A Simplified Production Model for the Northern California Current:

investigating the effect of interannual variability in copepod community composition

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Goals:

- 1) Develop a model of lower trophic level production in the Oregon upwelling ecosystem
- 2) Keep the model simple - use simple physical model that can be run with a minimum of required driving variables
- 3) Evaluate model quality against time-series measurements of nutrients, Chl a, copepod biomass
- 4) Use model as platform to test alternate configurations of the biological structure:
  - Sensitivity to parameter-set choice
  - Effect of inter-annual variability in copepod community composition

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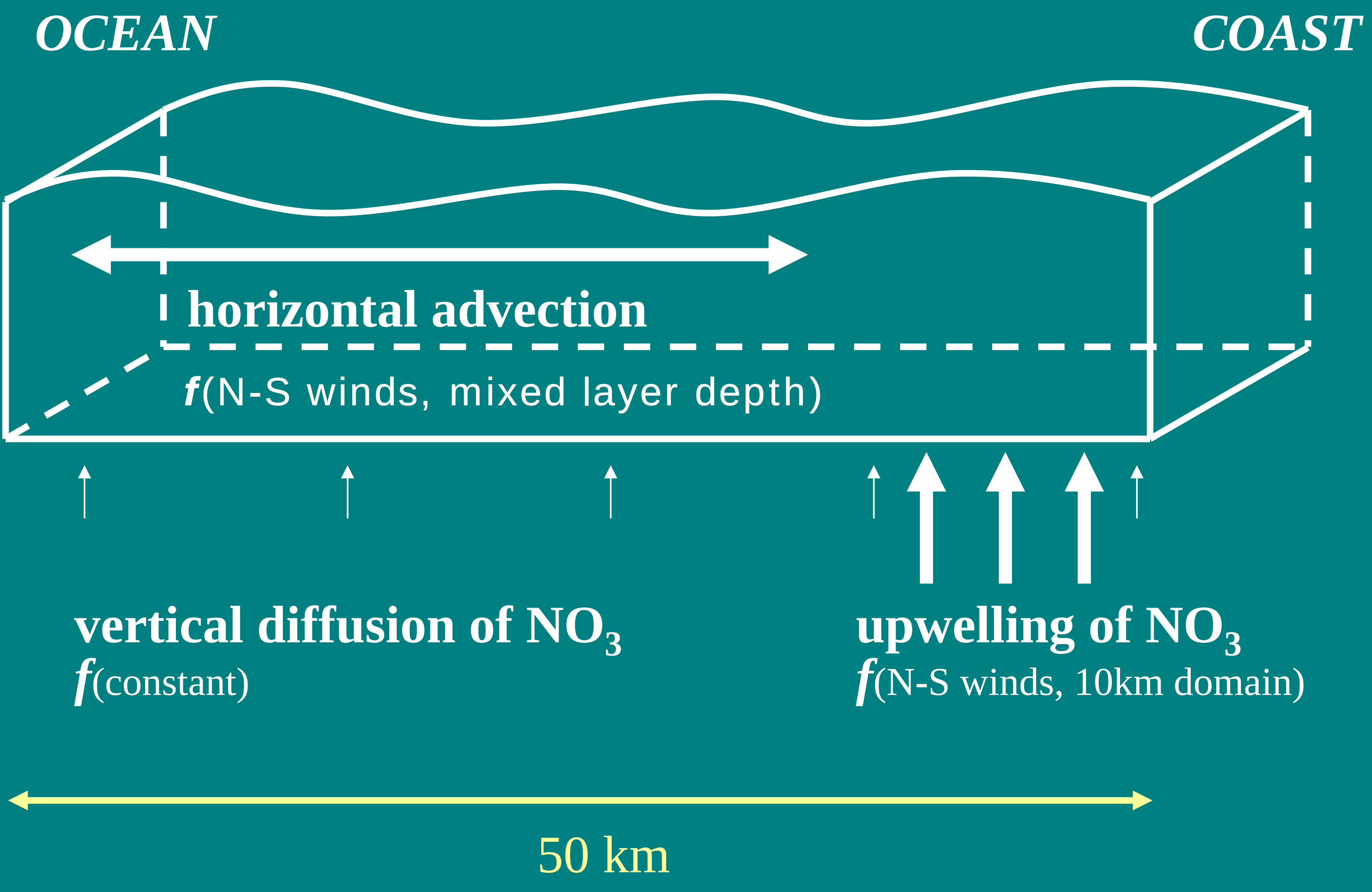
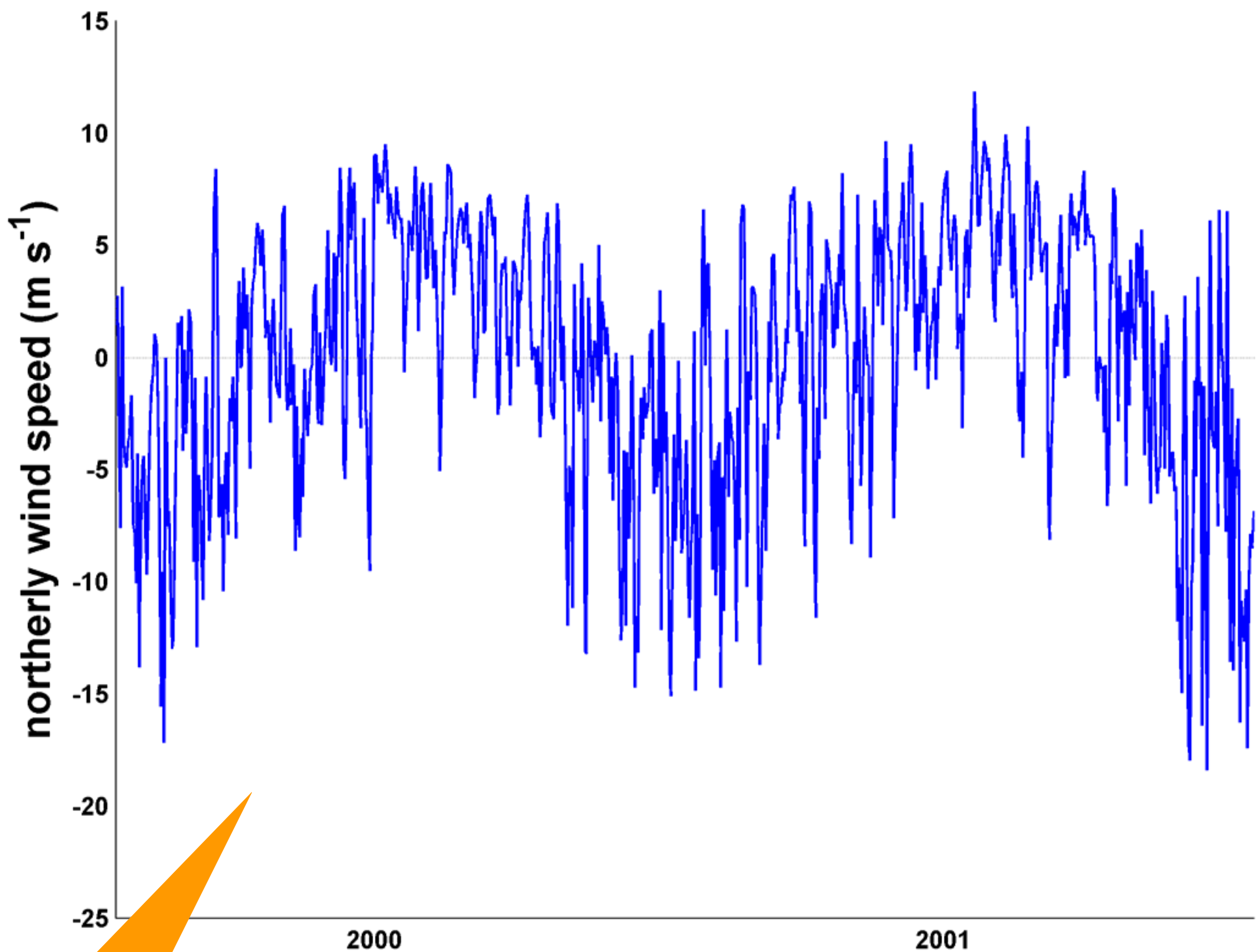
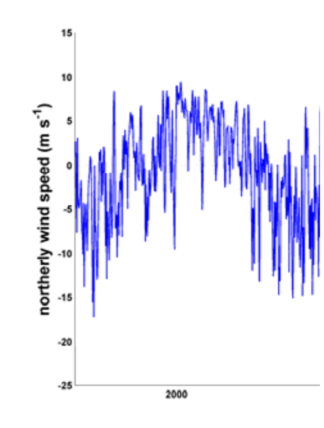
Physical Platform

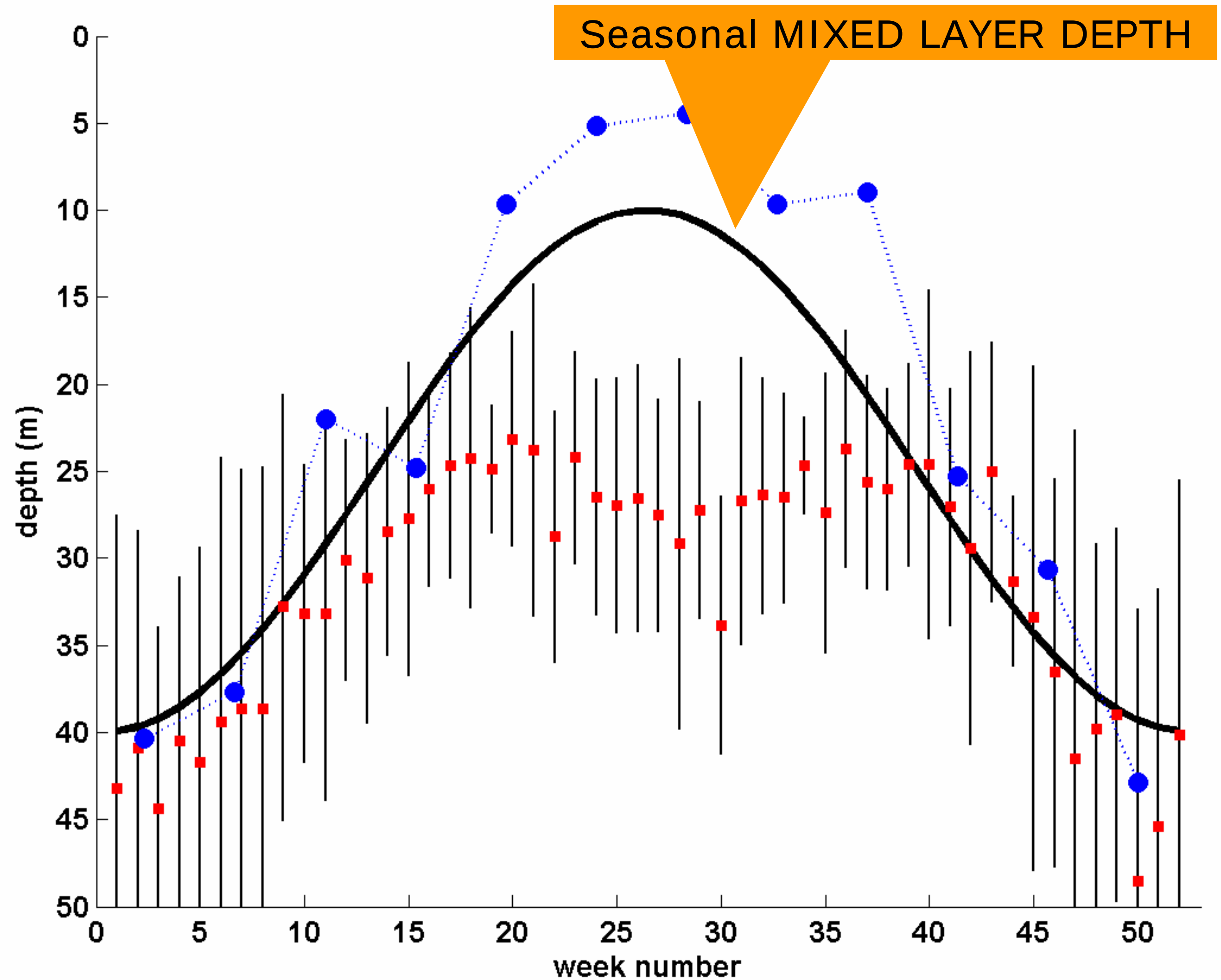




Pressure-field WINDS
(NOAA: SWFSC, ERD)
www.pfeg.noaa.gov

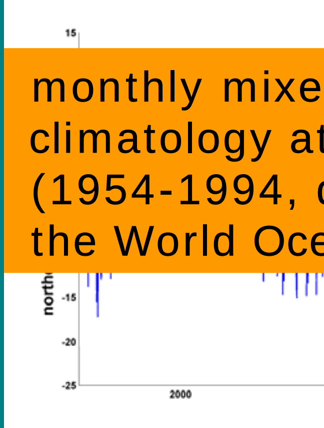


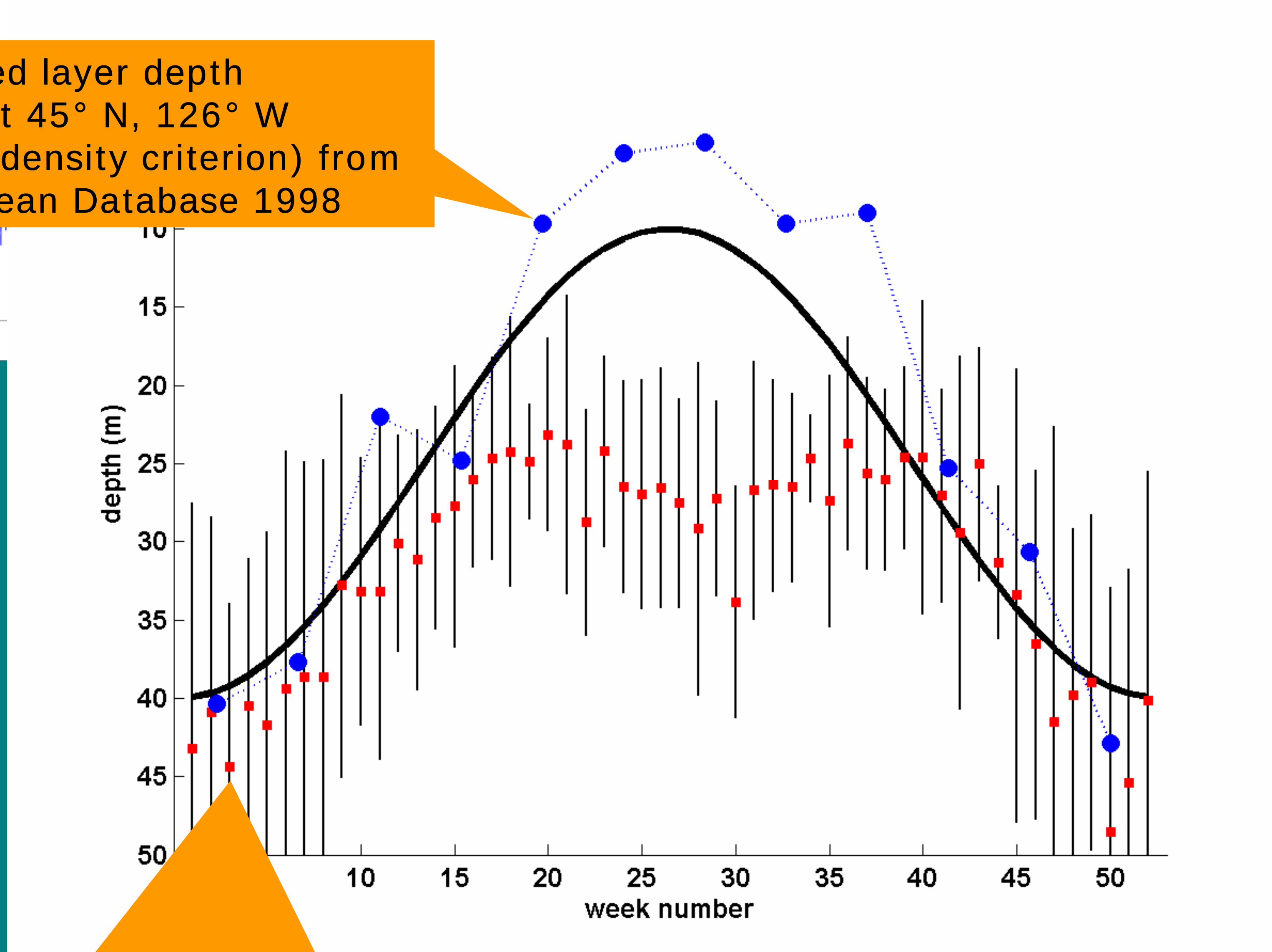
northerly wind speed (m s-1)
15
10
5
0
-5
-10
-15
-20
-25
2000



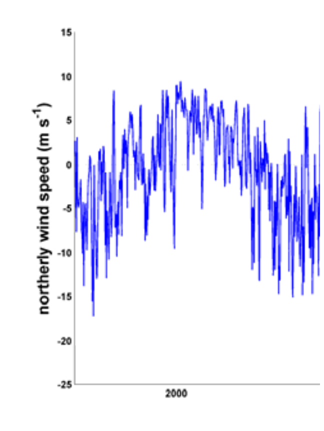
Seasonal MIXED LAYER DEPTH
depth (m)
0
5
10
15
20
25
30
35
40
45
50
week number
0
5
10
15
20
25
30
35
40
45
50

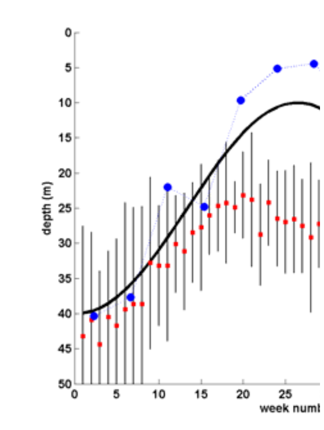
monthly mixed layer depth climatology at 45° N, 126° W (1954-1994, density criterion) from the World Ocean Database 1998

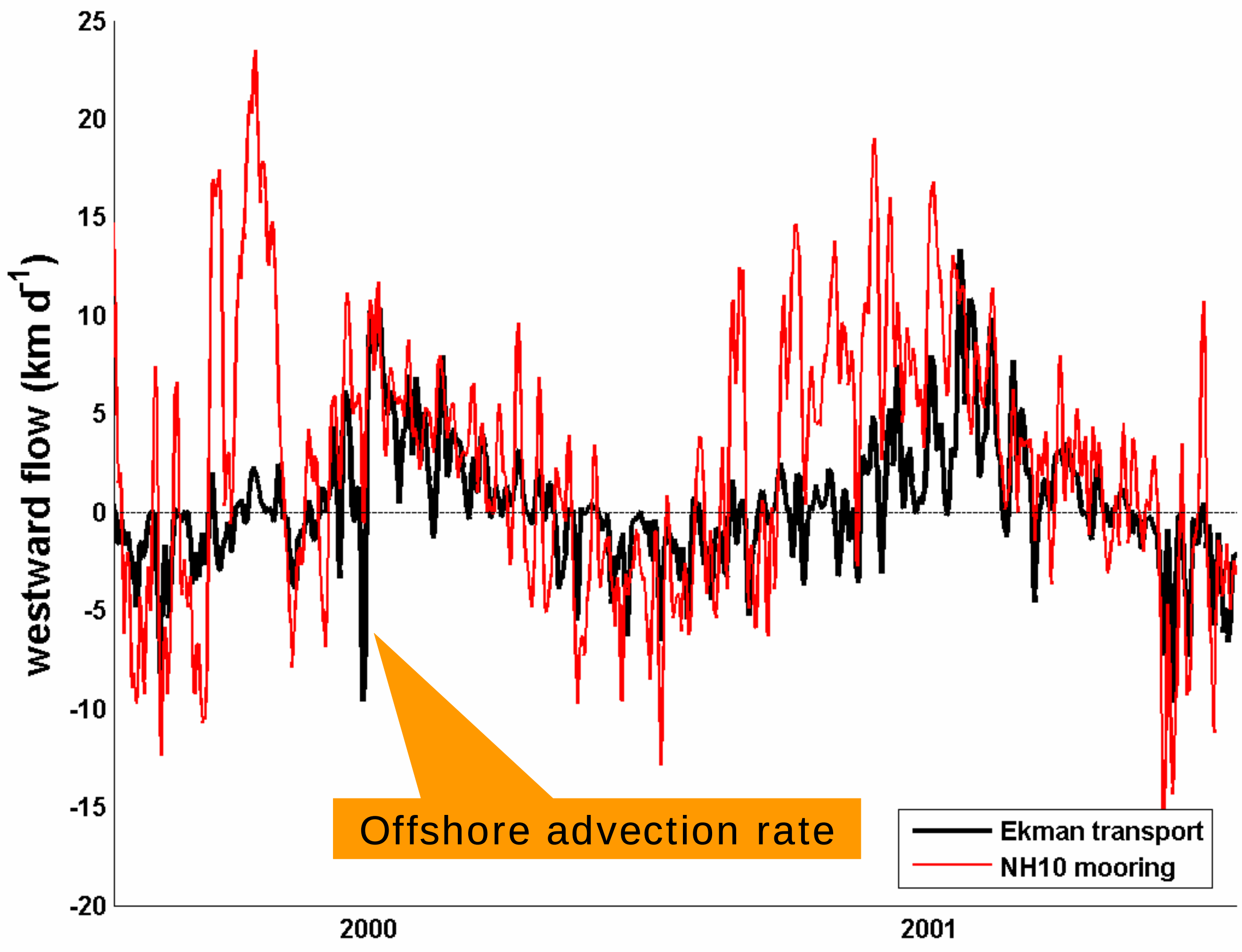


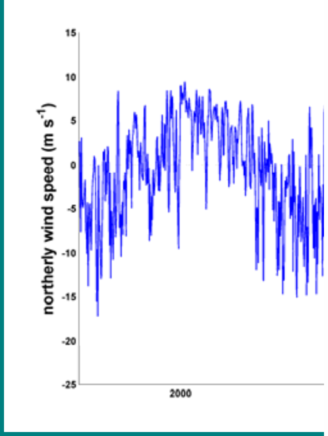


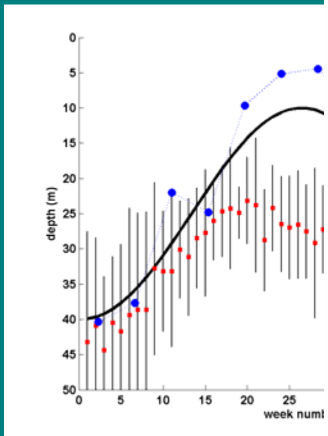
Theoretical weekly mean Ekman depth from wind data

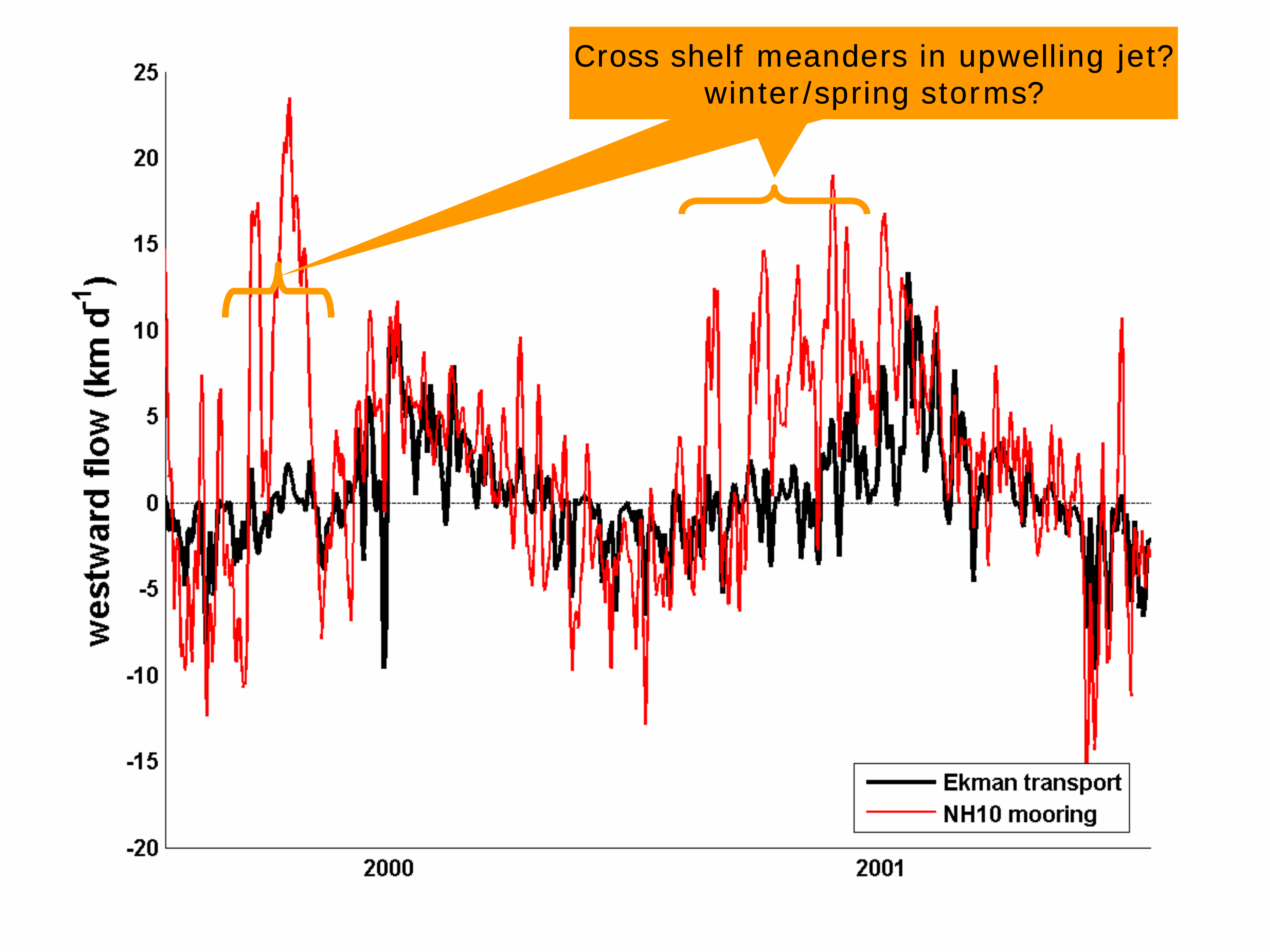

northerly wind speed (m s-1)
2000


depth (m)
week numb


westward flow (km d-1)
2000
2001
Offshore advection rate
Ekman transport
NH10 mooring



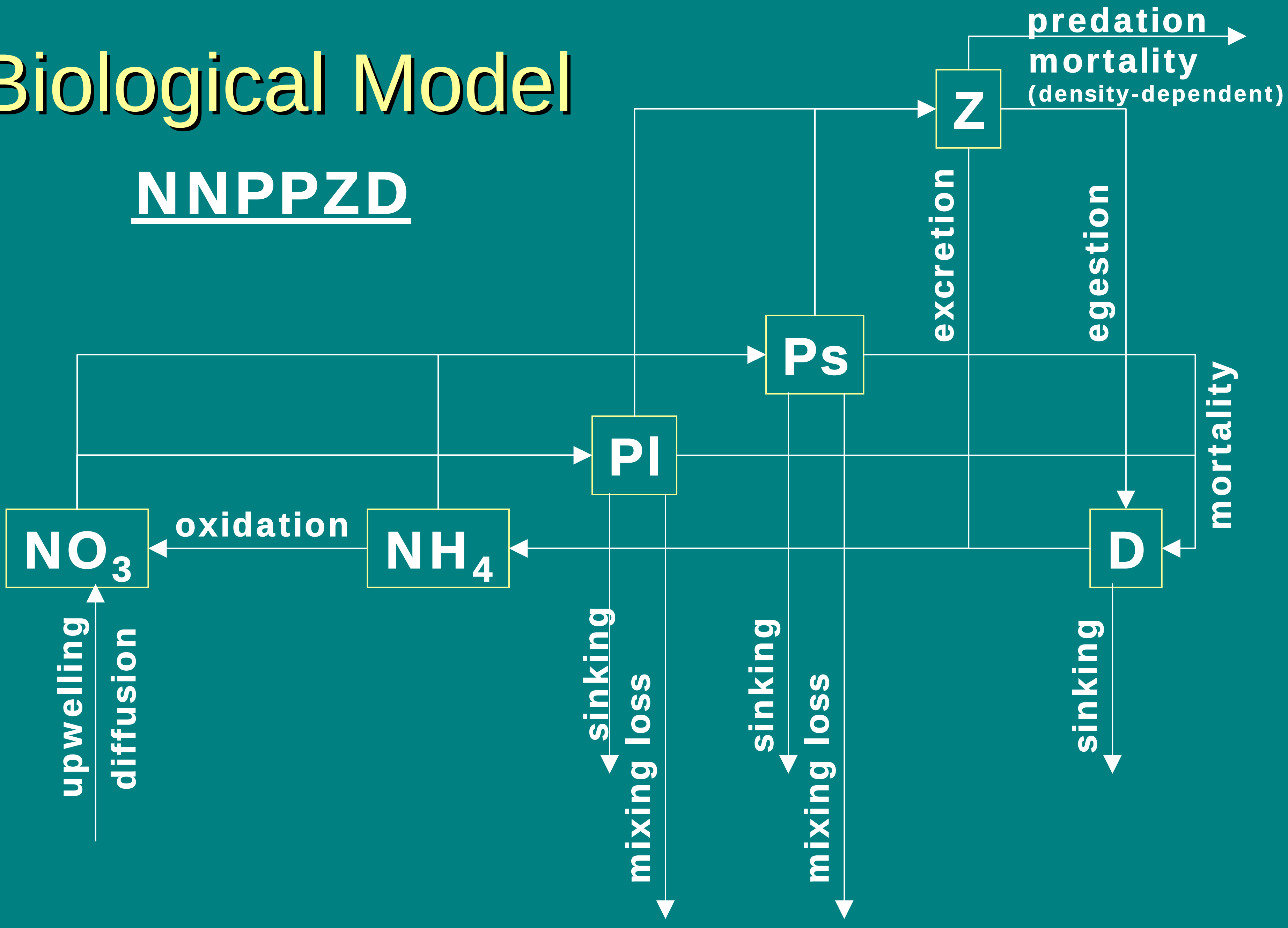


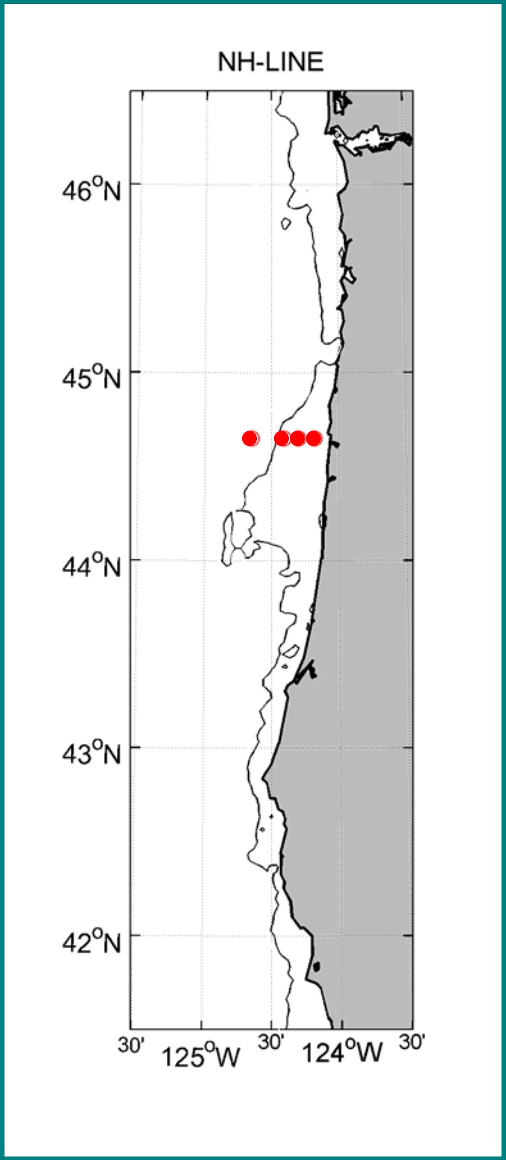


moored ADCP current measurements (upper 10 to 50m mean; station NH-10)
(Current data provided by M Kosro, OSU)

Biological Model

NNPPZD





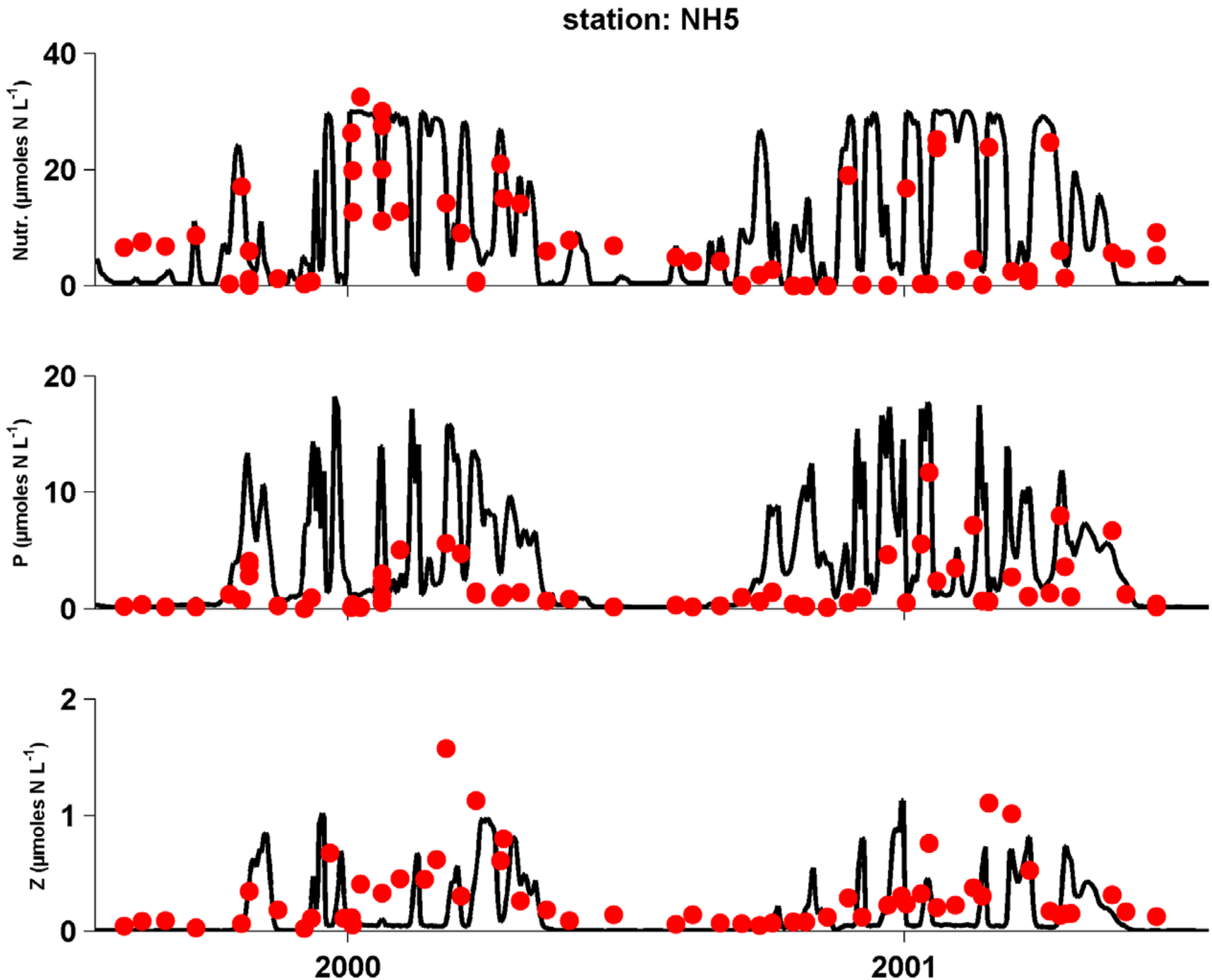
Model Quality Measured Against:

NH-Line Hydrographic and Zooplankton Time Series

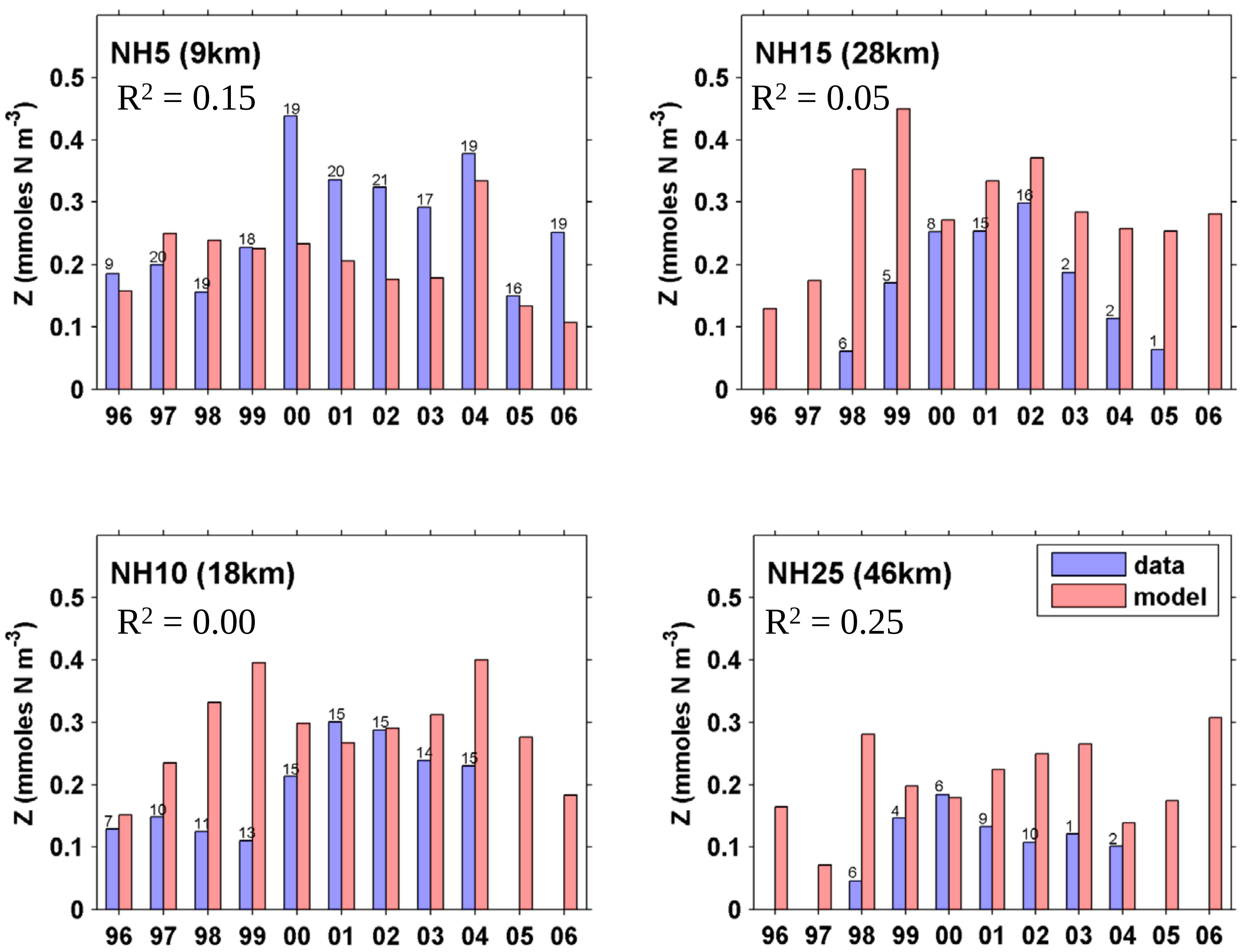
(Peterson et al.)

*Bi-weekly Sampling (***1996 – present***):*

- nutrients
- Chl a (surface)
- copepod biomass (upper 100m)



station: NH5
Nutr. (µmoles N L-1)
P (µmoles N L-1)
Z (µmoles N L-1)
0
20
40
0
10
20
0
1
2
2000
2001


NH5 (9km)
R2 = 0.15
NH15 (28km)
R2 = 0.05
NH10 (18km)
R2 = 0.00
NH25 (46km)
R2 = 0.25
data
model
Z (mmoles N m-3)
96 97 98 99 00 01 02 03 04 05 06

18 parameters

Phytoplankton_L			
α_L	0.031	$m^2 \cdot W^{-1} \cdot d^{-1}$	light response curve (P vs I)
V_L	2.46	d^{-1}	max. nutrient uptake rate
K_L	1.2	$mmol\ N \cdot m^{-3}$	half-saturation
Ξ_L	0.2	d^{-1}	non-grazing mortality
W_L	1.1	$m \cdot d^{-1}$	sinking rate
Ψ	1.46	$(mmol\ N \cdot m^{-3})^{-1}$	NO_3 uptake inhibition by NH_4
Phytoplankton_S			
α_S	0.025	$m^2 \cdot W^{-1} \cdot d^{-1}$	
V_S	0.24	d^{-1}	
K_S	0.14	$mmol\ N \cdot m^{-3}$	
Ξ_S	0.1	d^{-1}	
W_S	0.6	$m \cdot d^{-1}$	
Ψ	1.46	$(mmol\ N \cdot m^{-3})^{-1}$	
Zooplankton			
R_m	1.5	d^{-1}	max. grazing rate
Λ_L	0.2	$m^3 \cdot mmol\ N^{-1}$	Ivlev constant P_large
Λ_S	0.1	$m^3 \cdot mmol\ N^{-1}$	Ivlev constant P_small
γ	0.3		egestion fraction
ε	0.3	d^{-1}	excretion (respiration)
Γ	0.3	d^{-1}	mortality

18 parameters

1) To which parameters is system most <u>SENSITIVE</u>?

Phytoplankton$_L$			
α_L	0.031	$m^2 \cdot W^{-1} \cdot d^{-1}$	light response curve (P vs I)
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2) How does system sensitivity to any particular parameter change with value of other parameters?

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Zooplankton

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18 parameters

1) To which parameters is system most SENSITIVE?

2) How does system sensitivity to any particular parameter change with value of other parameters?

3) How do parameter values affect model QUALITY?

$Phytoplankton_L$

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Γ	0.3	d^{-1}	mortality

P_{large}

1

α_L
K_L
V_L

2

V_L
W_L
Ξ_L

P_{small}

3

α_S
K_S
V_S

4

V_S
W_S
Ξ_S

Z

5

ε, Γ
λ
R

5 sensitivity & quality experiments:

Parameters varied for each living component separately

P_{large}

1

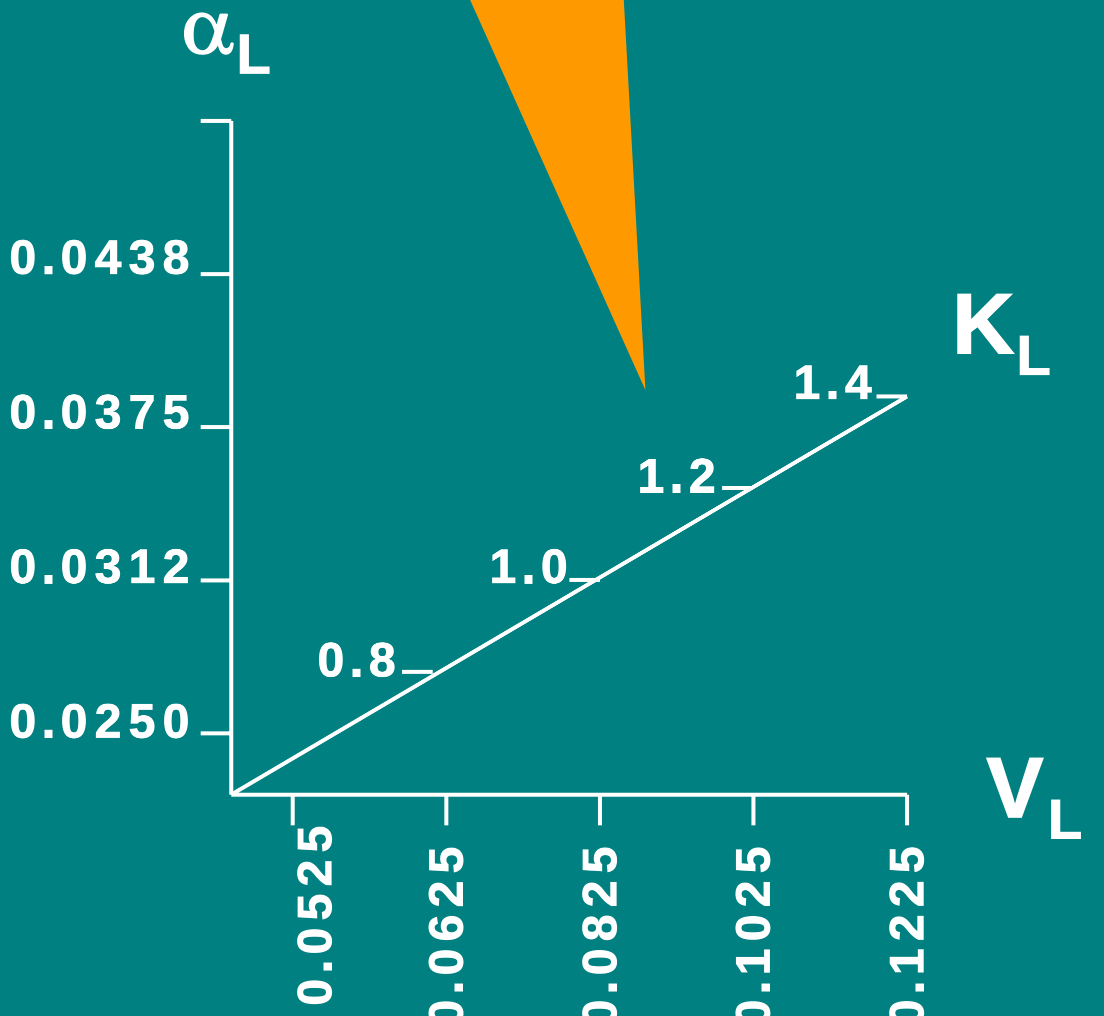
α_L

K_L

V_L

3 parameters varied at distinct values

All other parameters kept at base values



sensitivity metric

Fractional change of system (response variable) relative to fractional change in parameter value →

$$S(p) = \frac{\left(\frac{\Delta E(p)}{\Delta p}\right)}{\left(\frac{E(p_c)}{p_c}\right)}$$

← System response with respect to parameter change (slope)

← System state under base parameter value

← base parameter value

Response variables:
P, Z values
(I use April - September mean @ x = 18km)

[From: Yoshie et al. 2007 Ecol. Model. 202:26-37]

Zooplankton Response

P_{large}

1

α_L: 0.025 – 0.044

V_L \ K_L	0.8	1	1.2	1.4
0.053	0.7	0.7	0.7	0.7
0.063	0.7	0.8	0.8	0.8
0.083	0.8	0.8	0.8	0.8
0.103	0.8	0.8	0.8	0.8
0.123	0.8	0.8	0.9	0.9

V_L: 0.05 – 0.12

α_L \ K_L	0.8	1	1.2	1.4
0.025	0.6	0.6	0.6	0.6
0.031	0.6	0.6	0.6	0.7
0.038	0.6	0.7	0.7	0.7
0.044	0.7	0.7	0.7	0.7

K_L: 0.8 – 1.4

α_L \ V_L	0.05	0.06	0.08	0.10	0.12
0.025	0.3	0.3	0.3	0.3	0.3
0.031	0.3	0.3	0.3	0.3	0.3
0.038	0.3	0.3	0.3	0.3	0.3
0.044	0.3	0.3	0.3	0.3	0.3

2

Ξ_L: 0.1 – 0.2

V_L \ W_L	0.5	0.7	0.9	1.1	1.3
0.063	1.9	1.8	1.7	1.6	1.5
0.083	1.9	1.8	1.7	1.6	1.6
0.103	1.9	1.8	1.7	1.6	1.6

W_L: 0.5 – 1.3

V_L \ Ξ_L	0.1	0.15	0.2
0.063	0.7	0.6	0.5
0.083	0.7	0.6	0.5
0.103	0.7	0.6	0.5

V_L: 0.06 – 0.10

Ξ_L \ W_L	0.5	0.7	0.9	1.1	1.3
0.10	0.6	0.6	0.6	0.6	0.6
0.15	0.7	0.6	0.6	0.6	0.6
0.20	0.6	0.6	0.6	0.6	0.6

Z

5

ε, Γ: 0.2 – 0.3

R \ λ	0.1	0.2	0.3
0.50	0.2	0.3	0.3
1.00	0.4	1.4	2.3
1.50	1.4	3.5	4.7
2.00	2.7	4.6	4.5
2.50	3.7	4.4	3.7
3.00	4.1	3.9	2.3

R: 0.50 – 3.0

λ \ ε, Γ	0.2	0.3
0.1	2.1	1.2
0.2	3.1	2.3
0.3	3.0	2.6

λ: 0.1 – 0.3

R \ ε, Γ	0.2	0.3
0.50	0.1	0.0
1.00	1.0	0.3
1.50	2.5	1.4
2.00	2.9	2.3
2.50	2.3	2.3
3.00	1.2	1.8

Phytopankton Response

P_{large} — 1

α_L: 0.025 – 0.044

V_L \ K_L	0.8	1	1.2	1.4
0.053	0.1	0.1	0.1	0.1
0.063	0.2	0.2	0.2	0.2
0.083	0.3	0.3	0.3	0.3
0.103	0.3	0.3	0.3	0.3
0.123	0.3	0.3	0.3	0.3

V_L: 0.05 – 0.12

α_L \ K_L	0.8	1	1.2	1.4
0.025	0.2	0.2	0.2	0.2
0.031	0.3	0.3	0.3	0.3
0.038	0.3	0.3	0.3	0.3
0.044	0.3	0.3	0.3	0.3

K_L: 0.8 – 1.4

α_L \ V_L	0.05	0.06	0.08	0.10	0.12
0.025	0.1	0.1	0.1	0.1	0.1
0.031	0.1	0.1	0.1	0.1	0.1
0.038	0.1	0.1	0.1	0.1	0.0
0.044	0.1	0.1	0.1	0.0	0.0

2

Ξ_L: 0.1 – 0.2

V_L \ W_L	0.5	0.7	0.9	1.1	1.3
0.063	0.5	0.5	0.5	0.4	0.4
0.083	0.6	0.5	0.5	0.5	0.4
0.103	0.6	0.5	0.5	0.5	0.5

W_L: 0.5 – 1.3

V_L \ Ξ_L	0.1	0.15	0.2
0.063	0.2	0.2	0.2
0.083	0.3	0.2	0.2
0.103	0.3	0.2	0.2

V_L: 0.06 – 0.10

Ξ_L \ W_L	0.5	0.7	0.9	1.1	1.3
0.10	0.3	0.3	0.2	0.2	0.2
0.15	0.2	0.2	0.2	0.2	0.2
0.20	0.2	0.2	0.2	0.2	0.2

Z — 5

ε, Γ: 0.2 – 0.3

R \ λ	0.1	0.2	0.3
0.50	0.0	0.0	0.0
1.00	0.0	0.0	0.1
1.50	0.0	0.2	0.3
2.00	0.1	0.3	0.4
2.50	0.2	0.3	0.4
3.00	0.3	0.3	0.3

R: 0.50 – 3.0

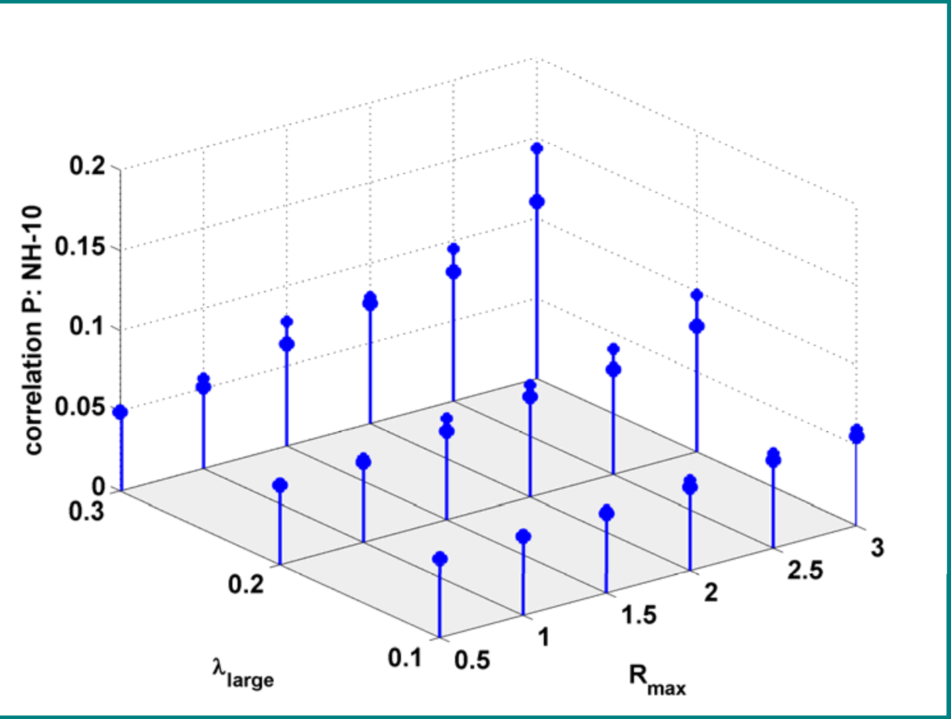
λ \ ε, Γ	0.2	0.3
0.1	0.1	0.1
0.2	0.3	0.2
0.3	0.4	0.3

λ: 0.1 – 0.3

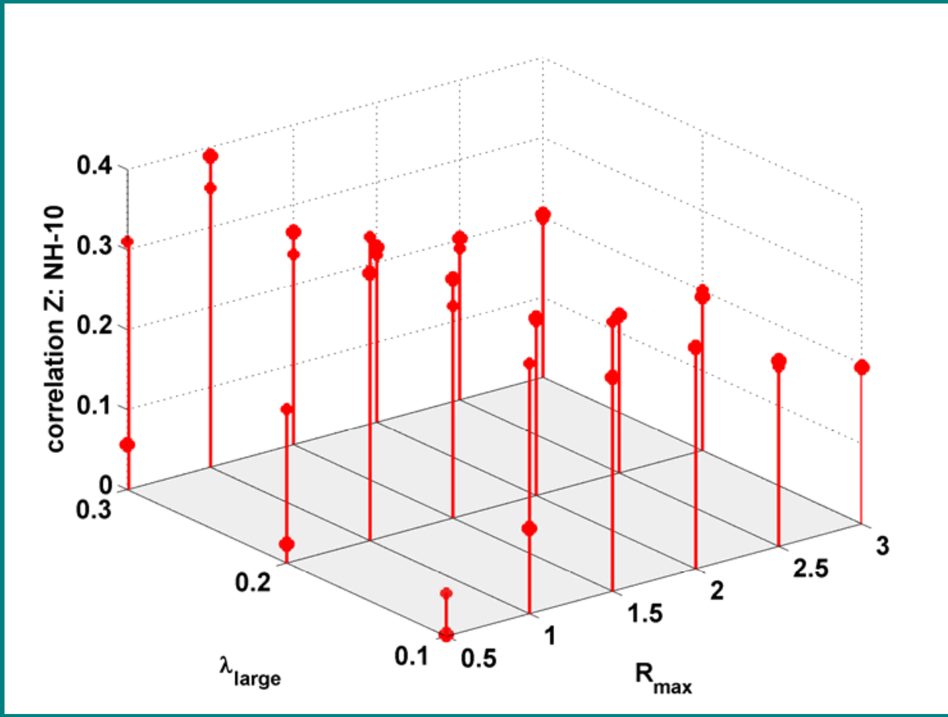
R \ ε, Γ	0.2	0.3
0.50	0.0	0.0
1.00	0.0	0.0
1.50	0.2	0.1
2.00	0.3	0.2
2.50	0.4	0.3
3.00	0.4	0.4

Model Quality:
Exp. 4: Z parameters

Phytoplankton correlation: NH10



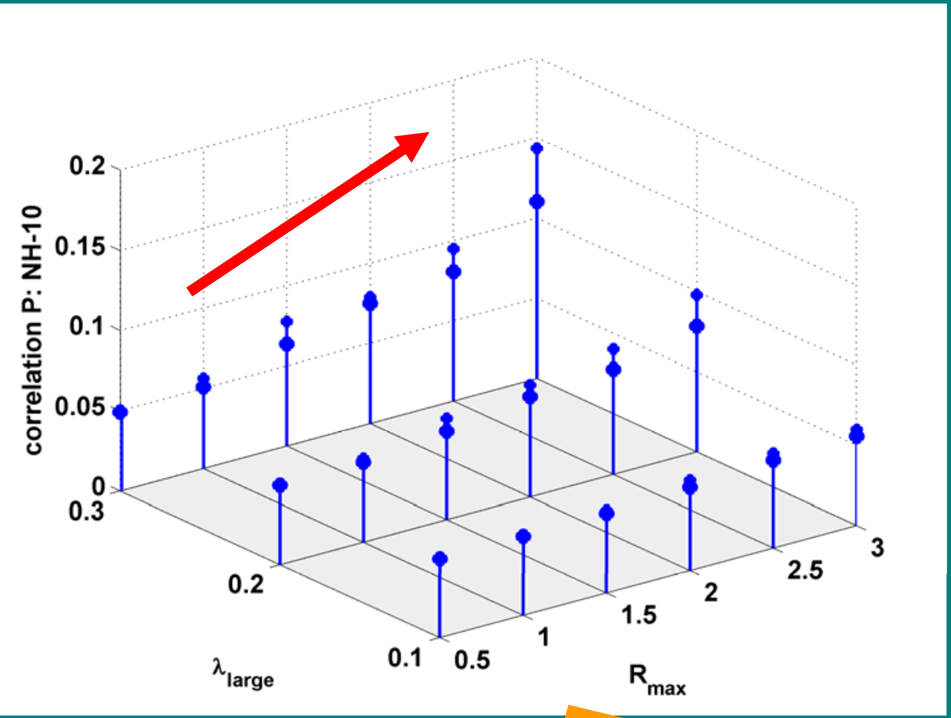
Zooplankton correlation: NH10



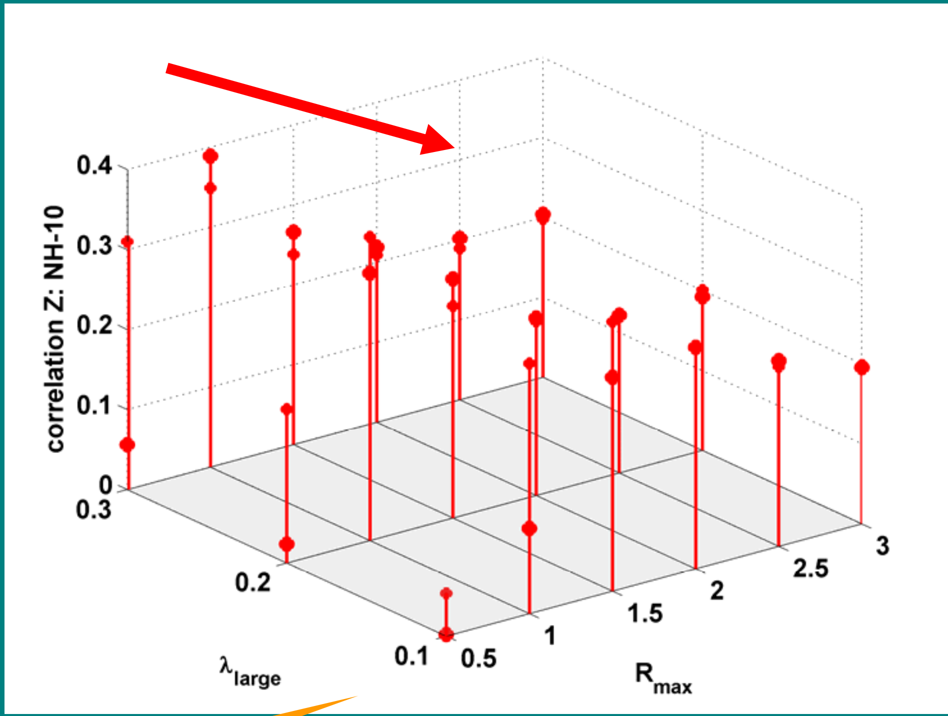
Model Quality:

Exp. 4: Z parameters

Phytoplankton correlation: NH10



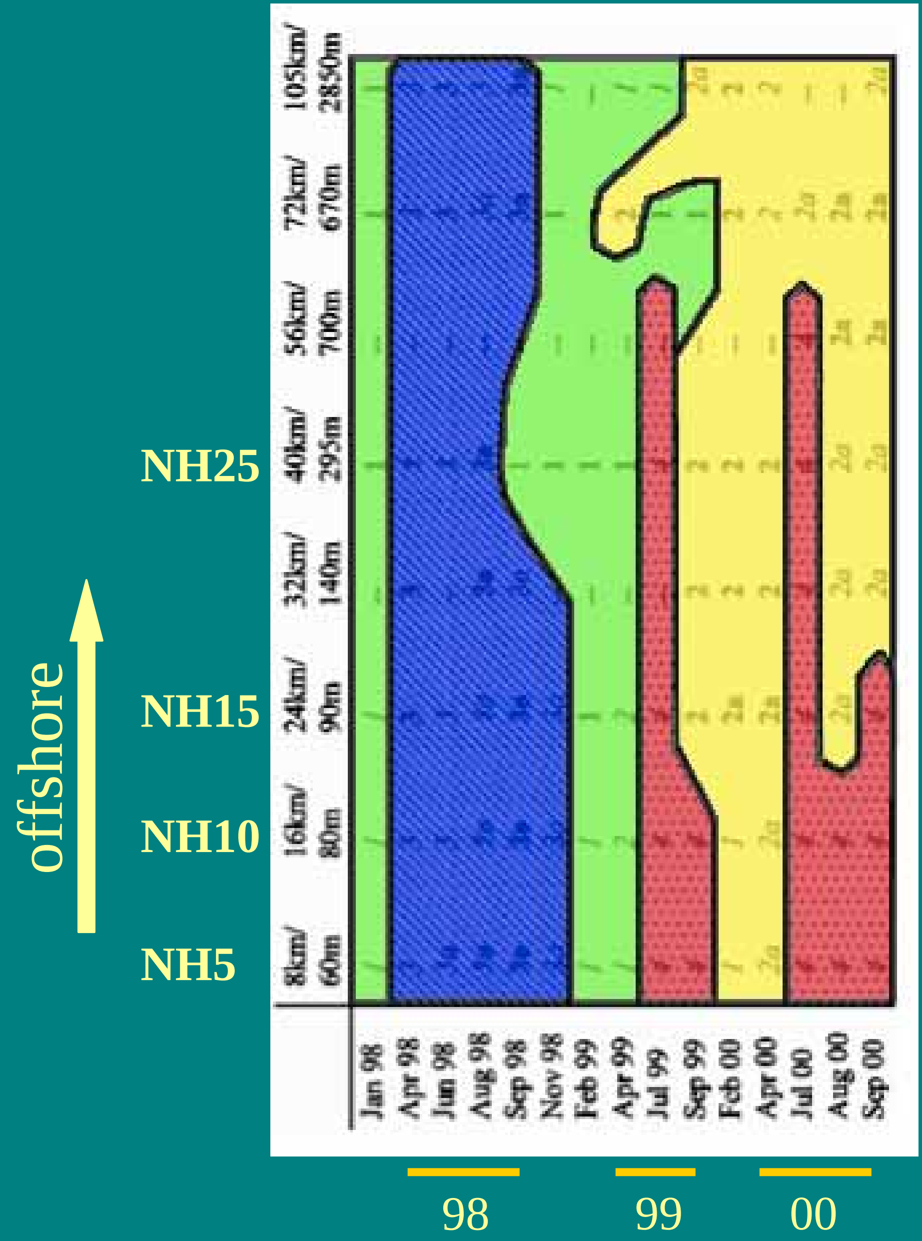
Zooplankton correlation: NH10



Difficult to optimize parameters for phytoplankton and zooplankton simultaneously

Oregon coastal copepod community

[Keister & Peterson 2003]

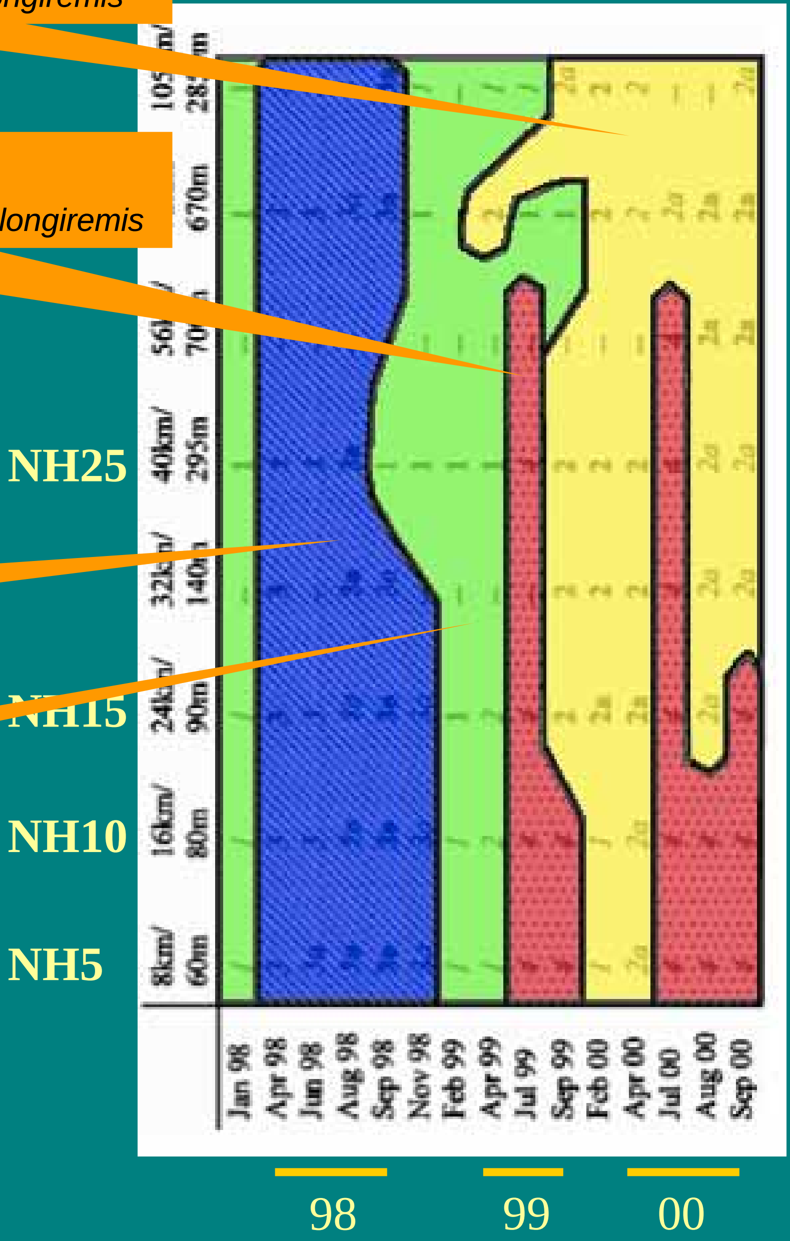


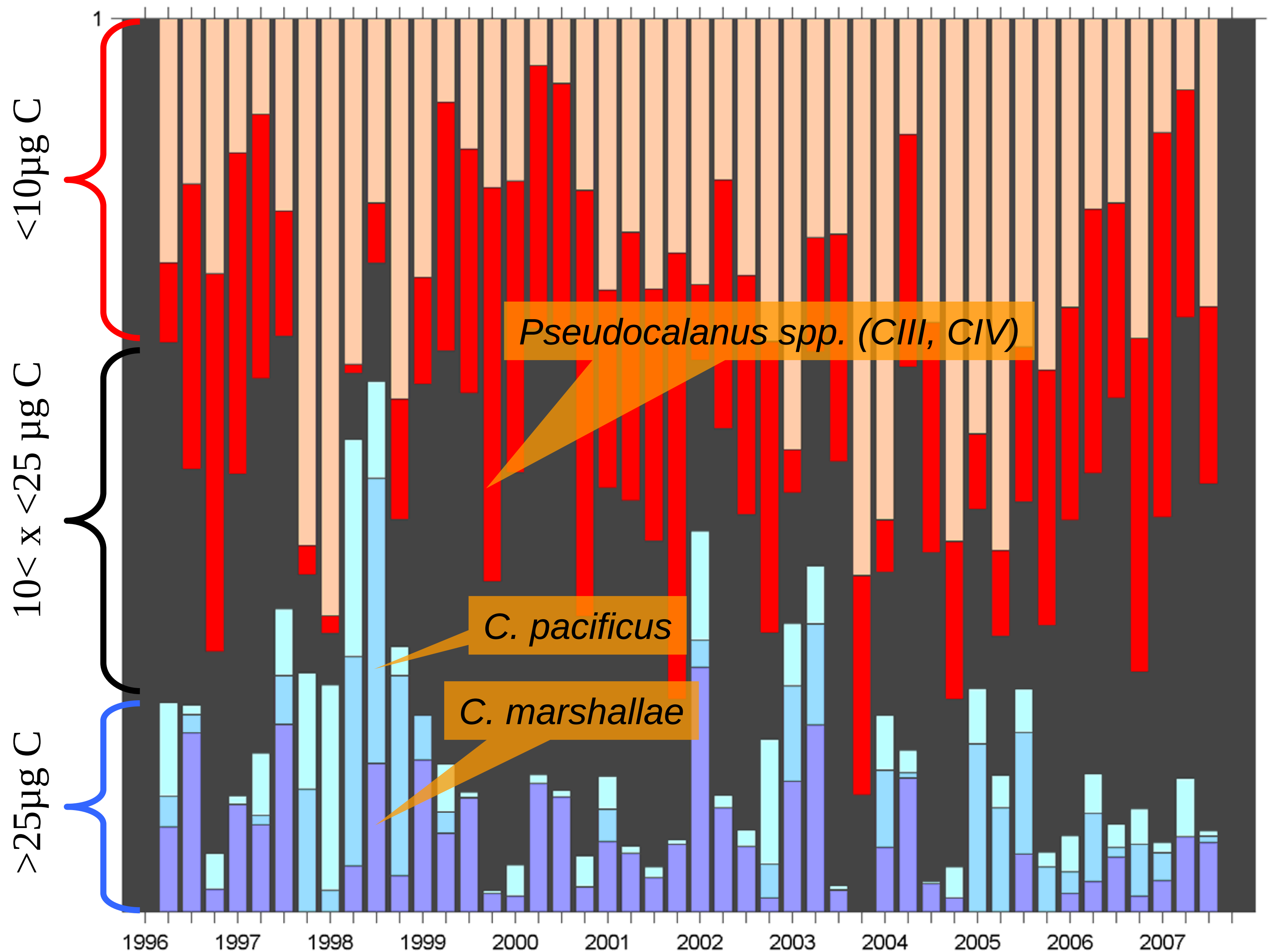
‘normal’ winter & offshore summer
Pseudocalanus spp., *Oithona similis*, *Acartia longiremis*

‘normal’ nearshore summer
Pseudocalanus spp., *Calanus marshallae, Oithona similis*, *Acartia longiremis*

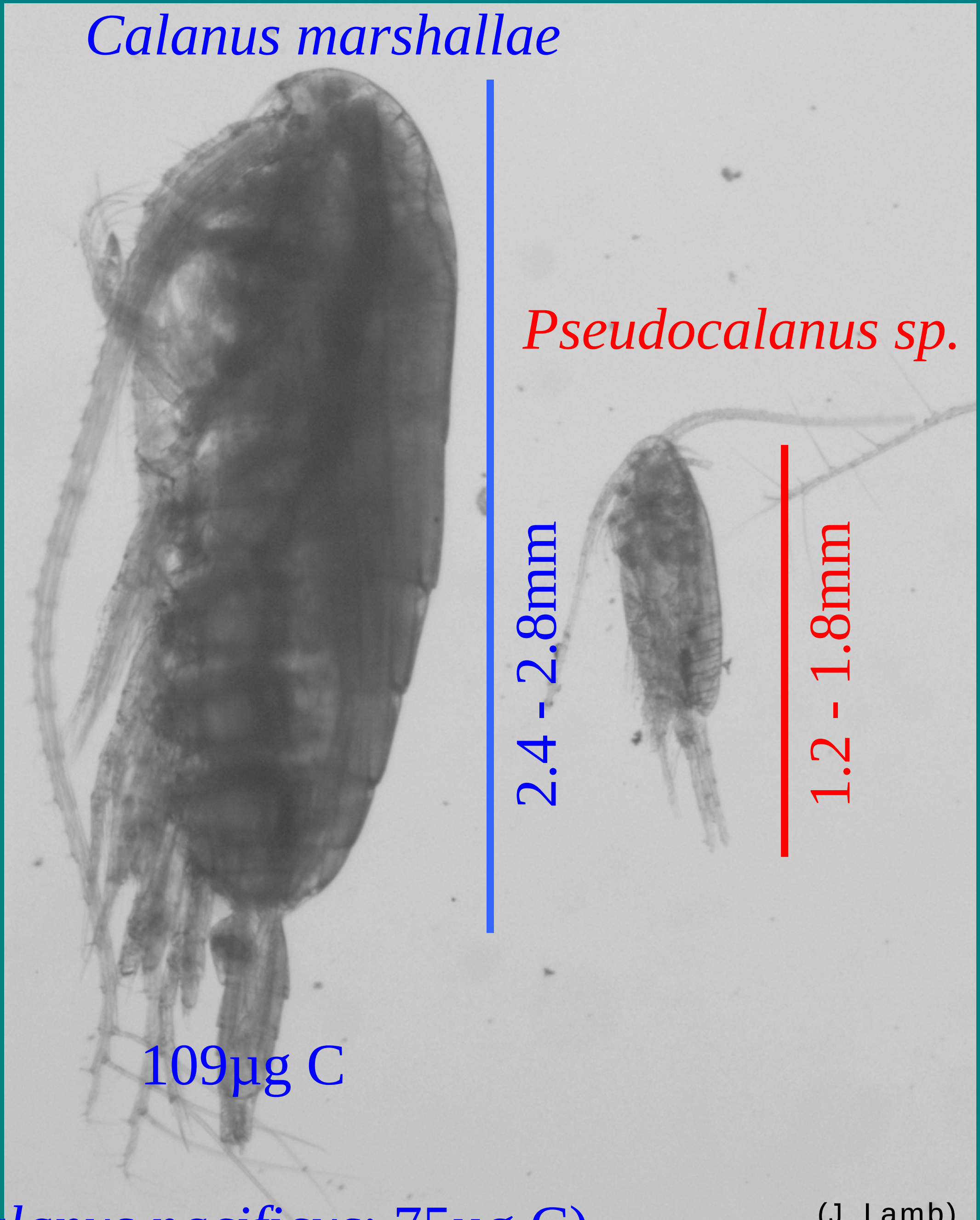
El Niño
Calanus pacificus, *Metridia* spp.

transition
Acartia danae, *Calocalanus tenuis*

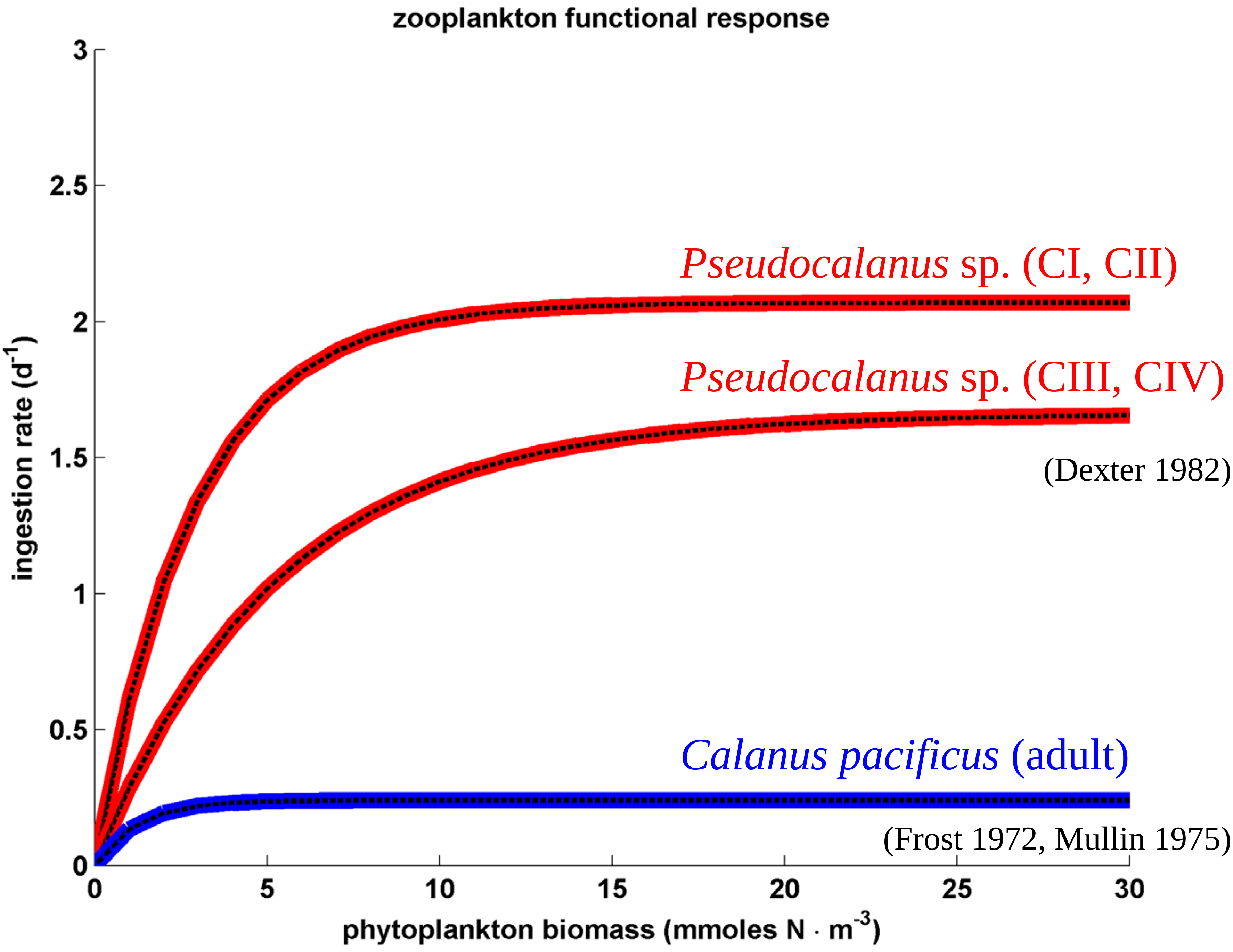


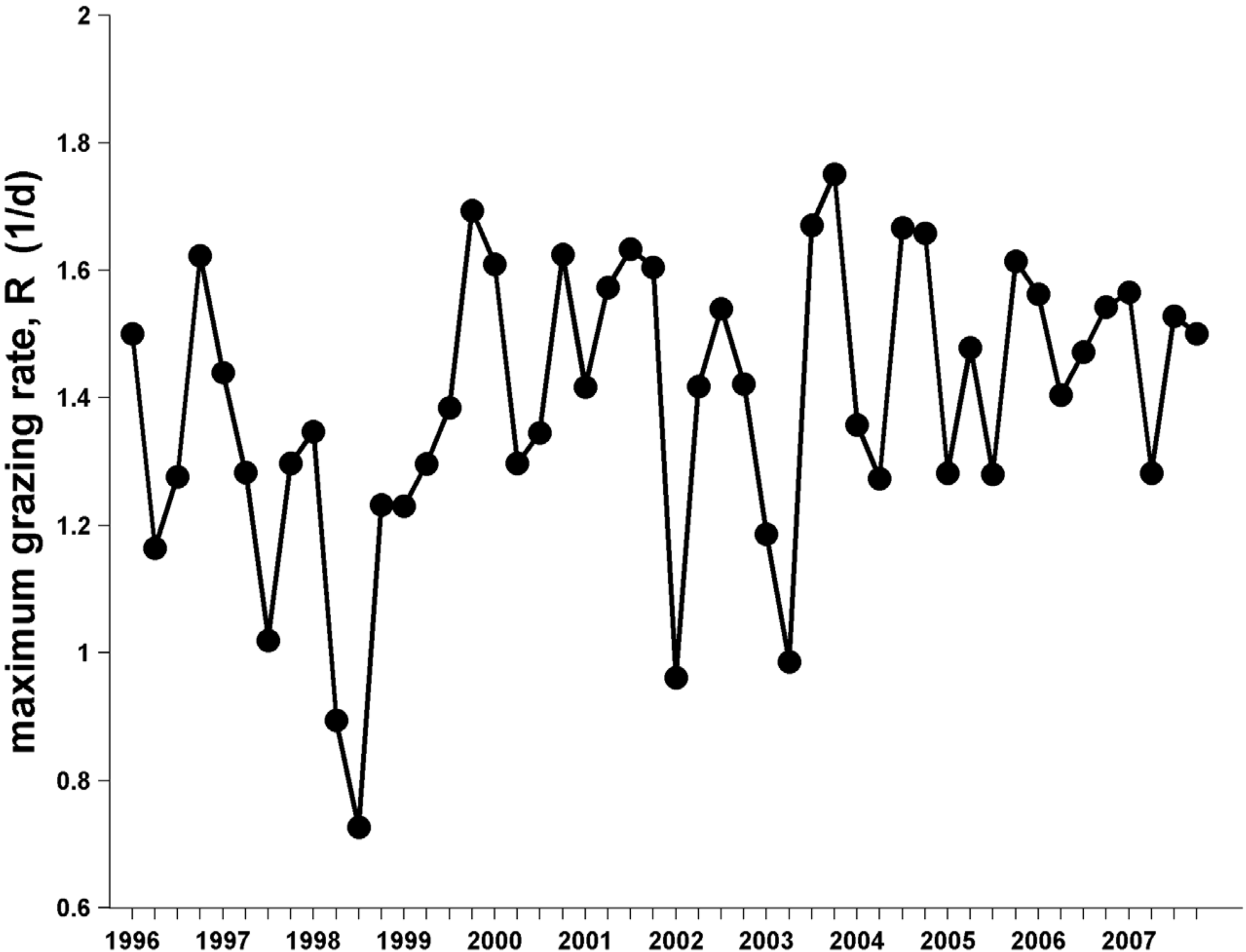


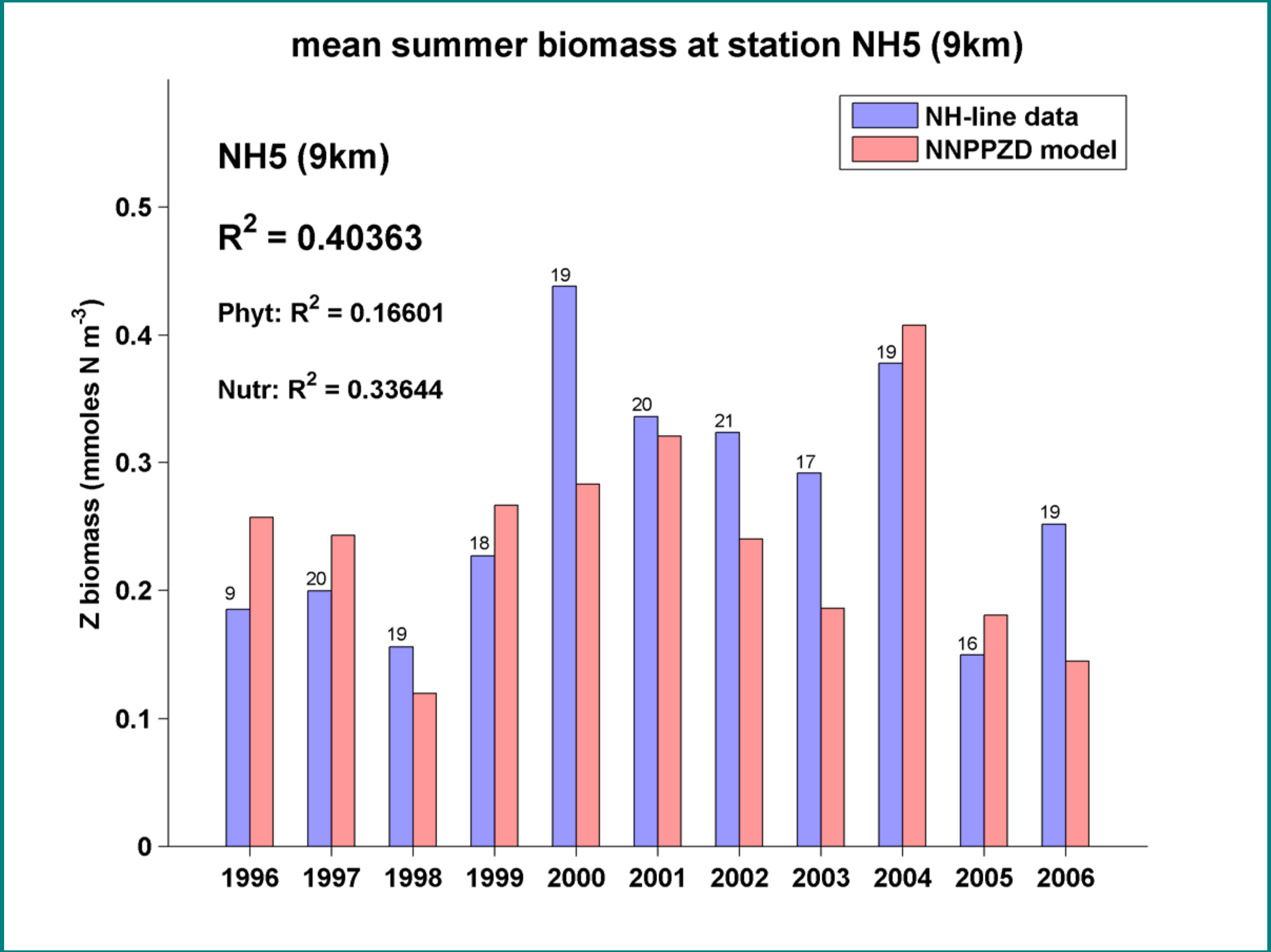
1
<10µg C
10< x <25 µg C
>25µg C
Pseudocalanus spp. (CIII, CIV)
C. pacificus
C. marshallae
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007

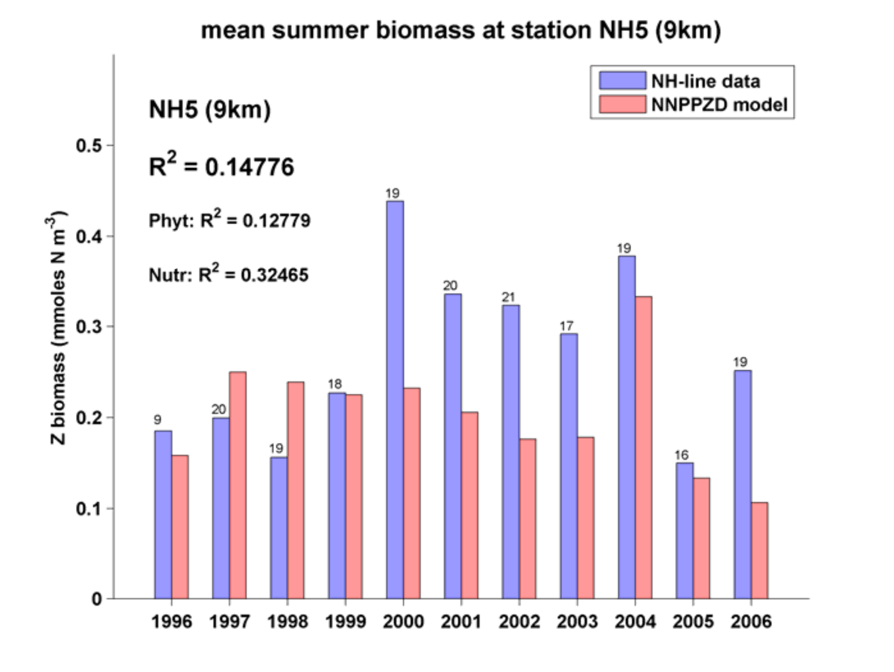


(*Calanus pacificus*: 75µg C)


zooplankton functional response
ingestion rate (d^-1)
phytoplankton biomass (mmoles N · m^-3)
3
2.5
2
1.5
1
0.5
0
5
10
15
20
25
30
Pseudocalanus sp. (CI, CII)
Pseudocalanus sp. (CIII, CIV)
(Dexter 1982)
Calanus pacificus (adult)
(Frost 1972, Mullin 1975)

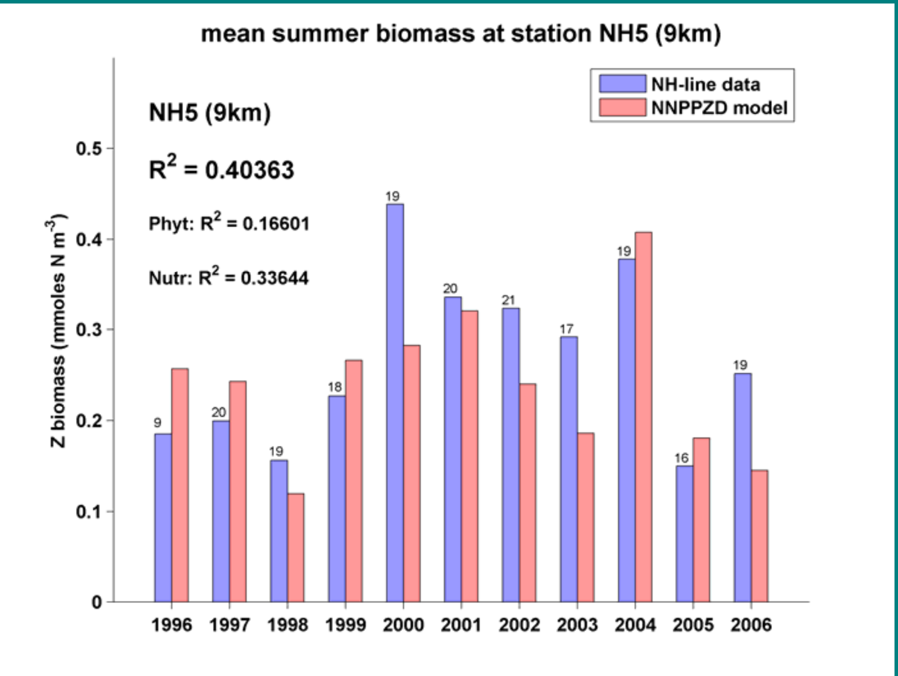

maximum grazing rate, R (1/d)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007


mean summer biomass at station NH5 (9km)
NH-line data
NNPPZD model
NH5 (9km)
R2 = 0.40363
Phyt: R2 = 0.16601
Nutr: R2 = 0.33644
Z biomass (mmoles N m-3)
0.5
0.4
0.3
0.2
0.1
0
9
20
19
18
19
20
21
17
19
16
19
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006



Inter-annual correlation

	NH5	NH10	NH15	NH25
Z	**0.15**	**0.00**	**0.05**	**0.25**
P	0.13	0.06	0.03	0.21
N	0.32	0.01	0.29	0.02



	NH5	NH10	NH15	NH25
Z	**0.40**	**0.22**	**0.43**	**0.27**
P	0.17	0.09	0.03	0.15
N	0.34	0.02	0.30	0.06

Summary

- Simple biological model & 1D physical model is able to replicate general seasonal and spatial patterns of zooplankton biomass
- There is NO parameter set that optimizes model's ability to reproduce both phytoplankton & zooplankton dynamics simultaneously
- Model's ability to capture observed inter-annual variability improves substantially when the copepod community composition is taken into account

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Copepod community off Oregon shaped by regional-scale processes - Any self-contained model must also be regional in scale

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  - Leah Feinberg
  - Tracy Shaw
  - Jen Menkel
  - Cheryl Morgan
  - Hongsheng Bi
- Yvette Spitz
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(W Peterson)


(W Peterson)