Process Ecology: A Step Beyond Physics

Robert E. Ulanowicz
Arthur R. Marshall Laboratory
University of Florida

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Physics is inadequate to deal with:

- **History**
- **Dimensionality**
- **Logic**
- **Sufficiency**
- **Contingency**

Dimensionality

Physics ~ Objects moving to reversible *timeless* laws

vs.

Life ~ Configuration of irreversible *temporal* processes

Logic?

(Whitehead & Russell 1913)

Laws are logically equivalent to operations on homogeneous sets.

N for ecosystems often > 100 or 1,000

Sufficiency?

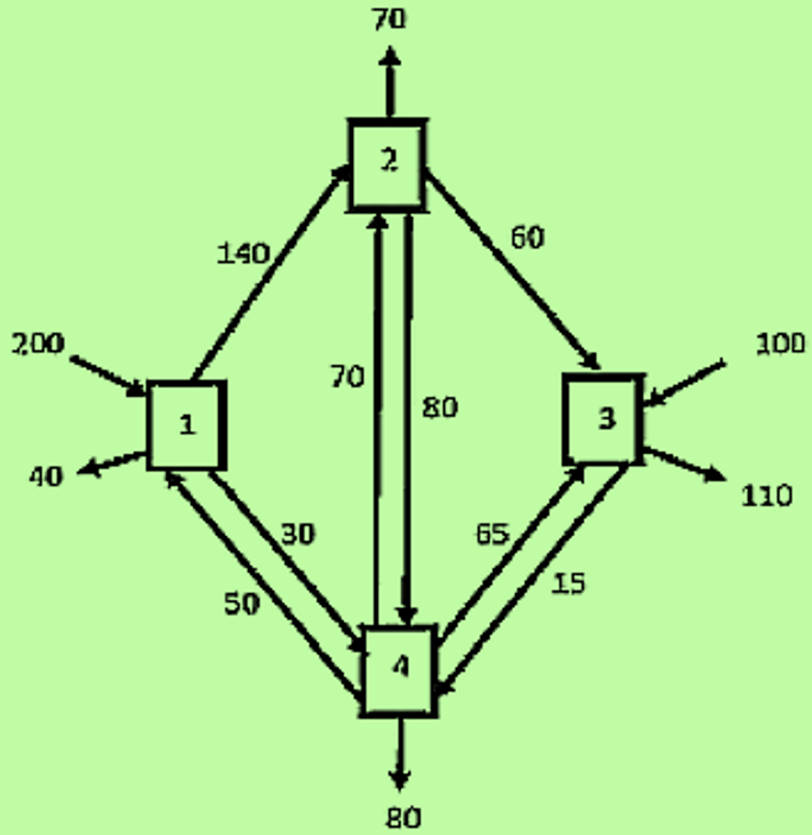
Roughly N! boundary value statements

$100! \sim 9.3 \times 10^{157}$

But only 10^{81} simple particles in *entire* universe!

$=>$ Boundary value is “unprestateable” (Kauffman)

Networks as Matrices



(a)

	1	2	3	4	Export
1	0	140	0	50	40
2	0	0	60	80	70
3	0	0	0	65	110
4	30	70	15	0	80
Import	200	0	100	0	0

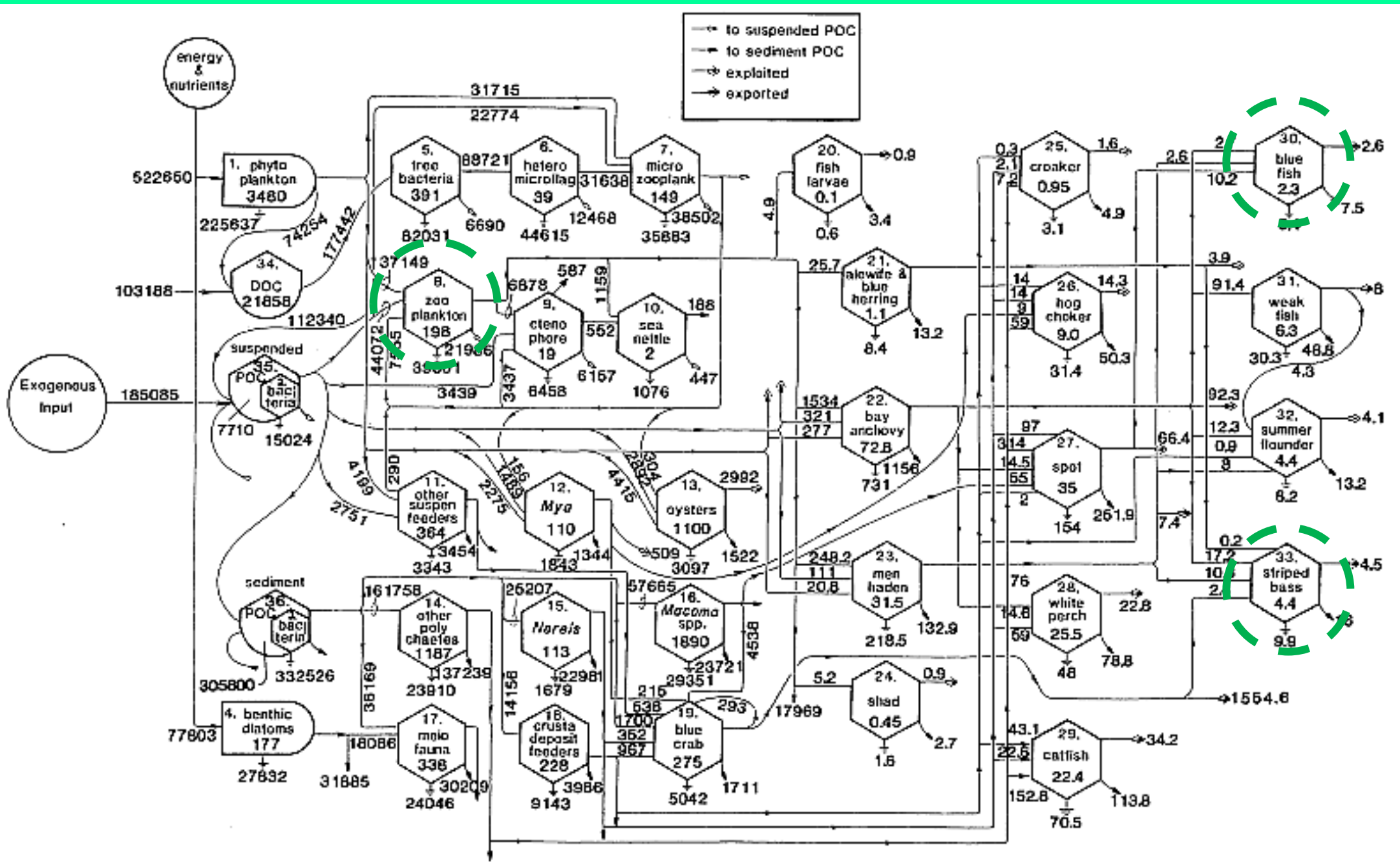
(b)

Flows Matrix

	1	2	3	4
1	0	140	0	50
2	0	0	60	80
3	0	0	0	65
4	30	70	15	0
Import	200	0	100	0
Tot. In	230	210	175	195

Dietary Matrix [G]

	1	2	3	4
1	0	0.667	0	0.256
2	0	0	0.343	0.411
3	0	0	0	0.333
4	0.13	0.333	0.086	0
Import	0.87	0	0.571	0
Diet	1.0	1.0	1.0	1.0


to suspended POC
to sediment POC
exploited
exported
energy & nutrients
Exogenous Input
185085
522650
103188
1. phyto plankton 3480
225637
74254
17442
34. DOC 21858
112340
suspended
35. POC + bacteria
7710
15024
sediment
36. POC + bacteria
305800
332526
4. benthic diatoms 177
77803
27632
31885
5. free bacteria 391
89721
82031
6690
6. hetero microflag 39
31638
44615
12468
7. micro zooplank 149
35883
38502
8. zoo plankton 198
37149
9. ctenophore 19
6878
587
8458
6157
10. sea nettle 2
1159
552
1076
188
447
3439
3437
44072
11. other suspen feeders 364
3454
3343
12. Mya 110
1344
1843
13. oysters 1100
2992
509
3097
1522
14. other polychaetes 1187
161758
137239
23910
15. Nereis 113
25207
22981
1679
16. Macoma spp. 1890
57665
23721
29351
4538
17. majo fauna 338
18086
30209
24046
18. crusta deposit feeders 228
14156
3986
9143
19. blue crab 275
1700
638
215
293
352
967
5042
1711
20. fish larvae 0.1
4.9
0.9
0.6
3.4
21. alewife & blue herring 1.1
25.7
8.4
13.2
22. bay anchovy 72.8
1534
321
277
731
1156
23. men haden 31.5
248.2
111
20.8
219.5
132.9
24. shad 0.45
5.2
0.9
1.6
2.7
17969
25. croaker 0.95
0.3
2.1
7.2
3.1
1.6
4.9
26. hog choker 9.0
14
14
9
59
31.4
14.3
50.3
27. spot 35
97
3.4
14.5
55
2
154
261.9
28. white perch 25.5
76
14.8
59
48
22.8
78.8
29. catfish 22.4
43.1
22.5
152.8
70.5
34.2
113.8
30. blue fish 2.3
2
10.2
7.5
31. weak fish 6.3
3.9
91.4
30.3
48.8
4.3
8
32. summer flounder 4.4
92.3
12.3
0.9
3
6.2
4.1
13.2
33. striped bass 4.4
0.2
17.2
10
2
9.9
4.5
66.4
7.4
1554.6

Indirect Dependencies

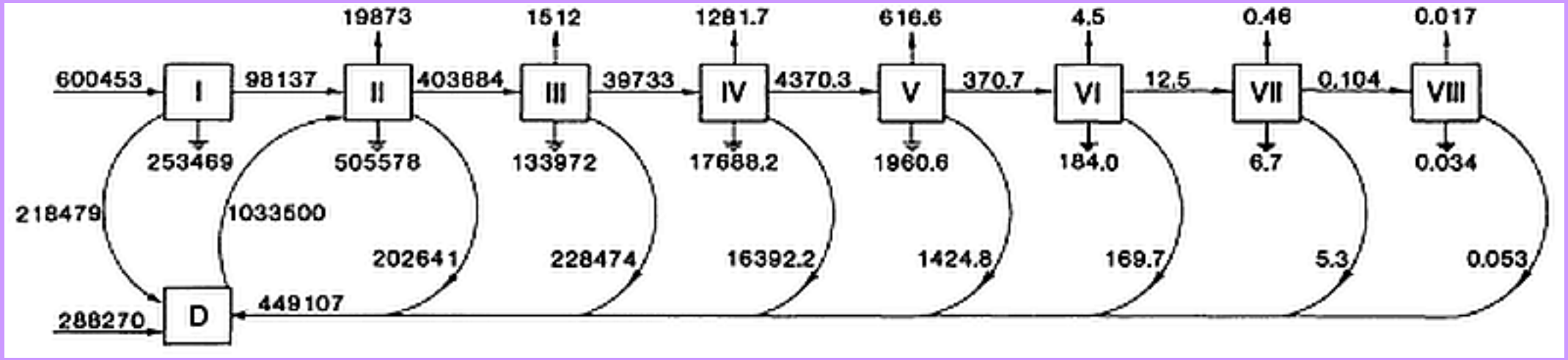
Striped Bass (a midwater predator) depends indirectly on zooplankton for 65.8 % of sustenance..

Bluefish (a bottom predator) depends indirectly on zoopankton for only 28.7% of its sustenance.

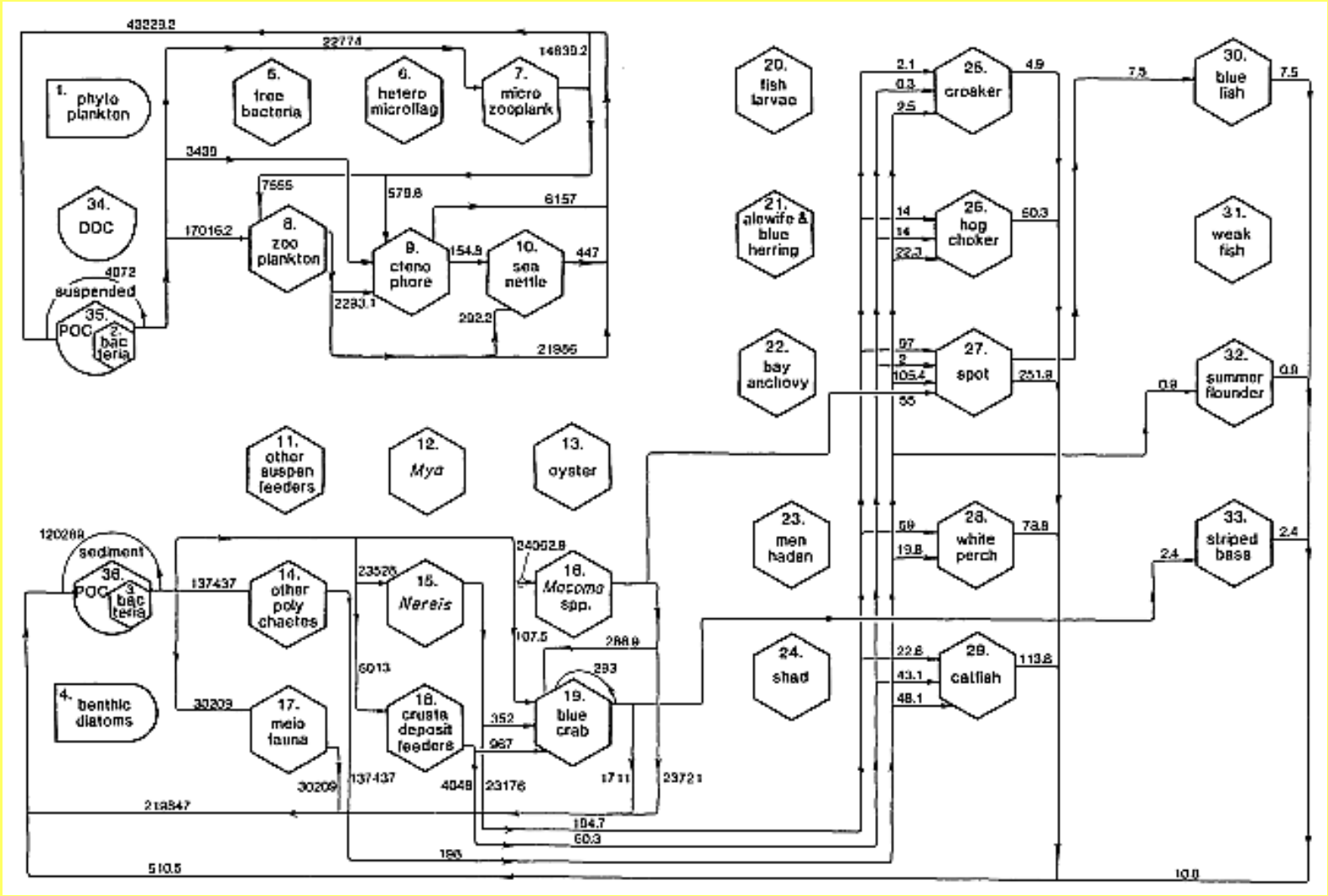
Effective Trophic Positions

Trophic ranking	Effective trophic level	Trophic ranking	Effective trophic level
1. Phytoplankton	1.00	19. *Nereis*	3.00
2. Dissolved organic carbon	1.00	20. *Macoma* spp.	3.00
3. Suspended POC	1.00	21. Crustacean deposit feeders	3.00
4. Sediment POC	1.00	22. Ctenophores	3.03
5. Benthic diatoms	1.00	23. Fish larvae	3.16
6. Suspended POC bacteria	2.00	24. Alewife and blue herring	3.16
7. Sediment POC bacteria	2.00	25. Shad	3.16
8. Free bacteria	2.00	26. Sea nettle	3.44
9. Oysters	2.08	27. Blue crab	3.51
10. *Mya arenaria*	2.09	28. Weakfish	3.84
11. Misc. suspension feeders	2.09	29. Striped bass	3.87
12. Zooplankton	2.16	30. Hogchoker	3.91
13. Meiofauna	2.67	31. White perch	3.98
14. Ciliates	2.75	32. Flounder	3.99
15. Menhaden	2.77	33. Spot	4.00
16. Bay anchovy	2.84	34. Croaker	4.00
17. Heterotrophic microflagellates	3.00	35. Catfish	4.00
18. Misc. polychaetes	3.00	36. Bluefish	4.59

Linear Trophic Pyramid



Aggregate Cycling in Chesapeake Mesohaline



Shannon Diversity

$$H = -\sum_{i,j} p_{ij} \log(p_{ij}) \geq 0$$

$$p_{ij} \sim \left(\frac{T_{ij}}{T_{..}}\right)$$

$$H = -\sum_{i,j} \left(\frac{T_{ij}}{T_{..}}\right) log \left(\frac{T_{ij}}{T_{..}}\right)$$

H as Complementary Components

$$H = -\sum_{i,j}\left(\frac{T_{ij}}{T_{..}}\right) log\left(\frac{T_{ij}}{T_{..}}\right)$$

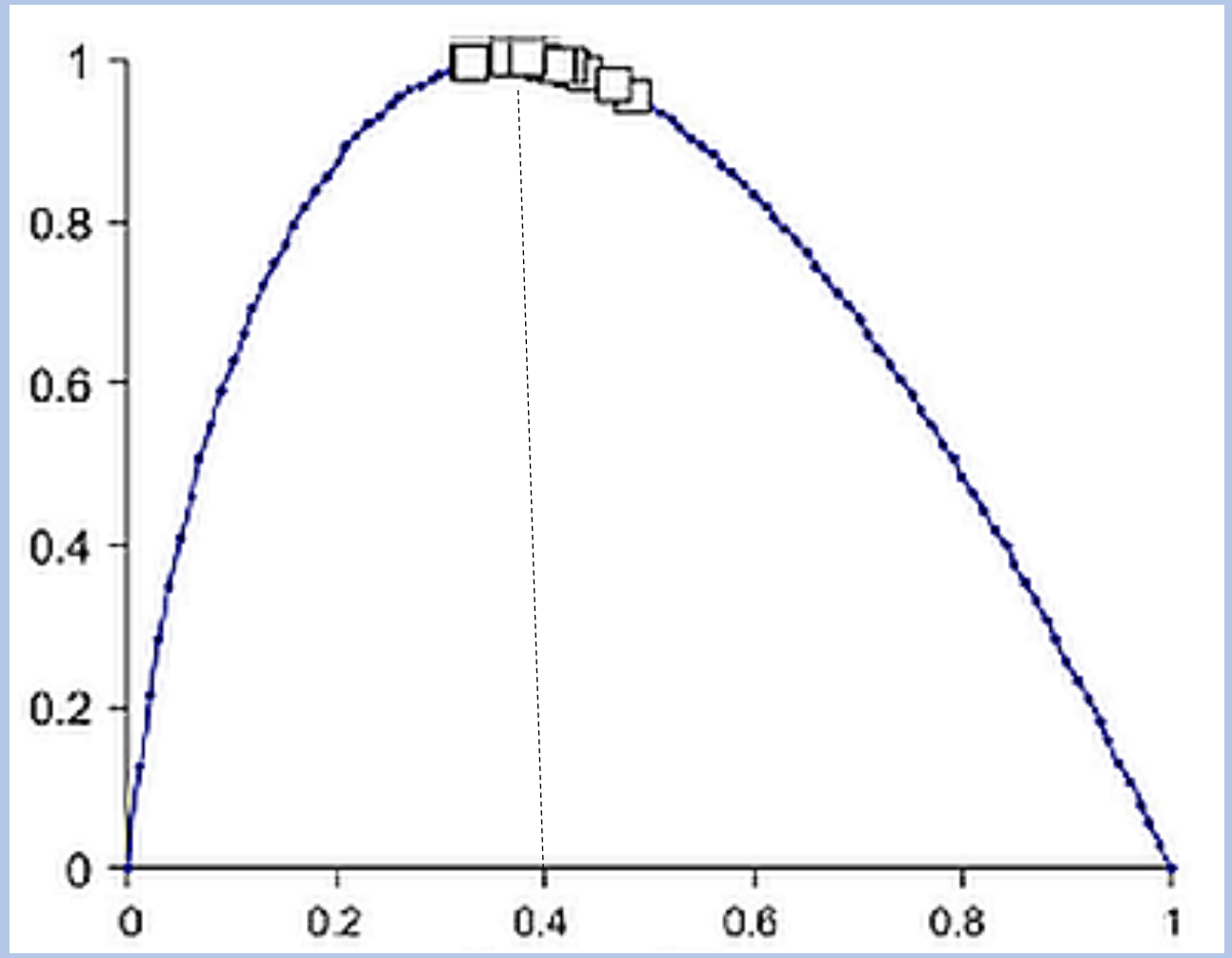
$$H = \sum_{i,j}\left(\frac{T_{ij}}{T_{..}}\right) \log\left(\frac{T_{ij}T_{..}}{T_{i.}T_{.j}}\right) - \sum_{i,j} \log\left(\frac{T_{ij}^2}{T_{i.}T_{.j}}\right)$$

H = A + Φ

(A, Φ both ≥ 0)

Cluster in “Window of Vitality”

F = -*ea*ln(*a*)
“Fitness”



$$a = \frac{A}{H}$$

$$1 \geq a \geq 0$$

a -- Degree of order

Changing T_{ij} to Optimize Fitness

$$\frac{\partial F}{\partial T_{ij}} = F' \frac{\partial a}{\partial T_{ij}} = 0$$

or

$$\frac{\partial F}{\partial T_{ij}} = \frac{F'}{C} \left\{ \log \left[\frac{T_{ij} T_{..}}{T_{i.} T_{.j}} \right] + a \log \left[\frac{T_{ij}^2}{T_{i.} T_{.j}} \right] \right\},$$

where F' is the derivative of F with respect to a, i.e.,

$$F' = -ea \left[\frac{\log(a)}{\log(e)} + 1 \right].$$

Templeton Foundation Press, 2009