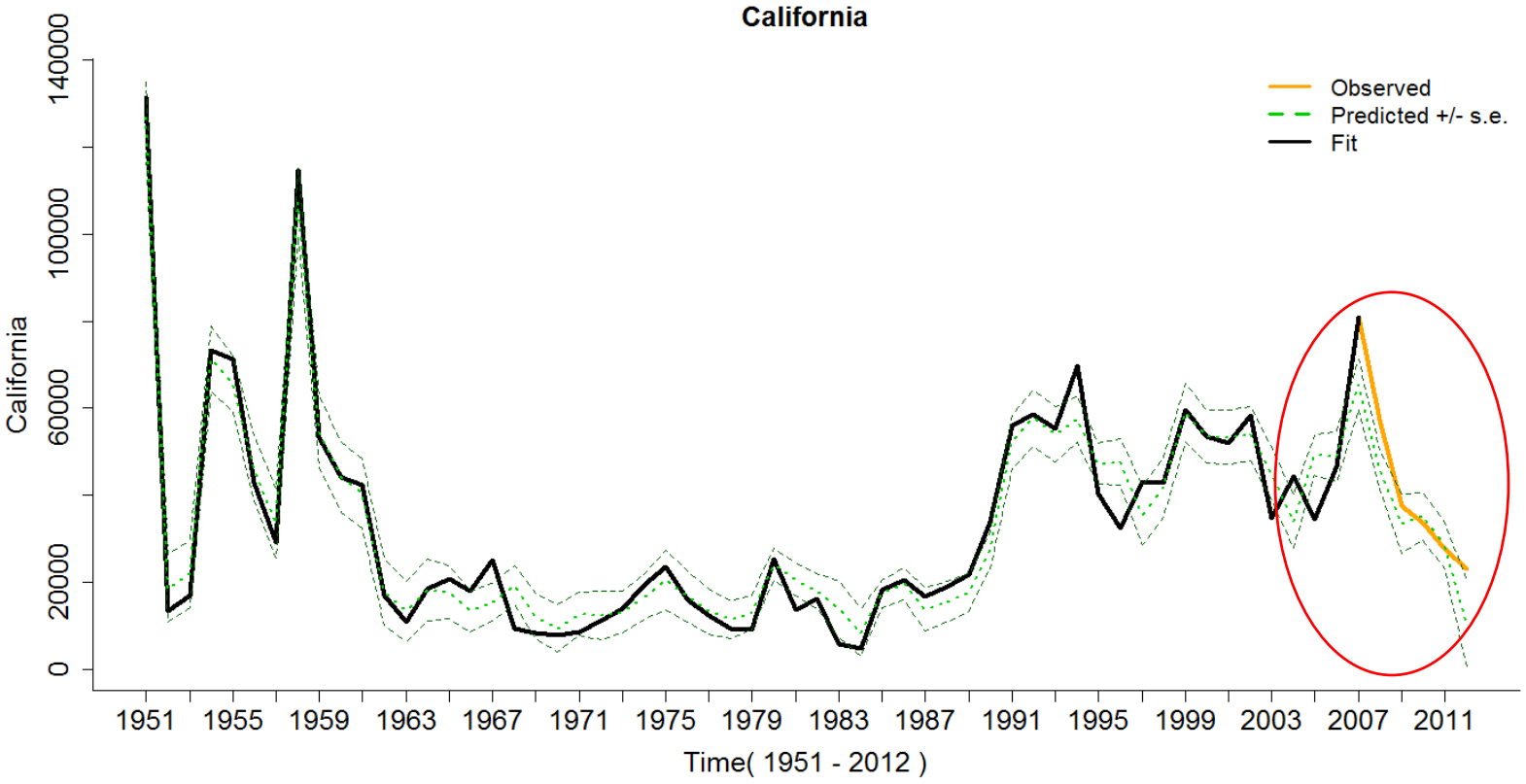
Canadá
EEUU
México

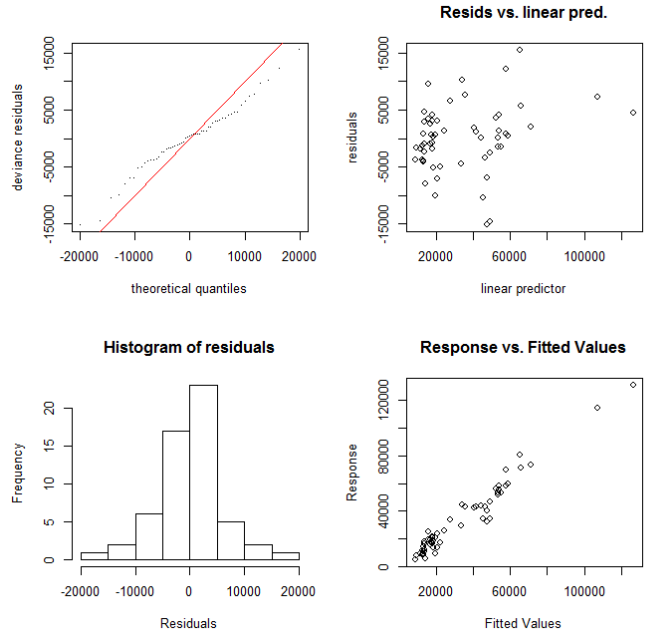

California
D.E. %
R-sq
BASIN + LOCAL
REGIONAL + LOCAL
BASIN + REGIONAL
0
25
50
75
100
Contribution (%)

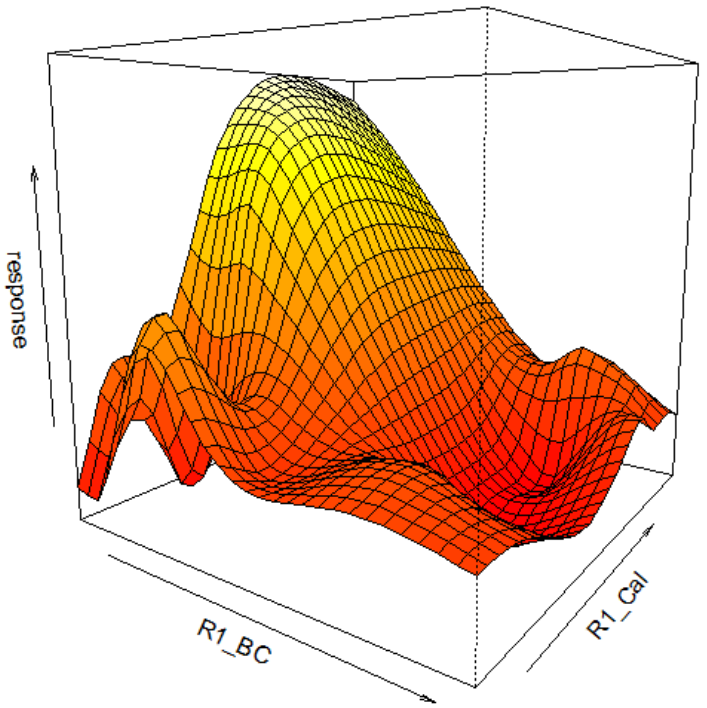

Total Sum of Residuals
30%
42%
28%
BASIN + REGIONAL
REGIONAL + LOCAL
BASIN + LOCAL


Mean Residual
31%
41%
28%
BASIN + REGIONAL
REGIONAL + LOCAL
BASIN + LOCAL

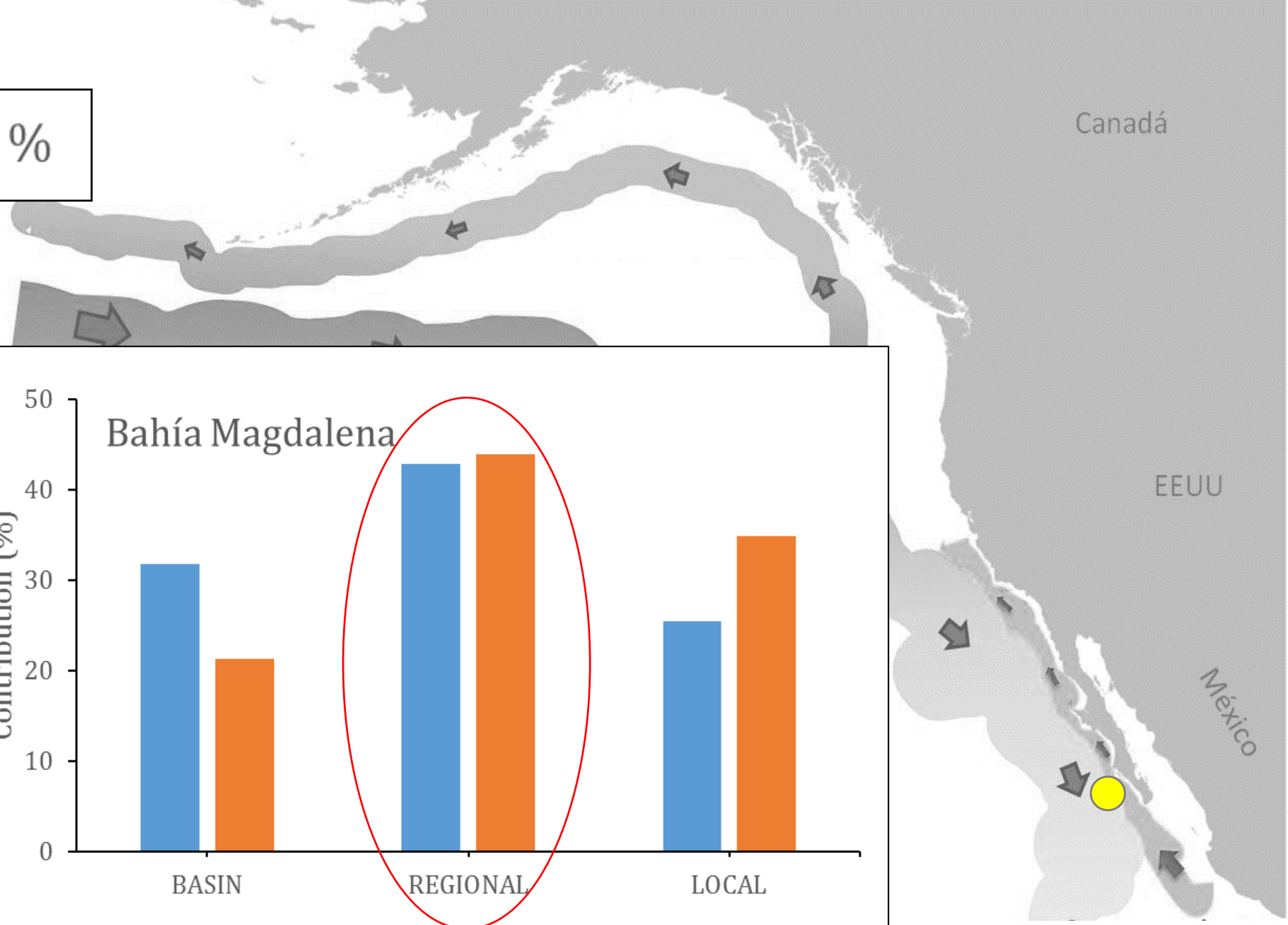
California GAM: R-squared = 0.899 Dev. Expl.= 95 %



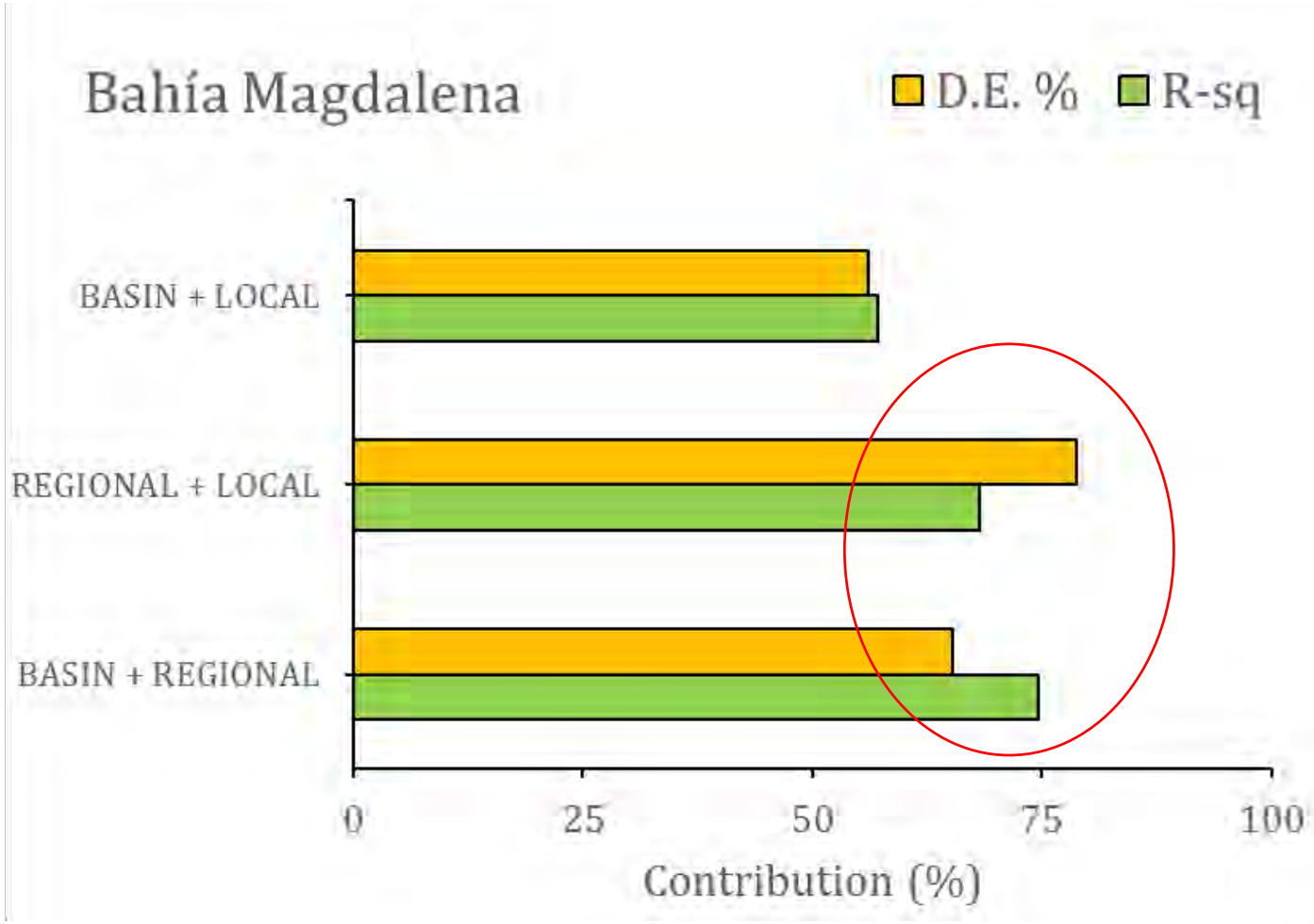


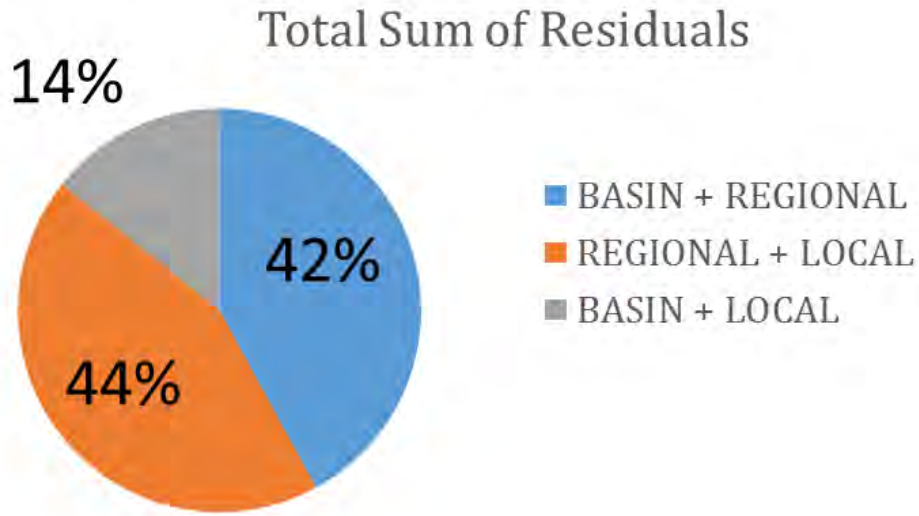


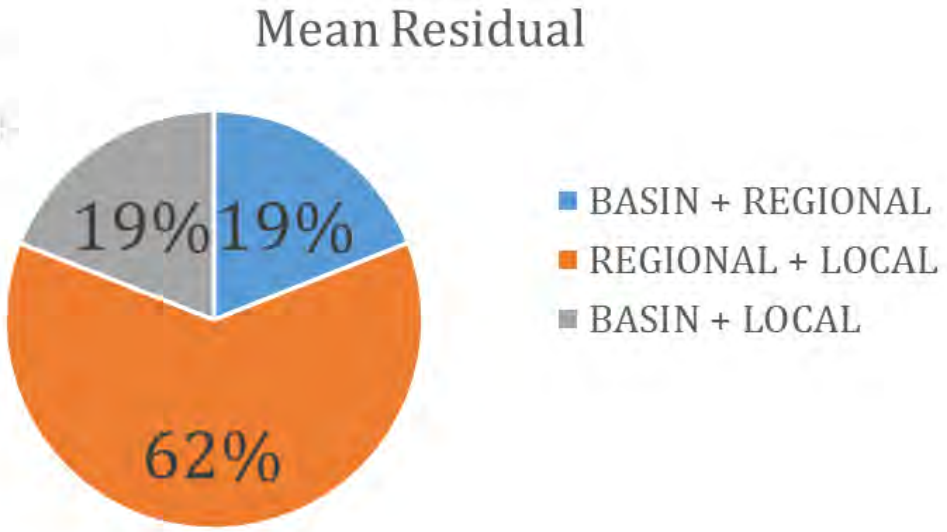
REGIONAL + LOCAL
1951 - 2009

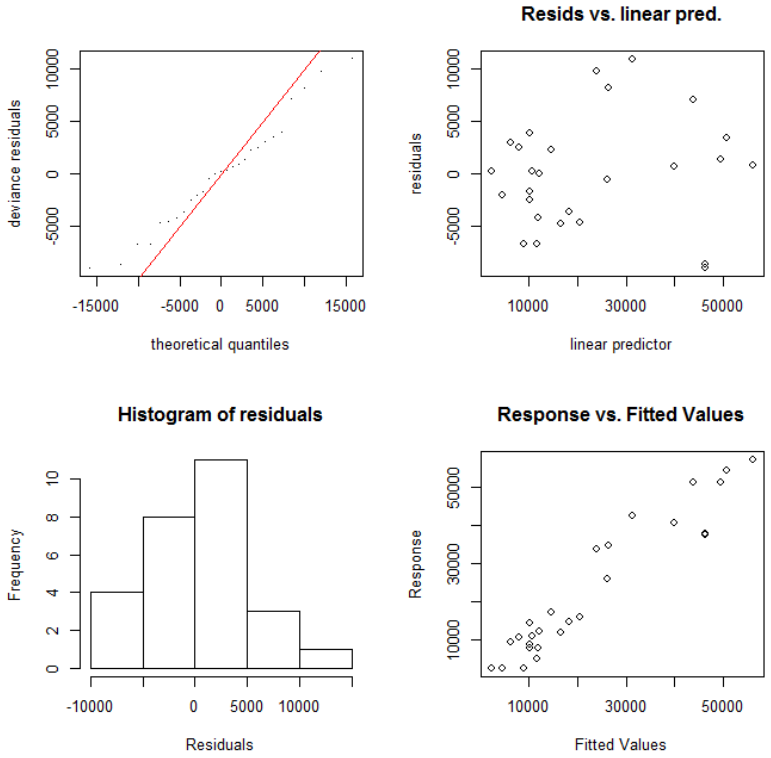

Canadá
EEUU
México

Bahía Magdalena
Contribution (%)
50
40
30
20
10
0
BASIN
REGIONAL
LOCAL
R-sq
D.E. %

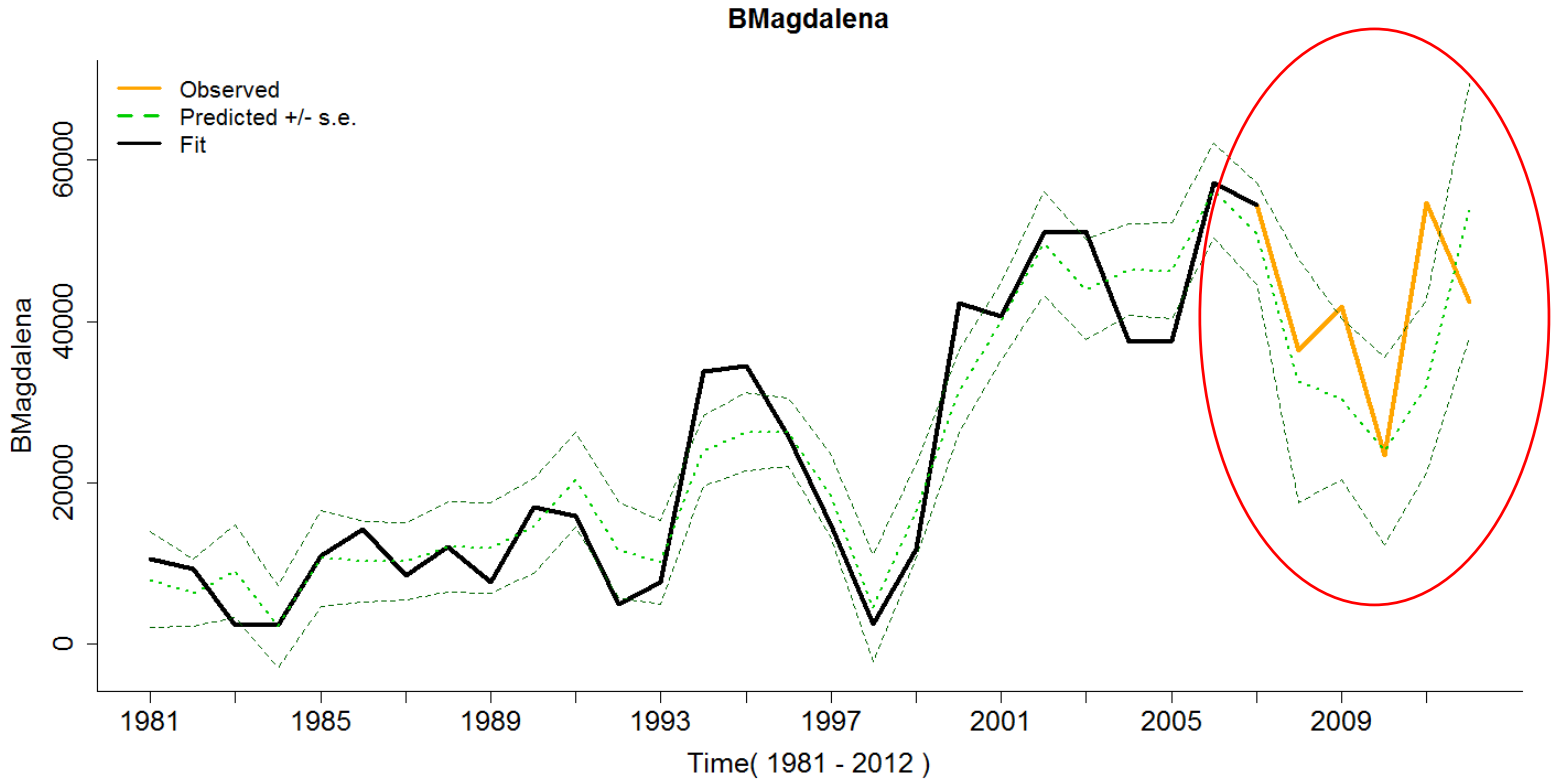

Bahía Magdalena
D.E. %
R-sq
BASIN + LOCAL
REGIONAL + LOCAL
BASIN + REGIONAL
0
25
50
75
100
Contribution (%)


Total Sum of Residuals
14%
42%
44%
BASIN + REGIONAL
REGIONAL + LOCAL
BASIN + LOCAL


Mean Residual
19%
19%
62%
BASIN + REGIONAL
REGIONAL + LOCAL
BASIN + LOCAL



Regional + Local
1981 - 2007



The appropriate representation of key physical/biological processes is a constant challenge to marine scientist and modelers.

Climate-catch models retain an important potential utility to inform management decisions, because of their relative simplicity.

Climate-catch models may guide complex modelling approaches

Primary productivity contribution to climate-catch models of Pacific sardine

Romeo Saldívar-Lucio, R. Martínez-Rincón, M. Morales,
S. Lluch-Cota, D. Lluch-Cota, C. Salvadeo y G. Ponce-Díaz.

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March 6-11, 2017
Victoria, BC, Canada

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