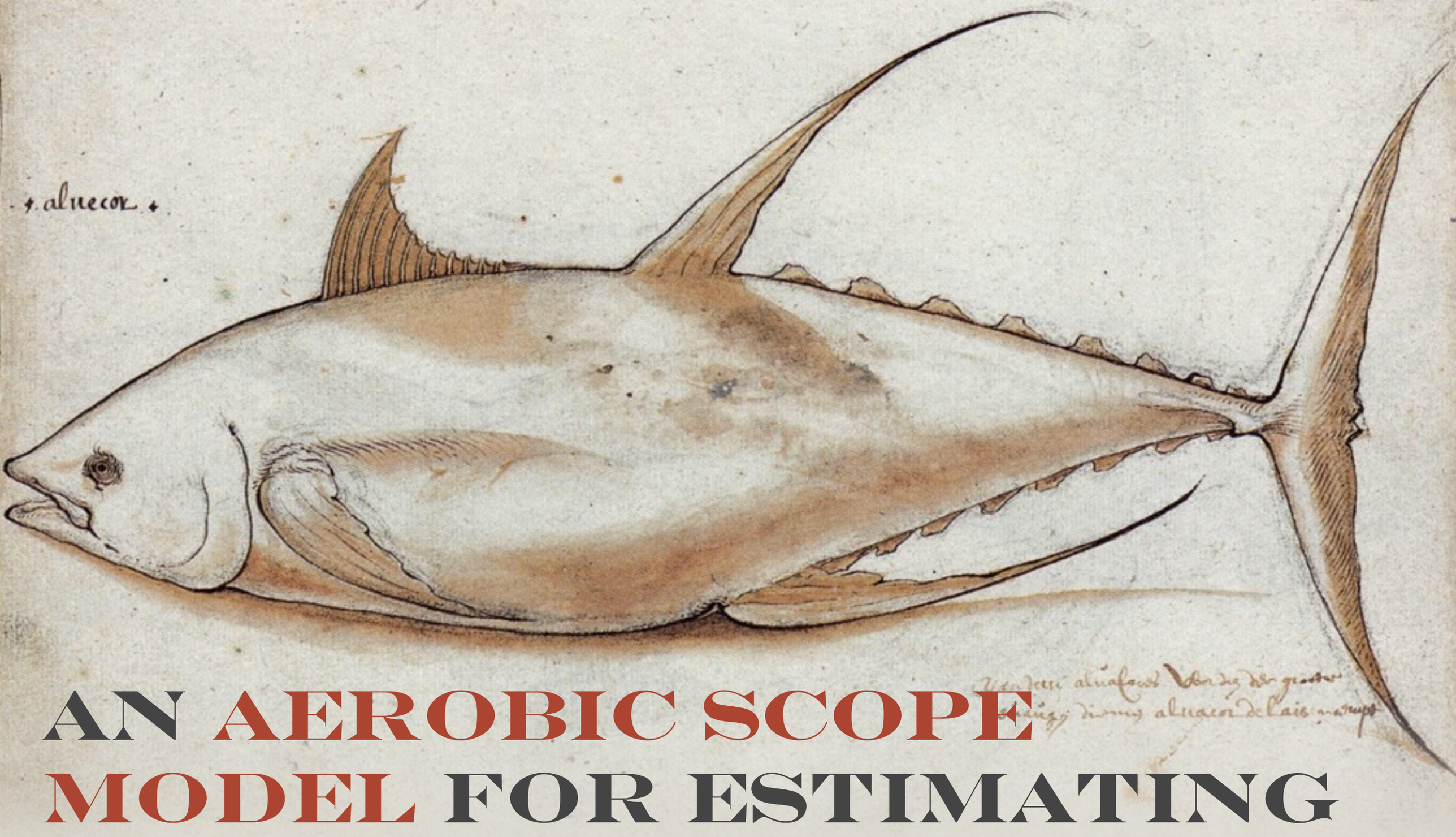


AN AEROBIC SCOPE MODEL FOR ESTIMATING LIMITS OF YELLOWFIN TUNA HABITAT

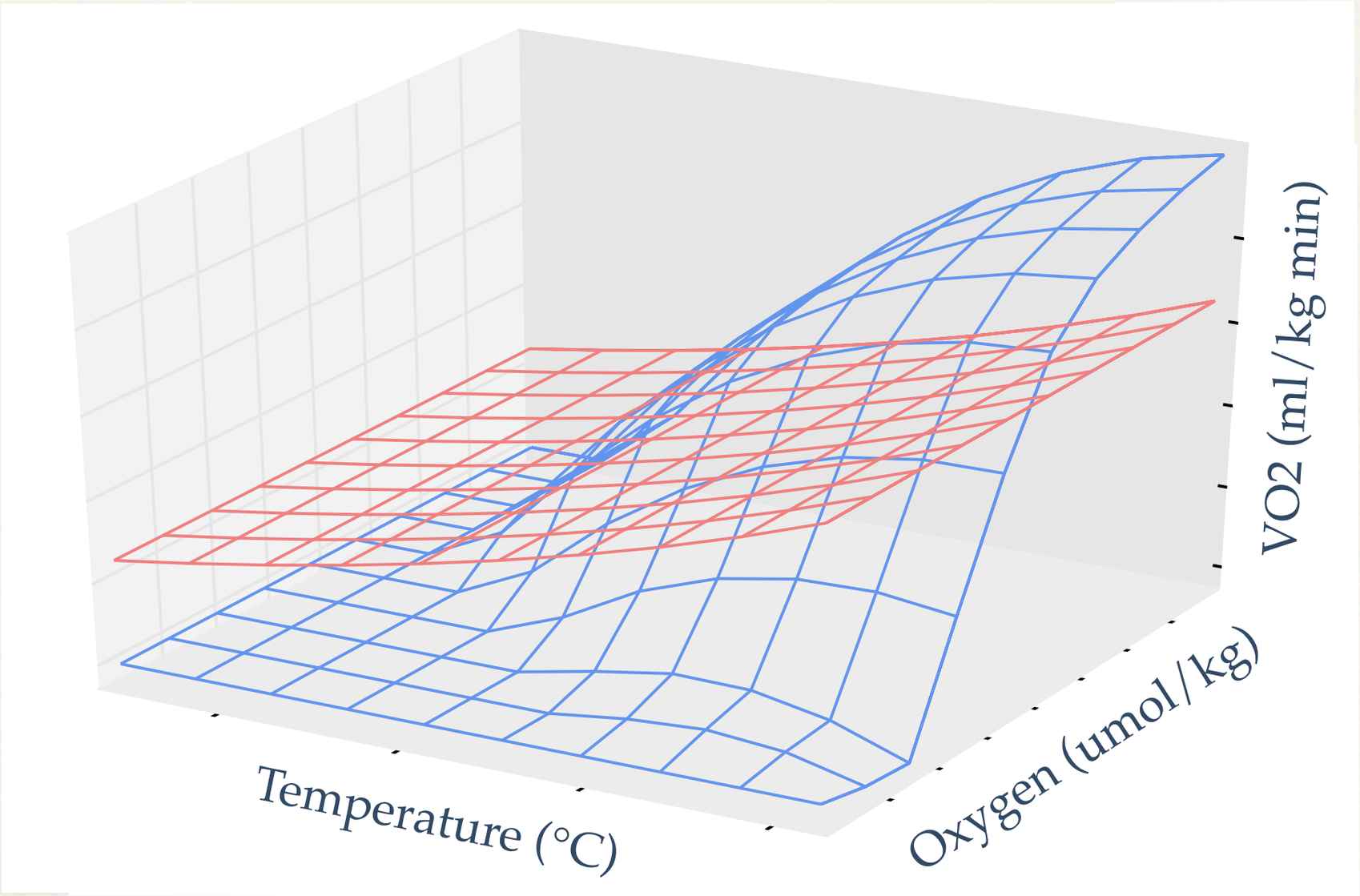
Gen Del Raye, Kevin Weng. University of Hawaii at Manoa

Goals: Semi-Mechanistic Modeling of Habitat Parameters

- Incorporate physiology into habitat models
- Enhance predictive capabilities for novel climate change environments
- Clarify mechanisms of multiple climate change effects on tunas
- Identify key variables for climate adaptation

Model concept

- Semi-empirical model of aerobic scope



Model concept

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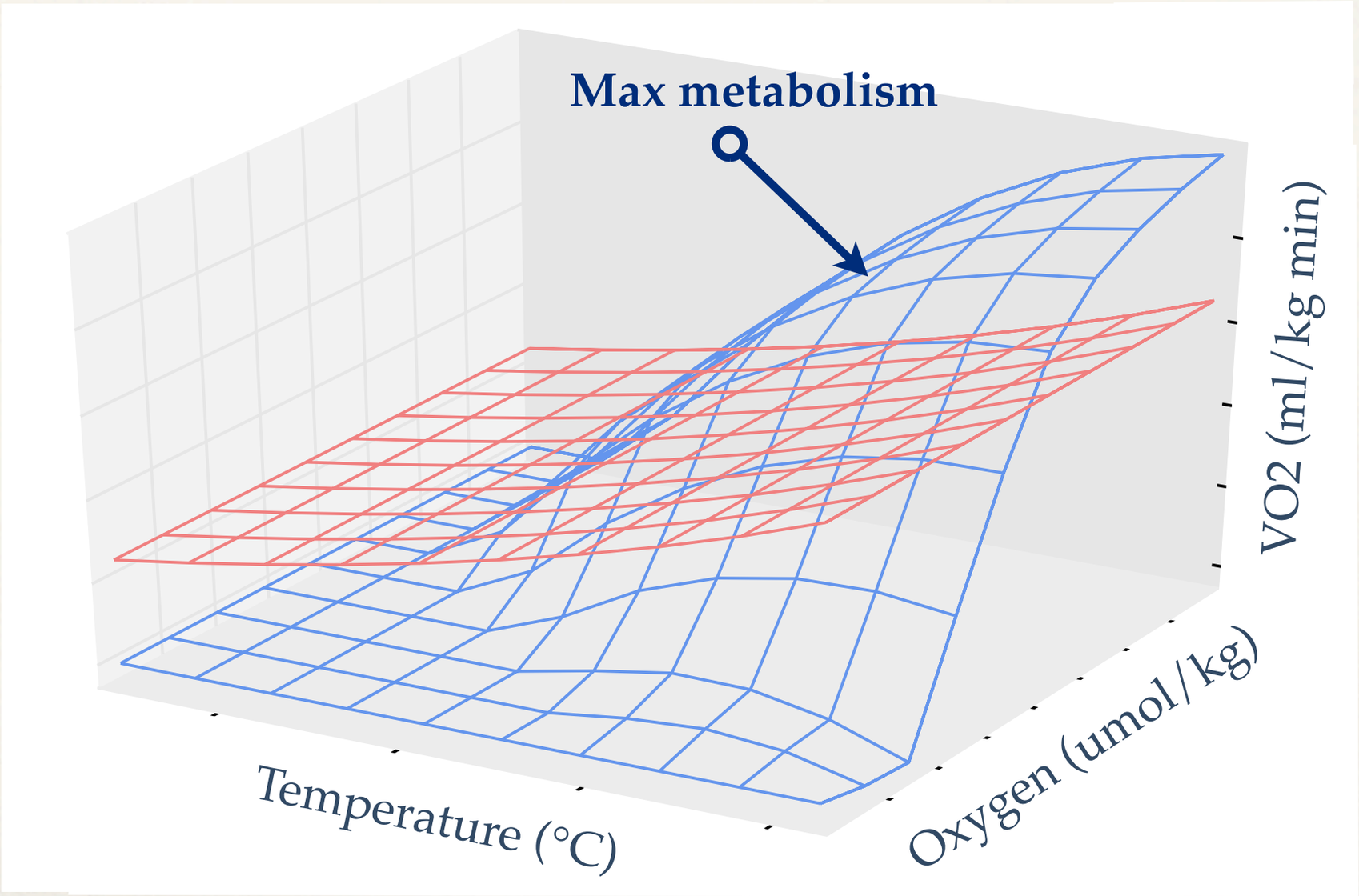

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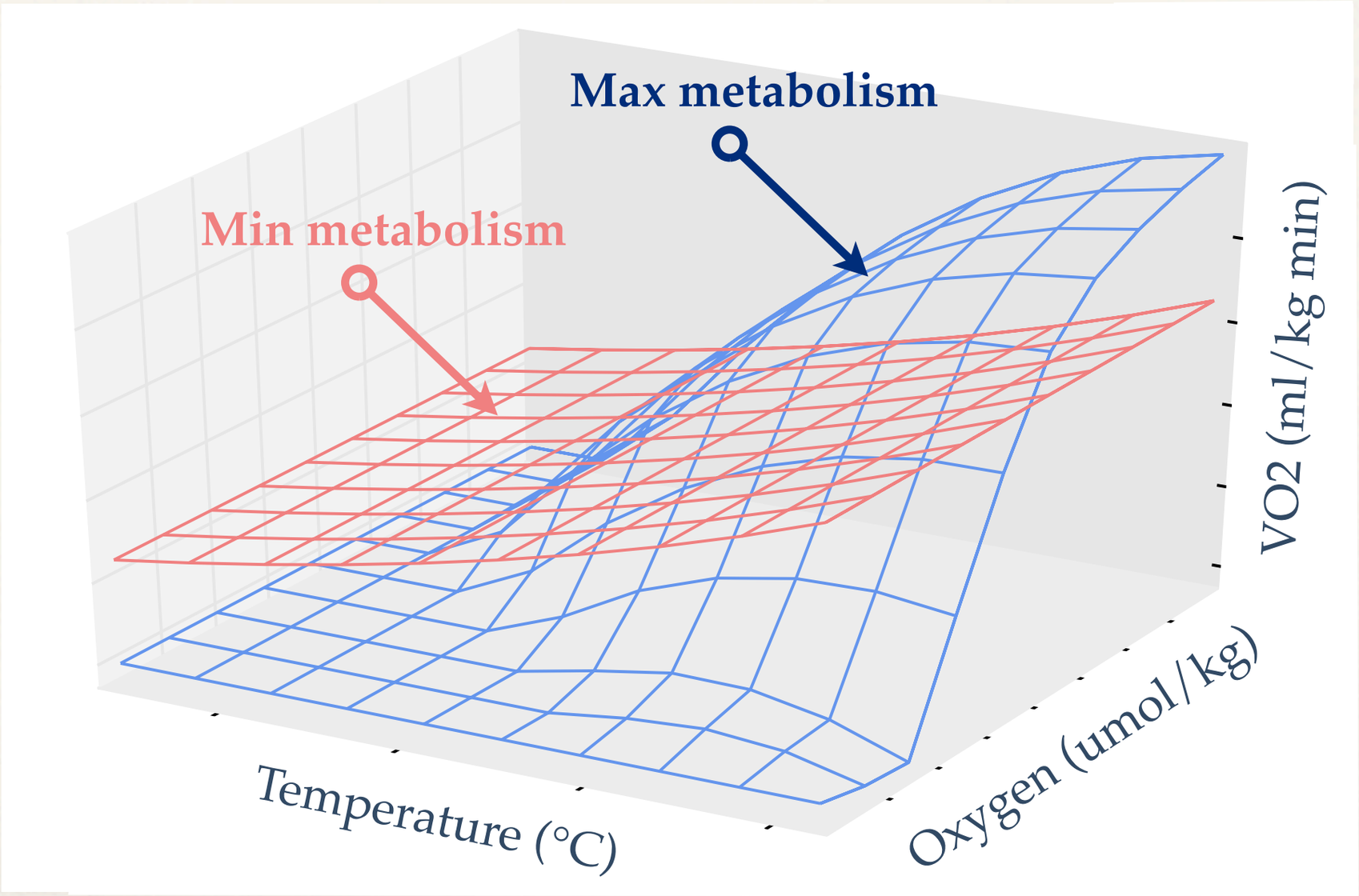

Model concept

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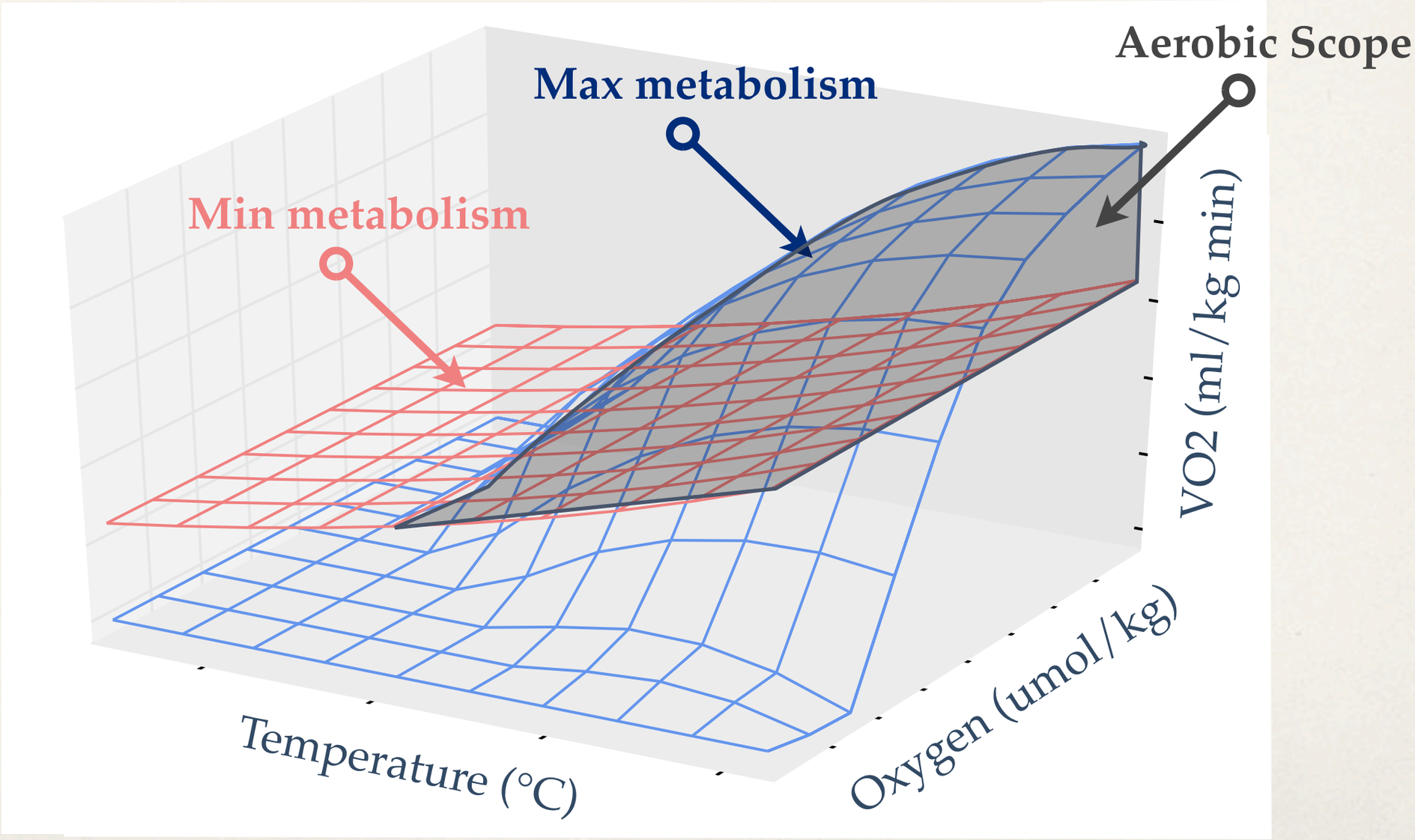
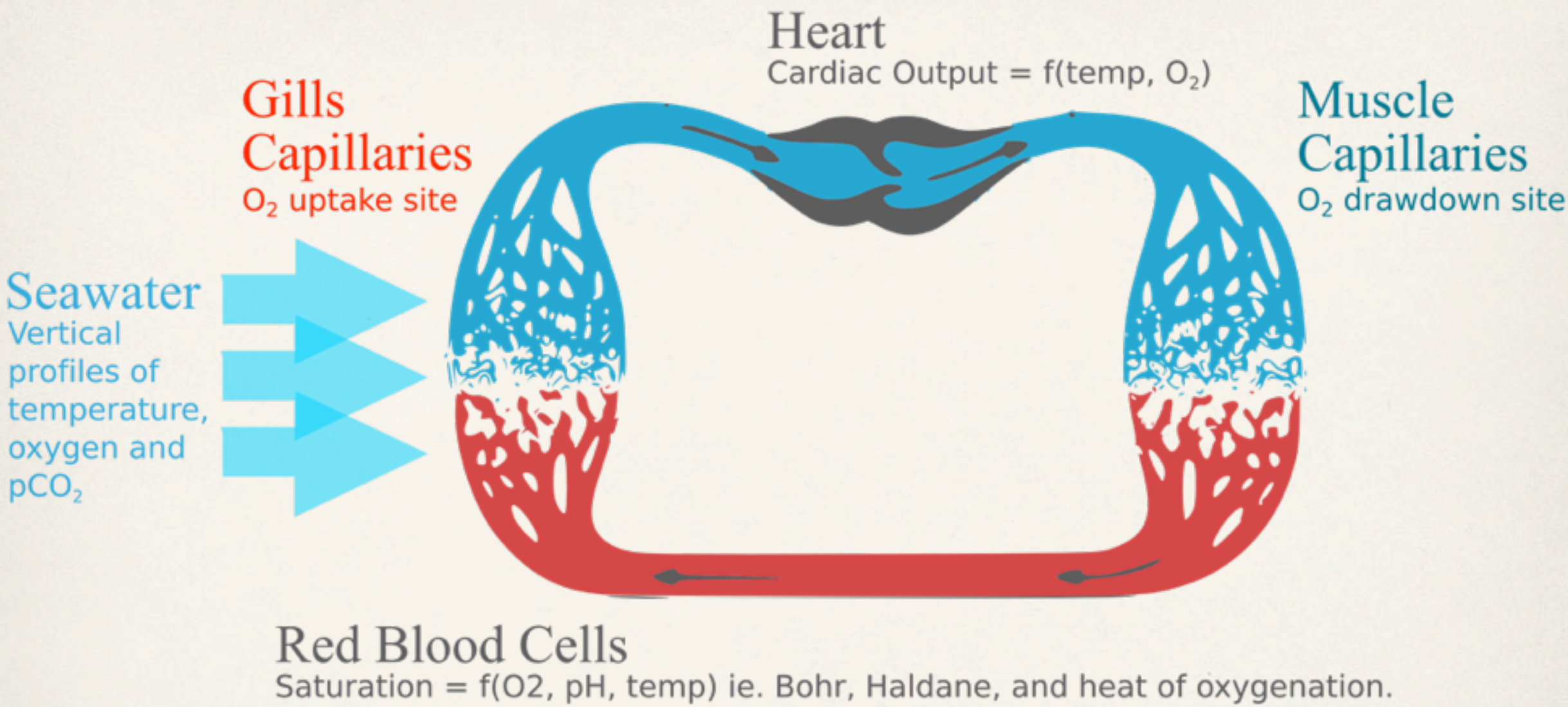


Model concept

- Envelope for all aerobic activities - growth, digestion, migration, reproduction, and acclimation (Claireaux and Lefrançois 2007)
- Decline necessitates reduction of energy budget
- **Permanent habitation is impossible** where aerobic scope is below zero
- Affected by **oxygen, temperature, CO2** (Pörtner 2002, Jensen 2004, Brewer and Peltzer 2009)



Peak Aerobic Metabolic Rate

Calculated according to Fick equation from cardiac and oxygen parameters.

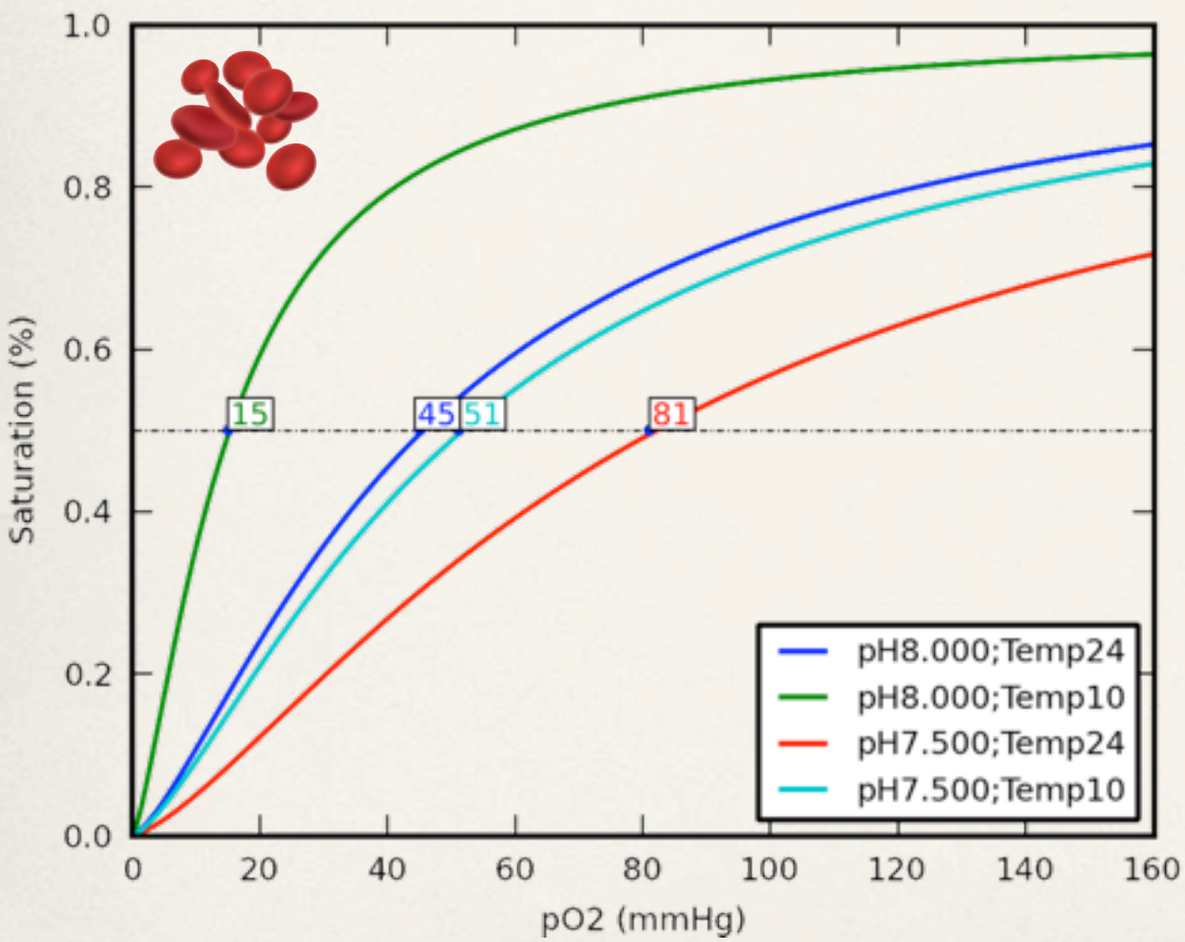
$$VO_{2\ peak} = Q(C_aO_2 - C_vO_2)$$

Key assumptions

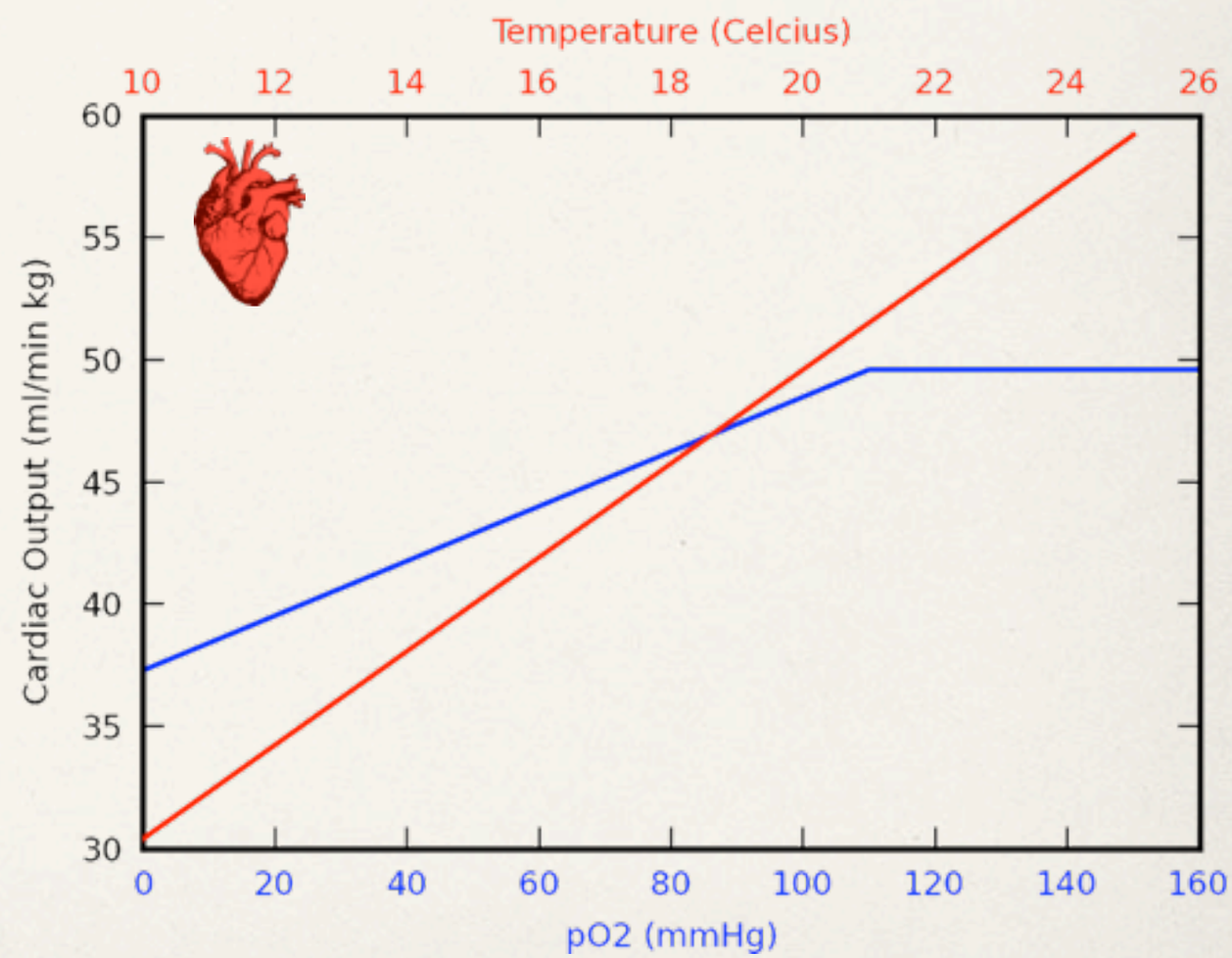
1. **Central limitation** of aerobic capacity (Bassett and Howley 1999)
2. Oxygen consumption primarily by **working muscles**
3. Multiple cardiac stressor have **additive effect**

Model Inputs

RBC oxygen binding



Peak Cardiac Output



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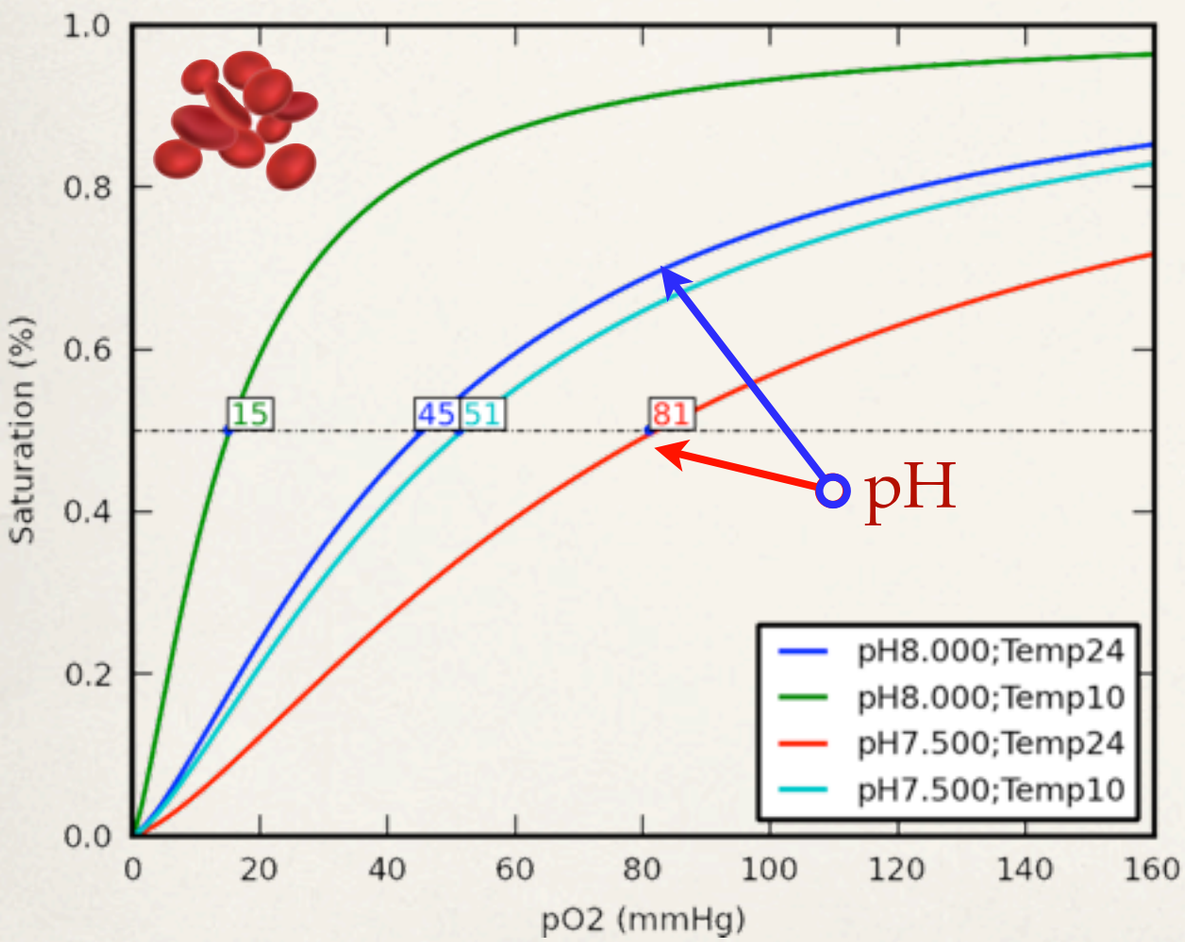

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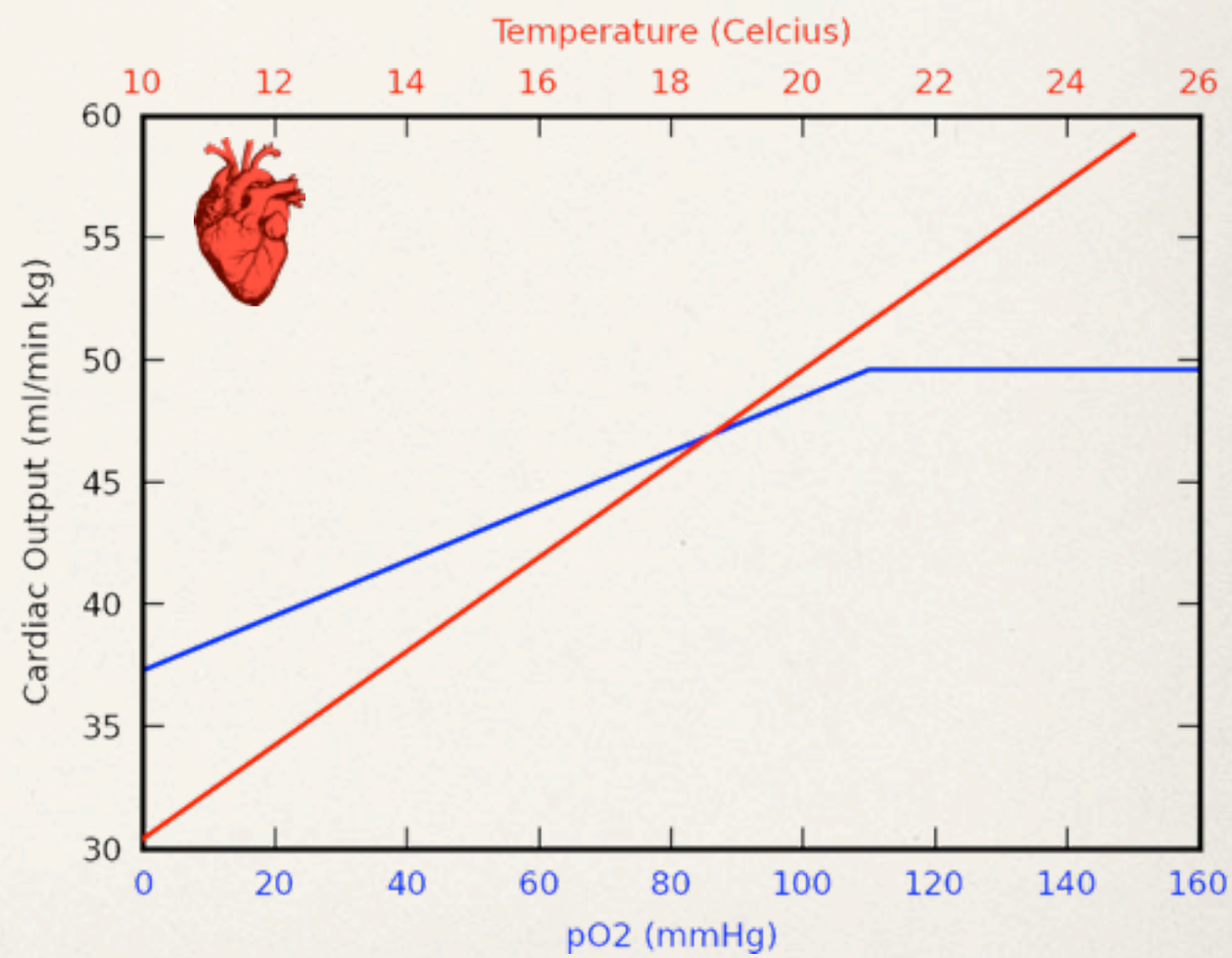

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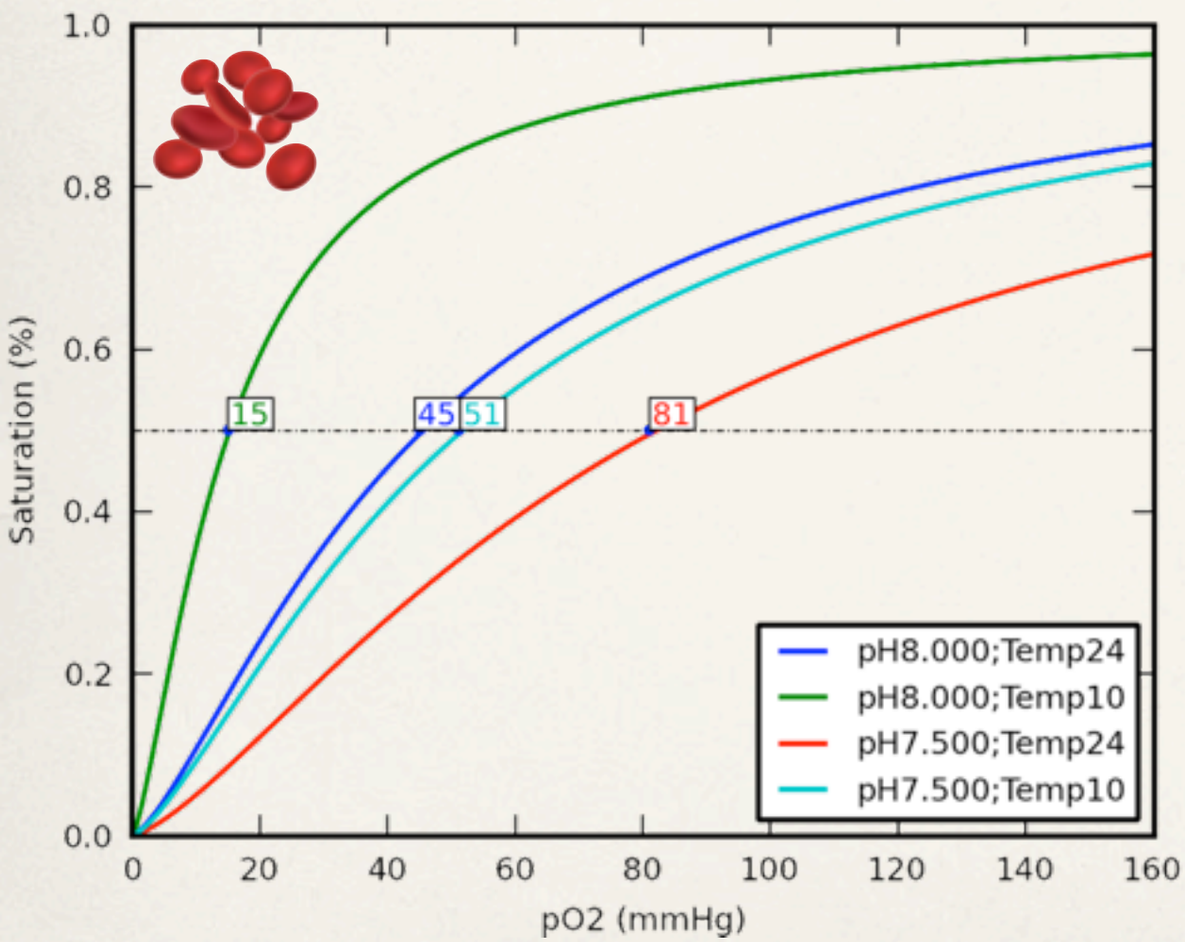

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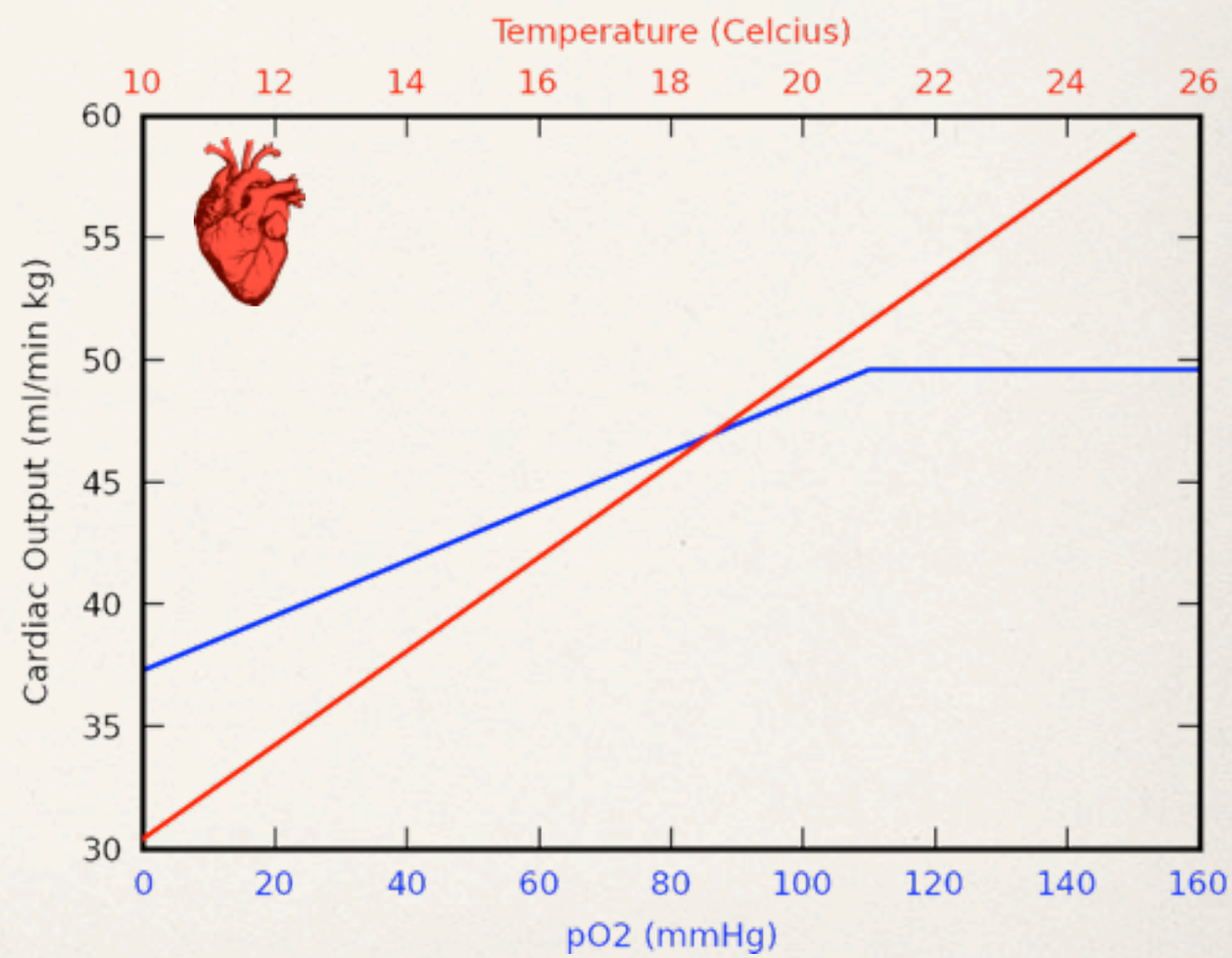

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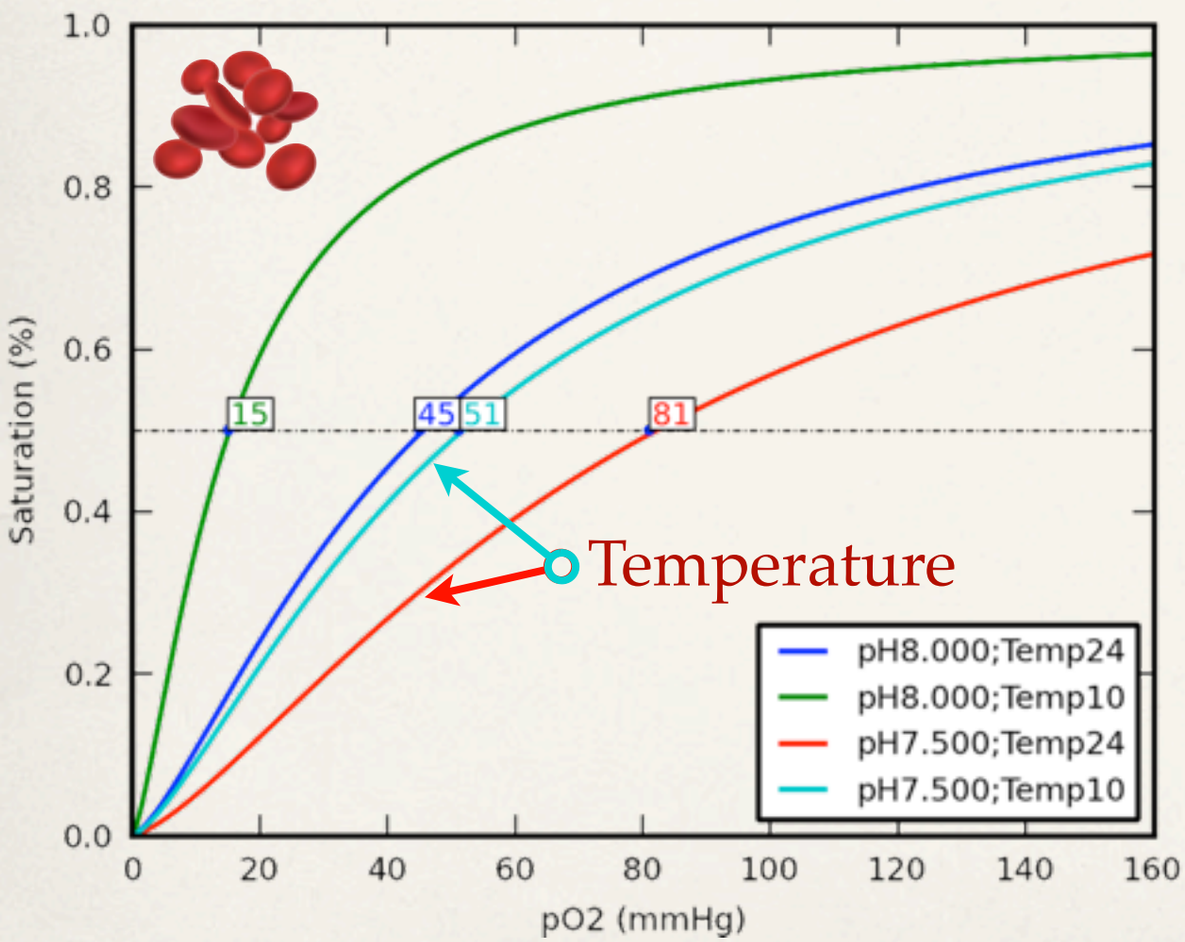

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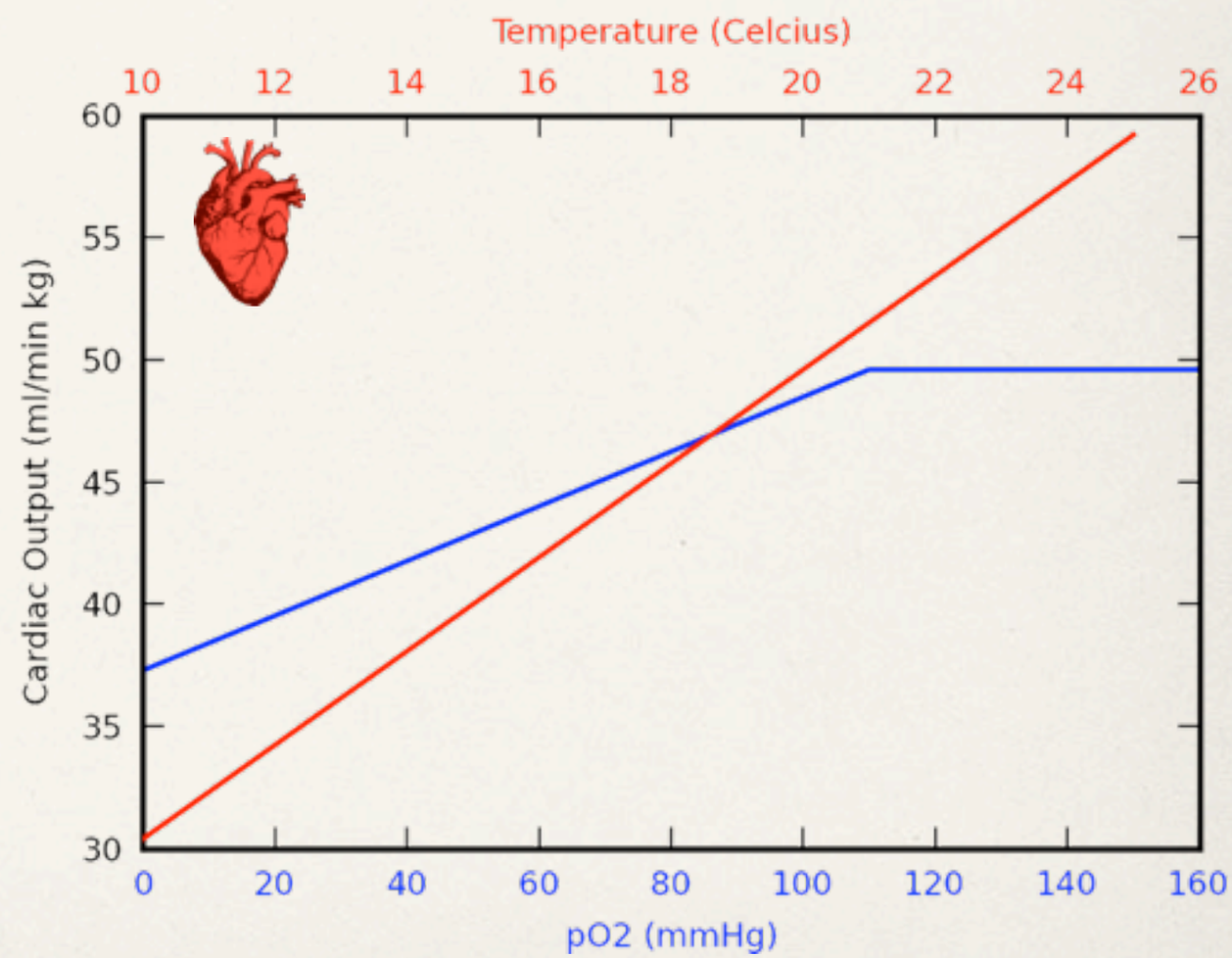

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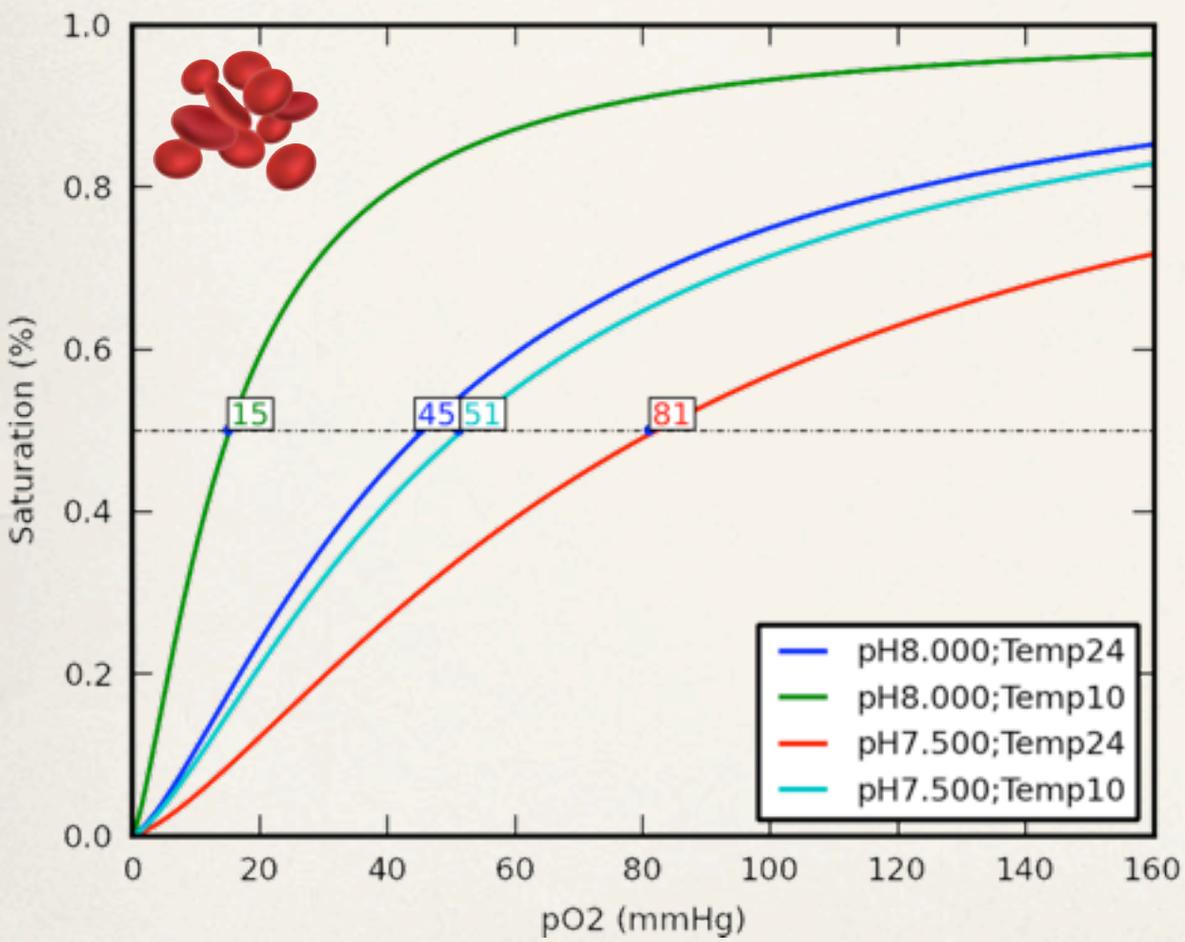

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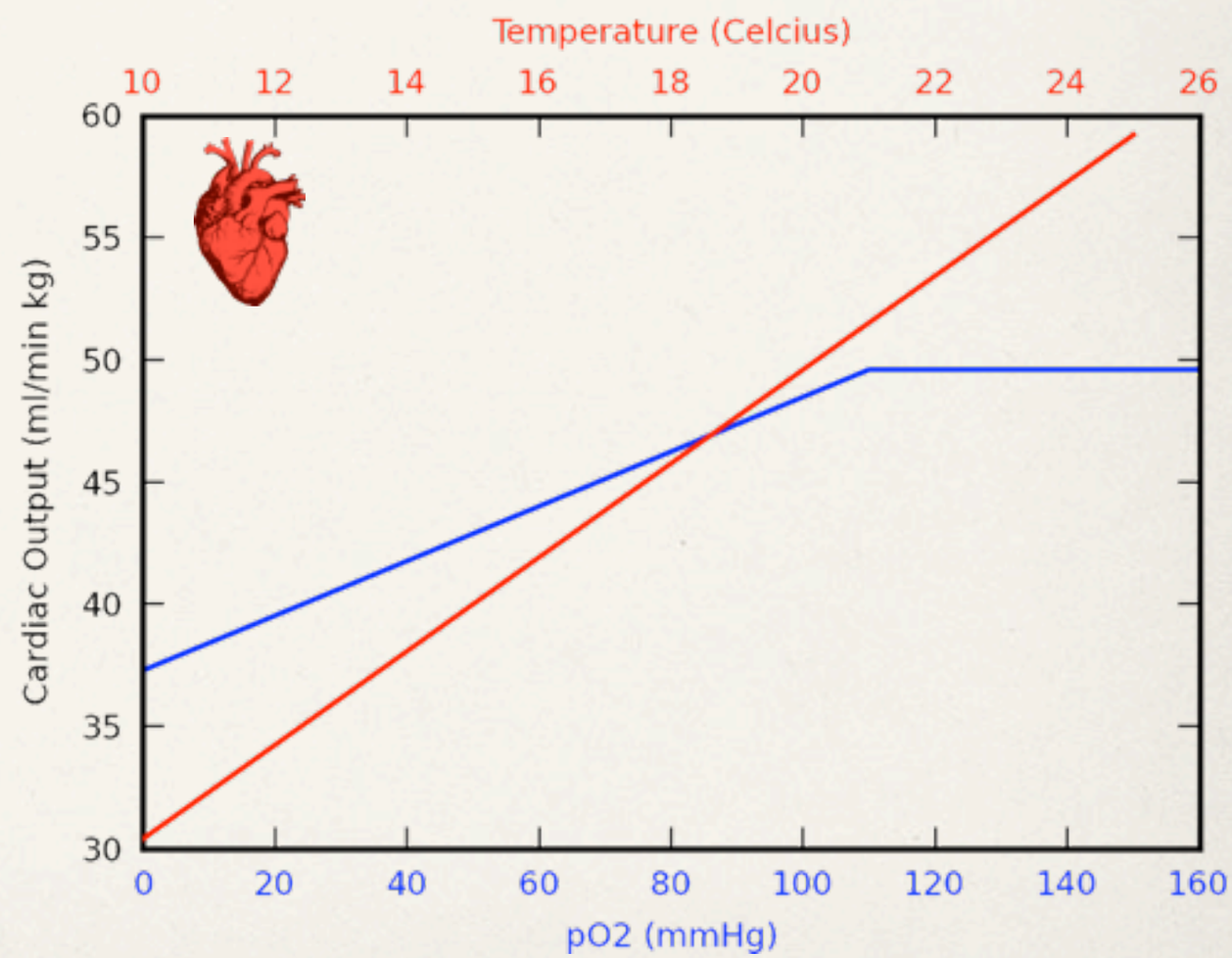

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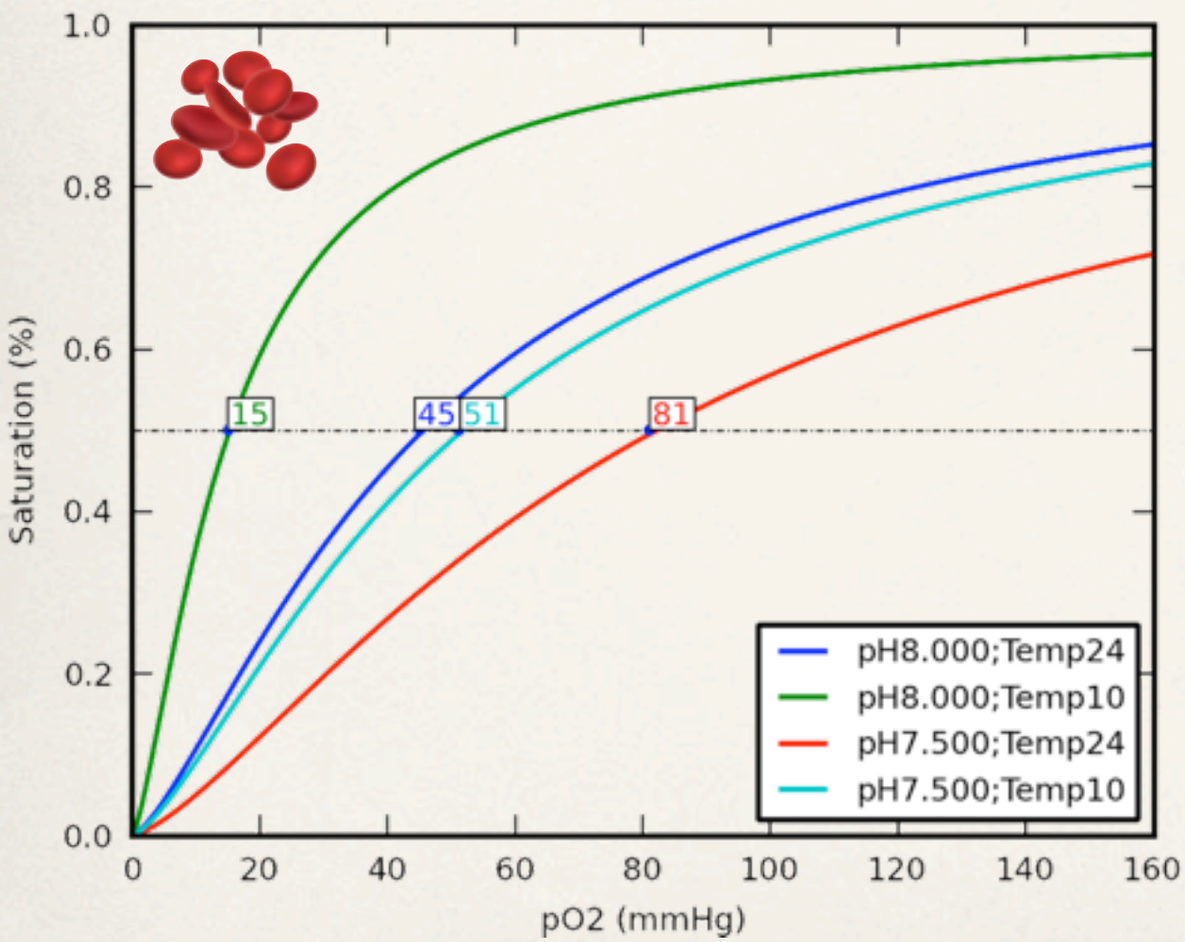

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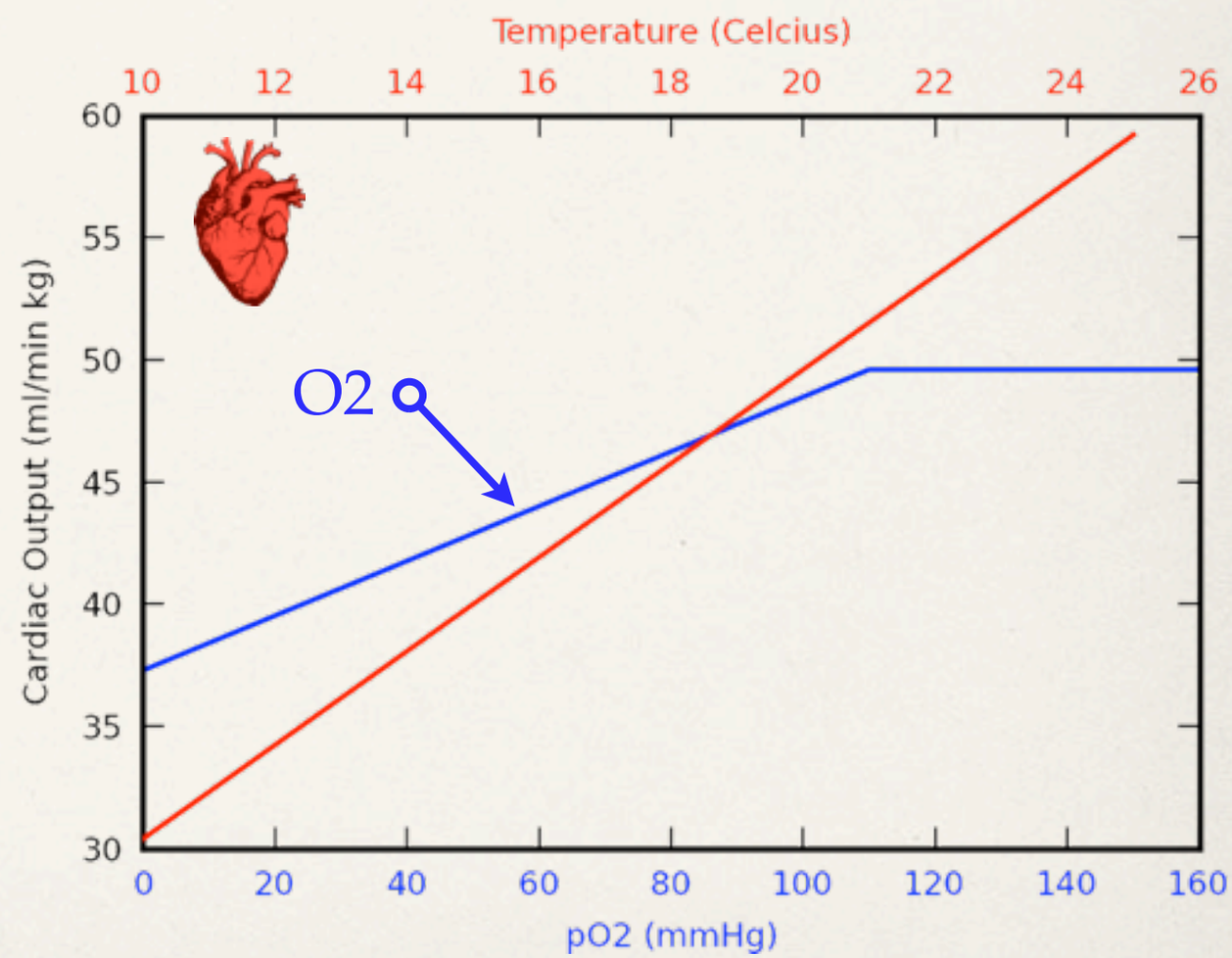

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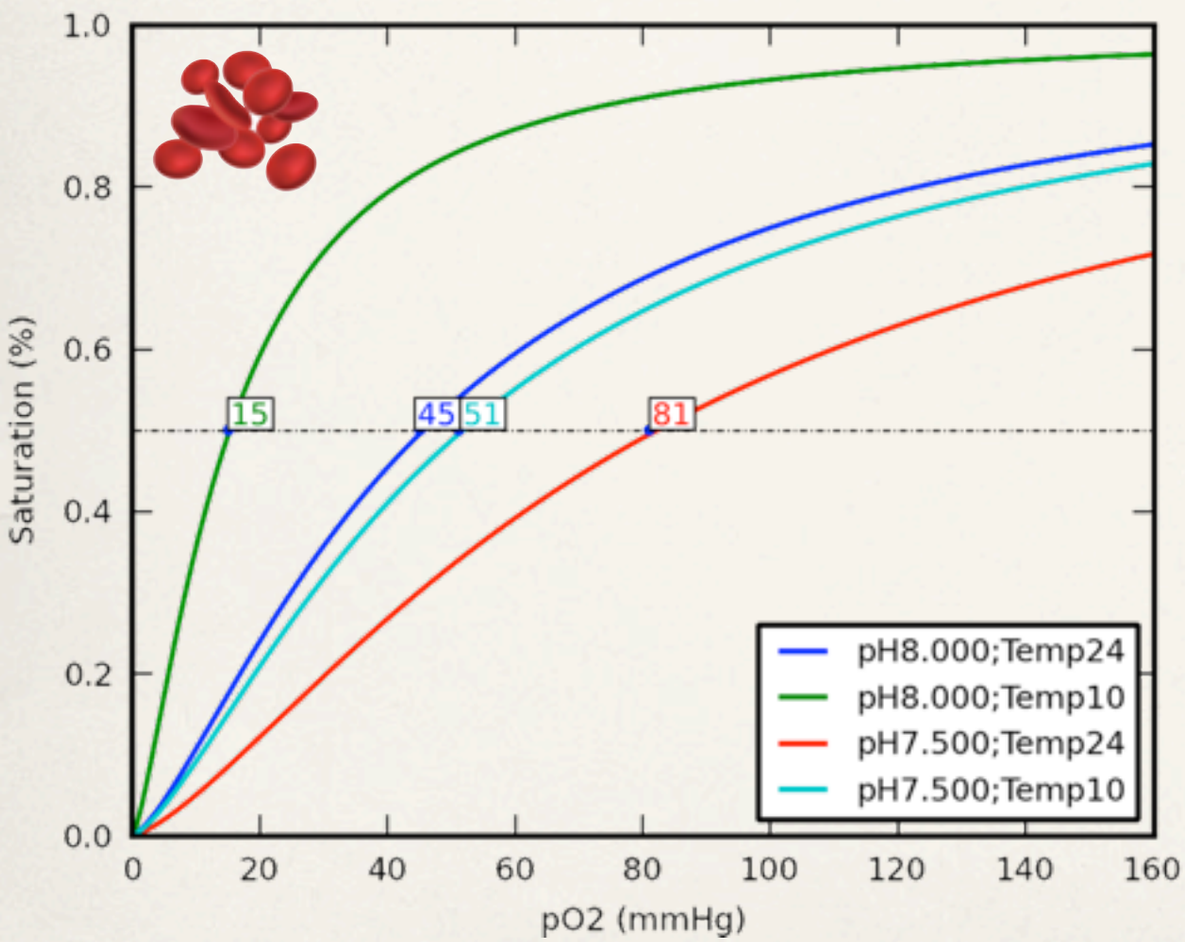

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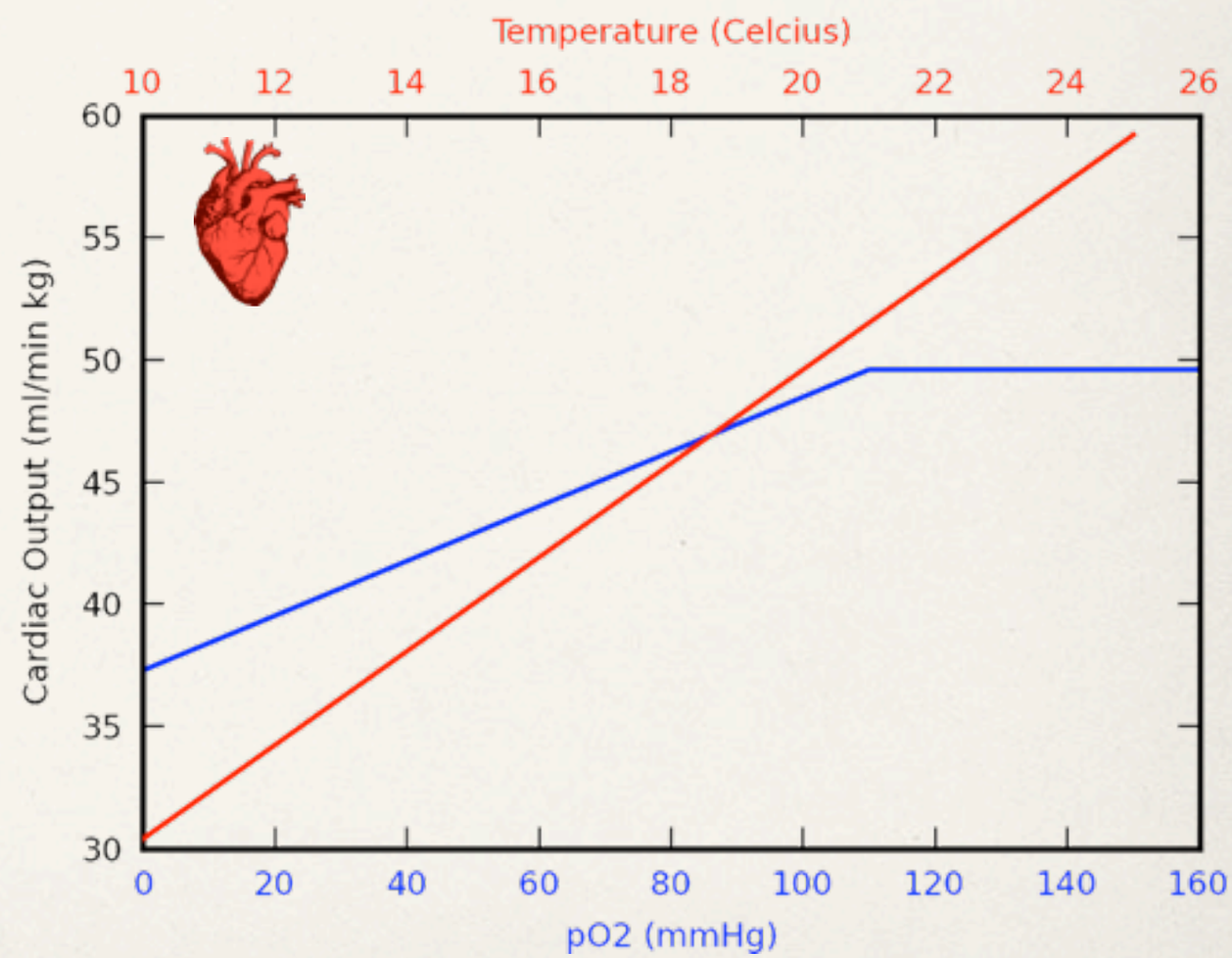

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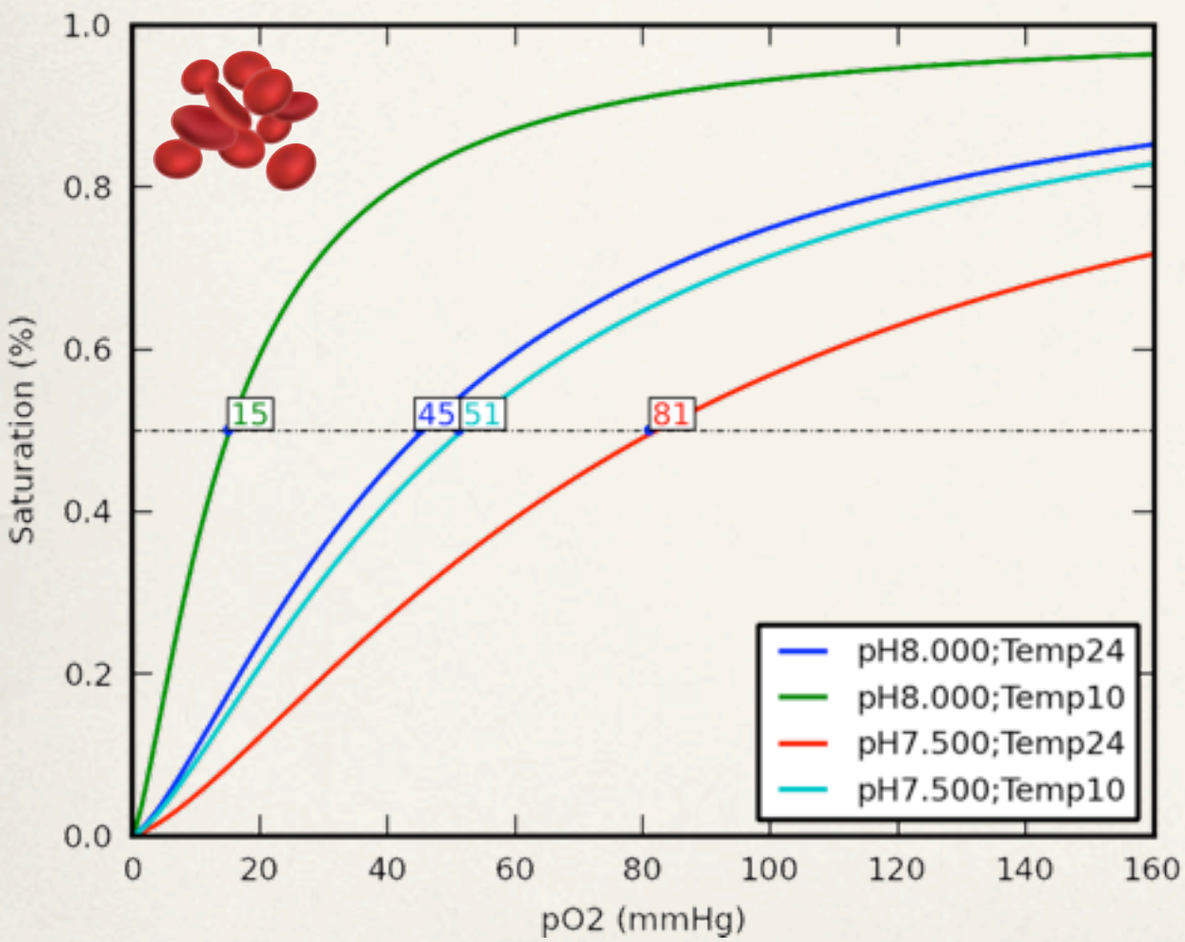

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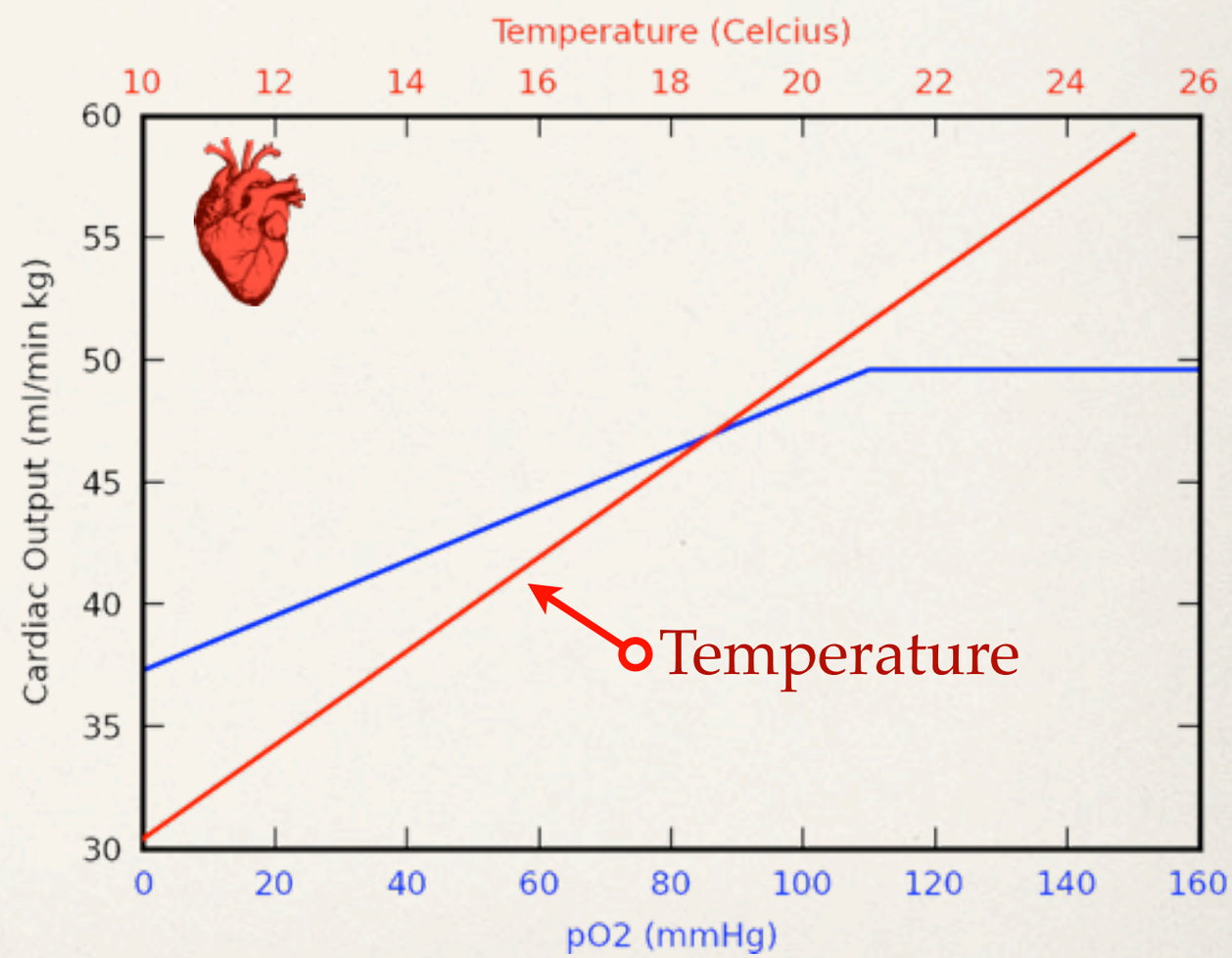

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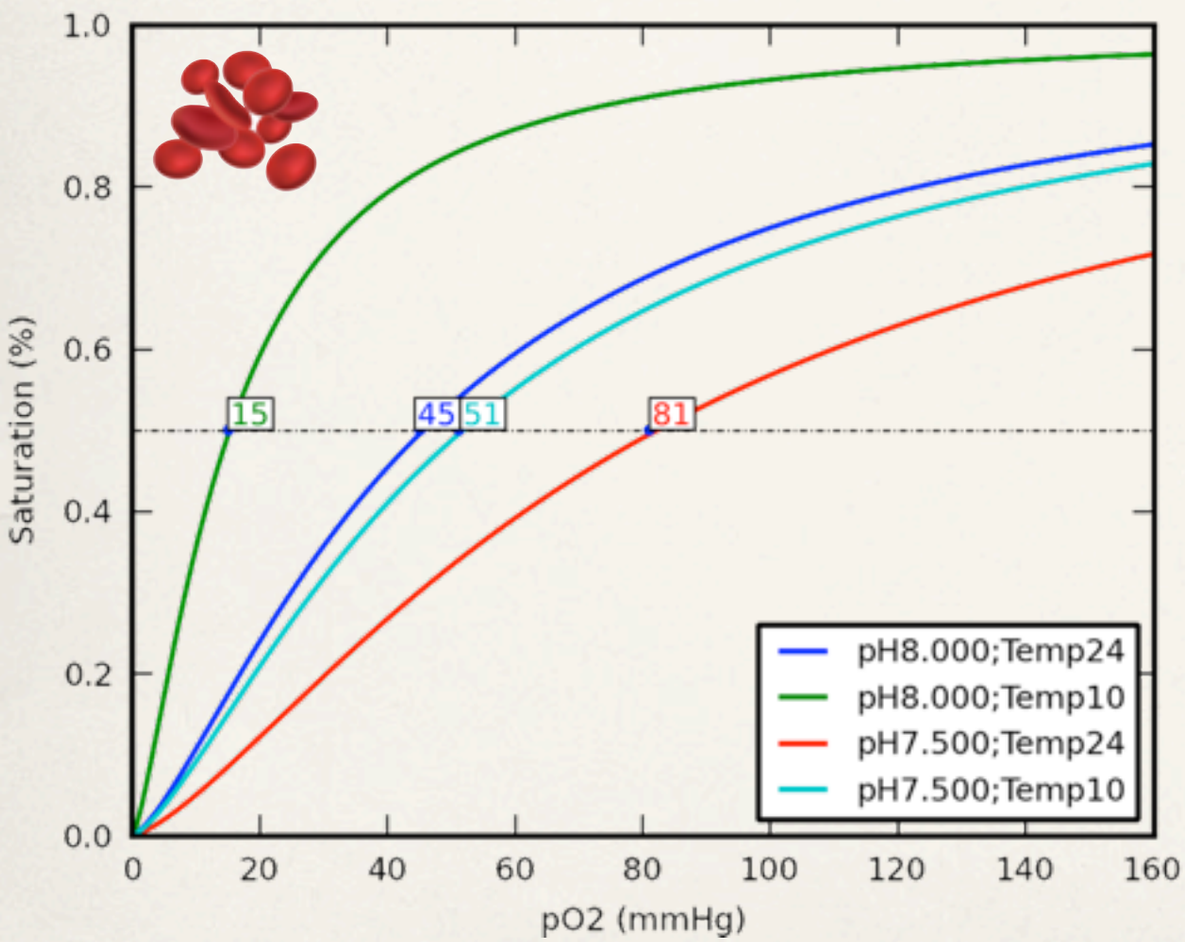

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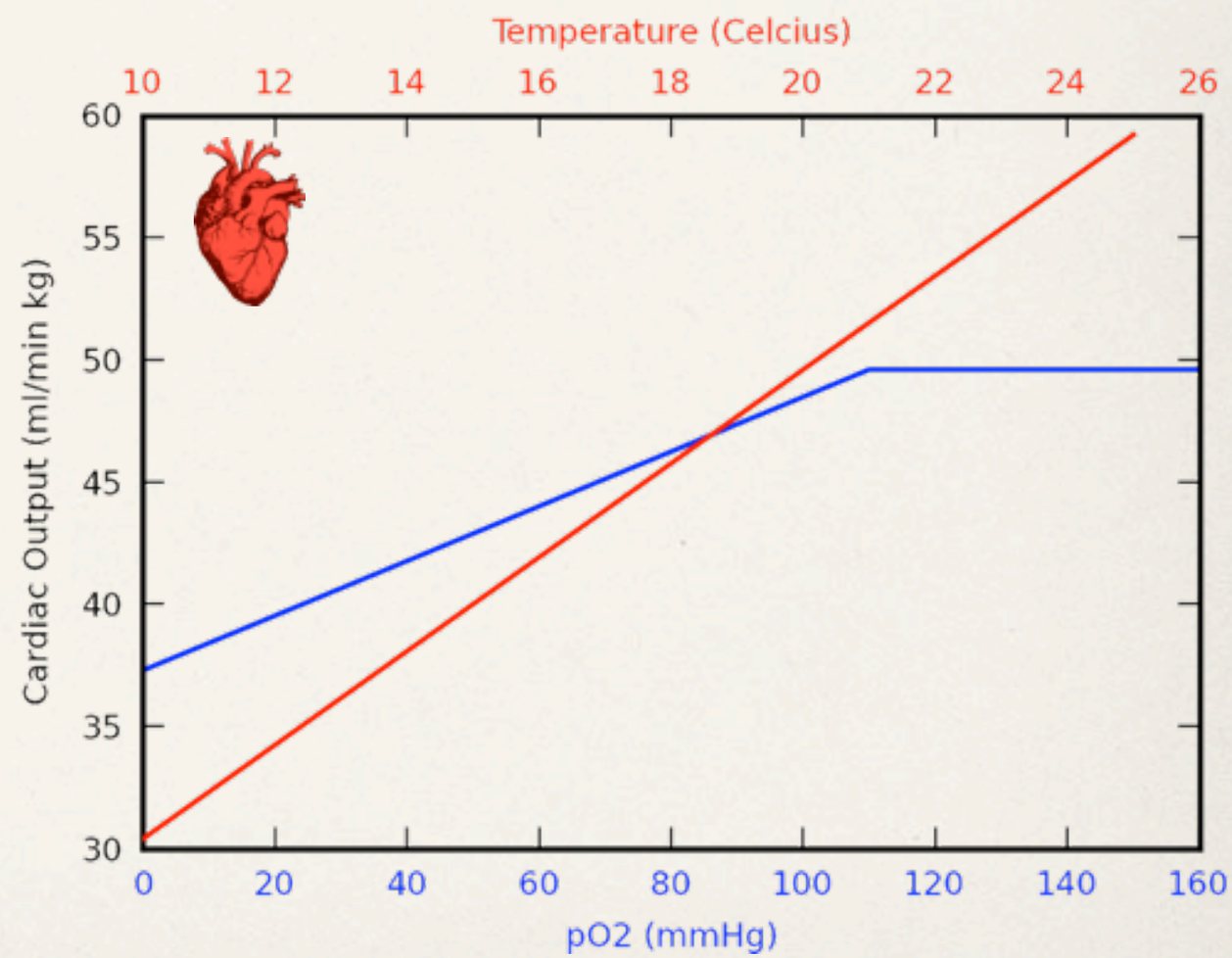
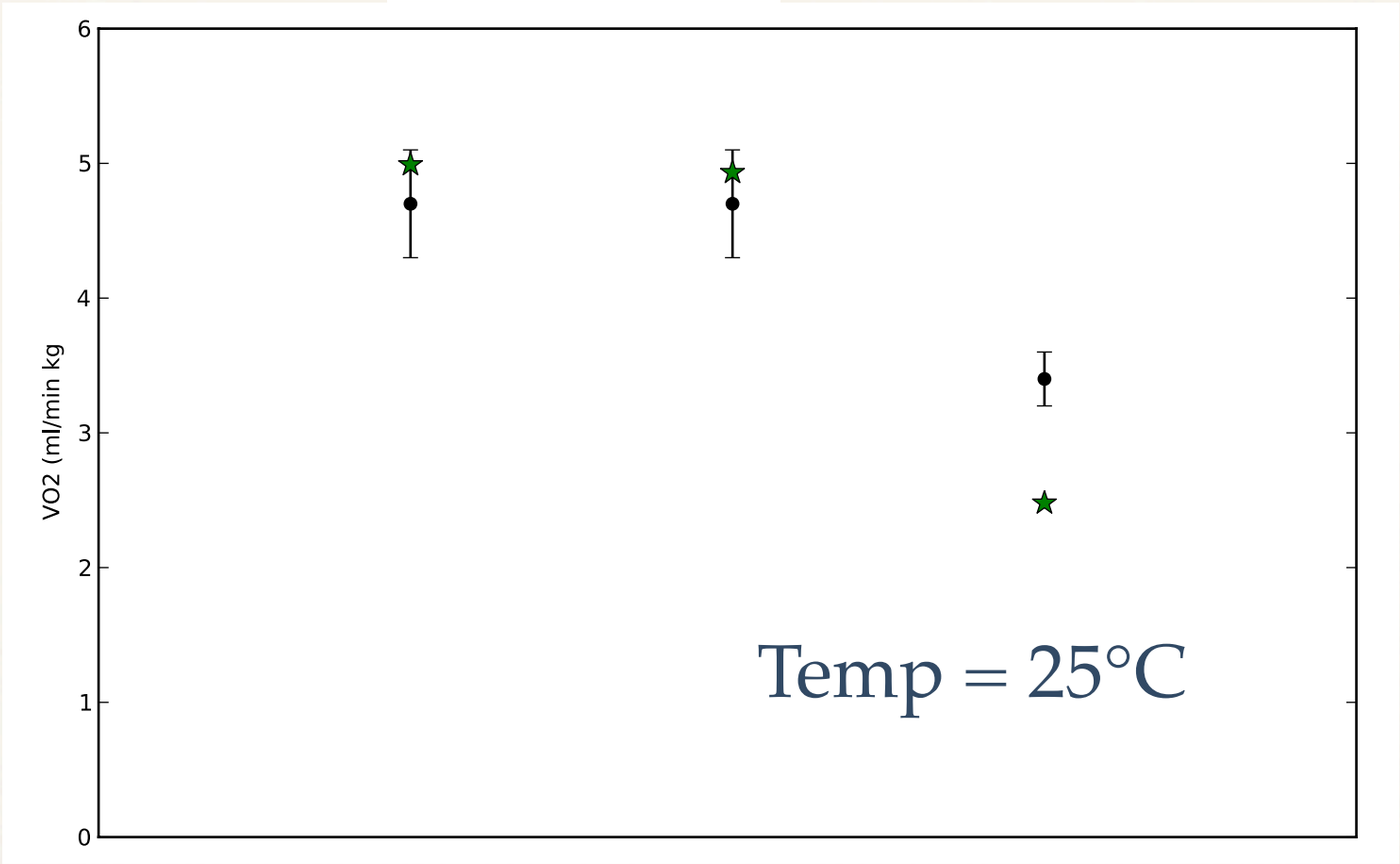
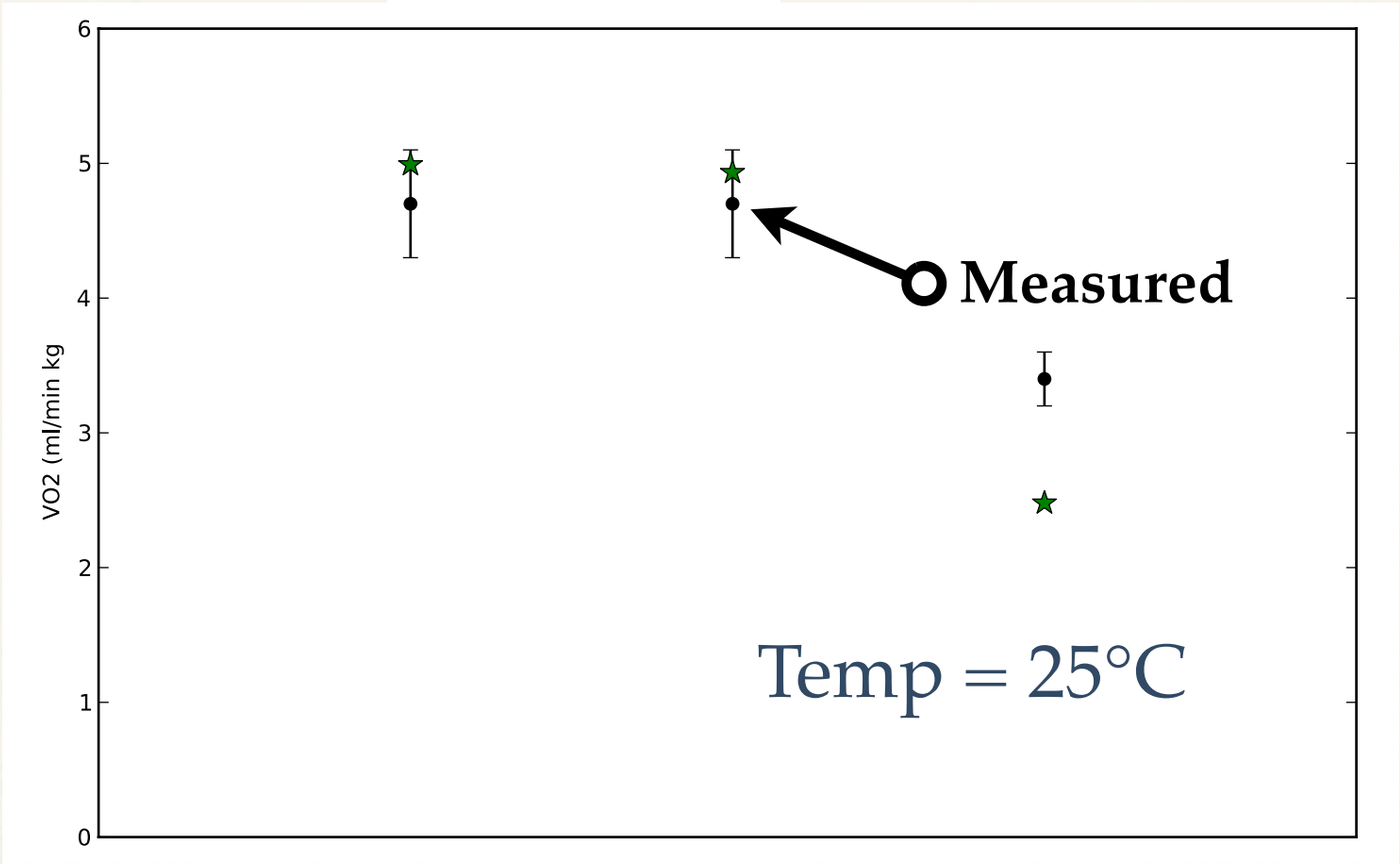


Model evaluation



Measured VO2 from Bushnell and Brill, 1992

Model evaluation



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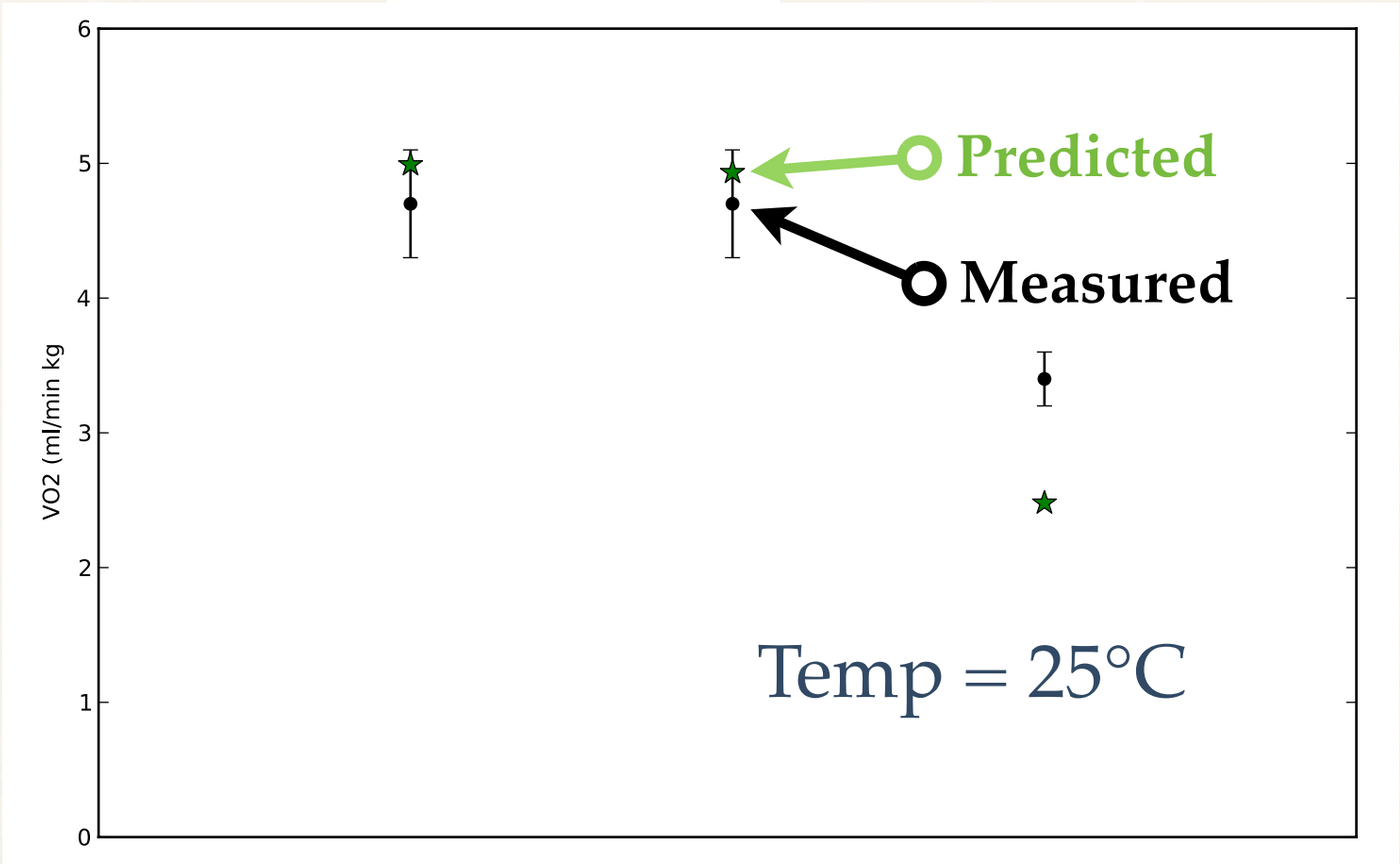

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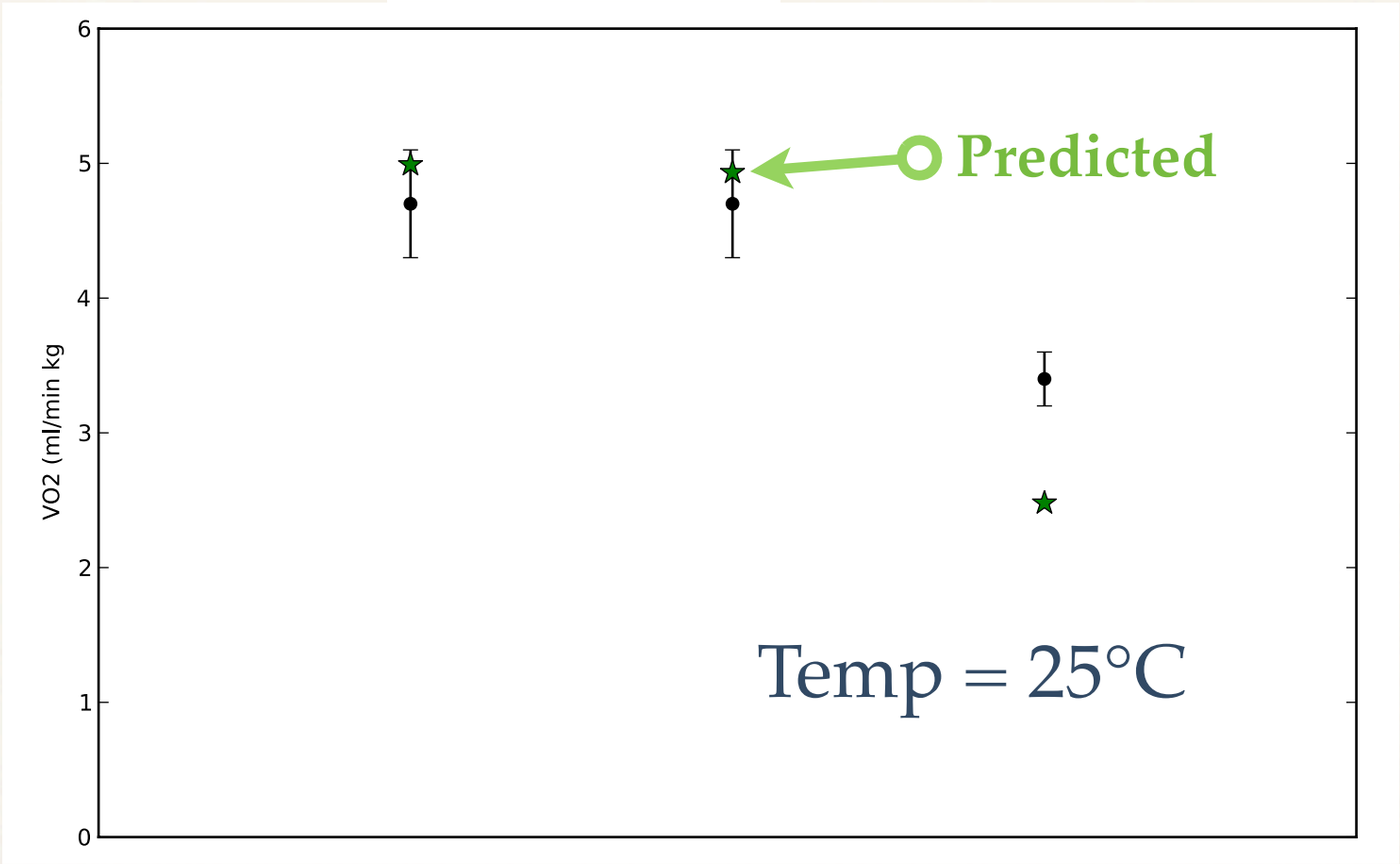

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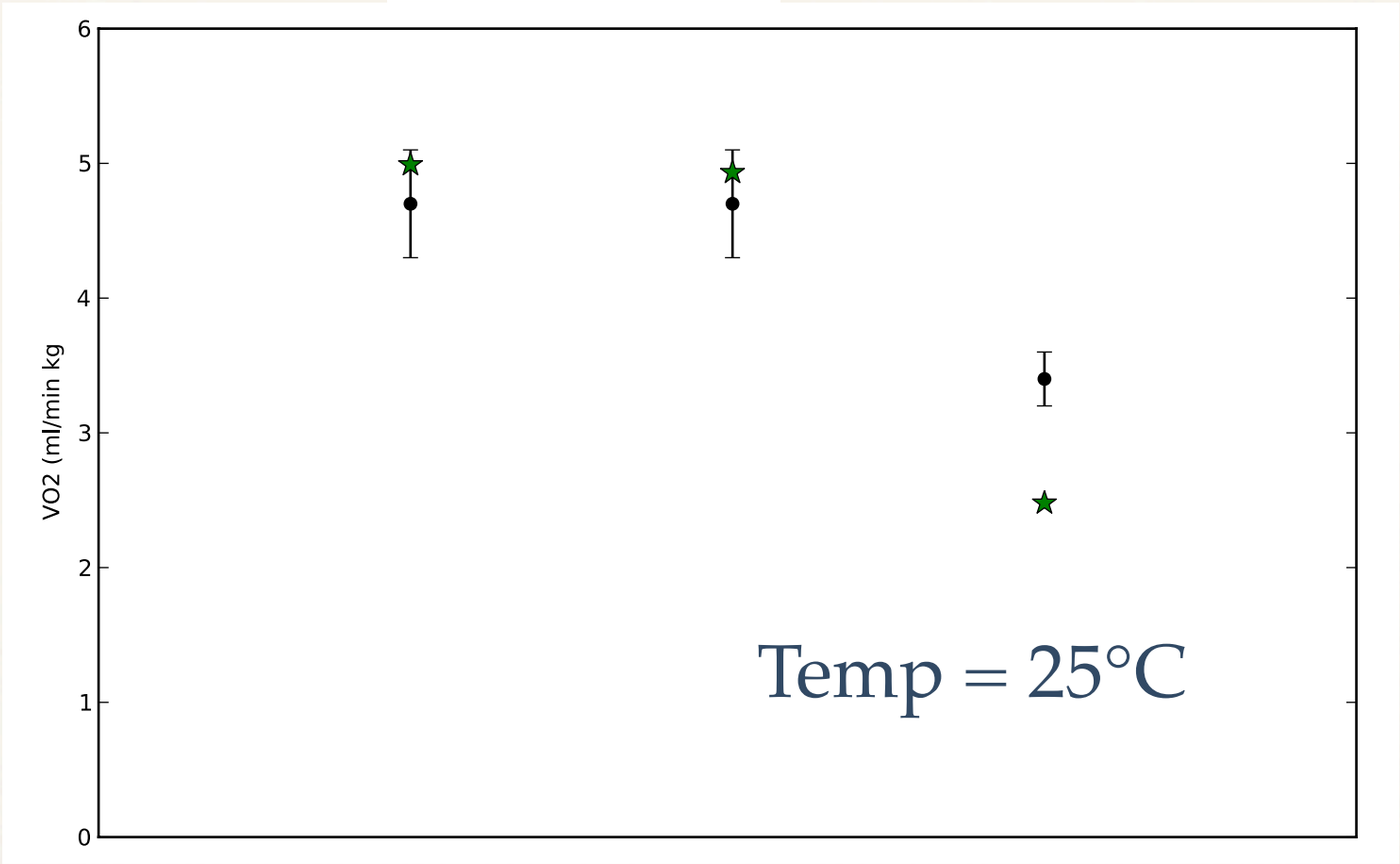

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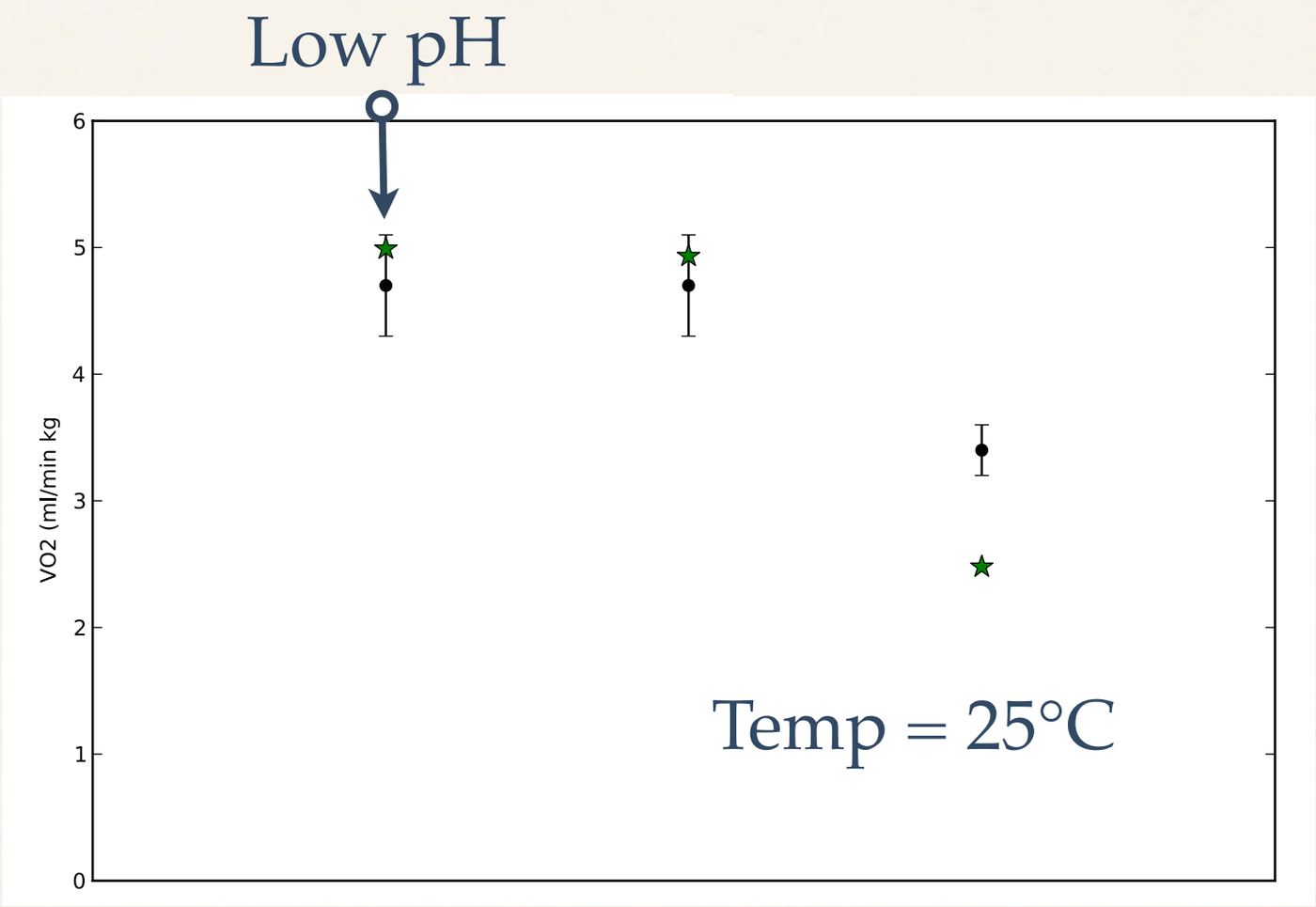

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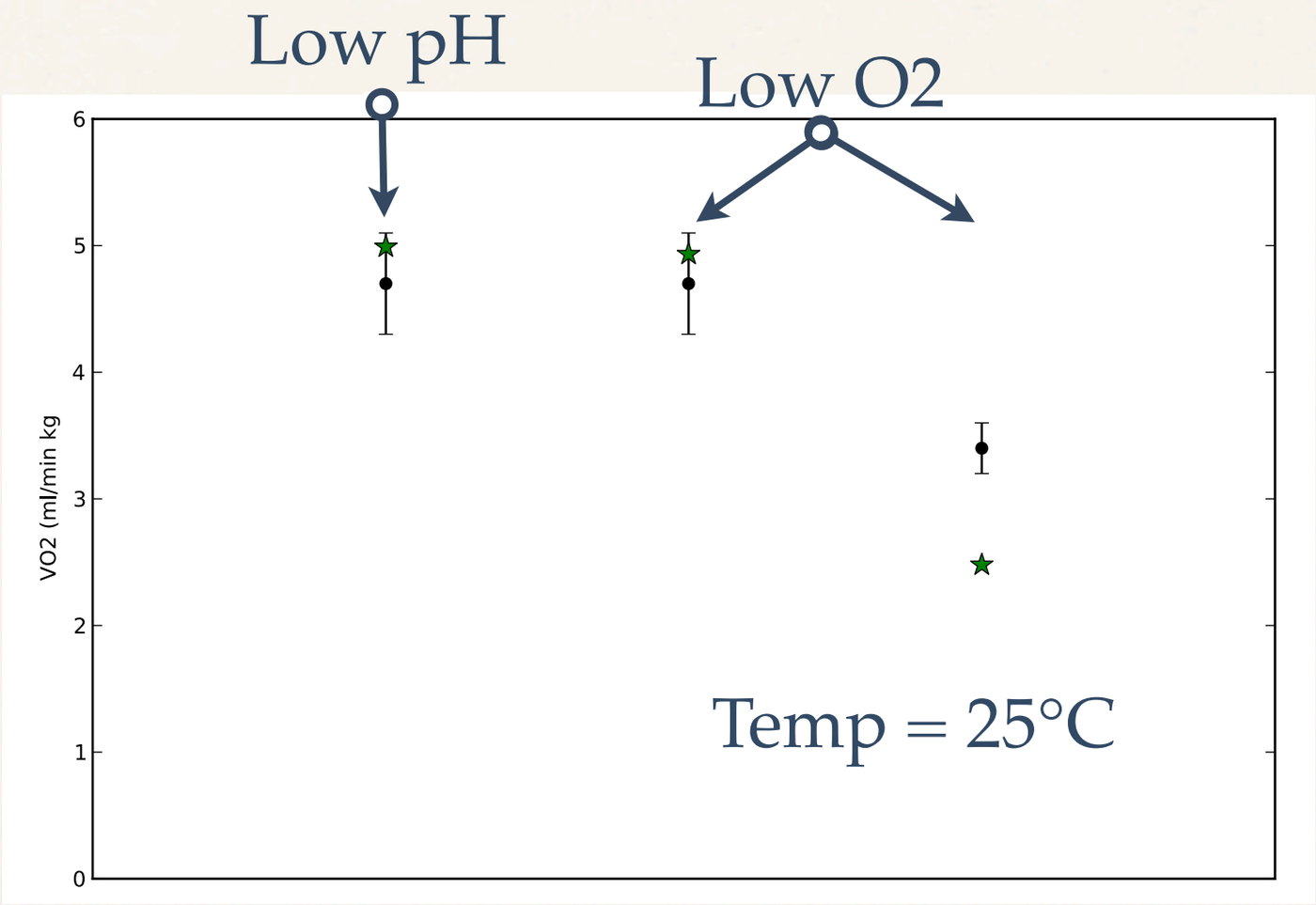

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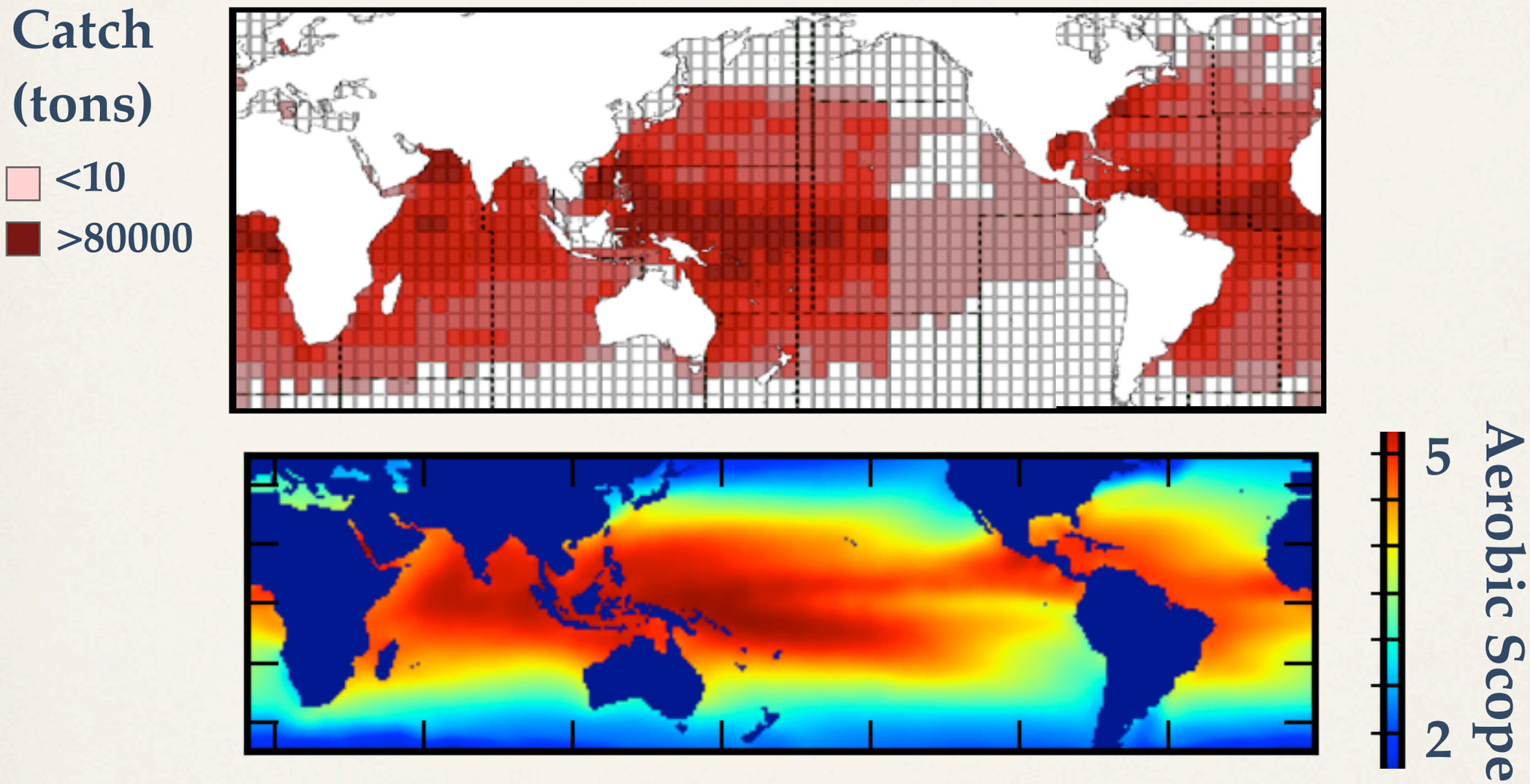
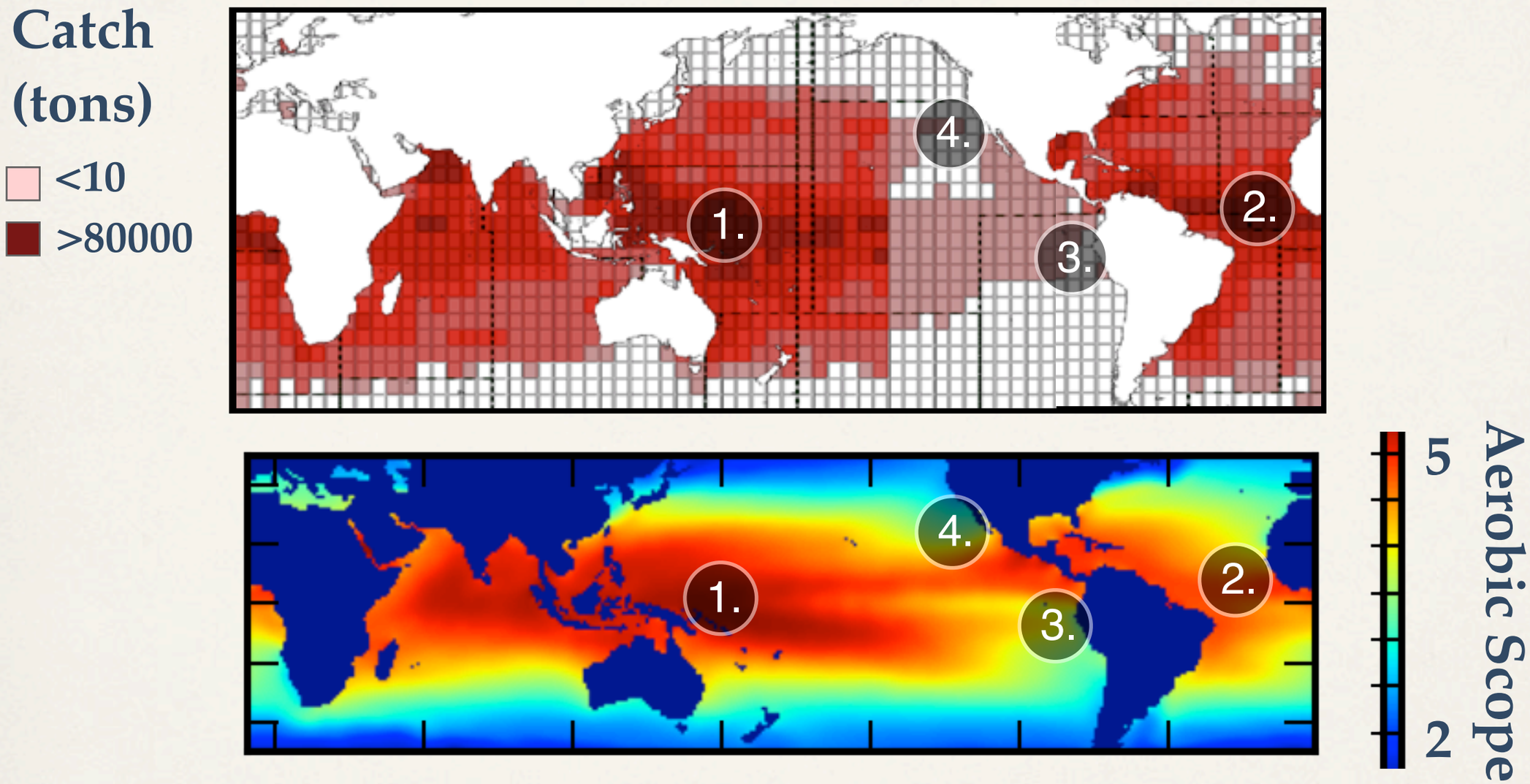


Environmental Data from WOA (2009) climatology
Yellowfin catch data from FAO



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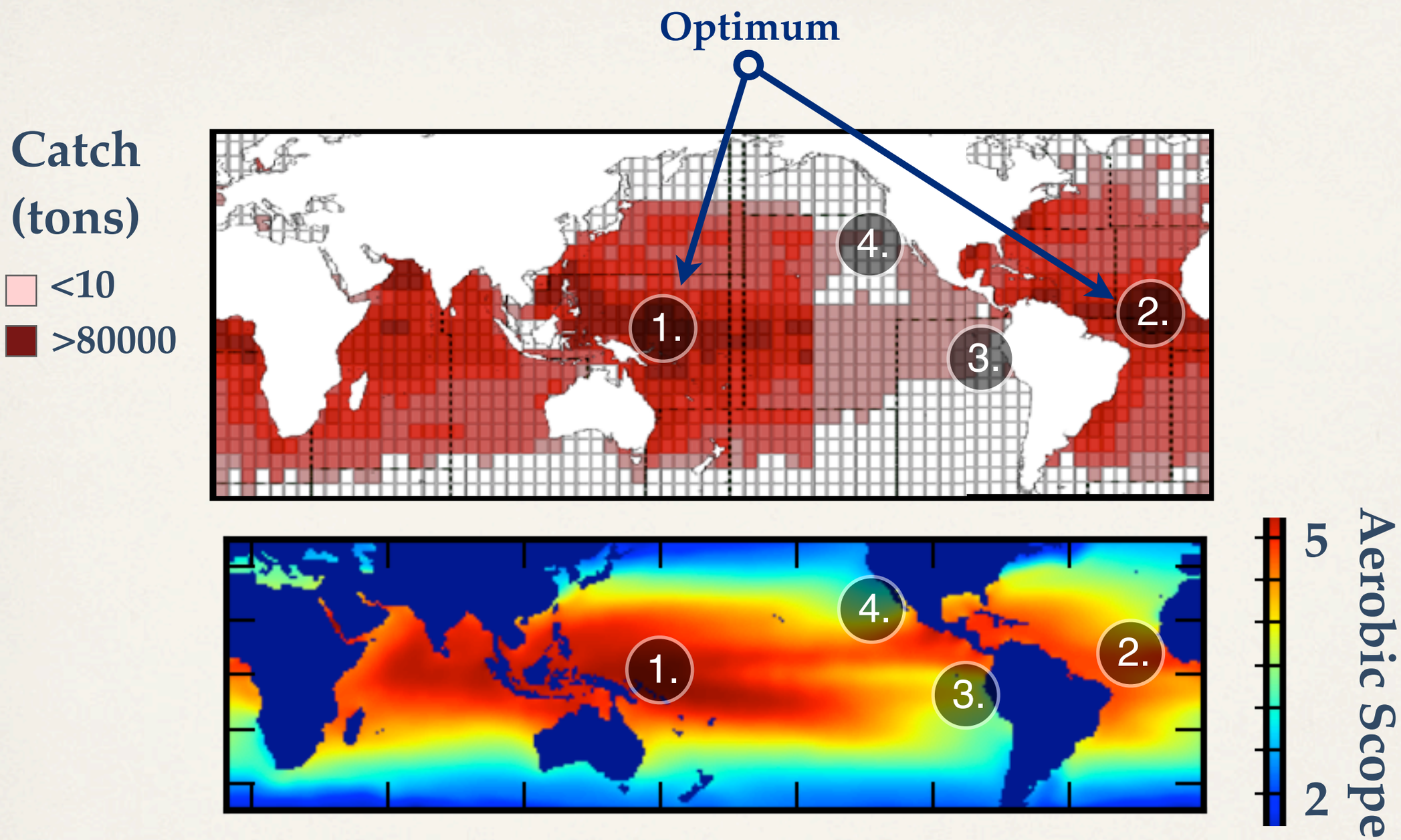

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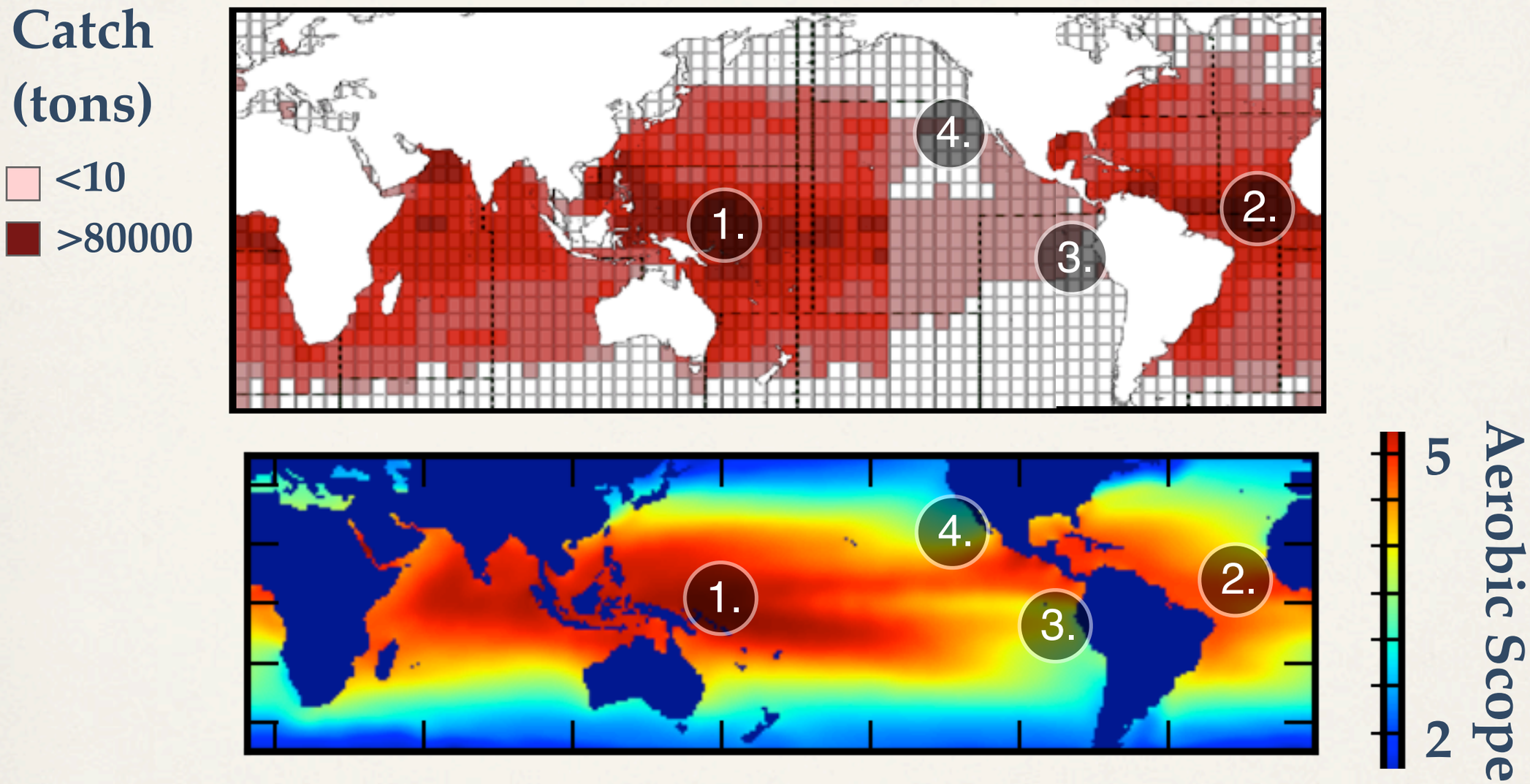

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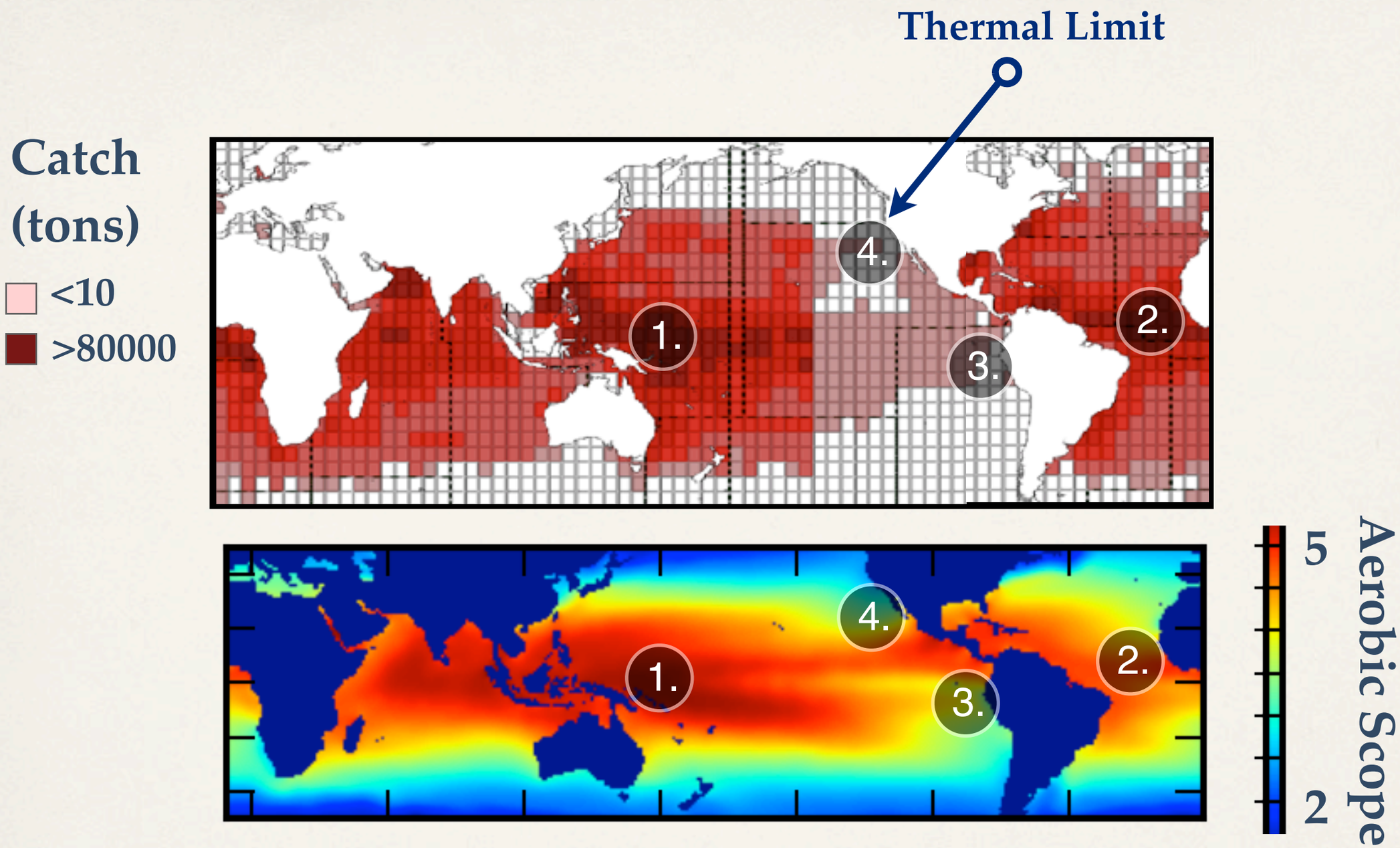

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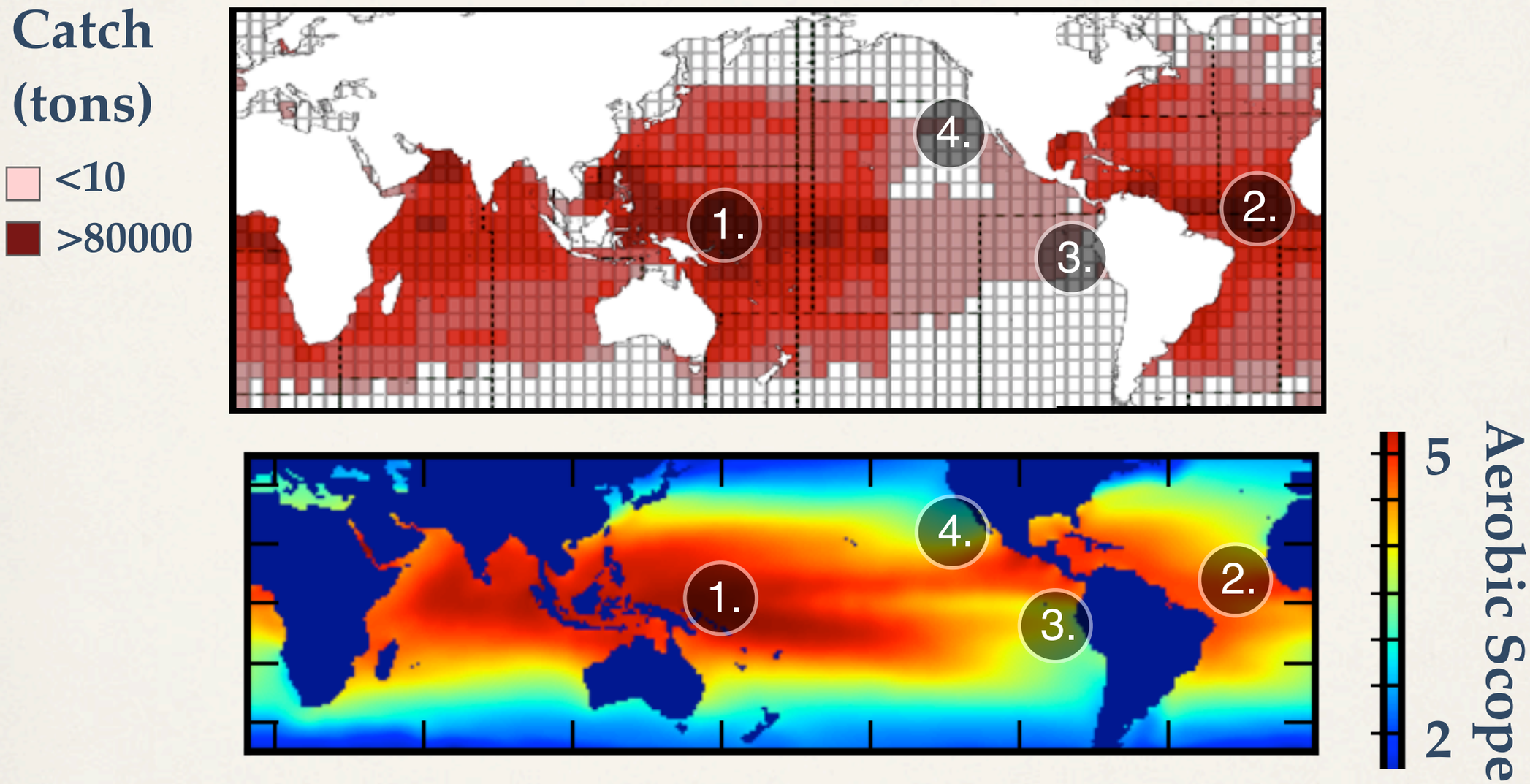

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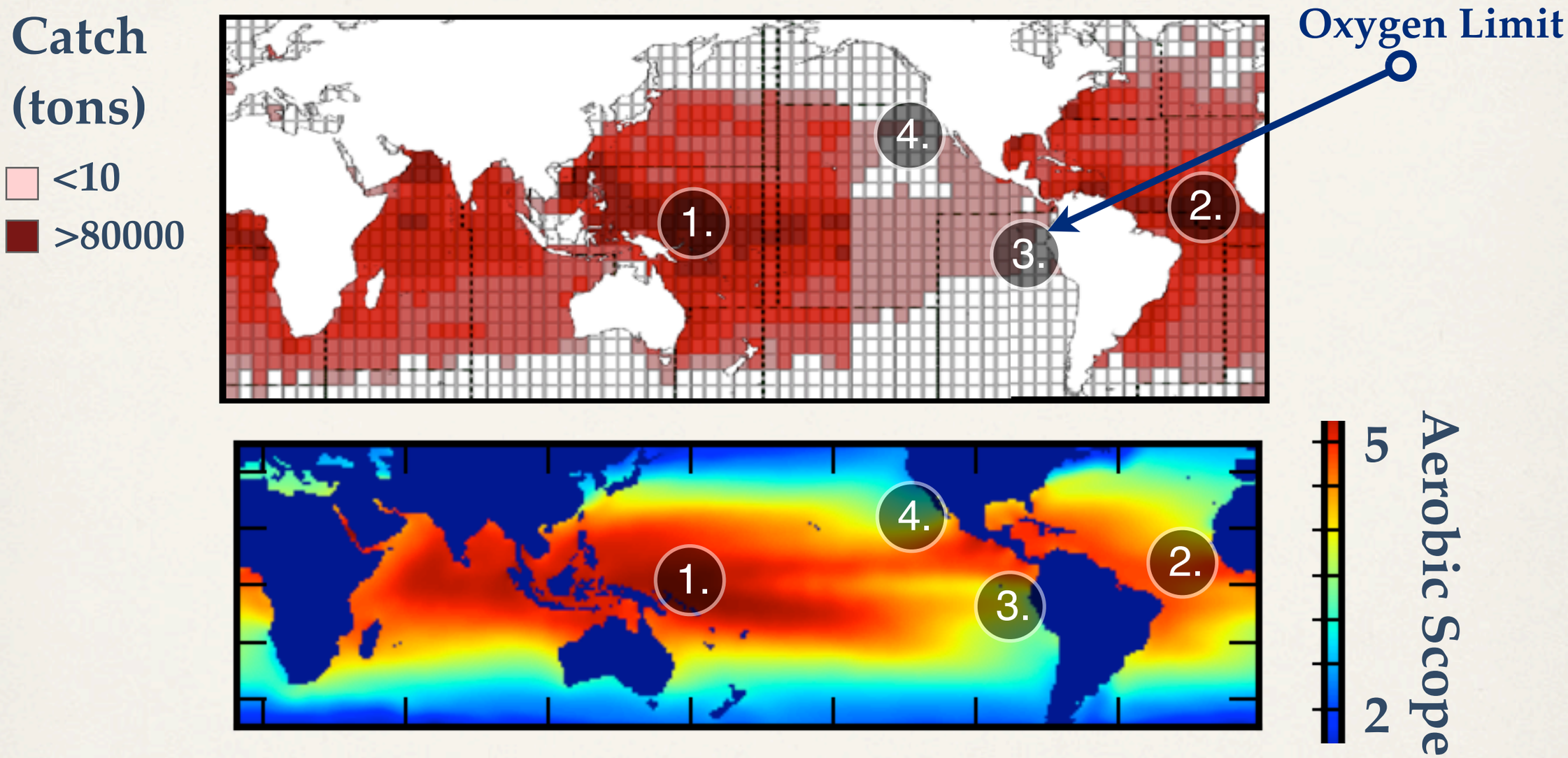

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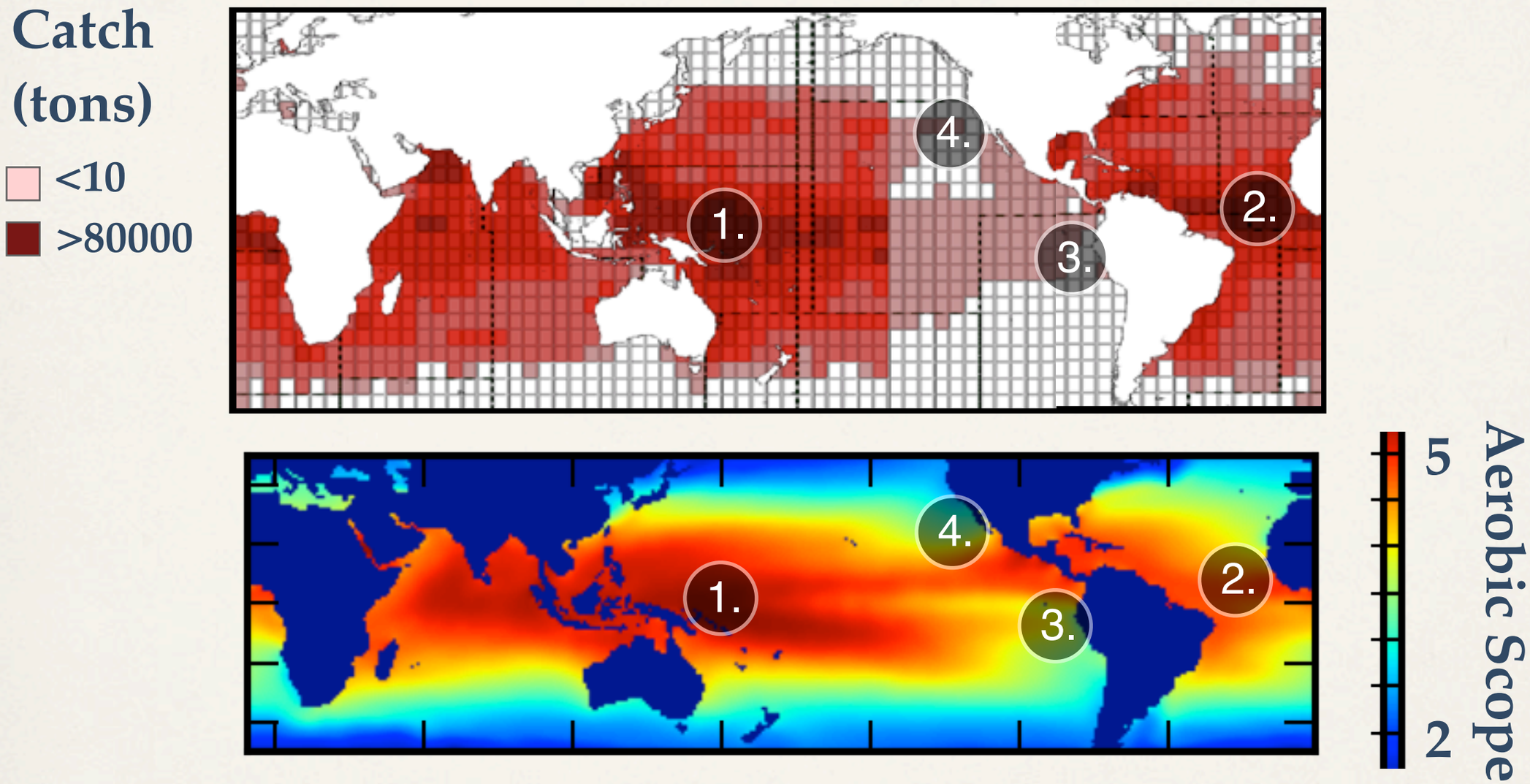

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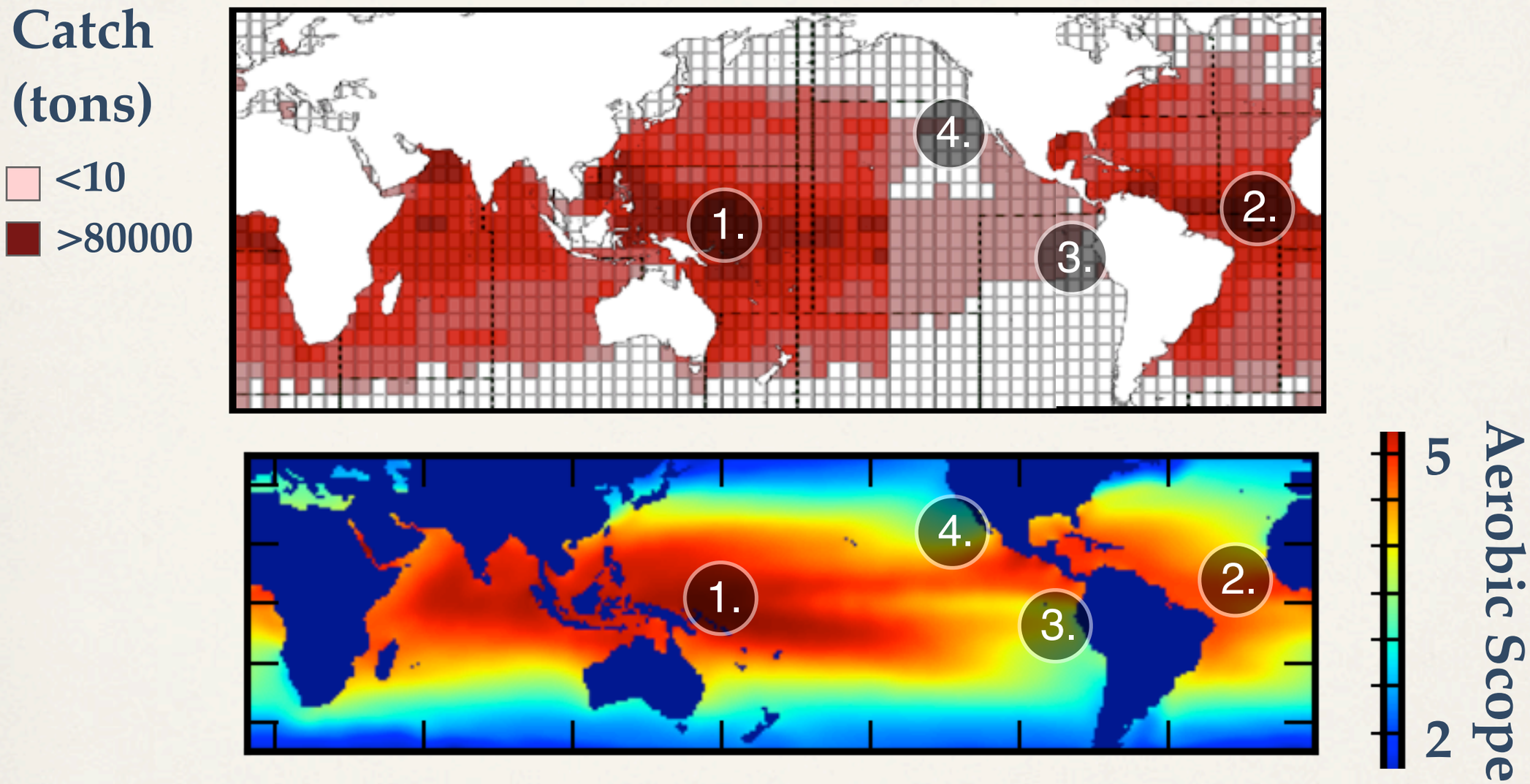

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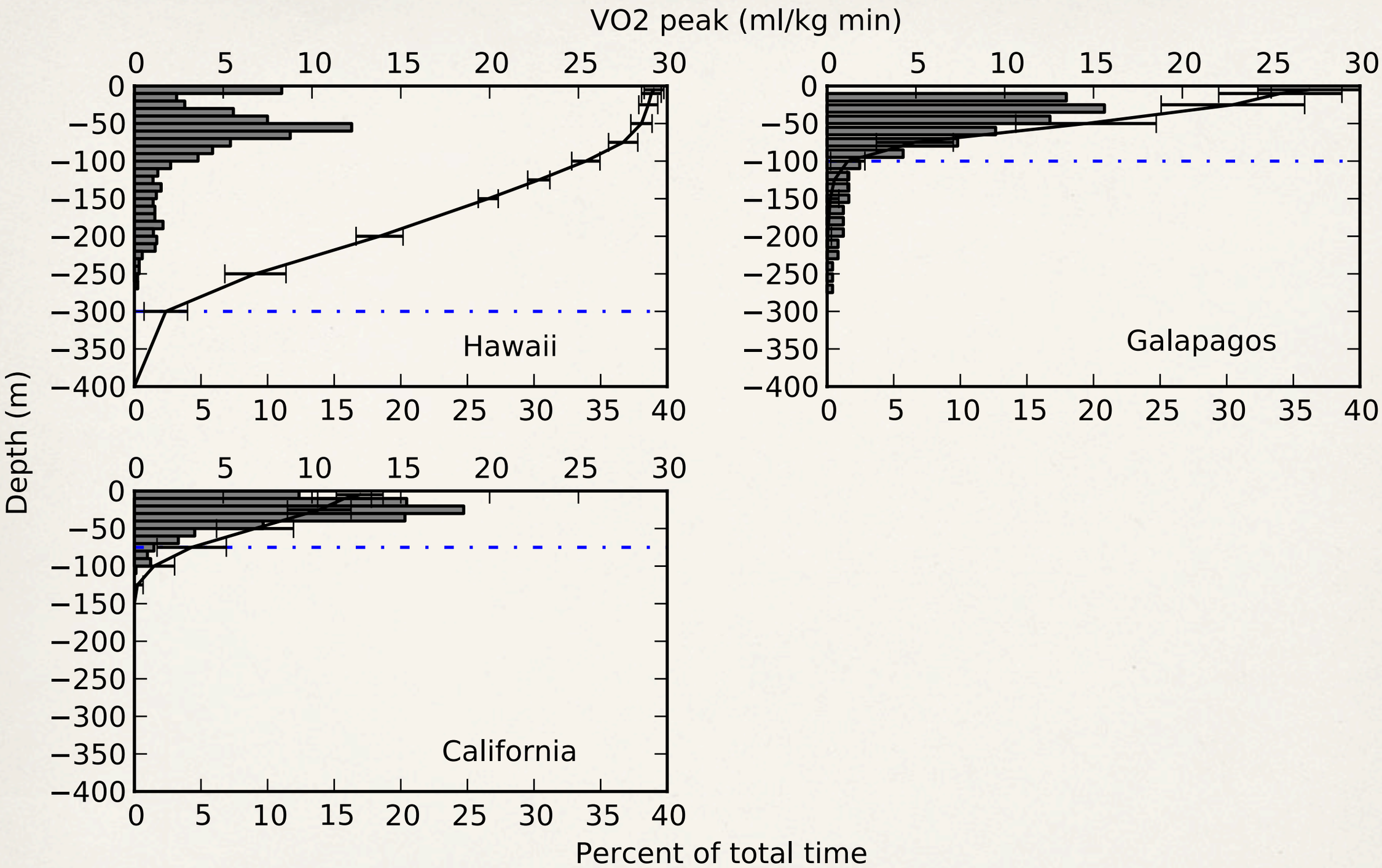
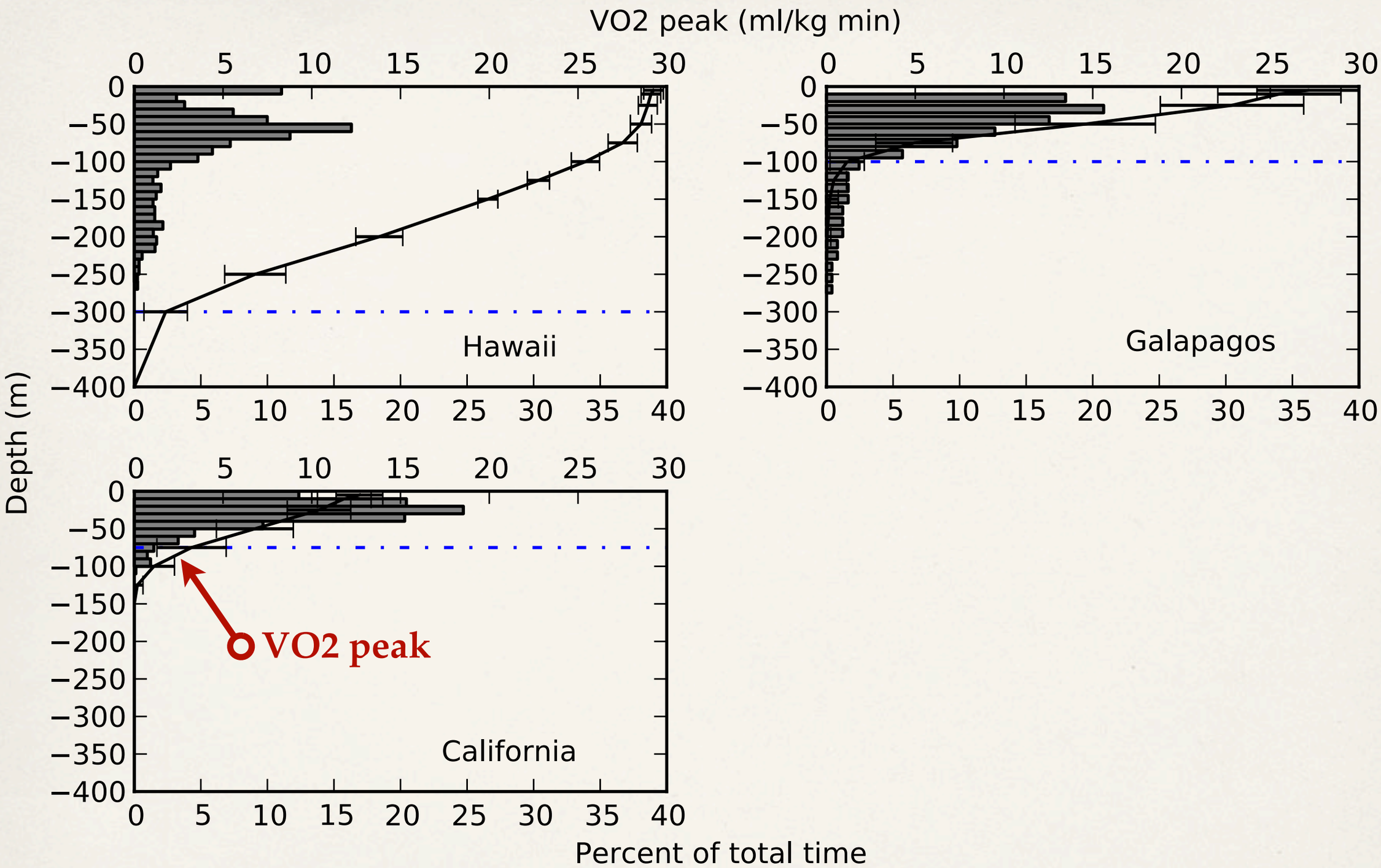


Tagging Data - **Hawaii:** Brill et al. 1999, **Galapagos:** Schaefer et al. 2009, **California:** Schaefer et al. 2007



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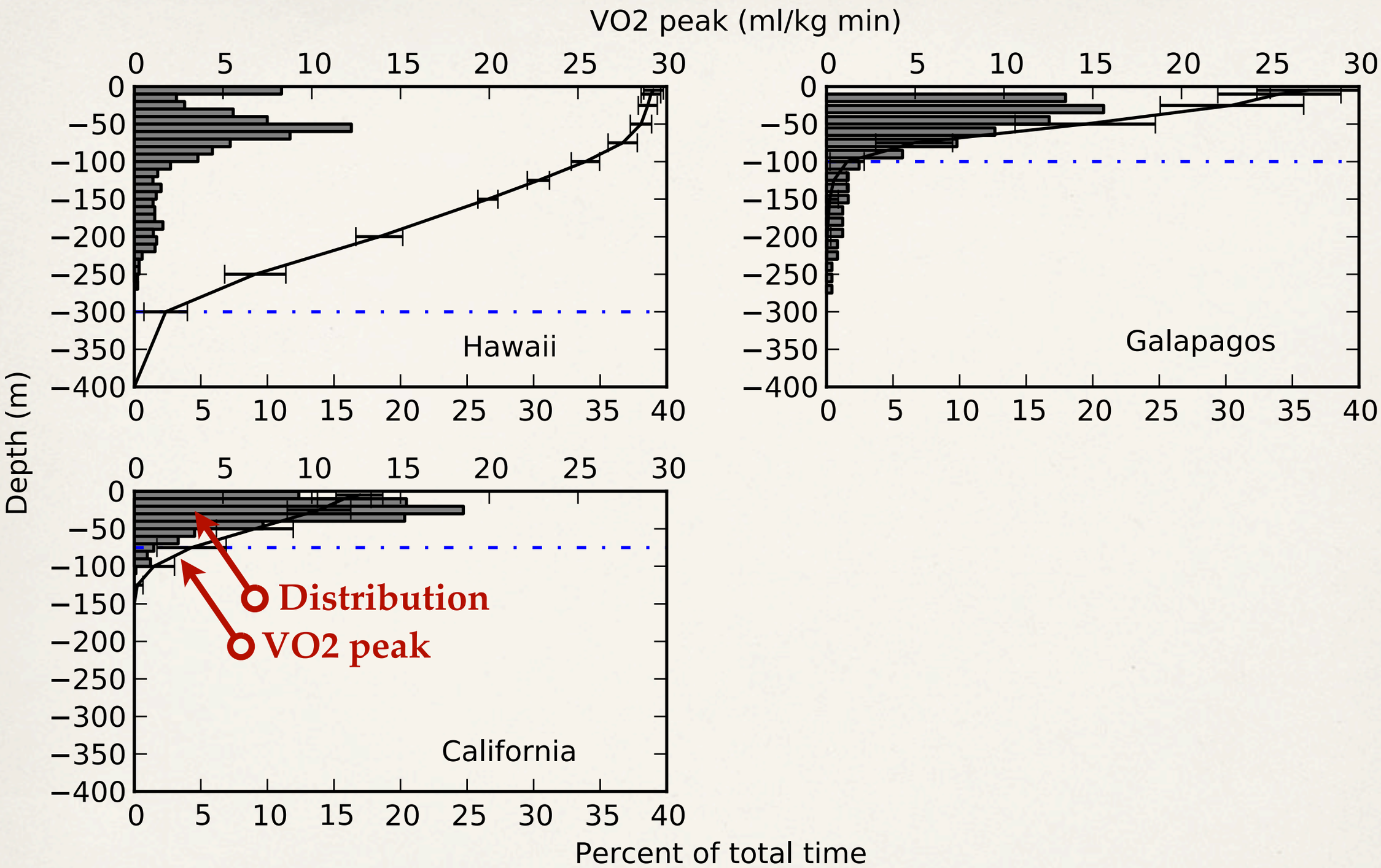

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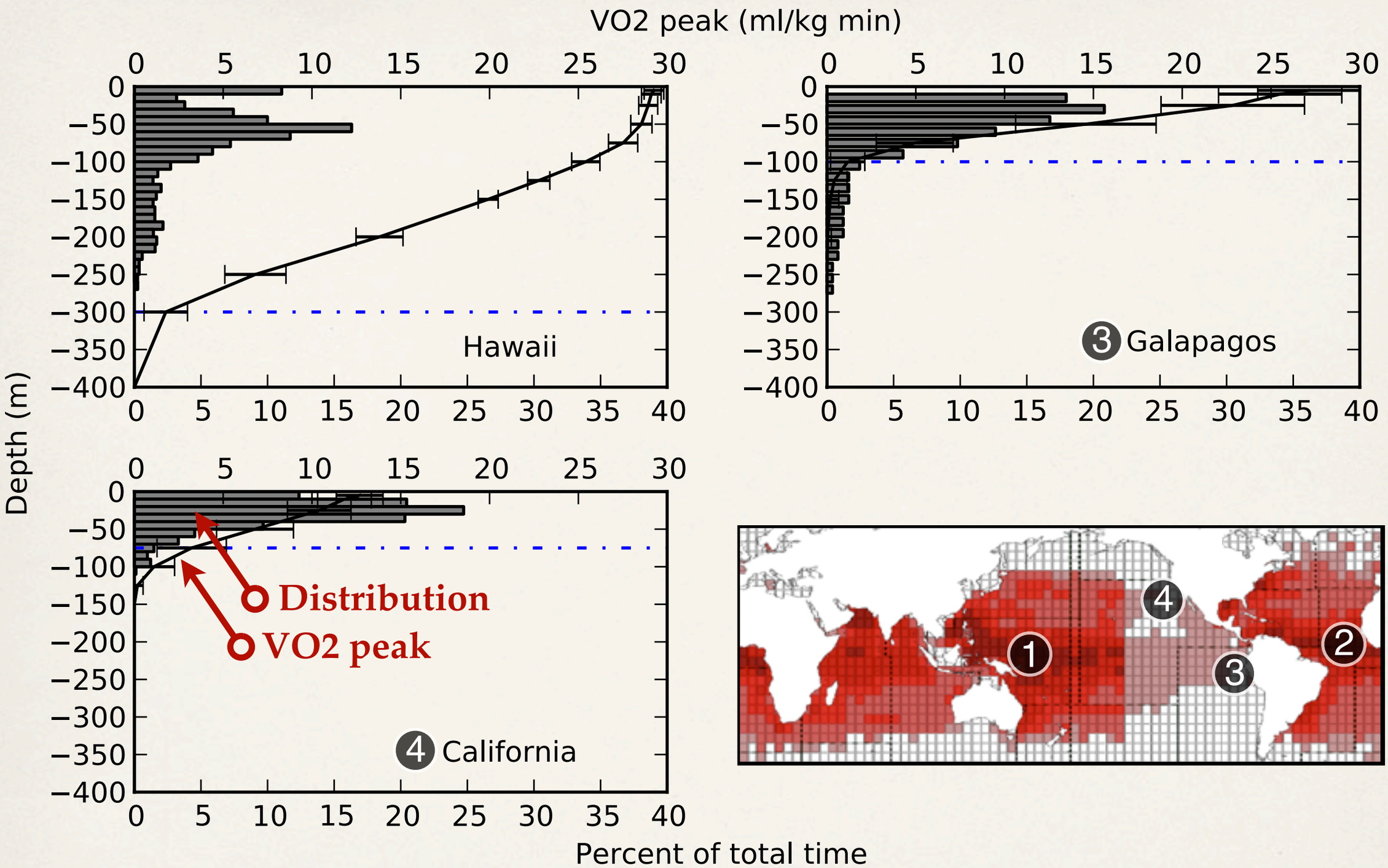

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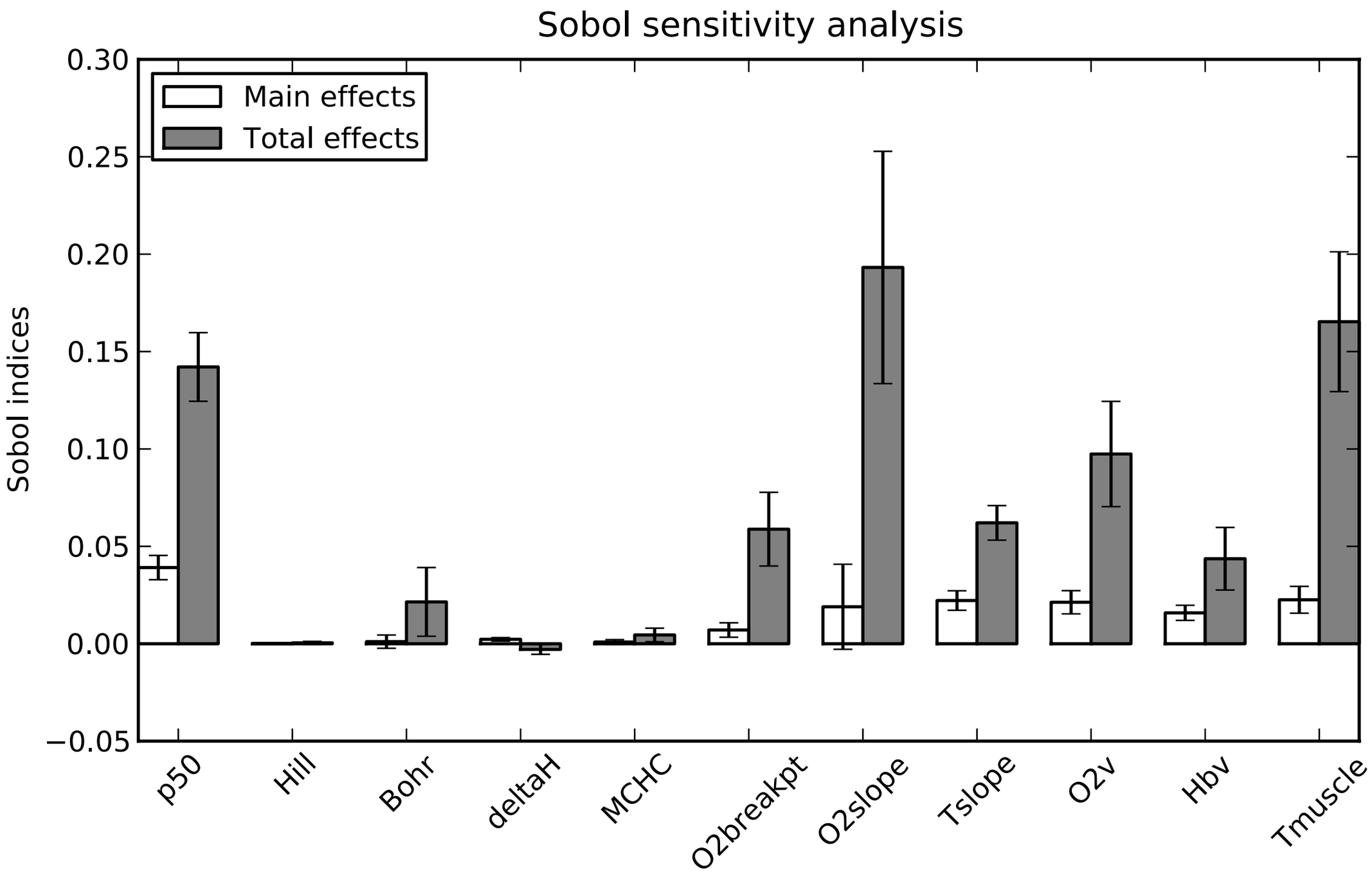
Sobol sensitivity analysis
Main effects
Total effects
Sobol indices
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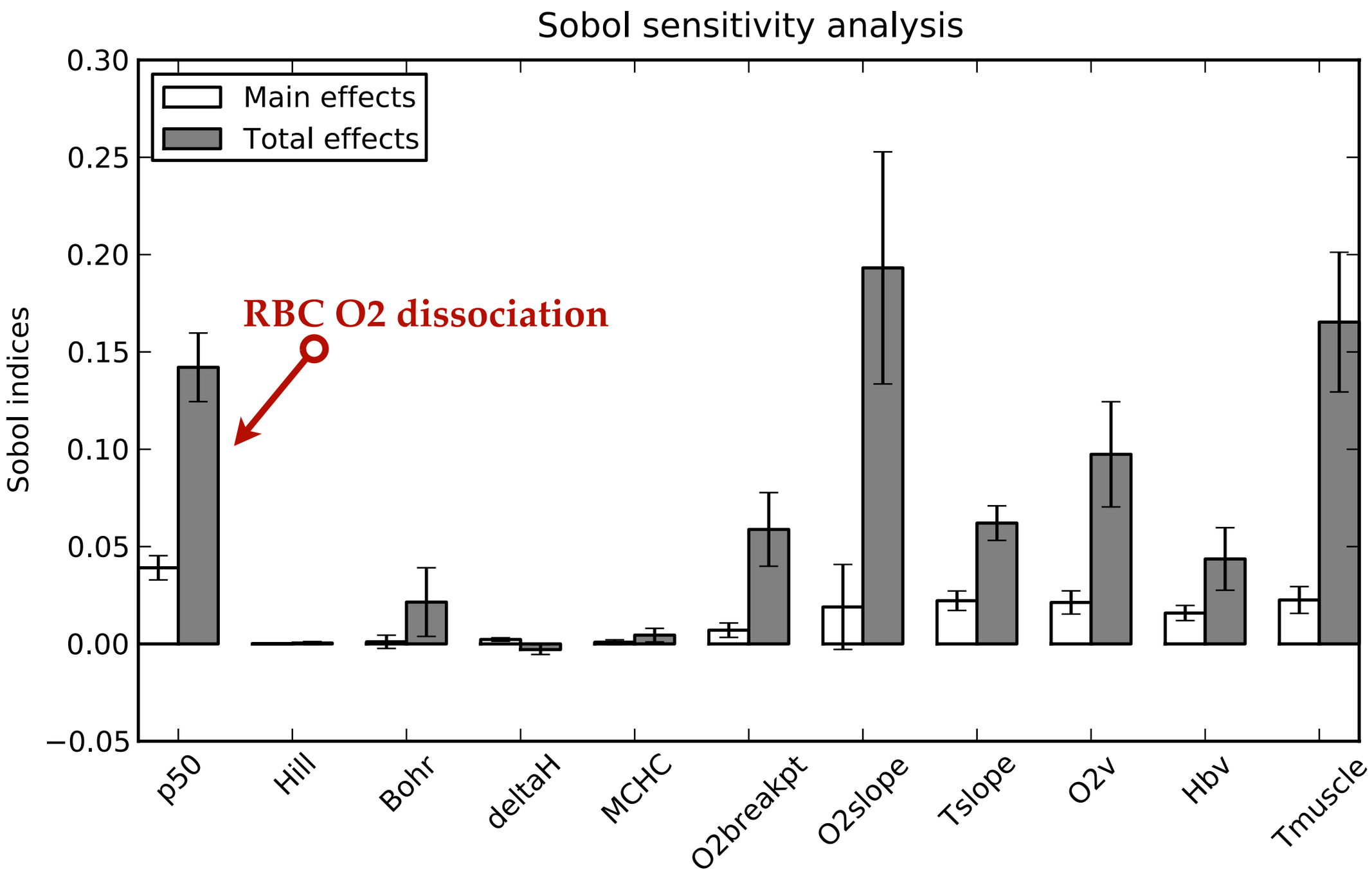
0.25
0.20
0.15
0.10
0.05
0.00
−0.05
p50
Hill
Bohr
deltaH
MCHC
O2breakpt
O2slope
Tslope
O2v
Hbv
Tmuscle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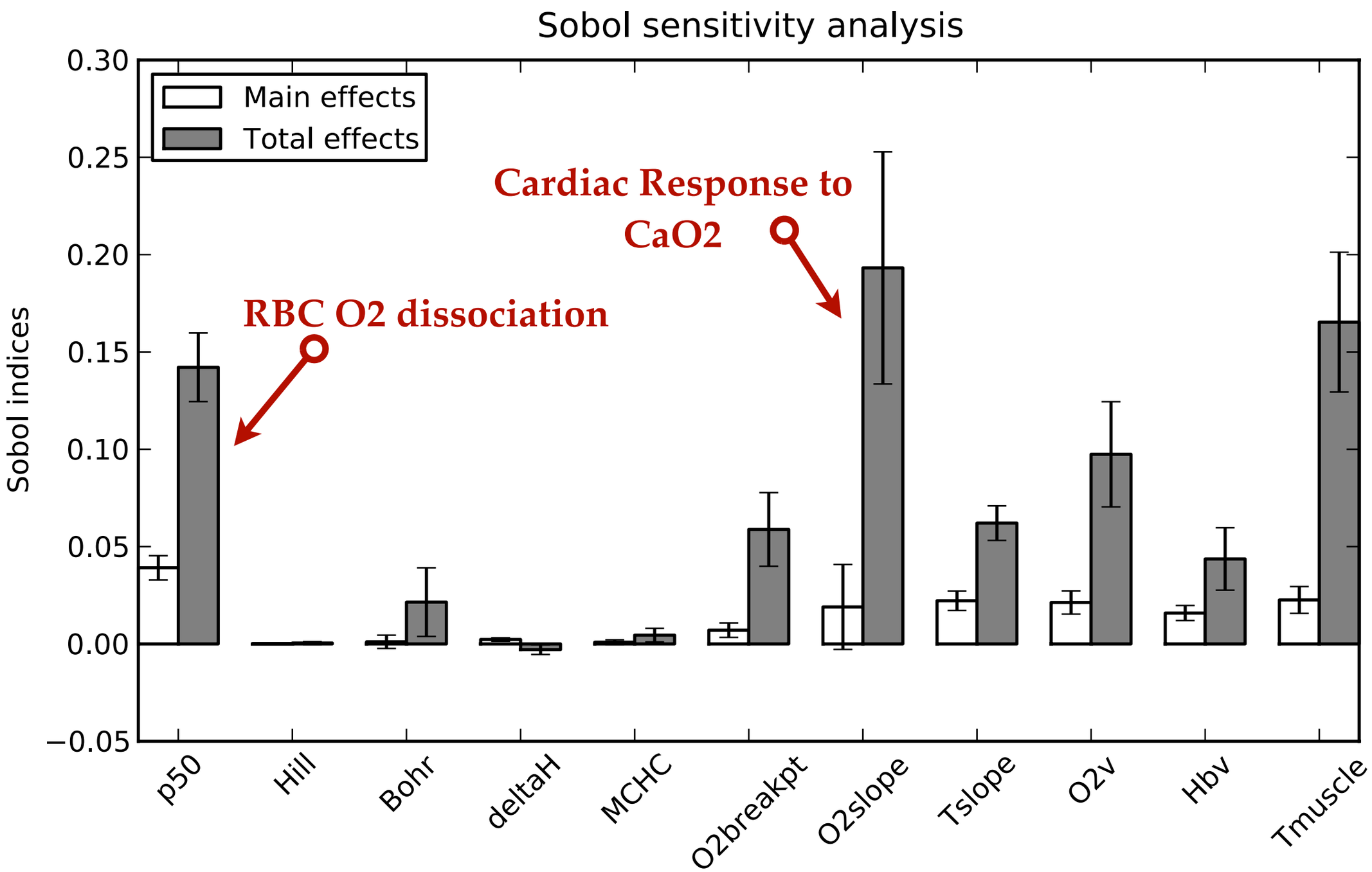
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Cardiac Response to CaO2
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O2slope
Tslope
O2v
Hbv
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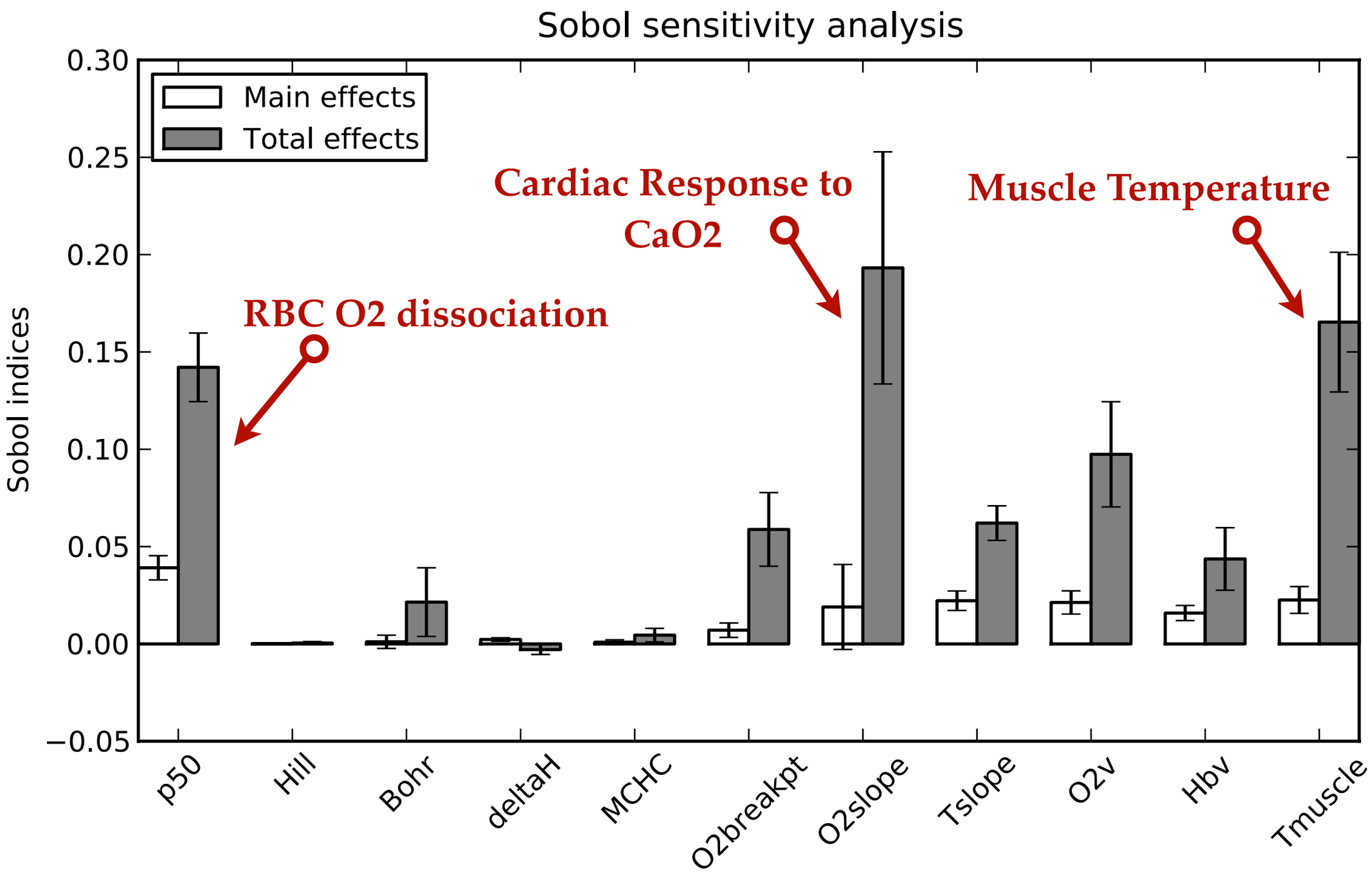
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Hill
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deltaH
MCHC
O2breakpt
O2slope
Tslope
O2v
Hbv
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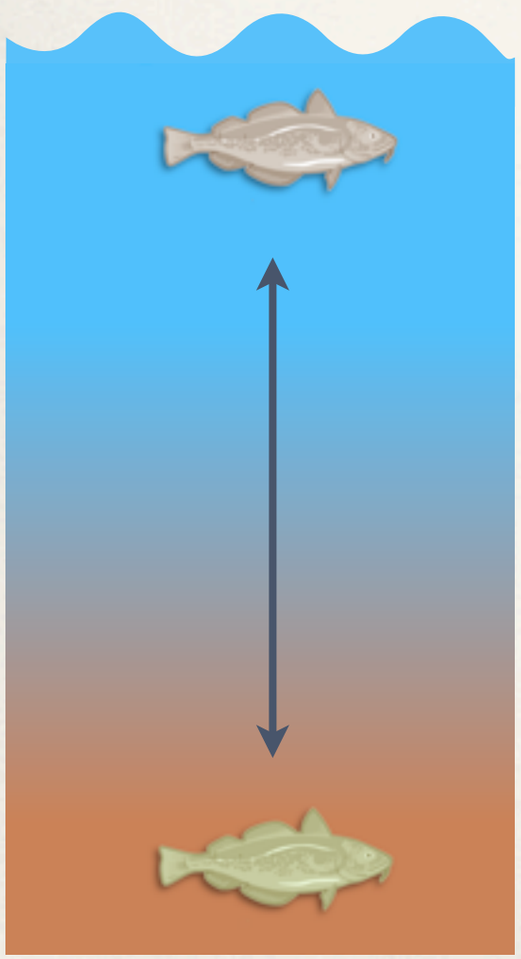
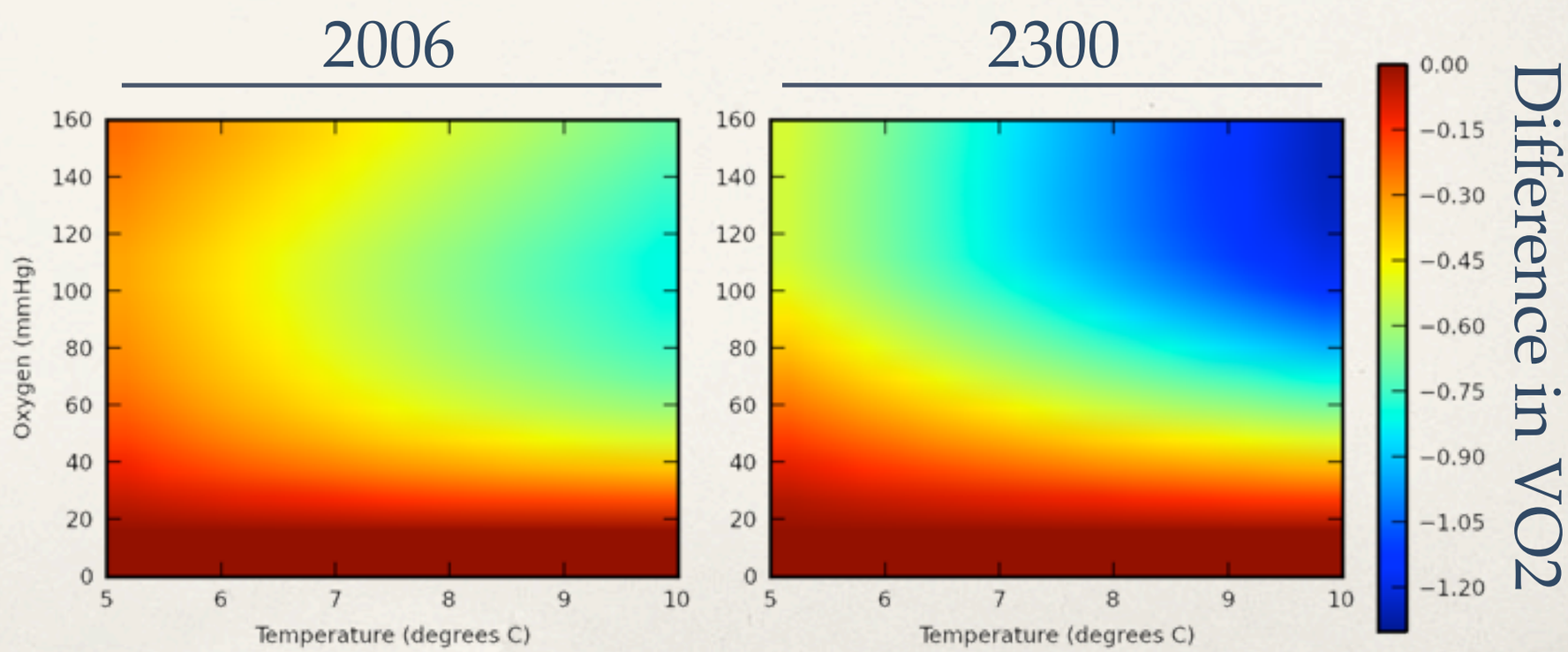
Future work

- Empirical model evaluation:
  - Aerobic scope measurements under simulated climate change
- Climate change prediction:



Change in peak metabolic rate between the surface and 350m according to CMIP5 projections



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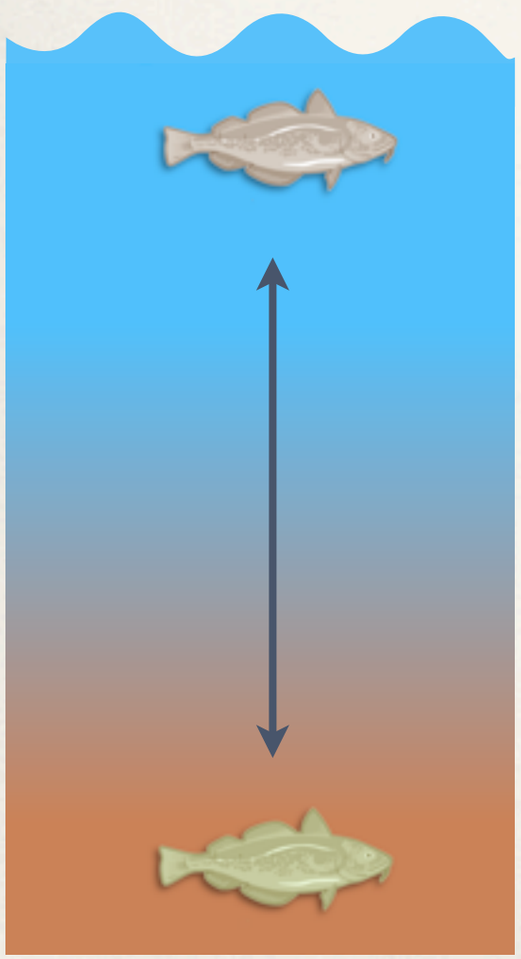
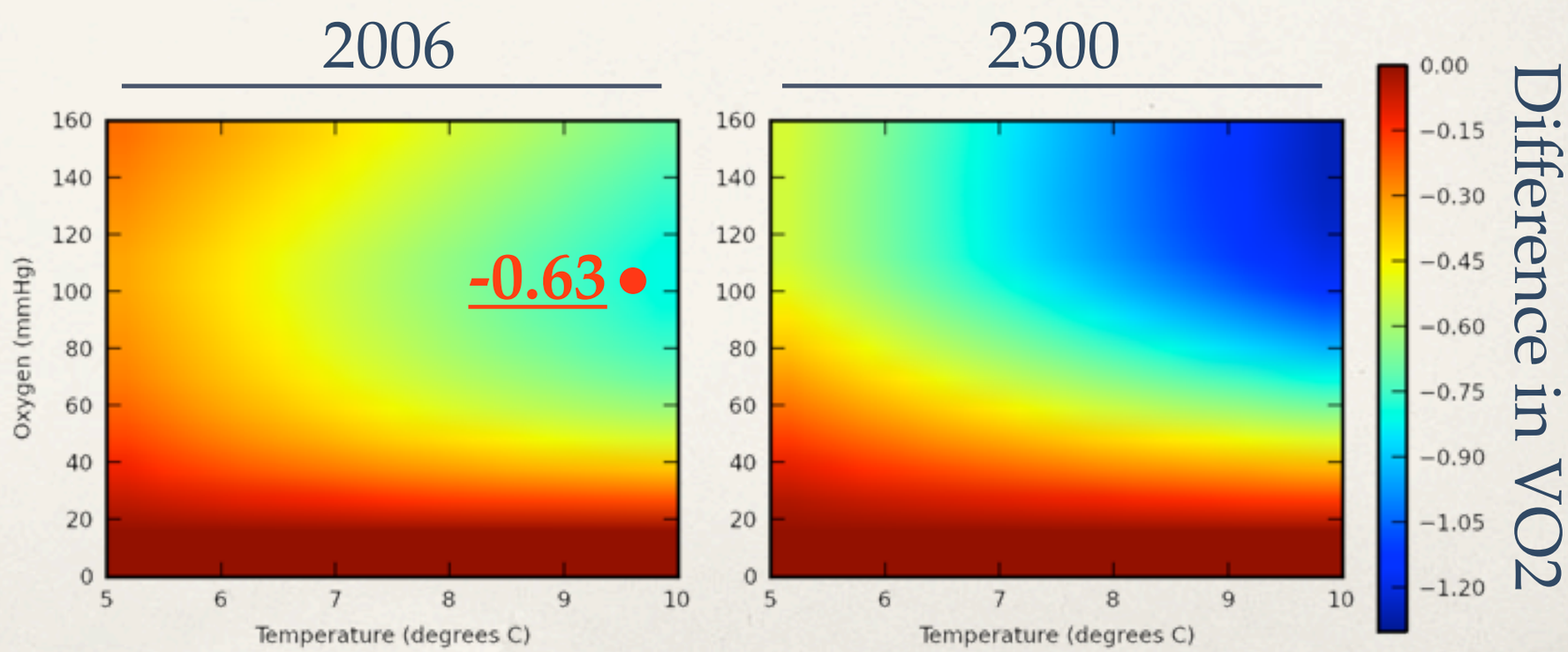
  - Aerobic scope measurements under simulated climate change
- Climate change prediction:

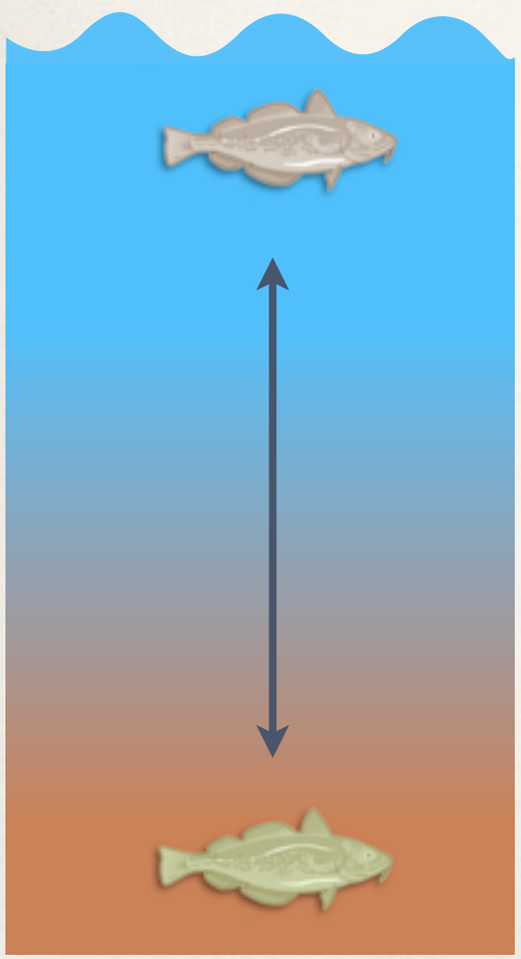


Change in peak metabolic rate between the surface and 350m according to CMIP5 projections

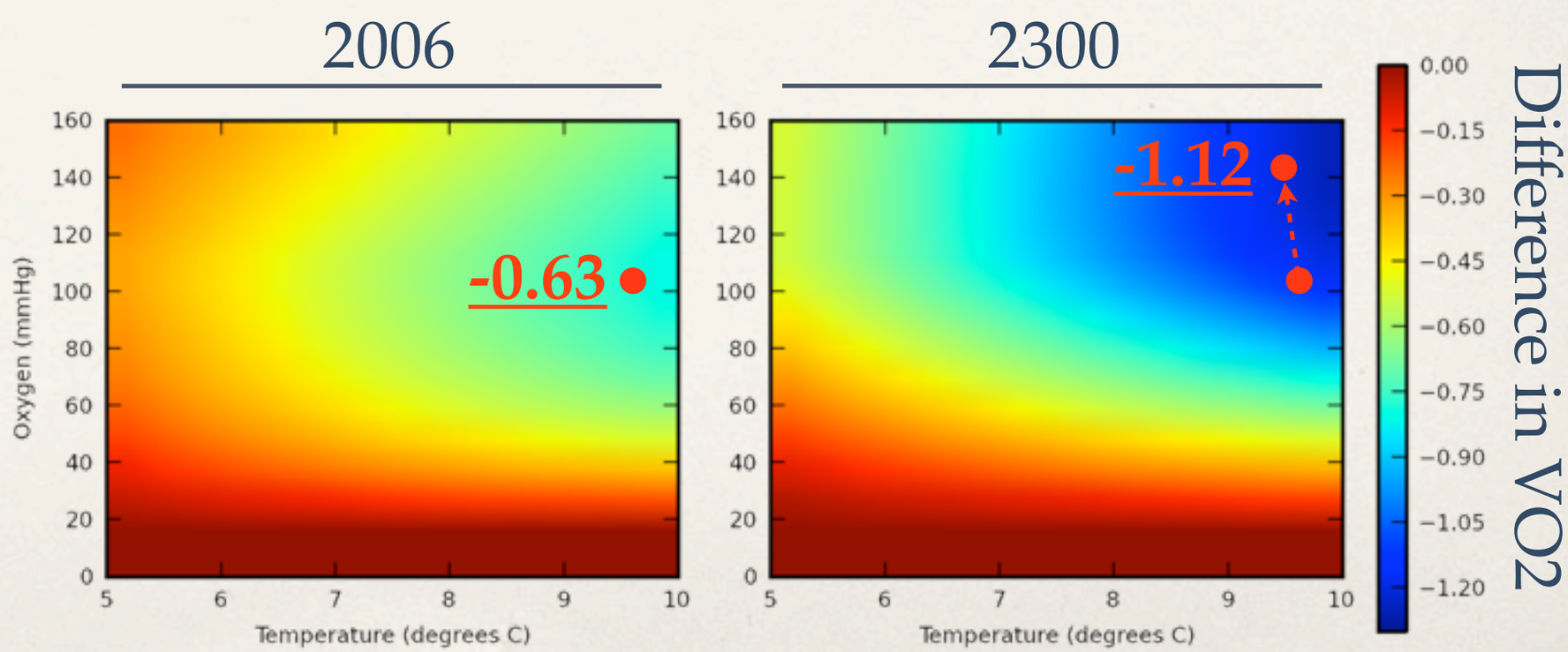


Future work

- Empirical model evaluation:
  - Aerobic scope measurements under simulated climate change
- Climate change prediction:



Change in peak metabolic rate between the surface and 350m according to CMIP5 projections



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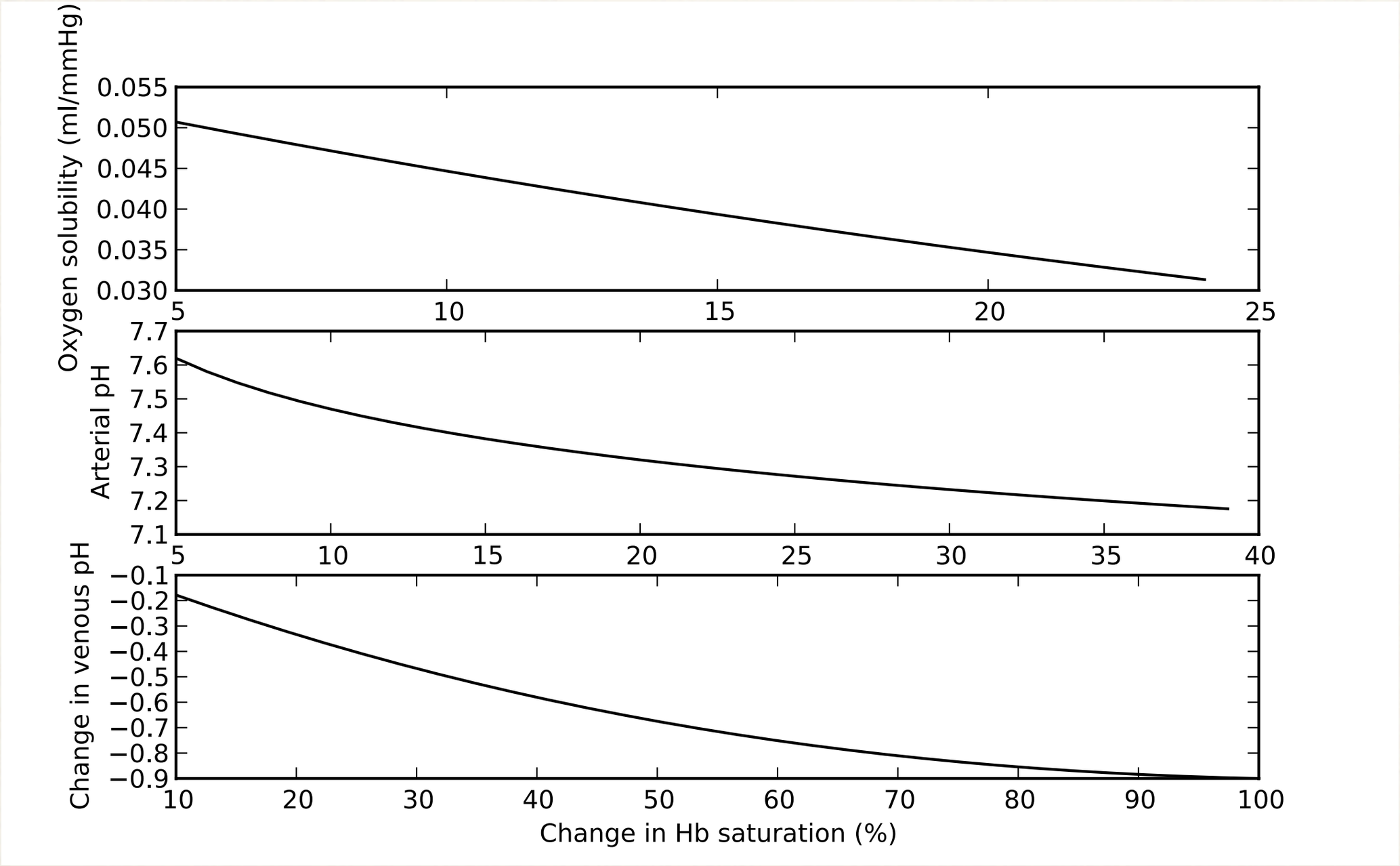
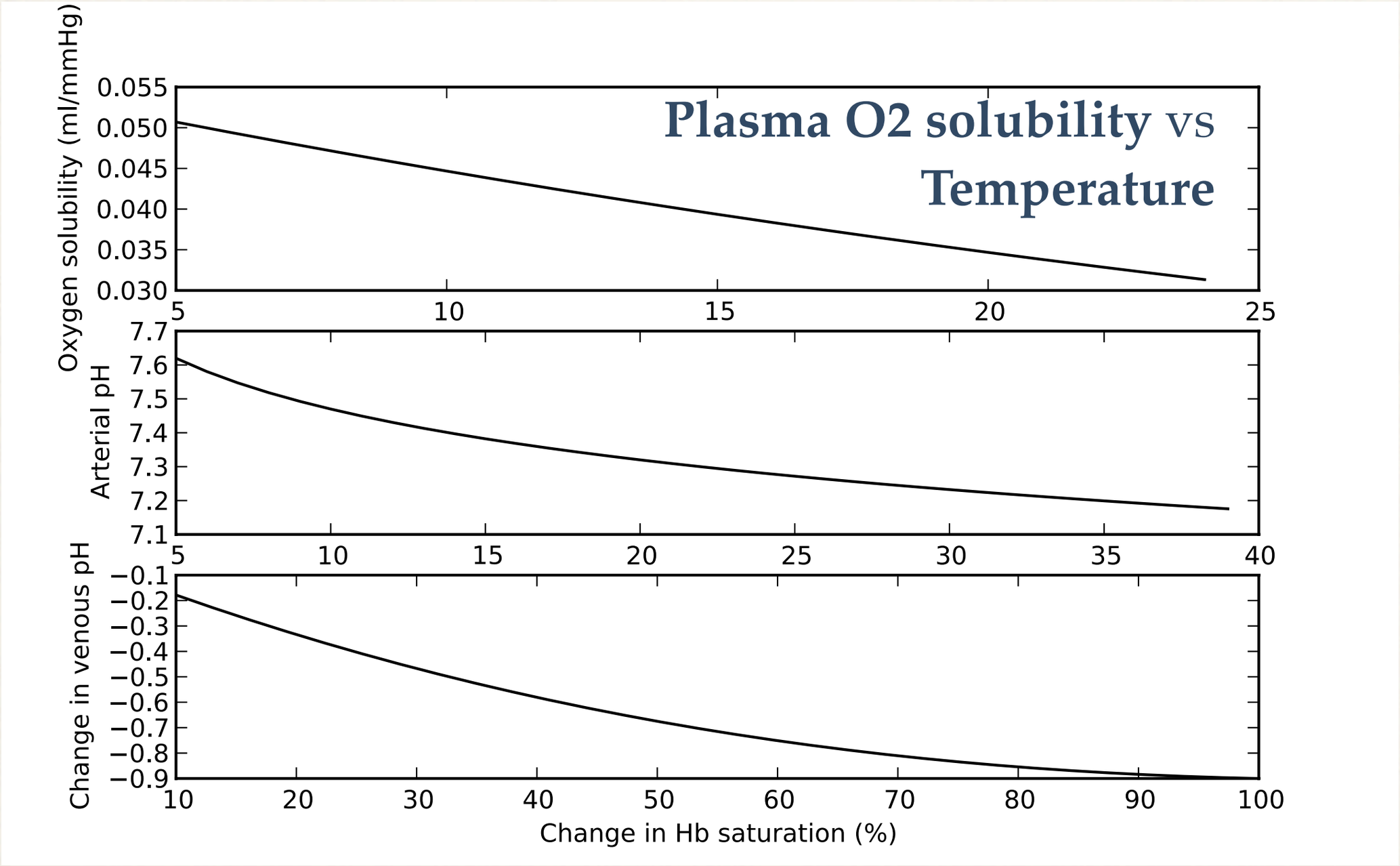
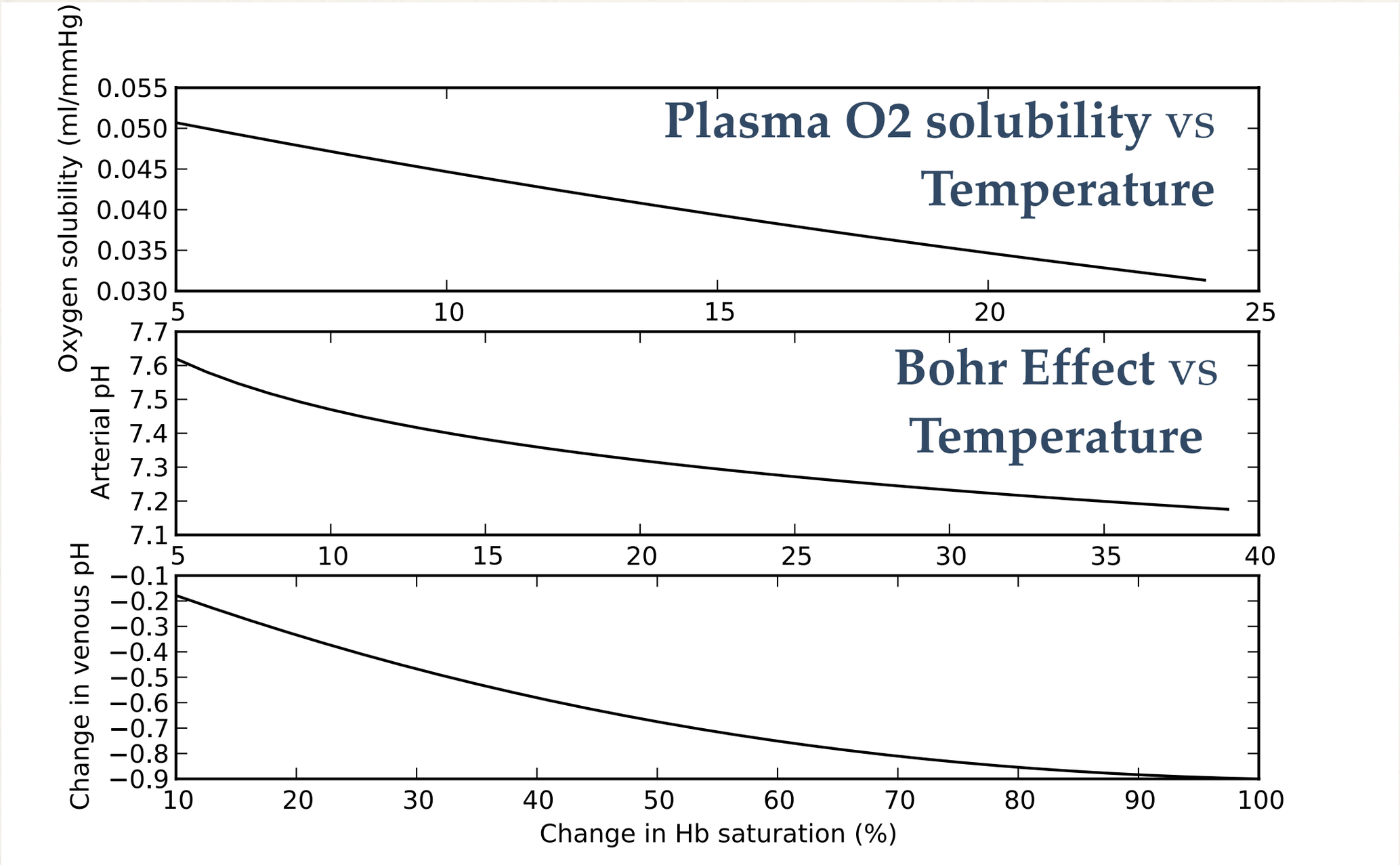
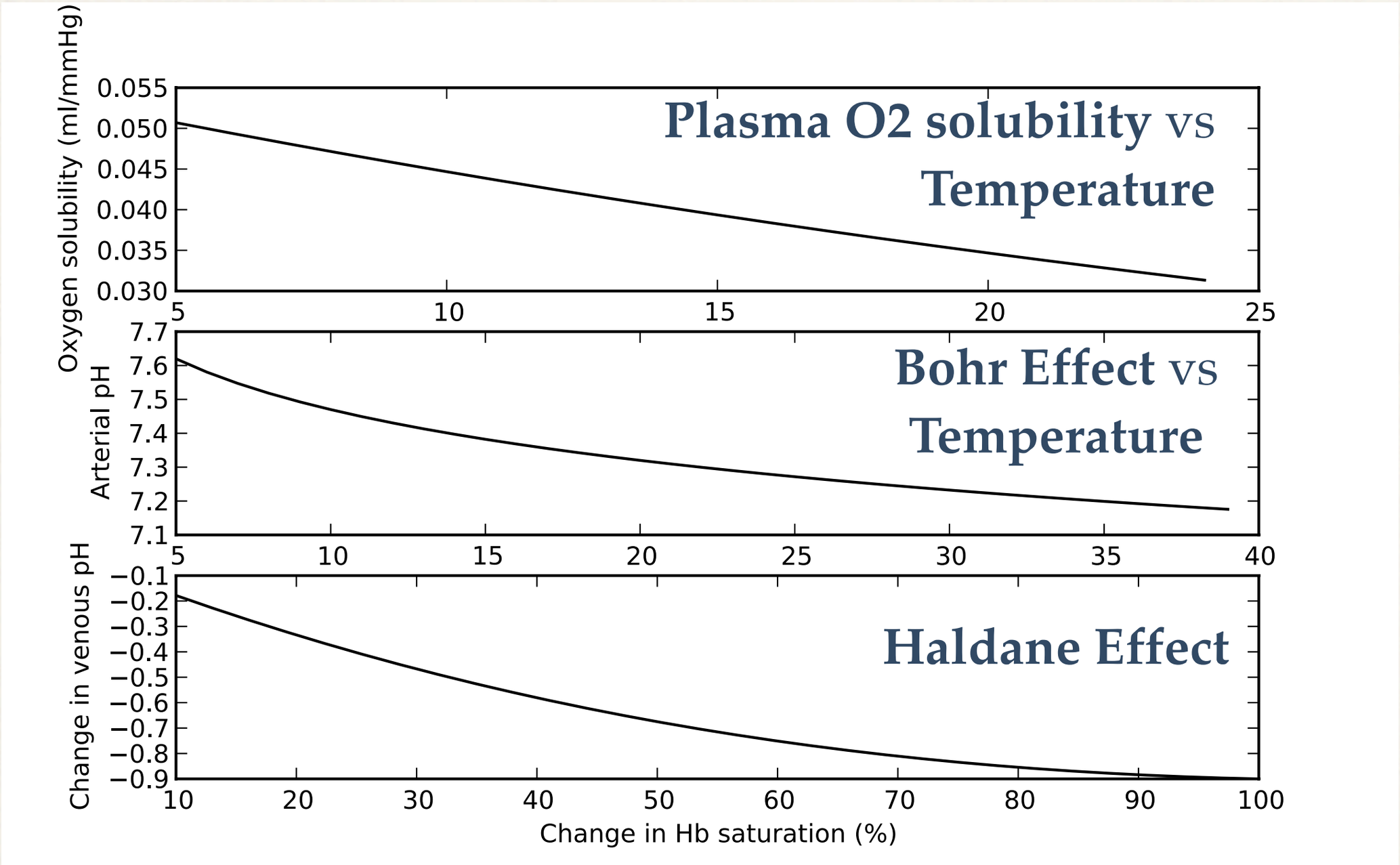
Key Data Inputs

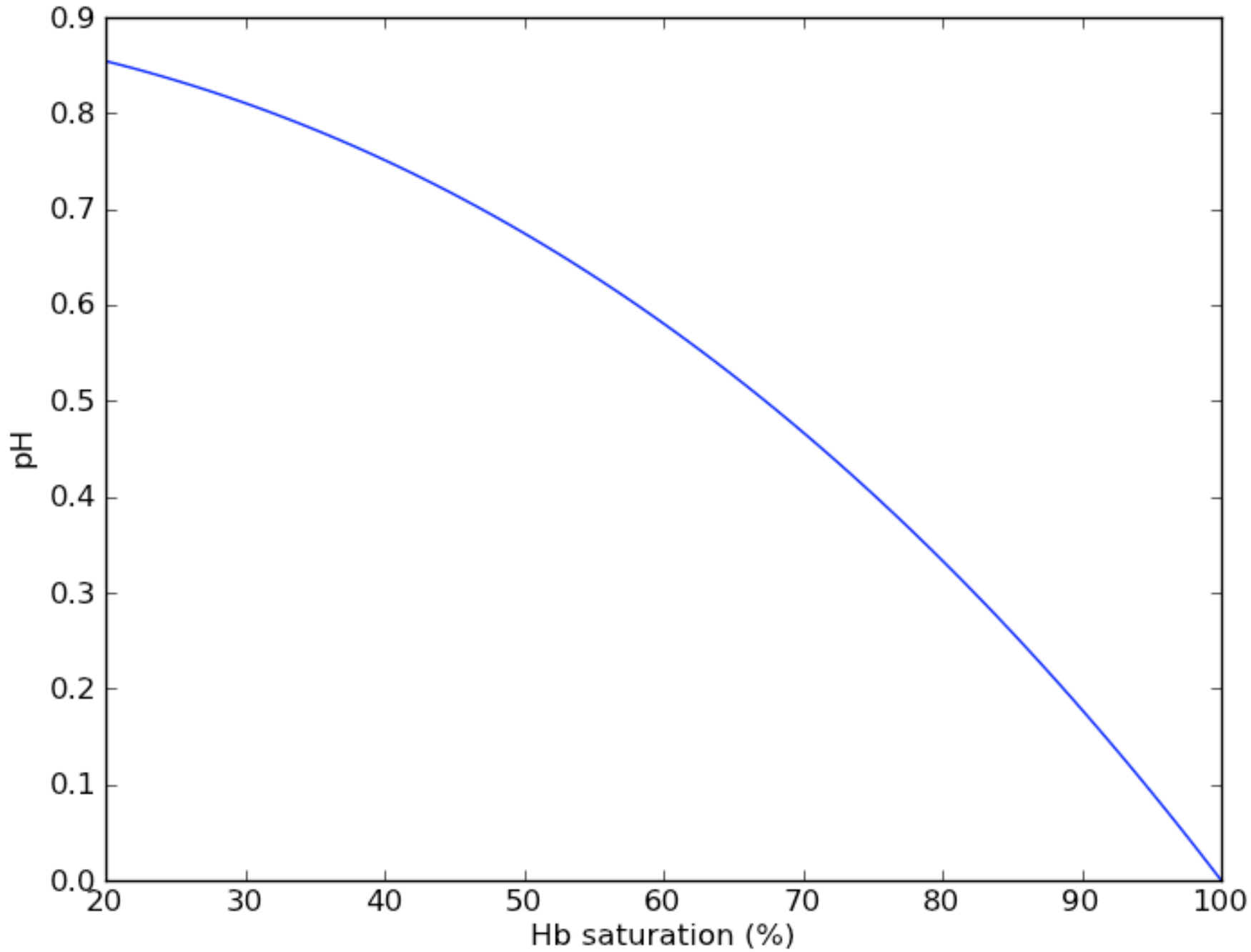
1. Blood pCO2 vs. RBC pH	*Brill et al. 1998*
2. O2 solubility in plasma	*Graham, 1987*
3. Temperature and O2 vs. peak Q	*Farwell et al. 1997*
4. Q10 Effect	*Dewar and Graham 1994*
5. Haldane Effect	*Lowe, Brill & Cousins 2000*
6. Heat of oxygen binding	*Lowe, Brill & Cousins 2000*
7. Bohr Effect	*Korsmeyer et al. 1997*


Oxygen solubility (ml/mmHg)
0.055
0.050
0.045
0.040
0.035
0.030
5
10
15
20
25
Arterial pH
7.7
7.6
7.5
7.4
7.3
7.2
7.1
5
10
15
20
25
30
35
40
Change in venous pH
−0.1
−0.2
−0.3
−0.4
−0.5
−0.6
−0.7
−0.8
−0.9
10
20
30
40
50
60
70
80
90
100
Change in Hb saturation (%)


Plasma O2 solubility vs Temperature
Oxygen solubility (ml/mmHg)
0.055
0.050
0.045
0.040
0.035
0.030
5
10
15
20
25
Arterial pH
7.7
7.6
7.5
7.4
7.3
7.2
7.1
5
10
15
20
25
30
35
40
Change in venous pH
−0.1
−0.2
−0.3
−0.4
−0.5
−0.6
−0.7
−0.8
−0.9
10
20
30
40
50
60
70
80
90
100
Change in Hb saturation (%)


Plasma O2 solubility vs Temperature
Oxygen solubility (ml/mmHg)
0.055
0.050
0.045
0.040
0.035
0.030
5
10
15
20
25
Bohr Effect vs Temperature
Arterial pH
7.7
7.6
7.5
7.4
7.3
7.2
7.1
5
10
15
20
25
30
35
40
Change in venous pH
−0.1
−0.2
−0.3
−0.4
−0.5
−0.6
−0.7
−0.8
−0.9
10
20
30
40
50
60
70
80
90
100
Change in Hb saturation (%)


Plasma O2 solubility vs Temperature
Oxygen solubility (ml/mmHg)
0.055
0.050
0.045
0.040
0.035
0.030
5
10
15
20
25
Bohr Effect vs Temperature
Arterial pH
7.7
7.6
7.5
7.4
7.3
7.2
7.1
5
10
15
20
25
30
35
40
Haldane Effect
Change in venous pH
−0.1
−0.2
−0.3
−0.4
−0.5
−0.6
−0.7
−0.8
−0.9
10
20
30
40
50
60
70
80
90
100
Change in Hb saturation (%)


0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
pH
20
30
40
50
60
70
80
90
100
Hb saturation (%)