Ocean Respiration: New Concepts, New Significance, and New Applications

T.T. Packard, N. Osma, I. Fernández-Urruzola, F. Maldonado, I. Martínez, A. Herrera, M. Tames-Espinosa, M. Gómez

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What is New in Ocean Respiration?

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3. Nutrient Retention Efficiency (NRE)

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4. Curvature of Respiration Profiles: Importance

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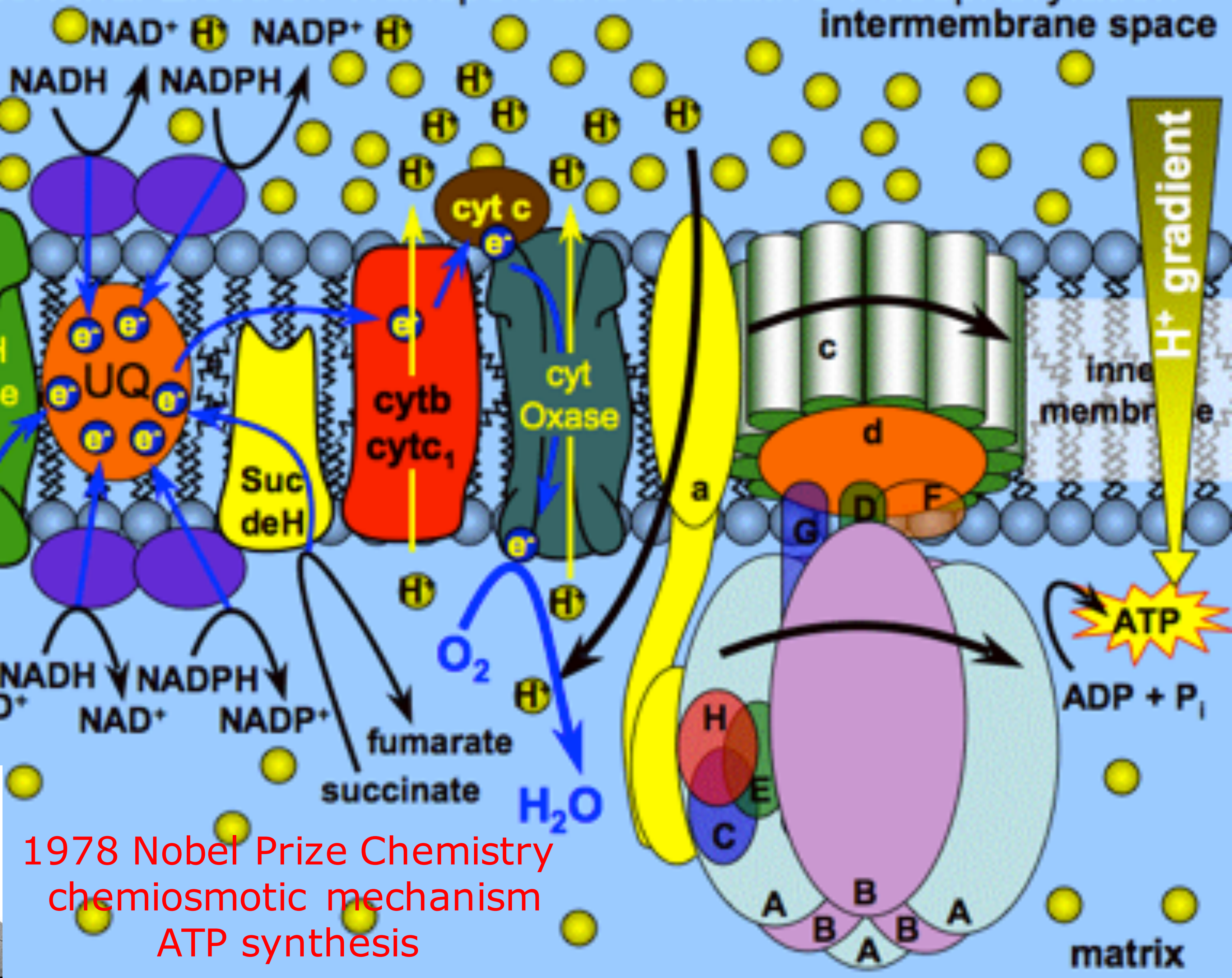
4. Curvature of Respiration Profiles: Importance
5. Benthic Respiration from Water-Column Respiration

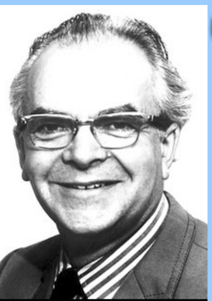
HETEROTROPHIC ENERGY PRODUCTION

A Calculation of ATP Production

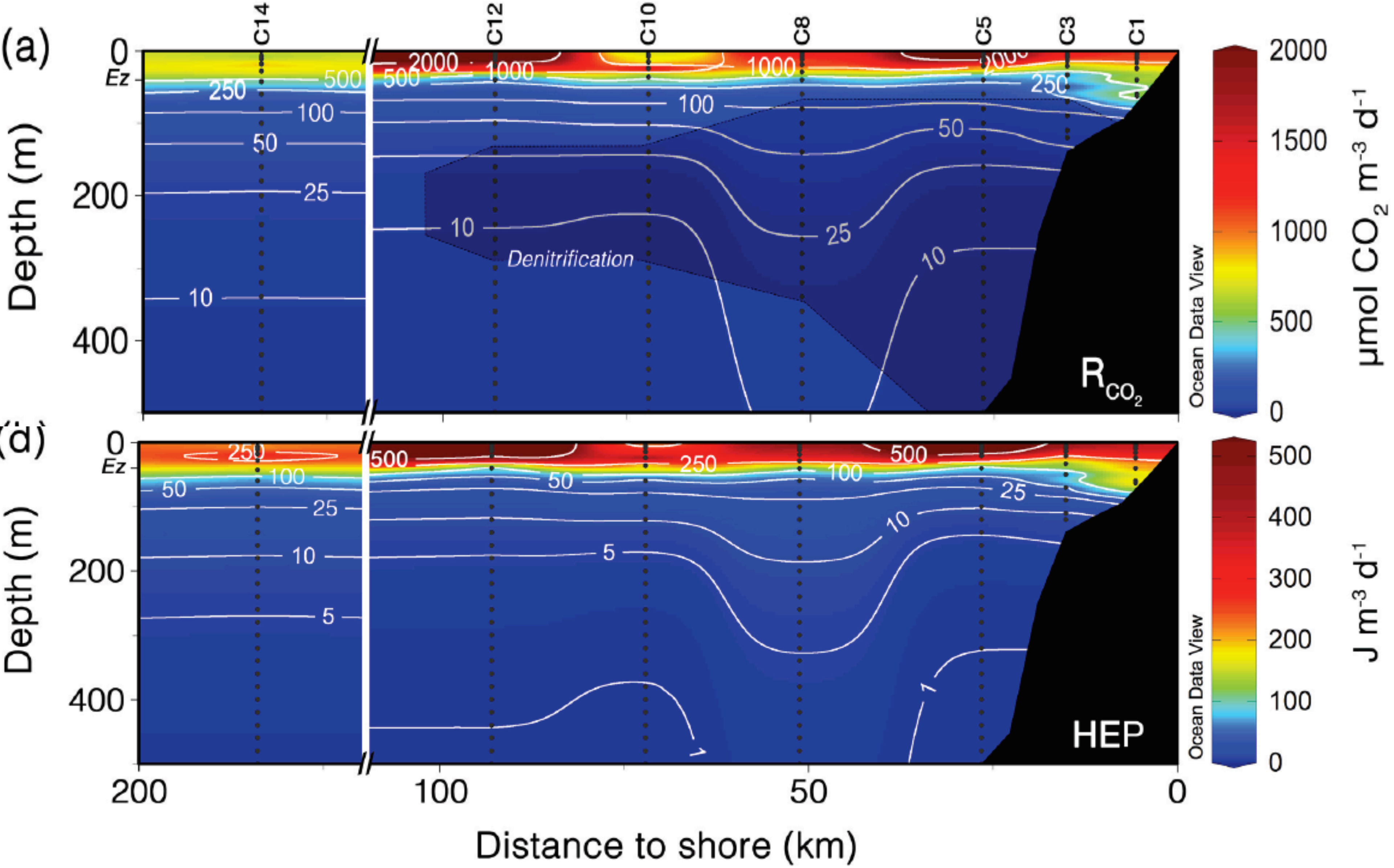
Based on nobelist, **Severo Ochoa's** finding of a 3:1 ratio between respiratory oxygen consumption and ATP production and on nobelist, **Peter Mitchell's** Chemosmotic explanation of ETS-OXPHOS coupling.

Mitochondrial Electron Transport and Oxidative Phosphorylation



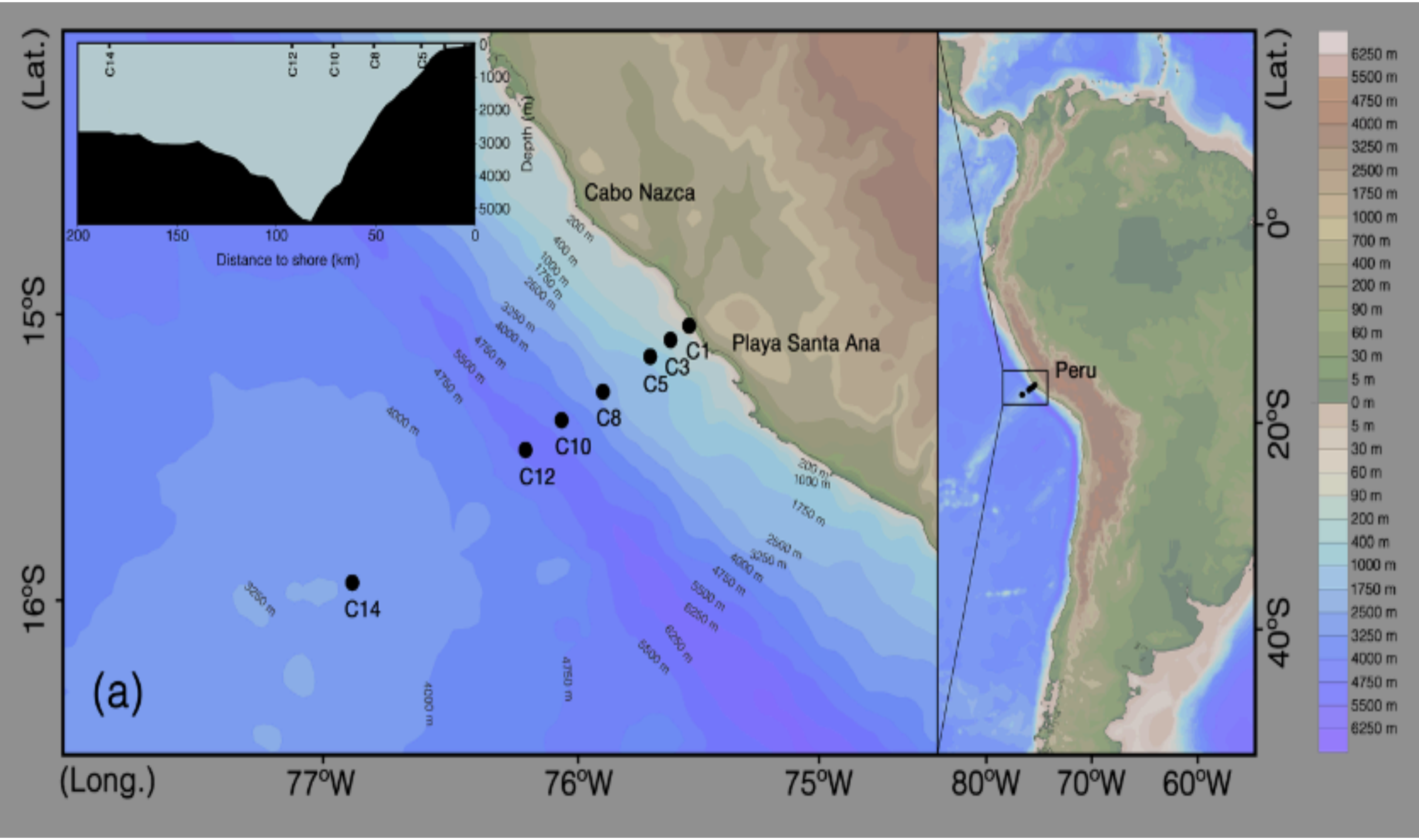


1978 Nobel Prize Chemistry
chemiosmotic mechanism
ATP synthesis



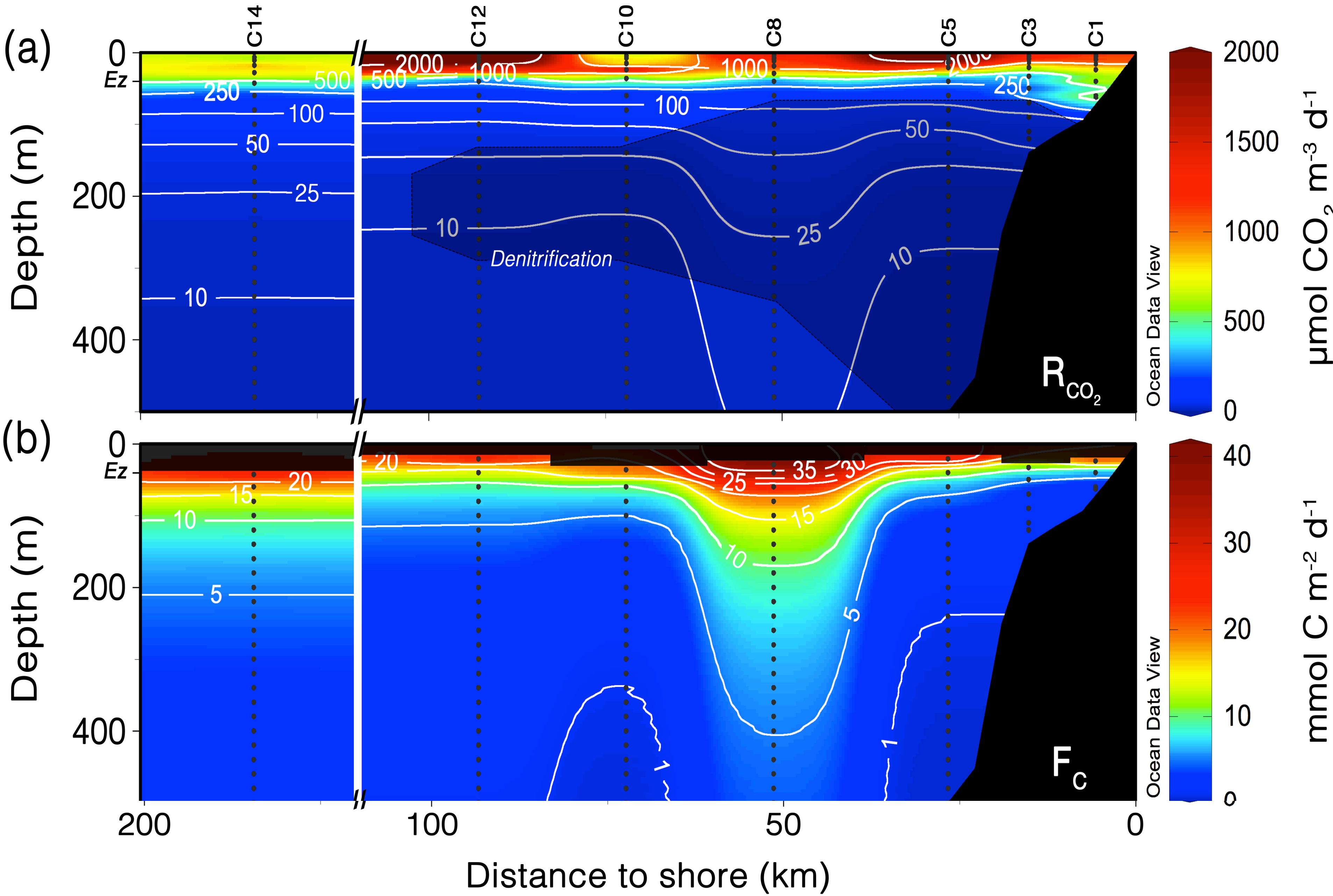
ETS ACTIVITY → RESPIRATION → ATP PRODUCTION (Joules/m³/day)

CUEA C-Line off 15°S Peru



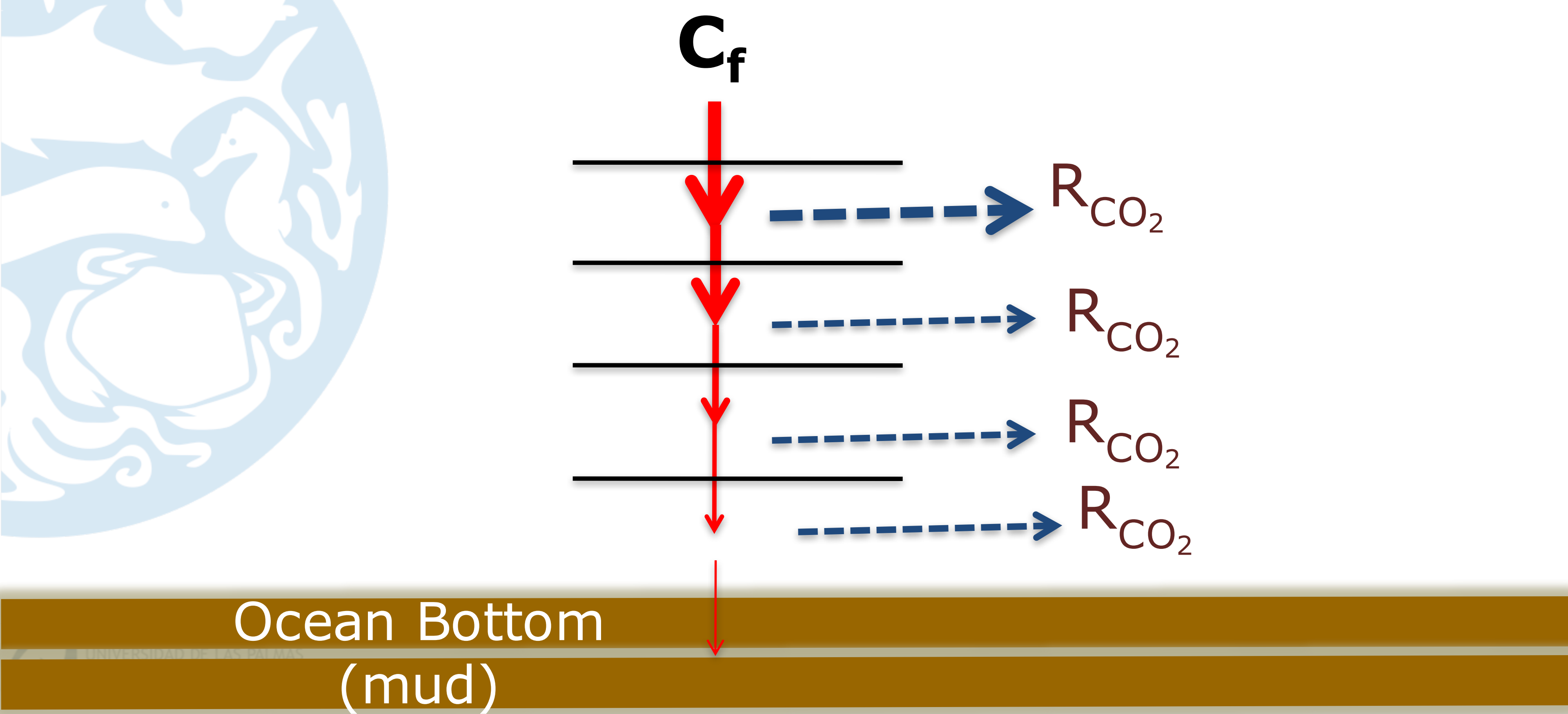
Carbon Flux from Respiration

Fc (mmol C m^{-2} d^{-1}) C-Line, Peru



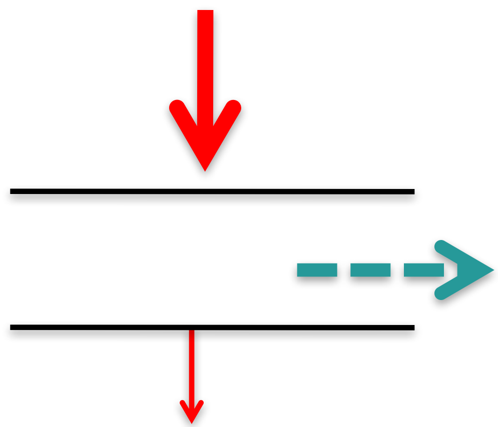
Carbon Flux = ∫(R) from Riley (1951)

$$F_{t\text{-}s} = \int_{z_t}^{z_s} R_t (z/z_t)^b \, dz = [R_t /((b+1)(z_t)^b)] \, [(z_s^{b+1}) - (z_t^{b+1})]$$



NRE = Nutrient Retention Efficiency

$$(F_{t\text{-}s})_1 = (d(POC)/dt)$$



$$(d(CO_2)/dt) = R_{CO_2}$$

$$(F_{t\text{-}s})_2$$

$$NRE = R_{CO_2}/(F_{t\text{-}s})_1$$

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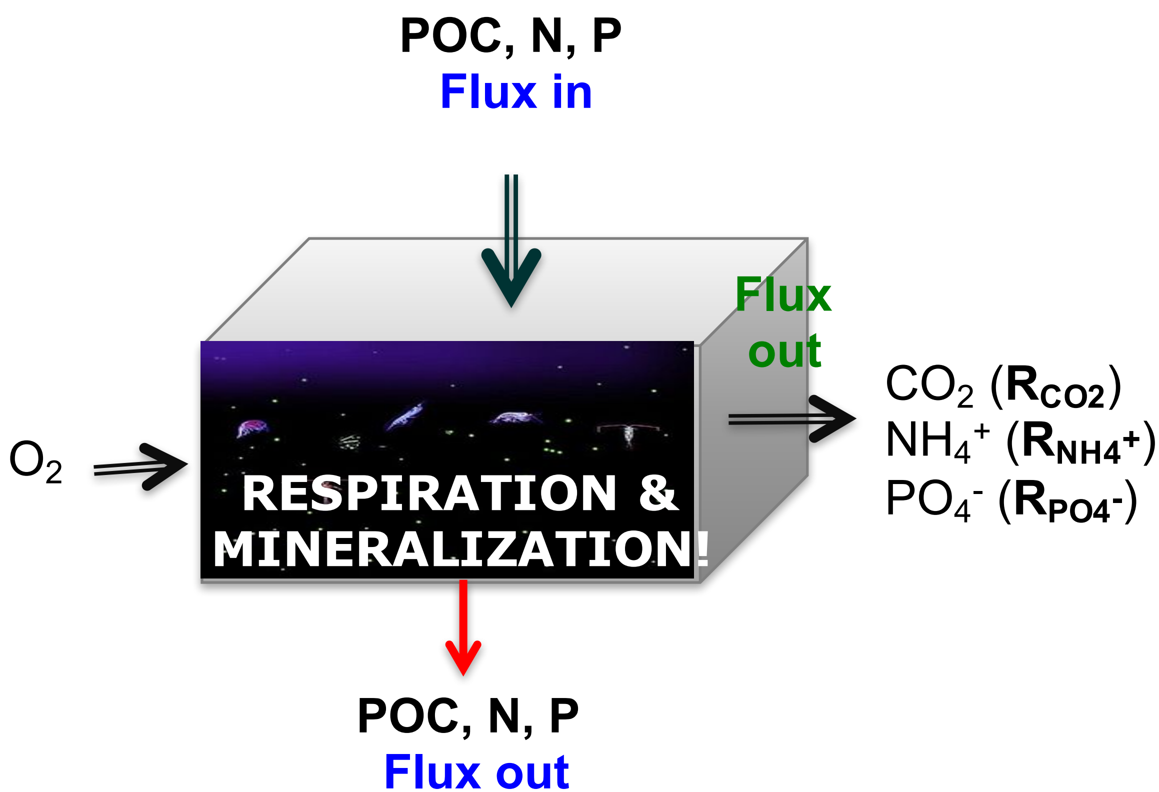
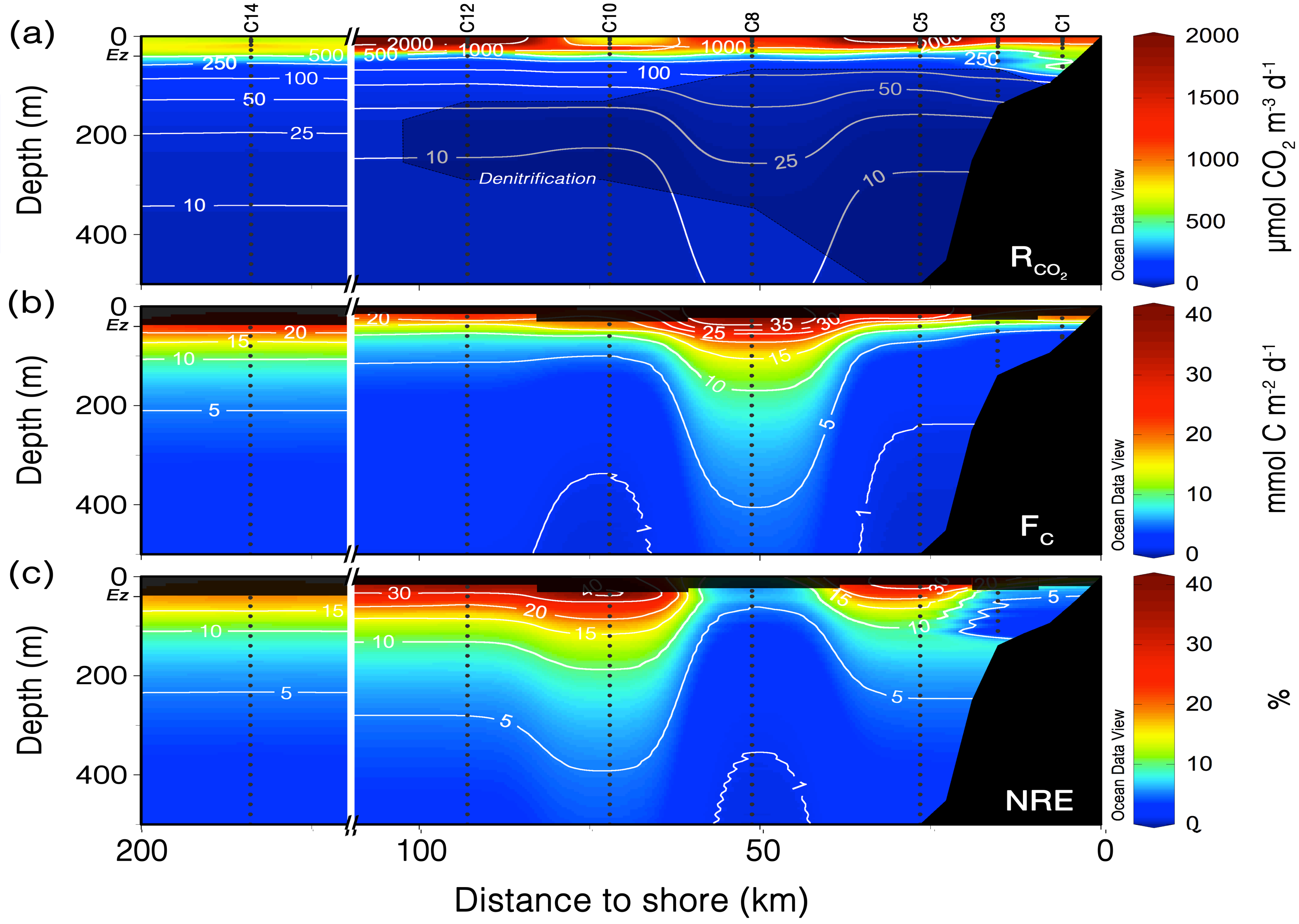
NUTRIENT RETENTION EFFICIENCY

Conceptual basis



EFFICIENCY WITH WHICH PLANKTON MINERALIZE POM

Permits nutrient recycling! **NRE =(ΔPOM Flux)/(Flux in)**



(a)
(b)
(c)
C14
C12
C10
C8
C5
C3
C1
Ez
Depth (m)
Denitrification
R_{CO_2}
F_C
NRE
Ocean Data View
μmol CO_2 m^{-3} d^{-1}
mmol C m^{-2} d^{-1}
%
Distance to shore (km)
200
100
50
0

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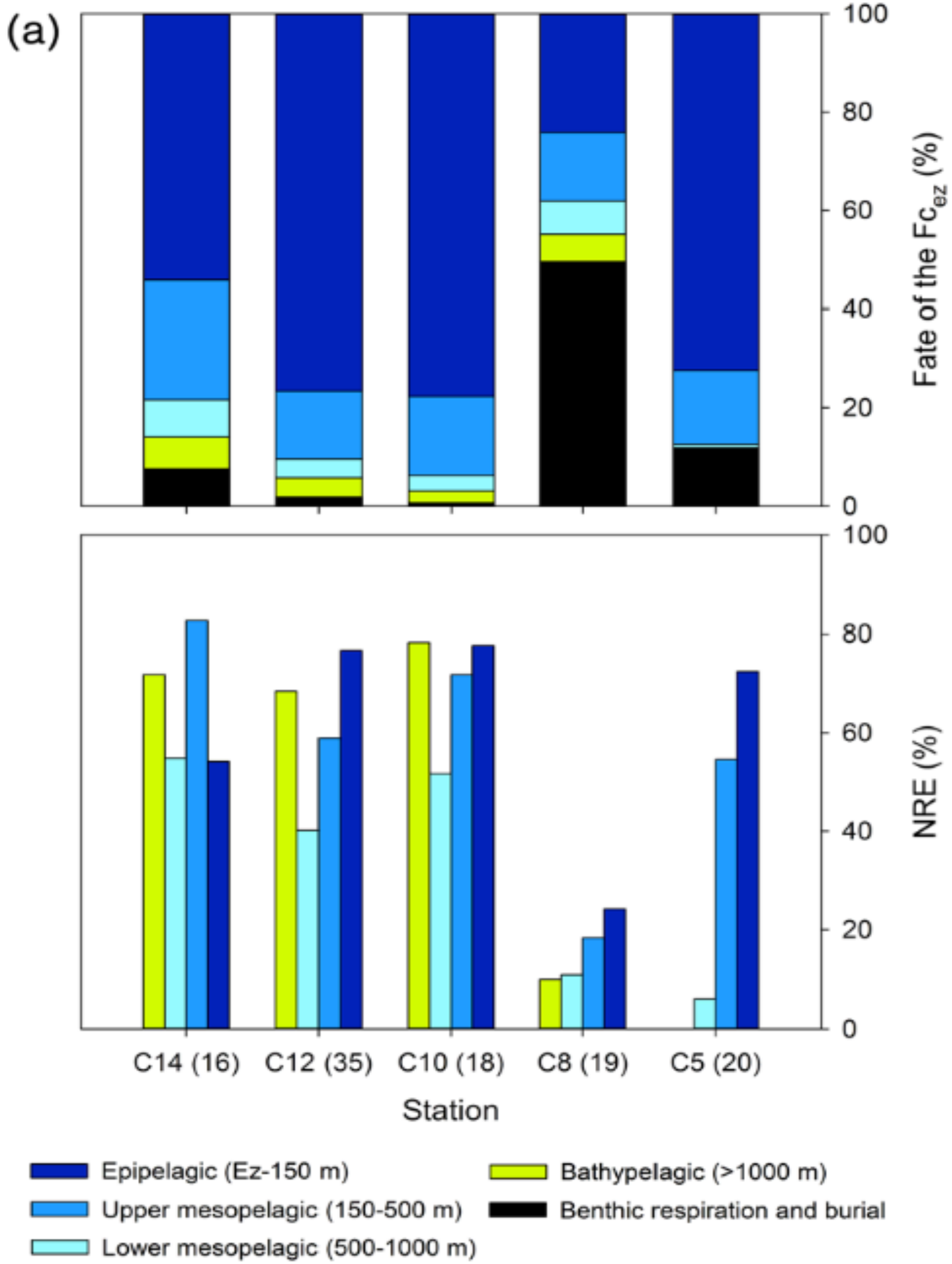

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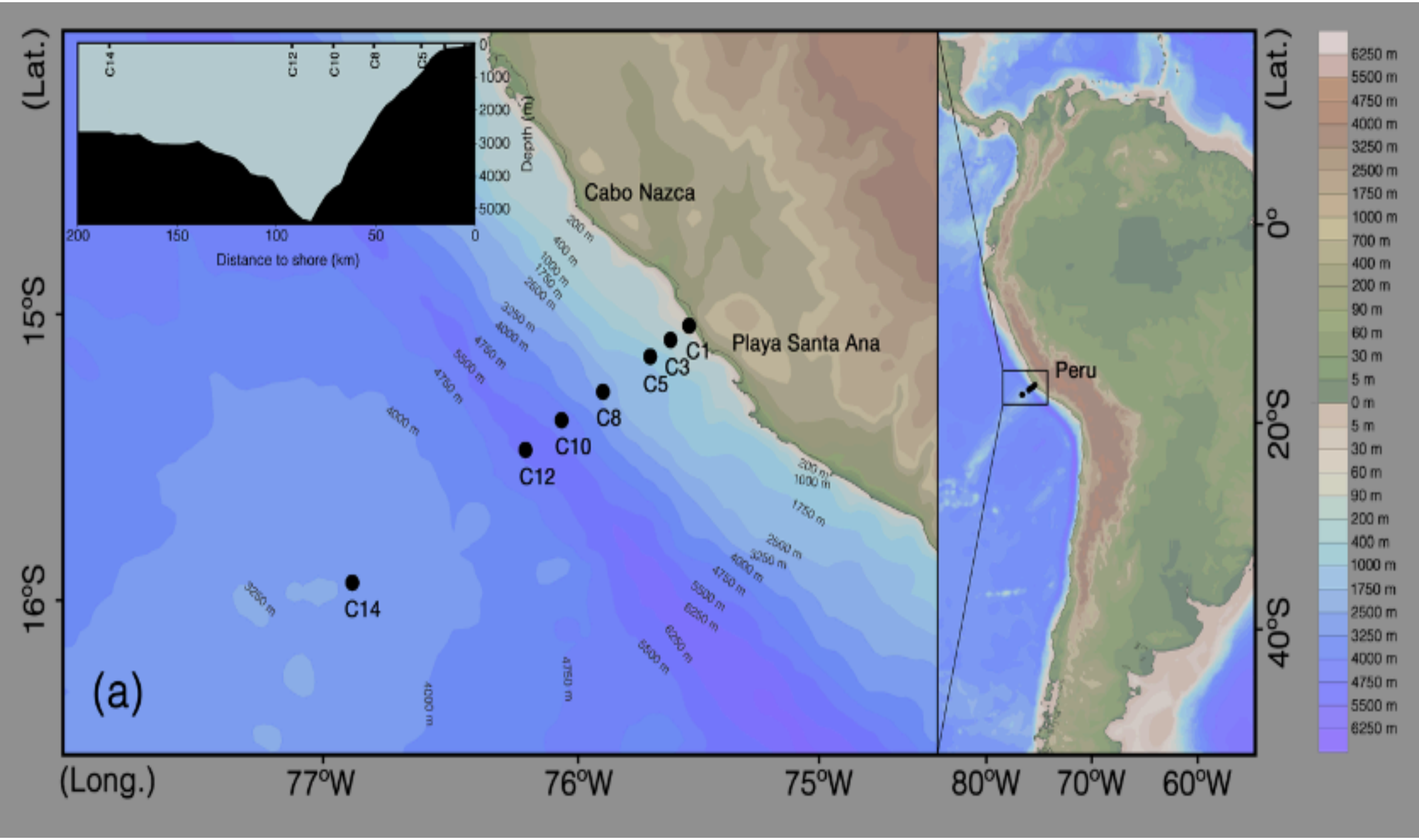
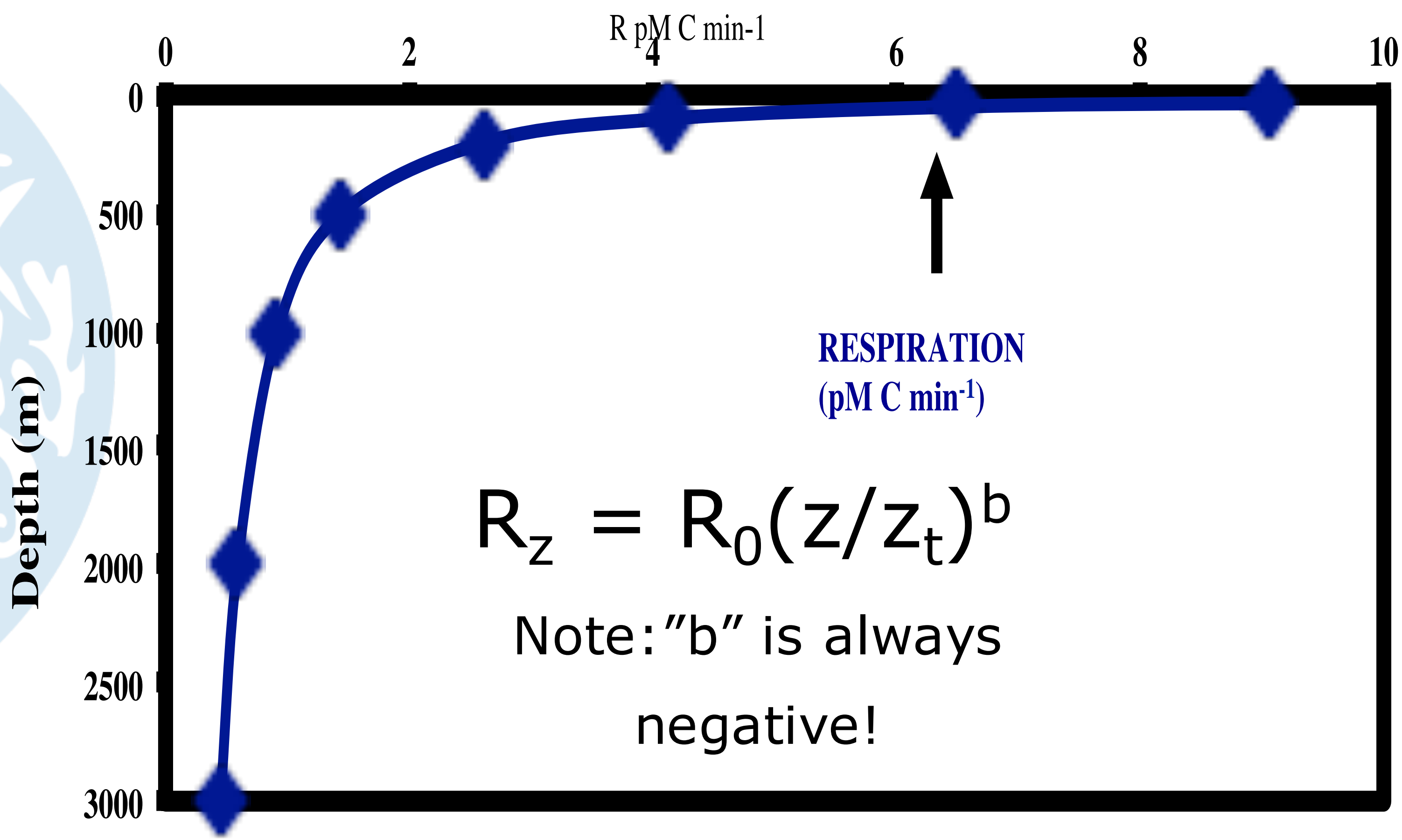
CUEA C-Line off 15°S Peru



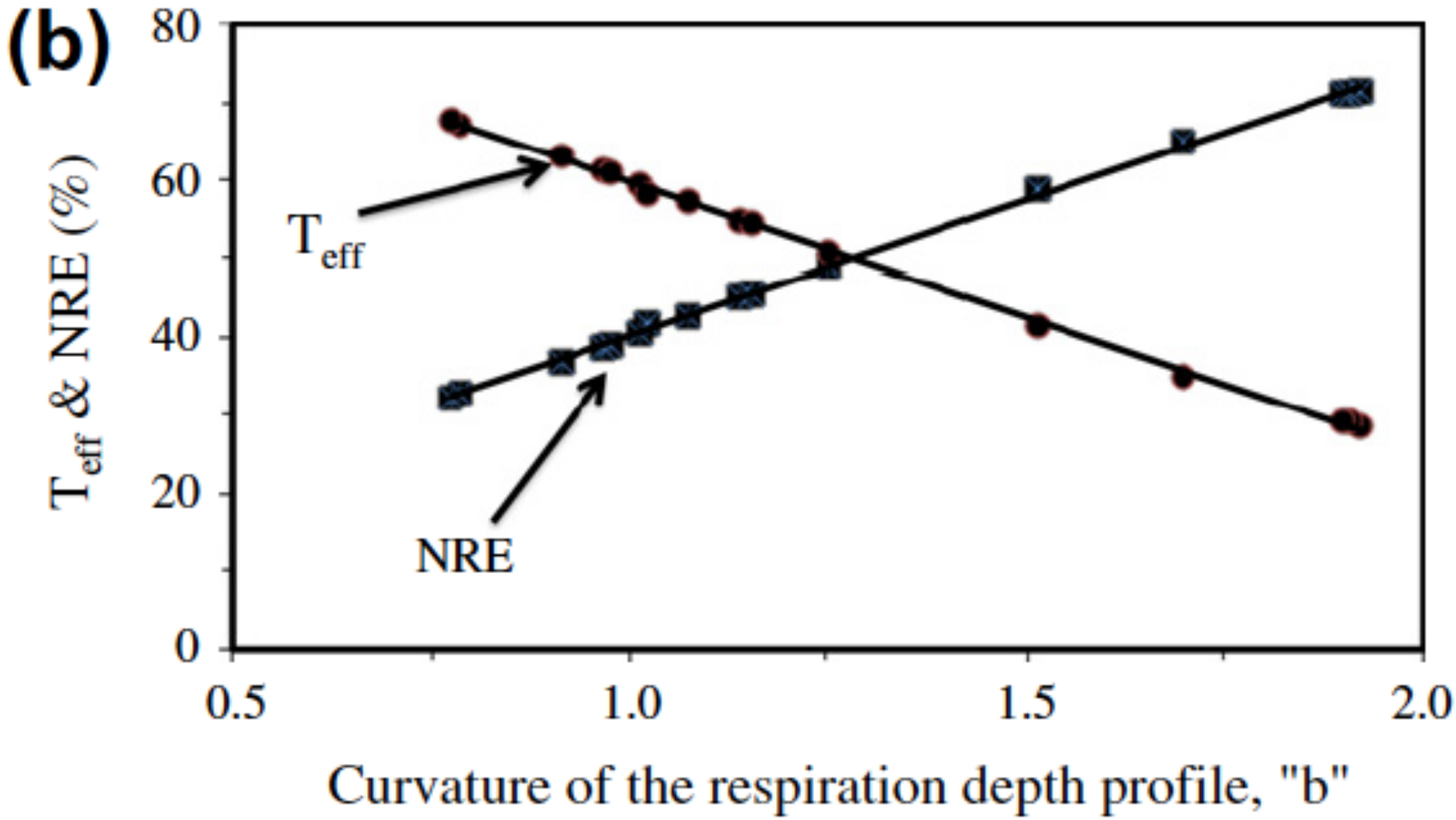
Importance of b, the curvature of the respiration equation



$$R_z = R_0(z/z_t)^b$$

Note: "b" is always negative!

Zooplankton $R_z = R_t(z/z_t)^{-b}$



From: Packard and Gómez, 2013

BENTHIC RESPIRATION & C-BURIAL

The indefinite integral of $R_z = R_t(z/z_t)^b$ with respect to depth (z) is:

$$F_c = \int R_t(z/z_t)^b \, dz = [R_t / ((b+1)(z_t)^b)] \, z^{b+1} + C$$

C = benthic respiration & C burial!

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BENTHIC R & C-Burial

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To calculate benthic respiration & C-burial we subtract the flux to the water column ($F_{t\text{-}s}$) from the flux to infinity (F_{∞}).

$$F_{t\text{-}s} = \int_{z_t}^{z_s} R_t (z/z_t)^b \, dz = [R_t /((b+1)(z_t)^b)] \, [(z_s^{b+1}) - (z_t^{b+1})]$$

$$F_{\infty} = \int_{z_t}^{\infty} R_t (z/z_t)^b \, dz = [R_t /((b+1)(z_t)^b)] \, [-z_t^{b+1}]$$

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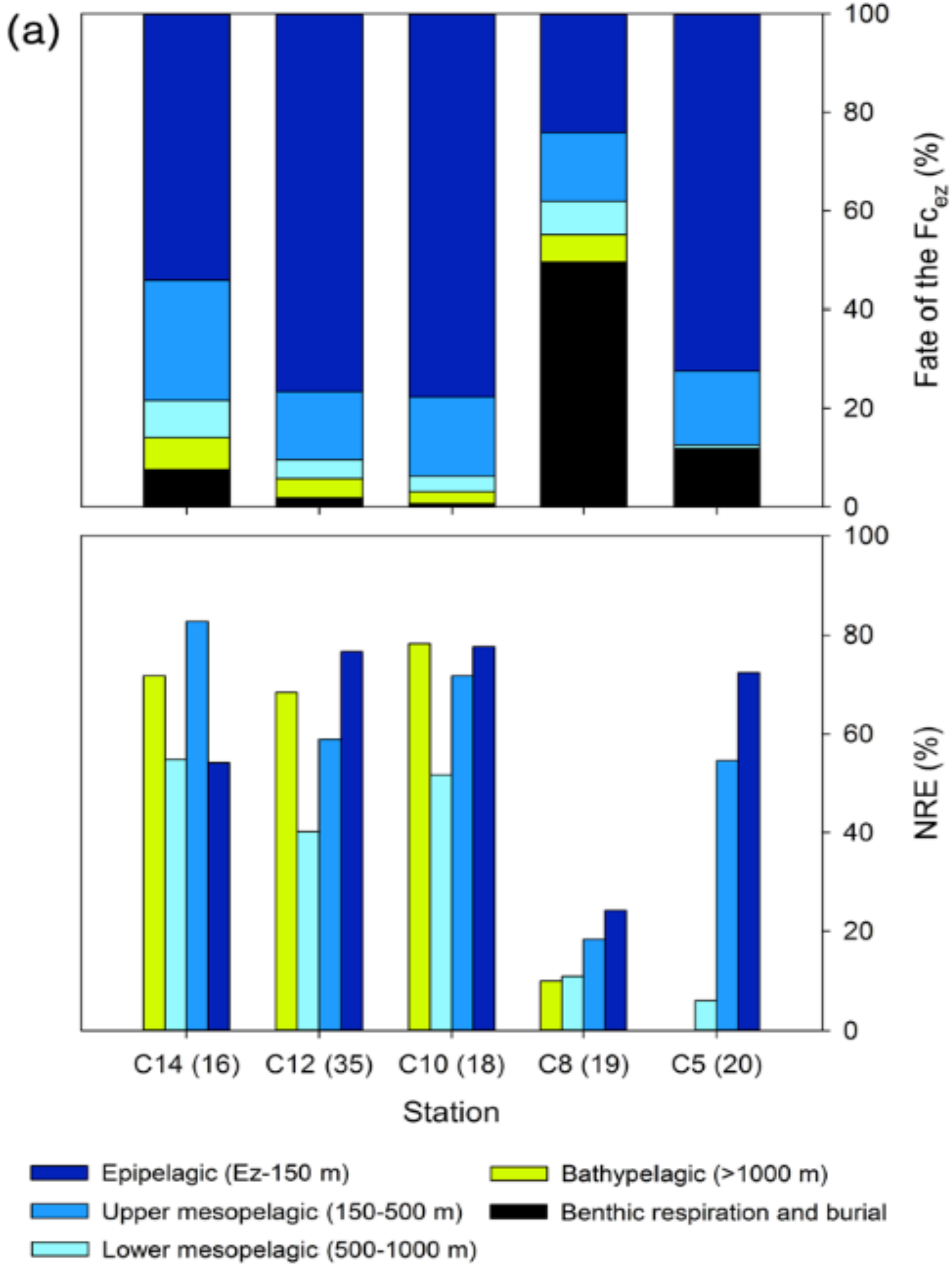

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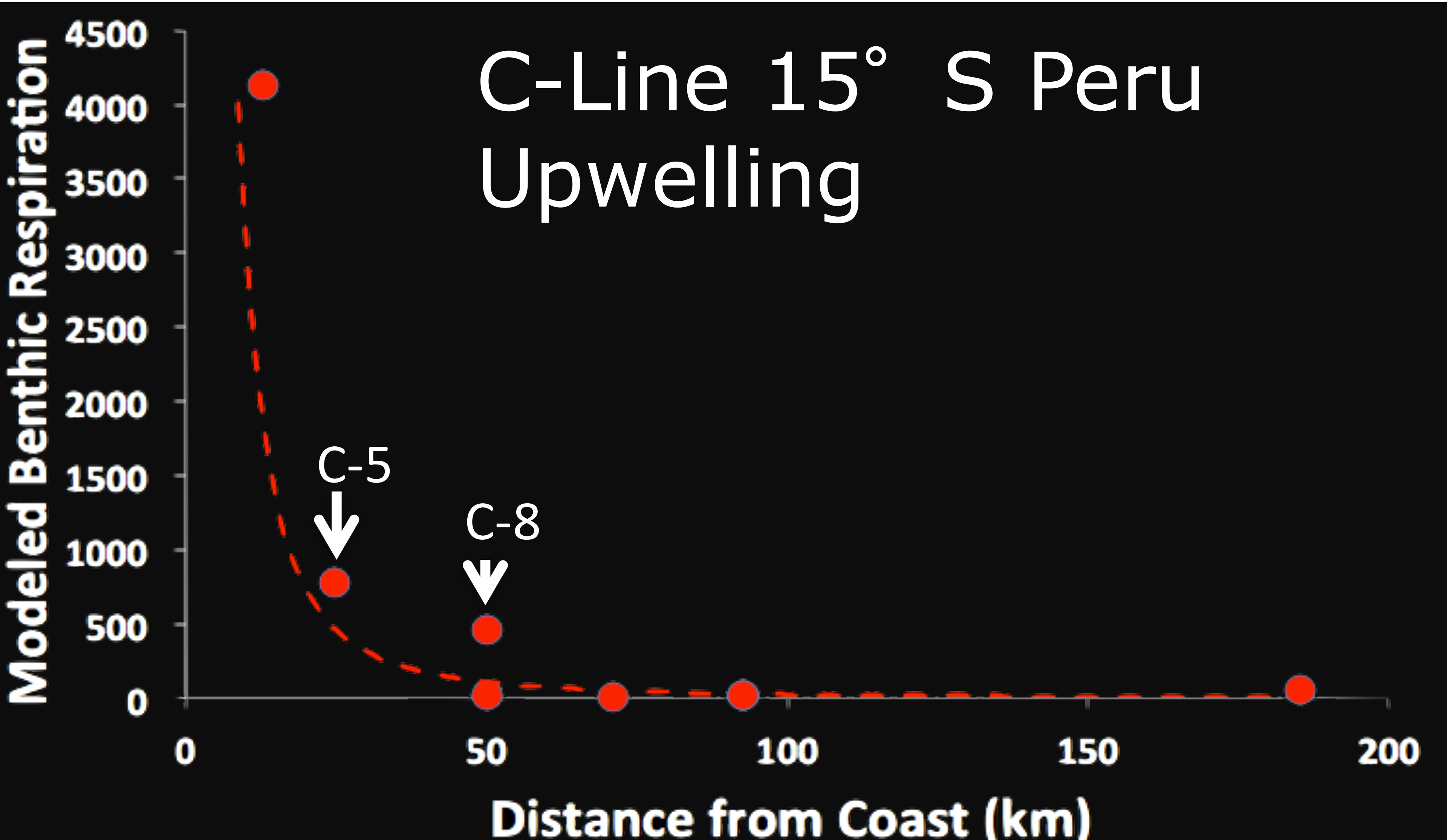
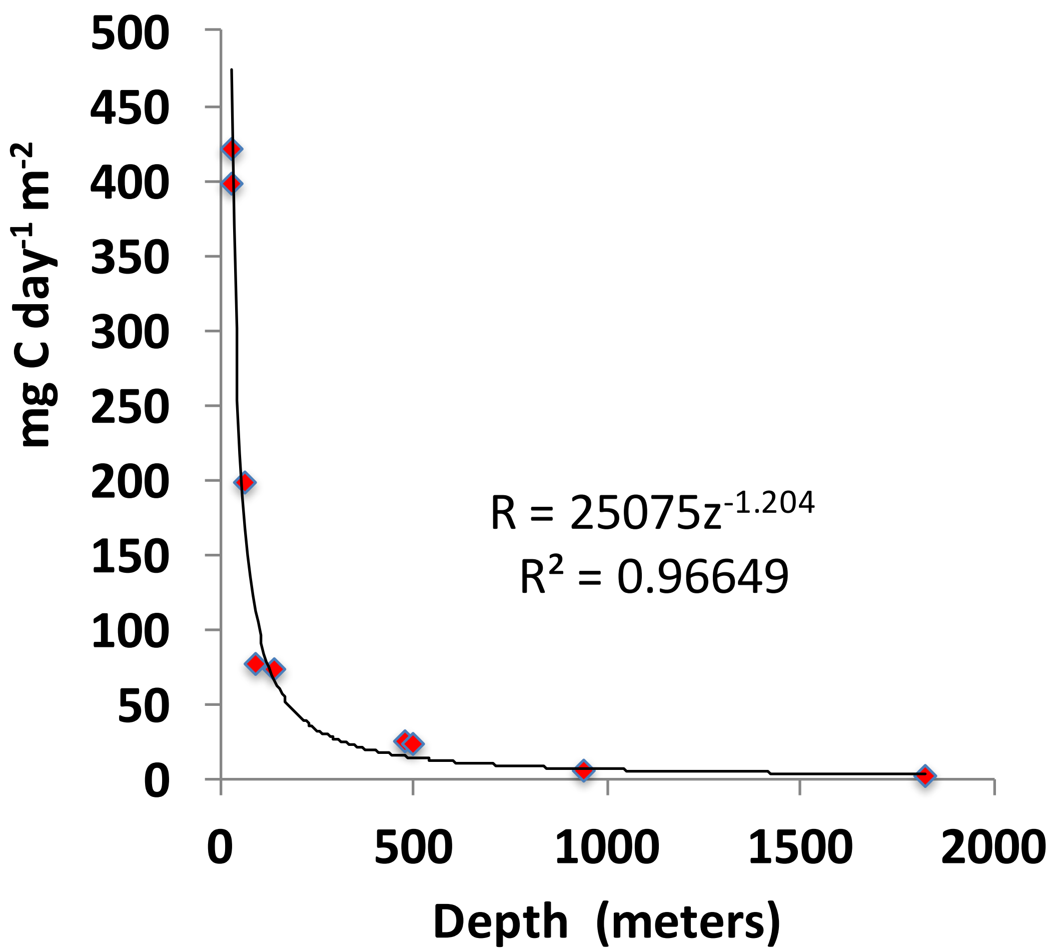
Modelled Benthic Respiration & C Burial ($\mu mol\ O_2\ m^{-2}\ d^{-1}$)



BENTHIC RESPIRATION

(CO_2 Production Rate)

NW African Upwelling (Christensen & Packard, 1978)



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1. Kinetic Assay cuts time

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3. 1/5 reagents needed & 1/5 cost

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4. Sonication used with zooplankton

What is New with the ETS ASSAY?

1. Kinetic Assay cuts time
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3. 1/5 reagents needed & 1/5 cost
4. Sonication used with zooplankton
5. Compared with He-tritium method

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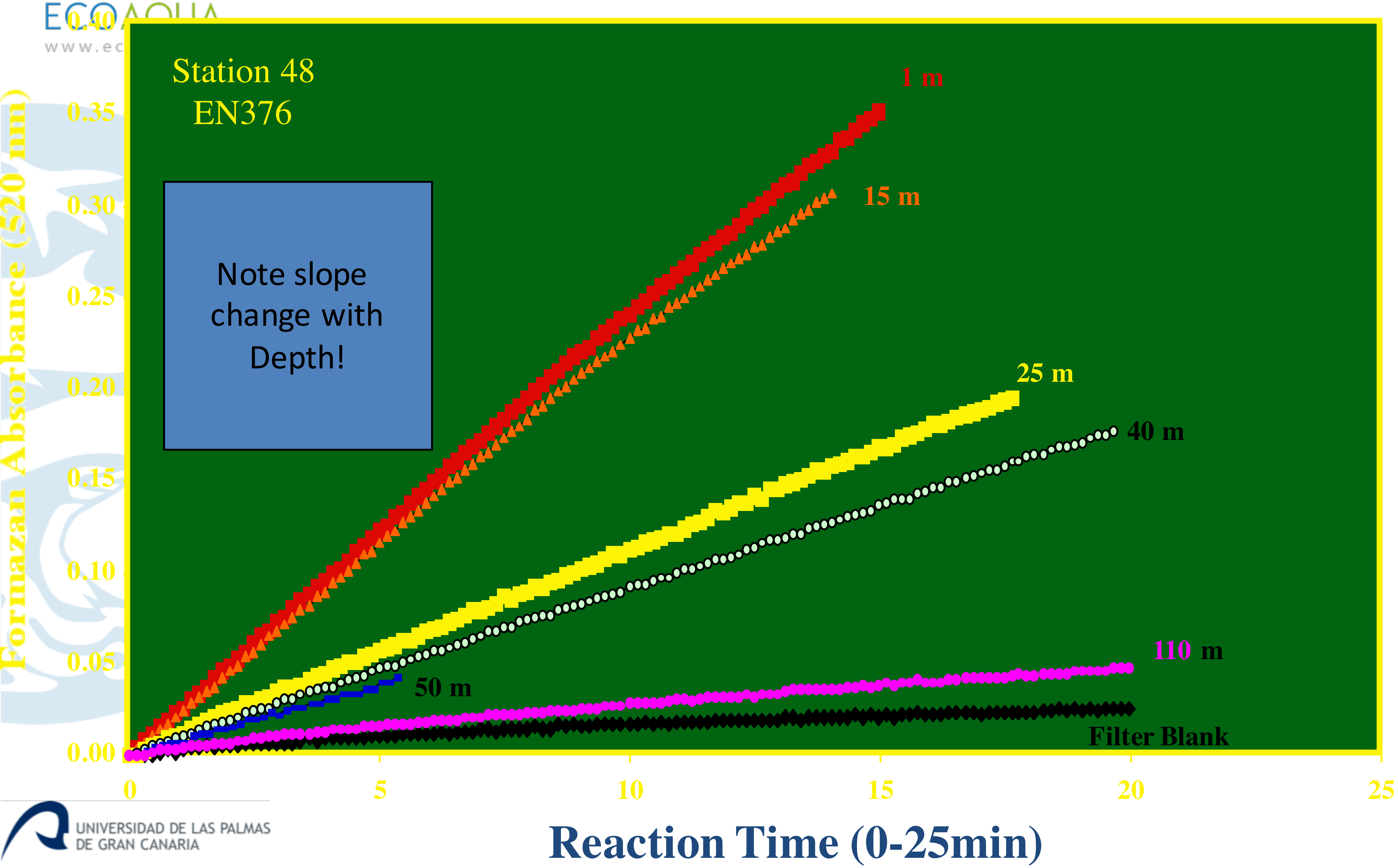
MEASUREMENT of ETS ACTIVITY
(Absorbance (0-0.400 in 1cm cuvettes)



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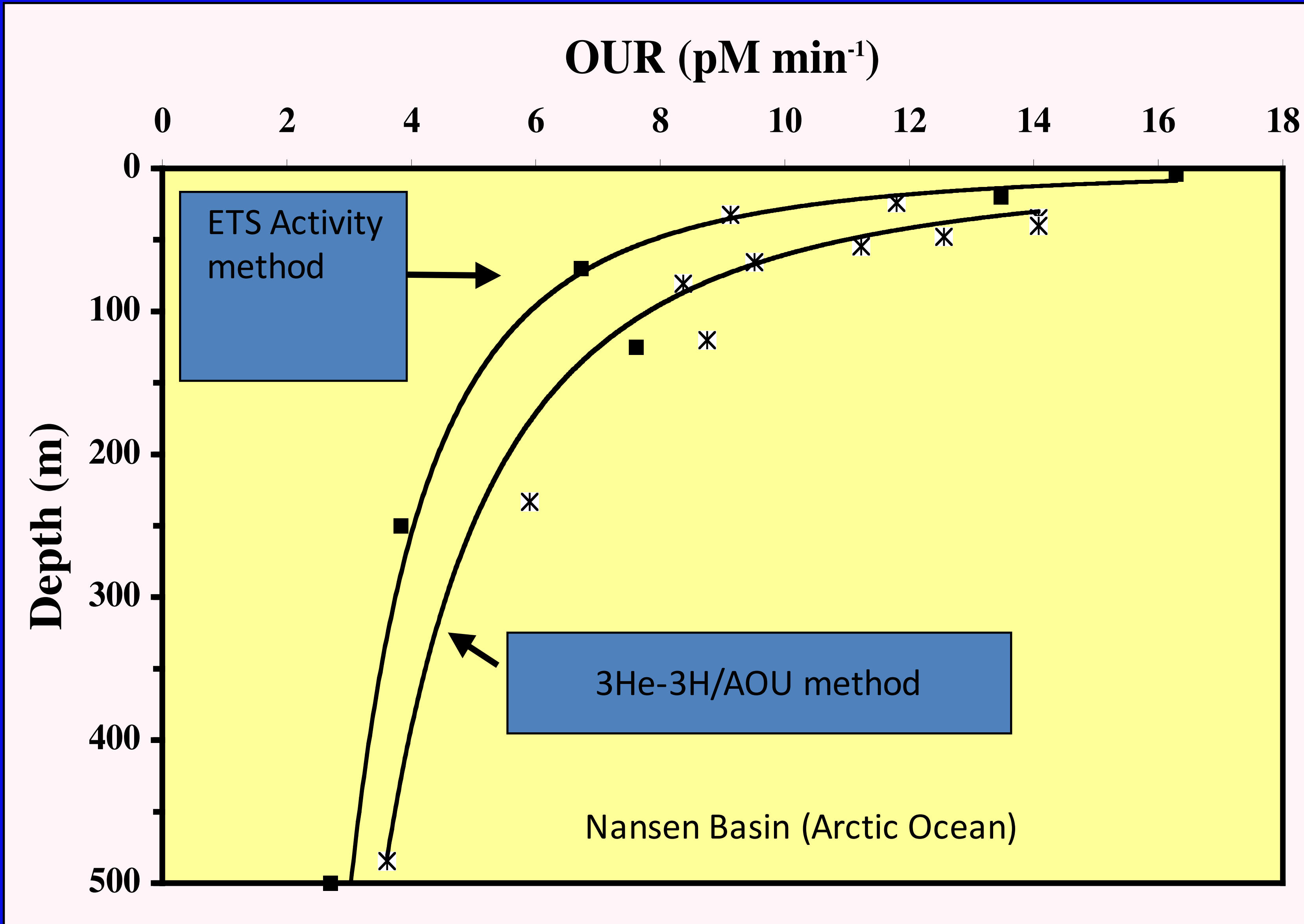
OUR (pM min-1)
0
2
4
6
8
10
12
14
16
18
Depth (m)
0
100
200
300
400
500
ETS Activity method
3He-3H/AOU method
Nansen Basin (Arctic Ocean)

Conclusions

HEP = Respiration x O/P

C Flux ocean sections → Respiration

NRE → R/C-Flux

Exponent (b), the curvature of R=f(z), controls NRE, C-FLUX & T_{eff}

Benthic respiration & C-burial → differences in C-flux integrations

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Modeling vertical carbon flux from zooplankton respiration

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ABSTRACT

The transport of carbon from ocean surface waters to the deep sea is a critical factor in calculations of planetary carbon cycling and climate change. This vertical carbon flux is currently thought to support the respiration of all the organisms in the water column below the surface, the respiration of the organisms in the benthos, as well as the carbon lost to deep burial. Accordingly, for conditions where the benthic respiration and the carbon burial are small relative to the respiration in the water column, and where horizontal fluxes are known or negligible, the carbon flux can be calculated by integrating the vertical profile of the water-column plankton respiration rate. Here, this has been done for the zooplankton component of the vertical carbon flux from measurements of zooplankton ETS activity south of the Canary Island Archipelago. From zooplankton ETS activity depth profiles, zooplankton respiration depth profiles were calculated and using the equations for the profiles as models, the epipelagic (3.05 μmol CO_2 m^{-3} h^{-1}),

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Peruvian upwelling plankton respiration: calculations of carbon flux, nutrient retention efficiency, and heterotrophic energy production

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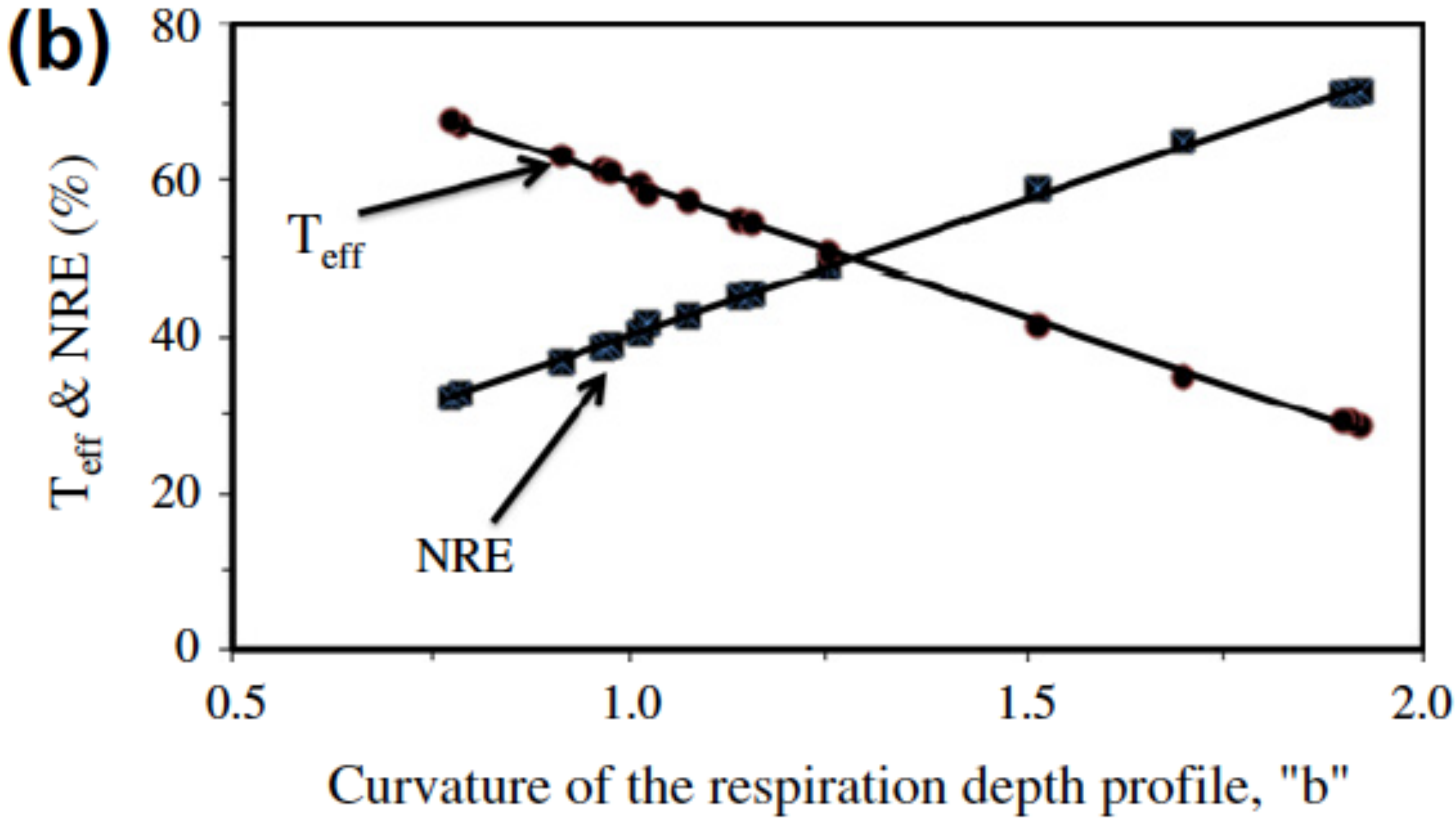
Zooplankton $R_z = R_t(z/z_t)^{-b}$



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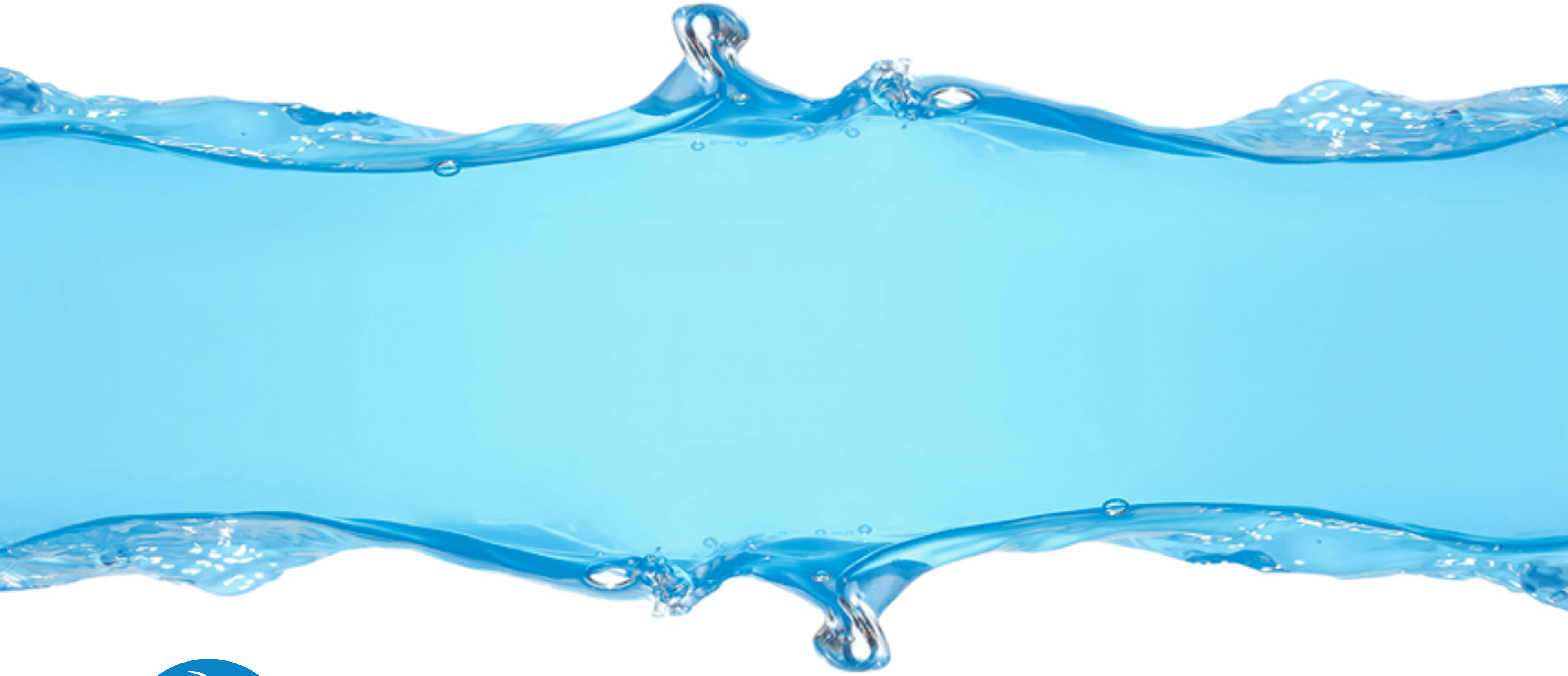

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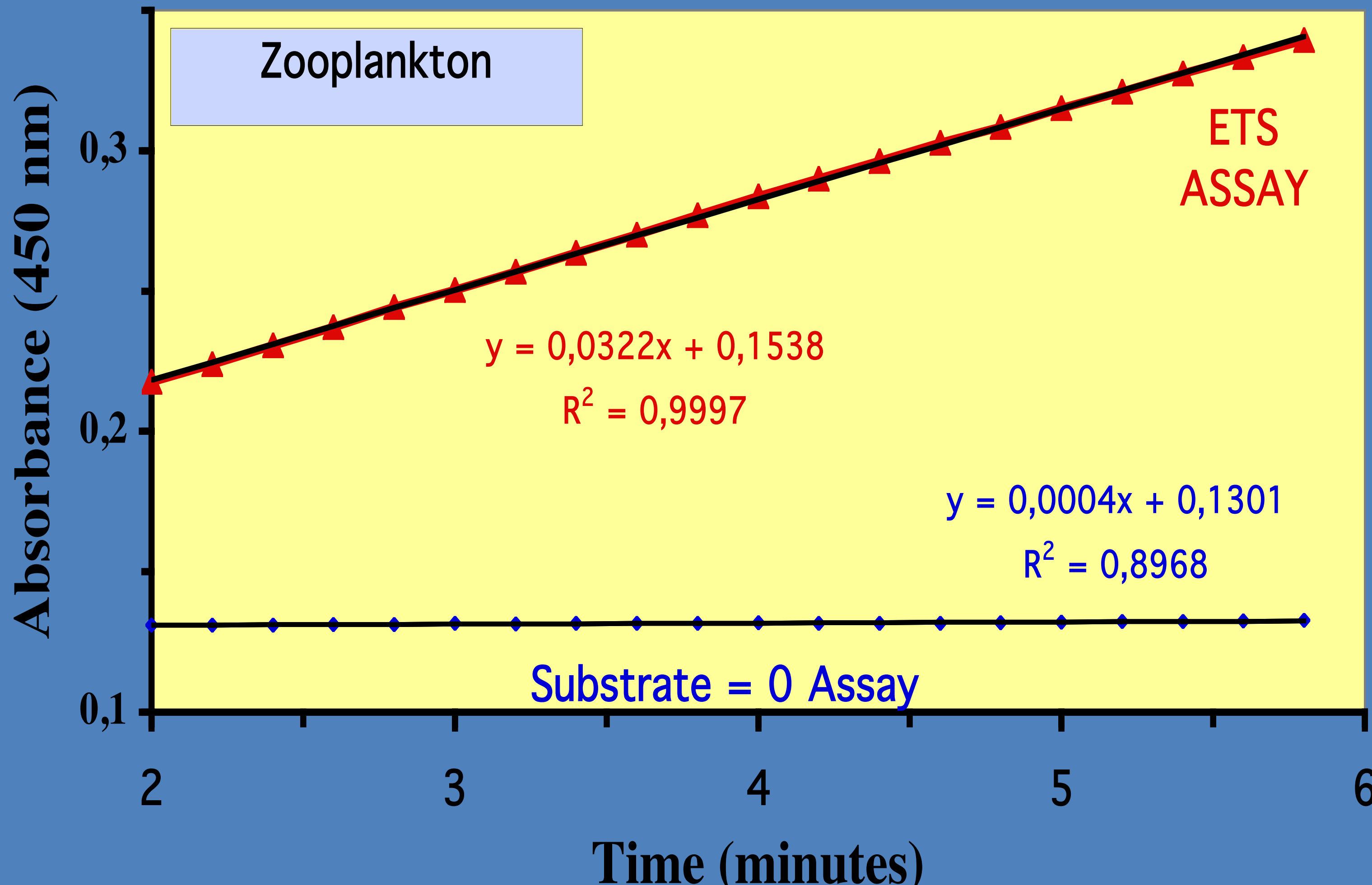
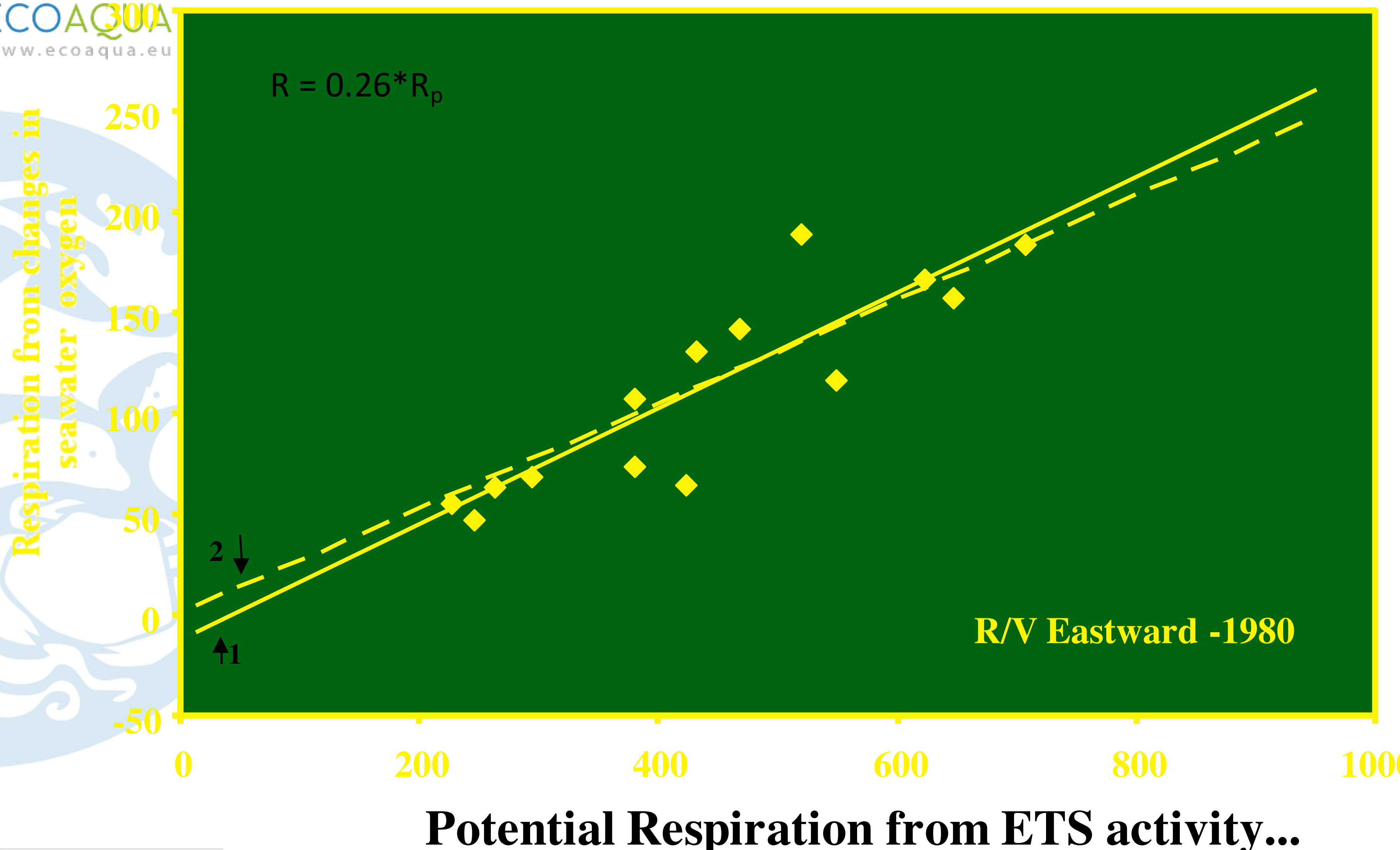
Sample 14E INT-ETS Activity





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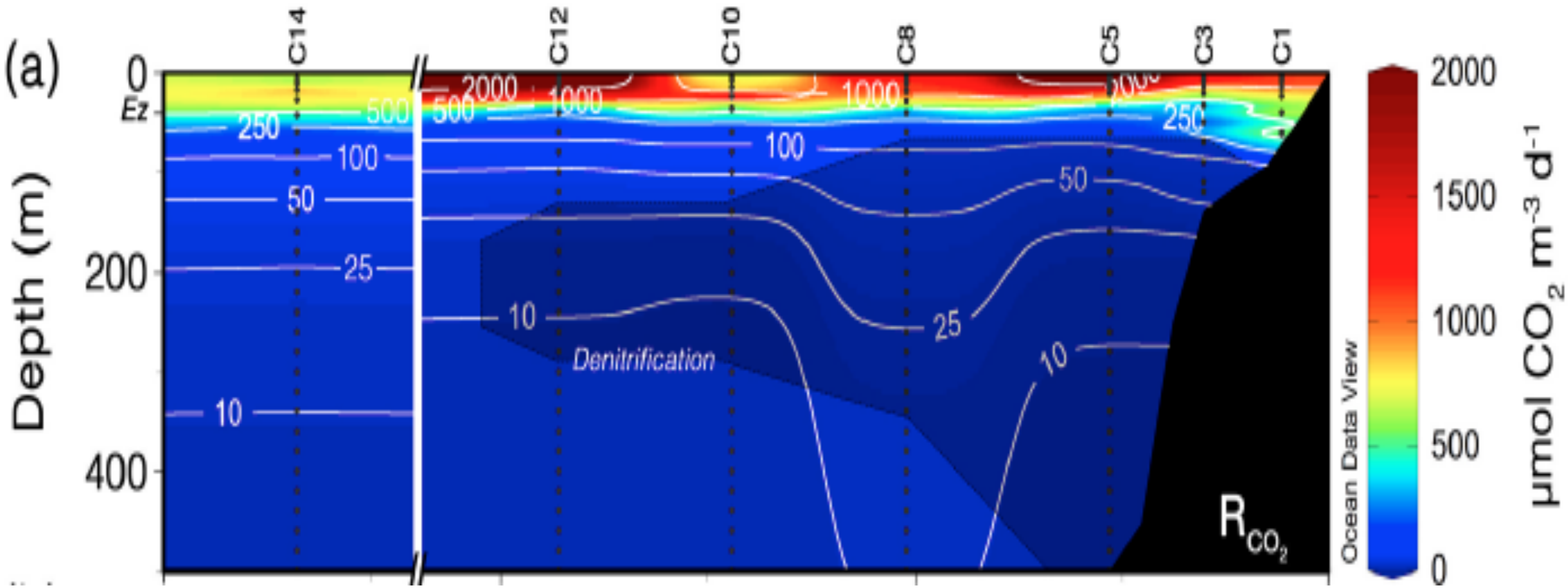
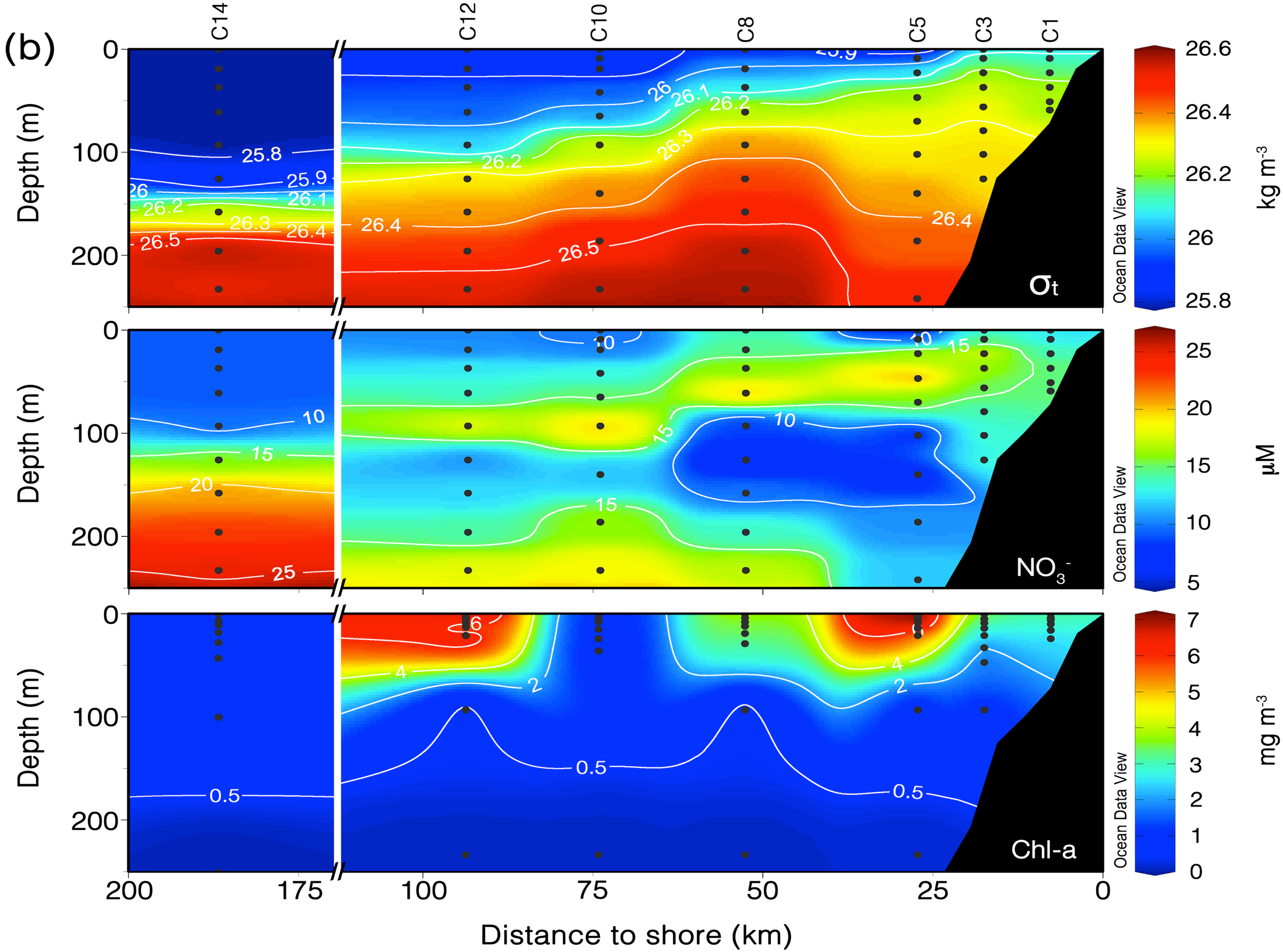
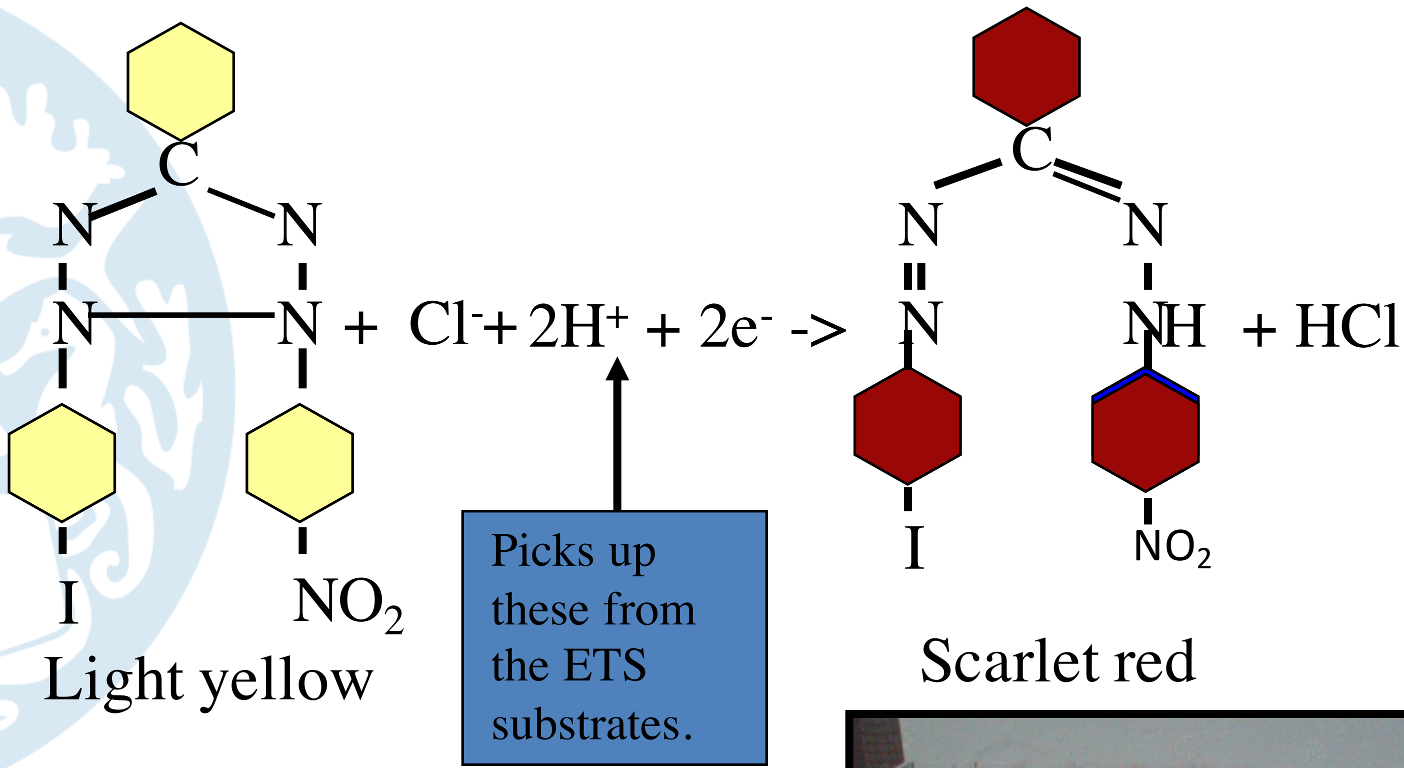
RESPIRATION TRANSECT
15°S PERU UPWELLING

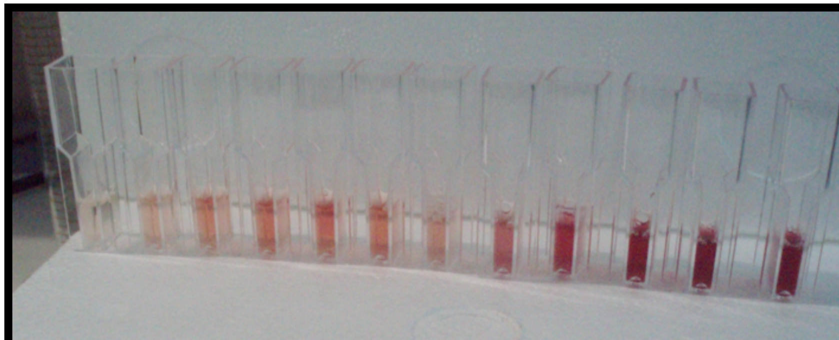




(b)
C14
C12
C10
C8
C5
C3
C1
Depth (m)
σt
NO3-
Chl-a
kg m-3
µM
mg m-3
Ocean Data View
Distance to shore (km)

INT (Tetrazolium Violet)
2-(4-iodophenyl)-3-(4-nitrophenyl)-5-phenyltetrazolium chloride





Basic Reaction of the ETS Assay

BENTHIC RESPIRATION & C-BURIAL

The indefinite integral of $R_z = R_t(z/z_t)^b$ with respect to depth (z) is:

$$F_c = \int R_t(z/z_t)^b \, dz = [R_t /((b+1)(z_t)^b)] \, z^{b+1} + C$$

C = benthic respiration & C burial!

BENTHIC R & C-Burial Model

To calculate benthic respiration & C-burial we substract the flux to the water column (F_{t-s}) from the flux to infinity (F_∞).

$$F_{t-s} = \int_{Z_t}^{Z_s} R_t(z/z_t)^b \, dz = [R_t /((b+1)(z_t)^b)] \, [(z_s^{b+1}) - (z_t^{b+1})]$$

$$F_\infty = \int_{Z_t}^{\infty} R_t(z/z_t)^b \, dz = [R_t /((b+1)(z_t)^b)] \, [-z_t^{b+1}]$$

BENTHIC RESPIRATION (CO_2 Production Rate)
NW African Upwelling (Christensen & Packard, 1978)