Food security, co-management and the ecosystem approach to fisheries

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African Great lakes Conference,
Entebbe 2-5 may

The big challenge

- With a growing population: How do we reconcile food and conservation?

Which fishing pattern gives the highest yield and least structural impact on the community ?

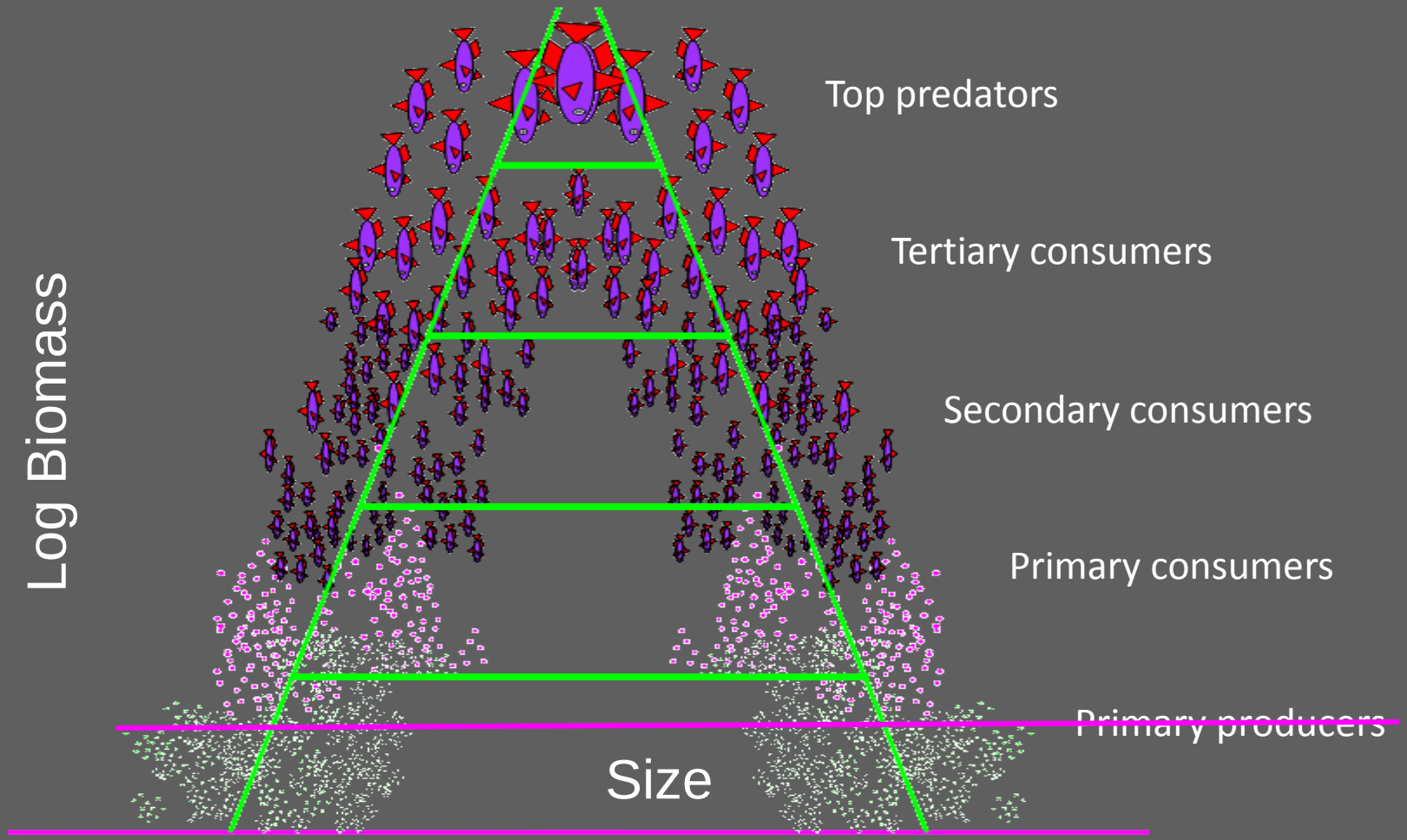
Johannesburg 2002 Declaration § 31 (a):

«Stocks should be kept at biomass levels that can produce maximum sustainable yields (MSY).»

CBD Malawi principles for Ecosystem Approach:

«A key feature of the ecosystem approach includes conservation of ecosystem structure and functioning»

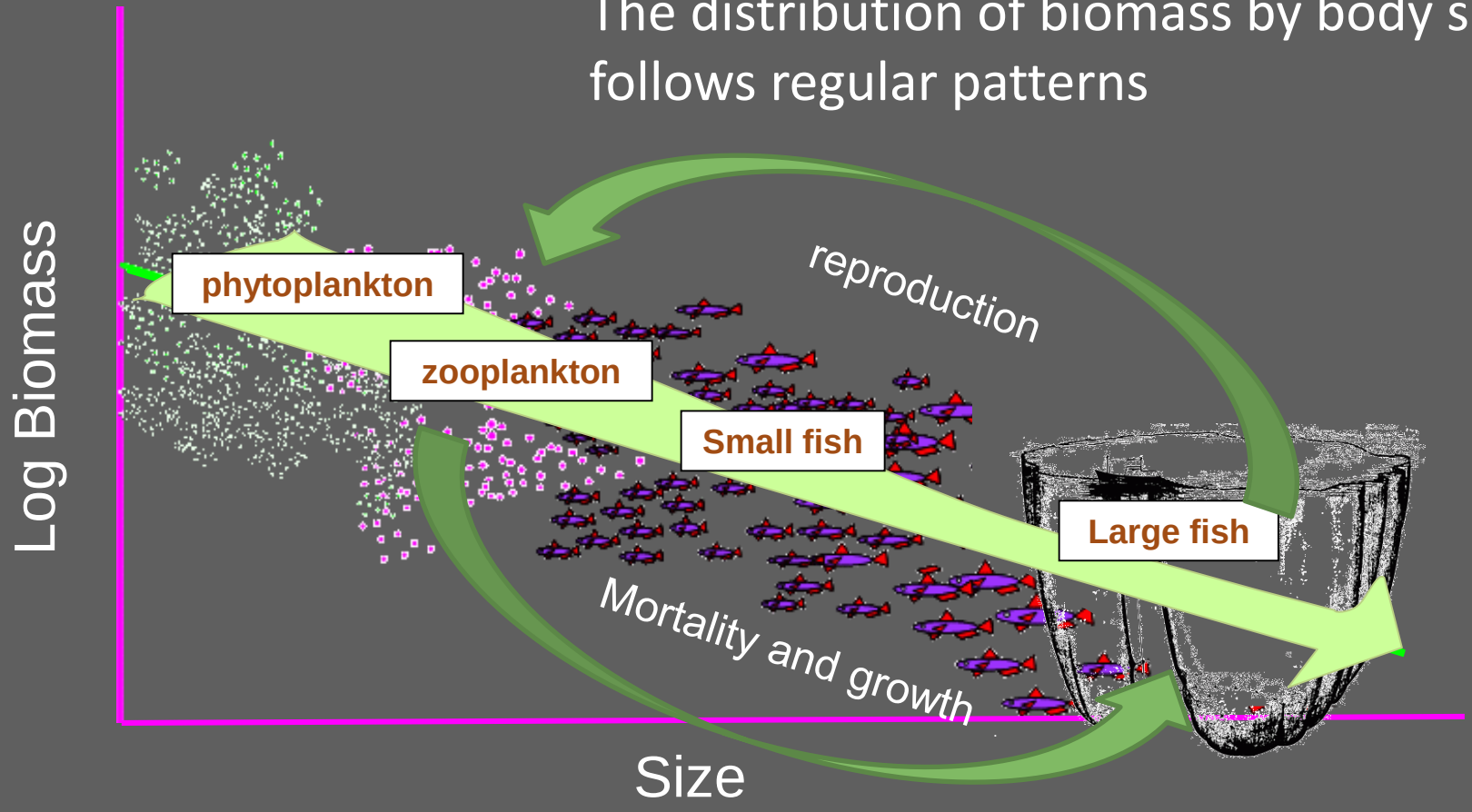
The aquatic food web is size structured…



..abundance is inversely correlated with size

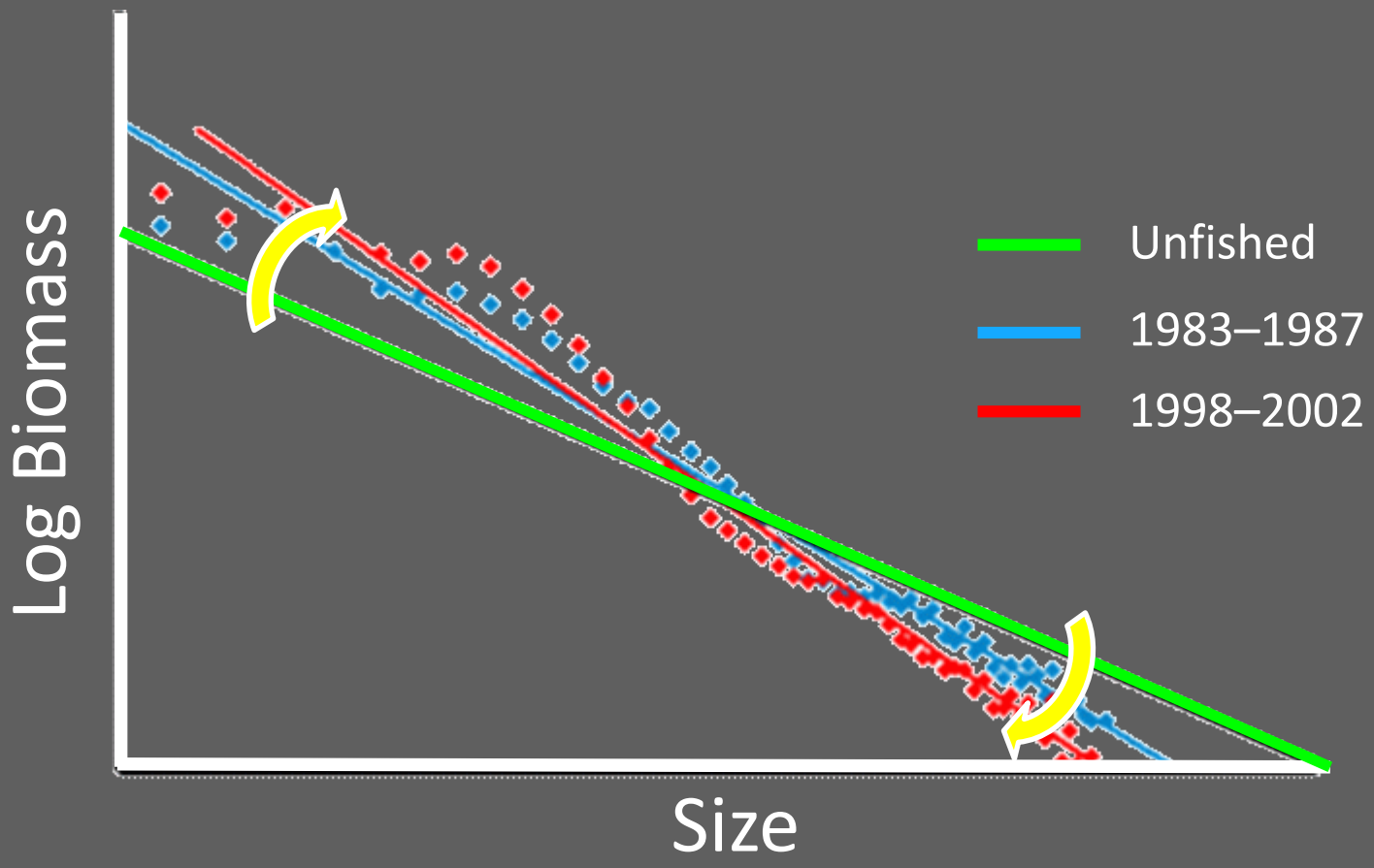
Community size spectrum

The distribution of biomass by body size follows regular patterns



Under conventional selective fishing slope and intercept will change

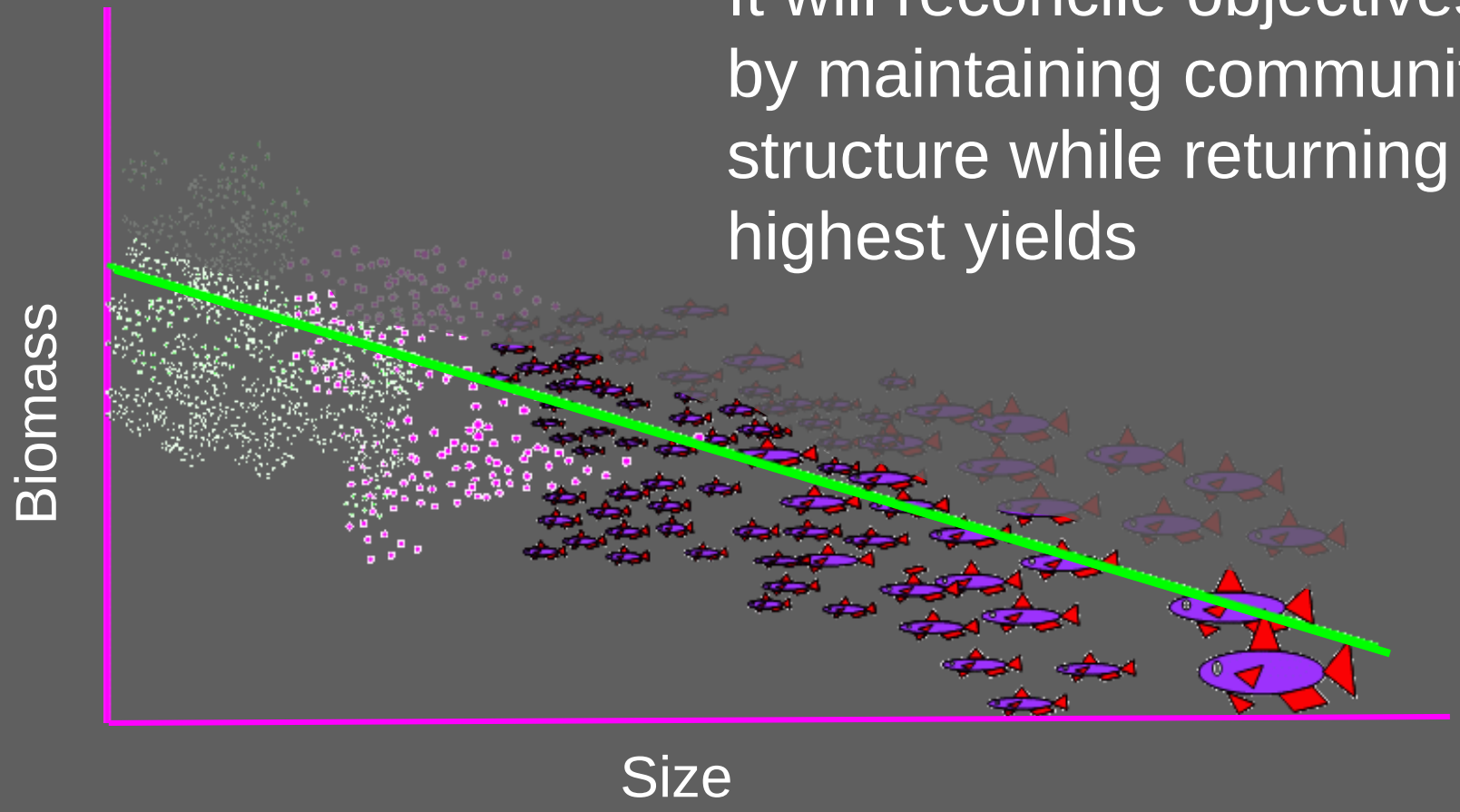
Changes in the North Sea



Garcia et al. 2012

Balanced harvesting… (Garcia et al 2012)

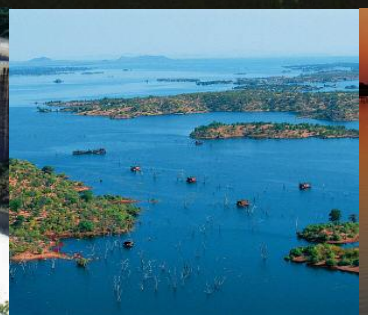
It will reconcile objectives by maintaining community structure while returning highest yields



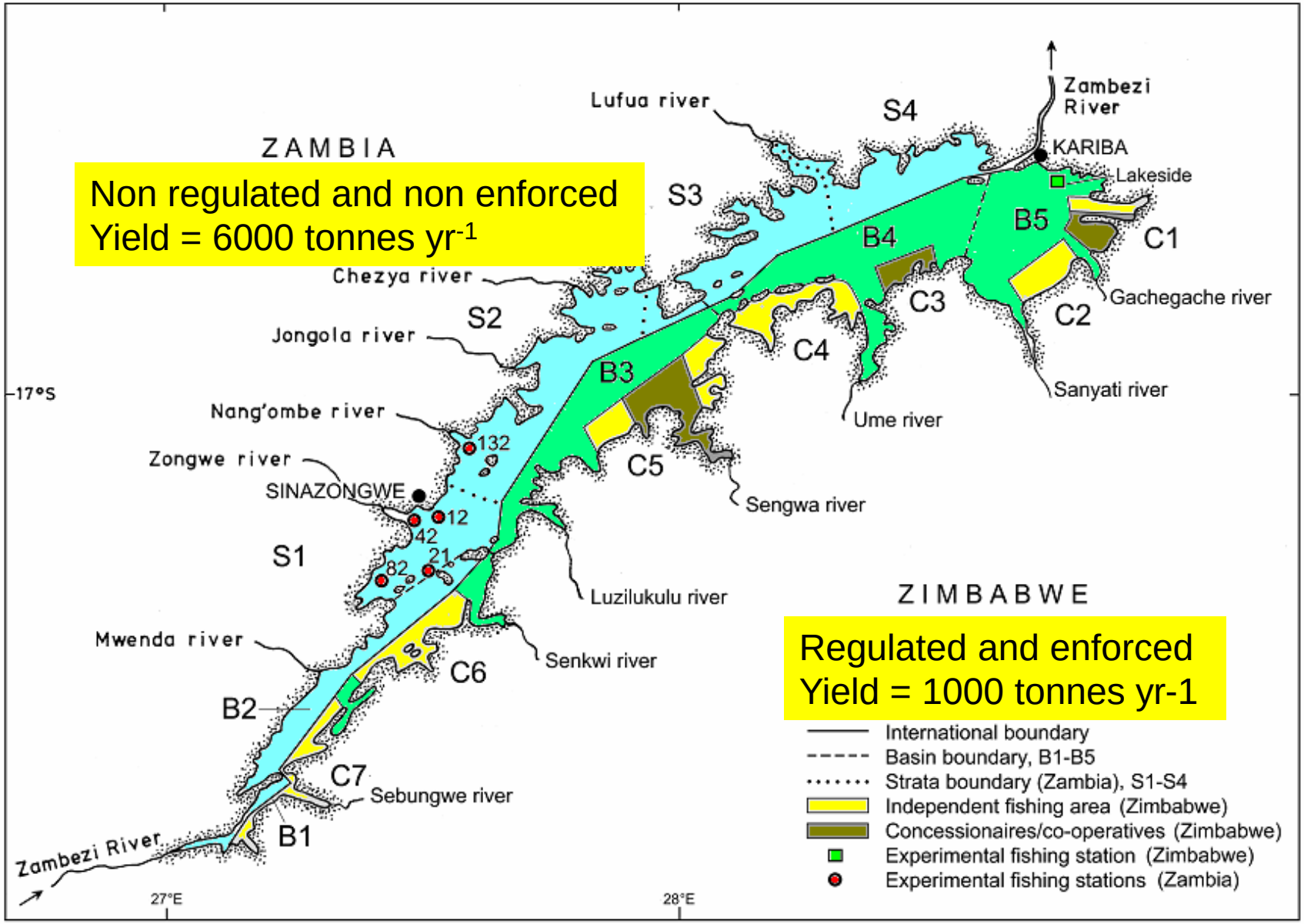
.. is fishing as many sizes and species as possible in proportion to natural productivity

Lake Kariba

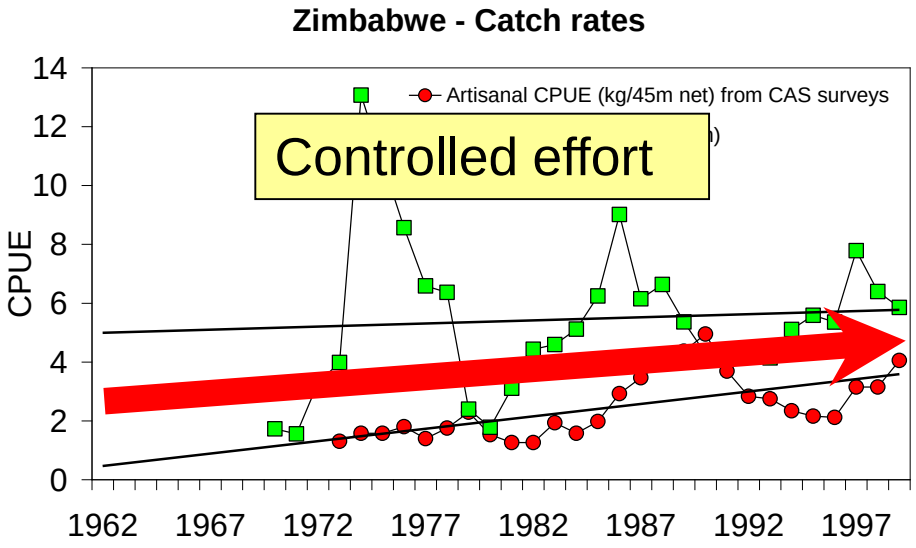
Zambezi River

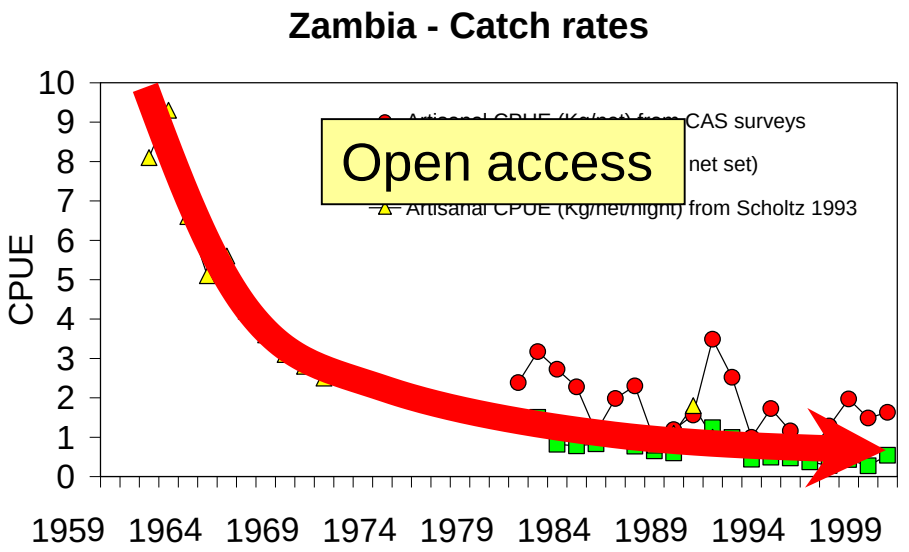


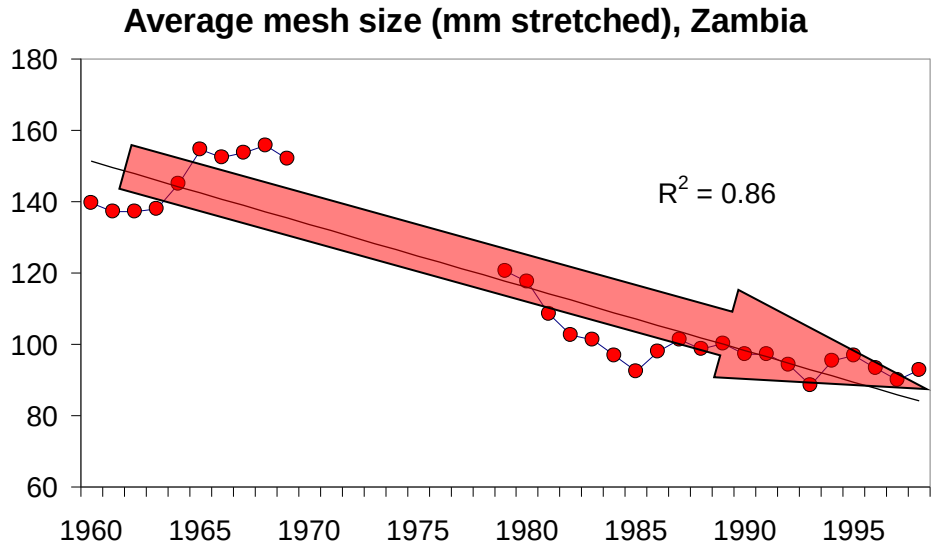
Lake Kariba


ZAMBIA
Non regulated and non enforced
Yield = 6000 tonnes yr-1
Lufua river
S4
Zambezi River
KARIBA
Lakeside
S3
B4
B5
C1
Chezya river
S2
Jongola river
C3
C2
Gachegache river
C4
B3
17°S
Nang'ombe river
Sanyati river
Ume river
132
Zongwe river
C5
SINAZONGWE
Sengwa river
12
42
S1
21
82
Luzilukulu river
ZIMBABWE
Regulated and enforced
Yield = 1000 tonnes yr-1
Mwenda river
Senkwi river
C6
B2
International boundary
Basin boundary, B1-B5
Strata boundary (Zambia), S1-S4
Independent fishing area (Zimbabwe)
Concessionaires/co-operatives (Zimbabwe)
Experimental fishing station (Zimbabwe)
Experimental fishing stations (Zambia)
C7
Sebungwe river
B1
Zambezi River
27°E
28°E

Lake Kariba

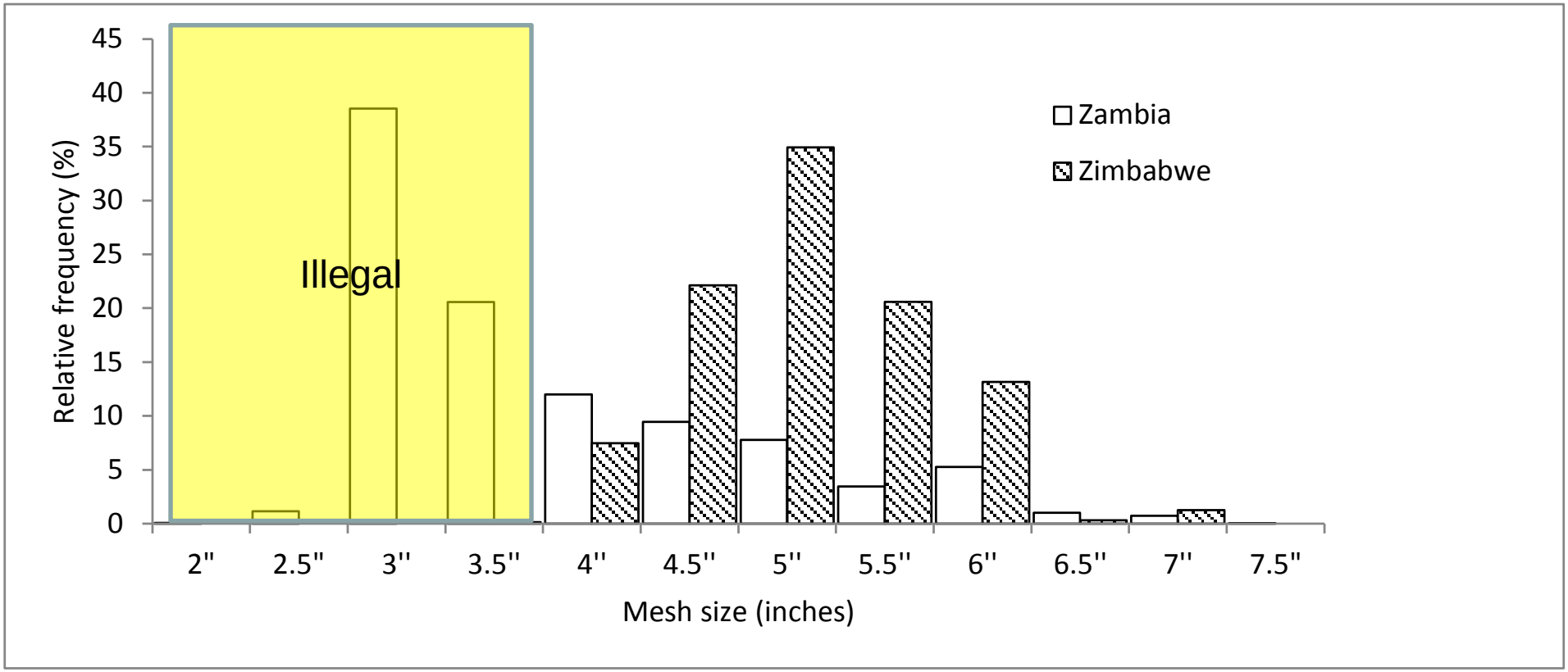




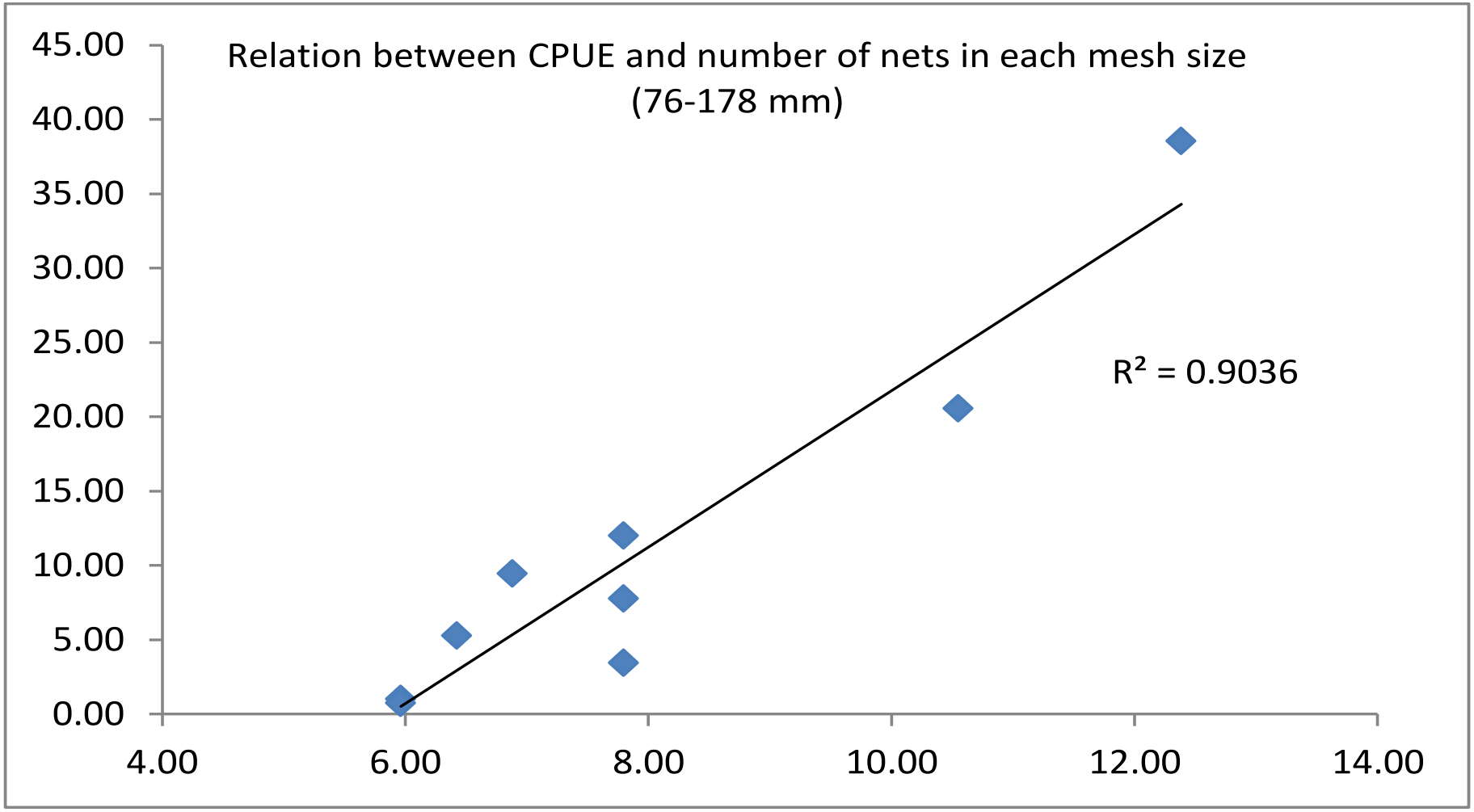


Kolding et al. (2003)

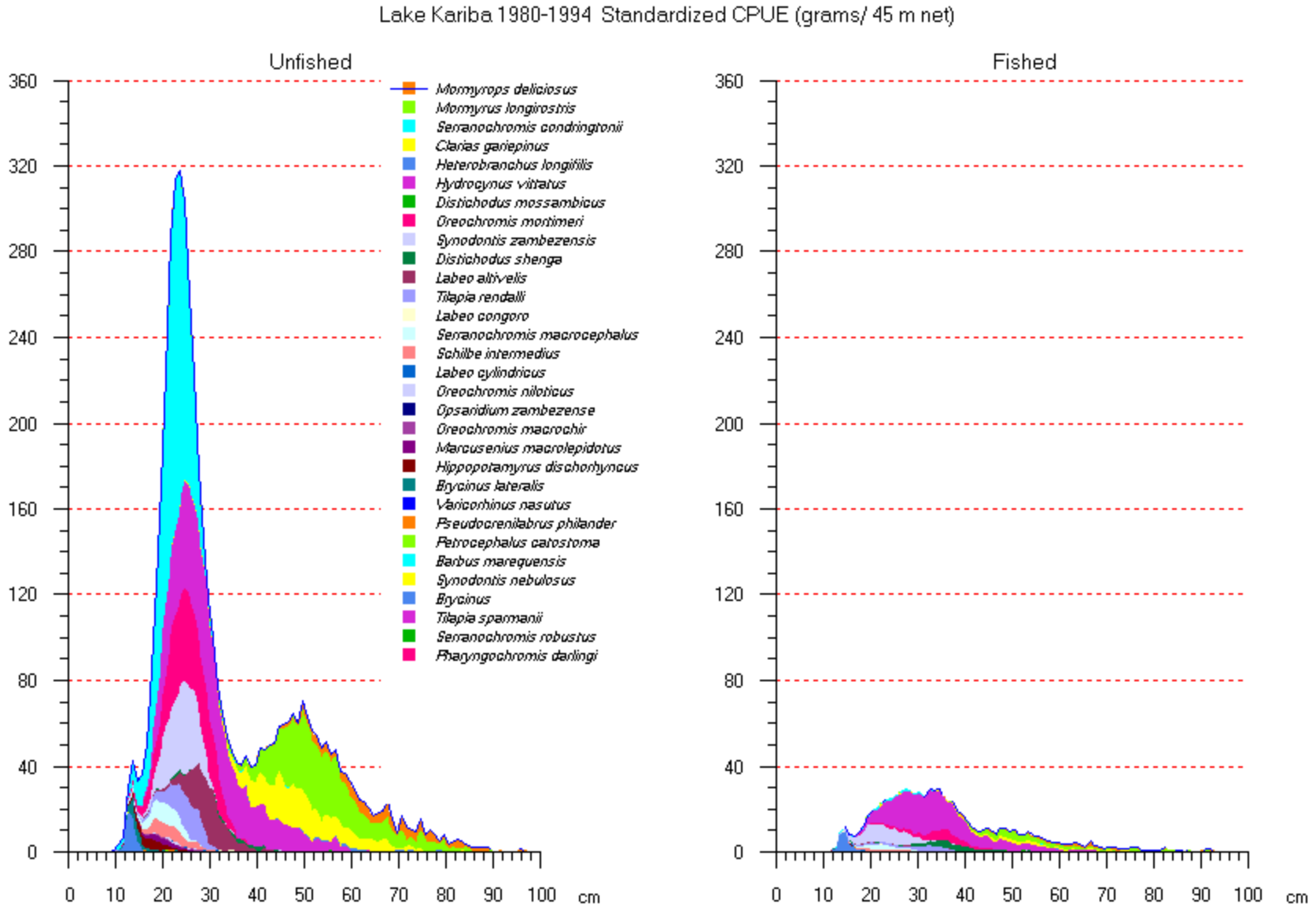
Mesh size distributions



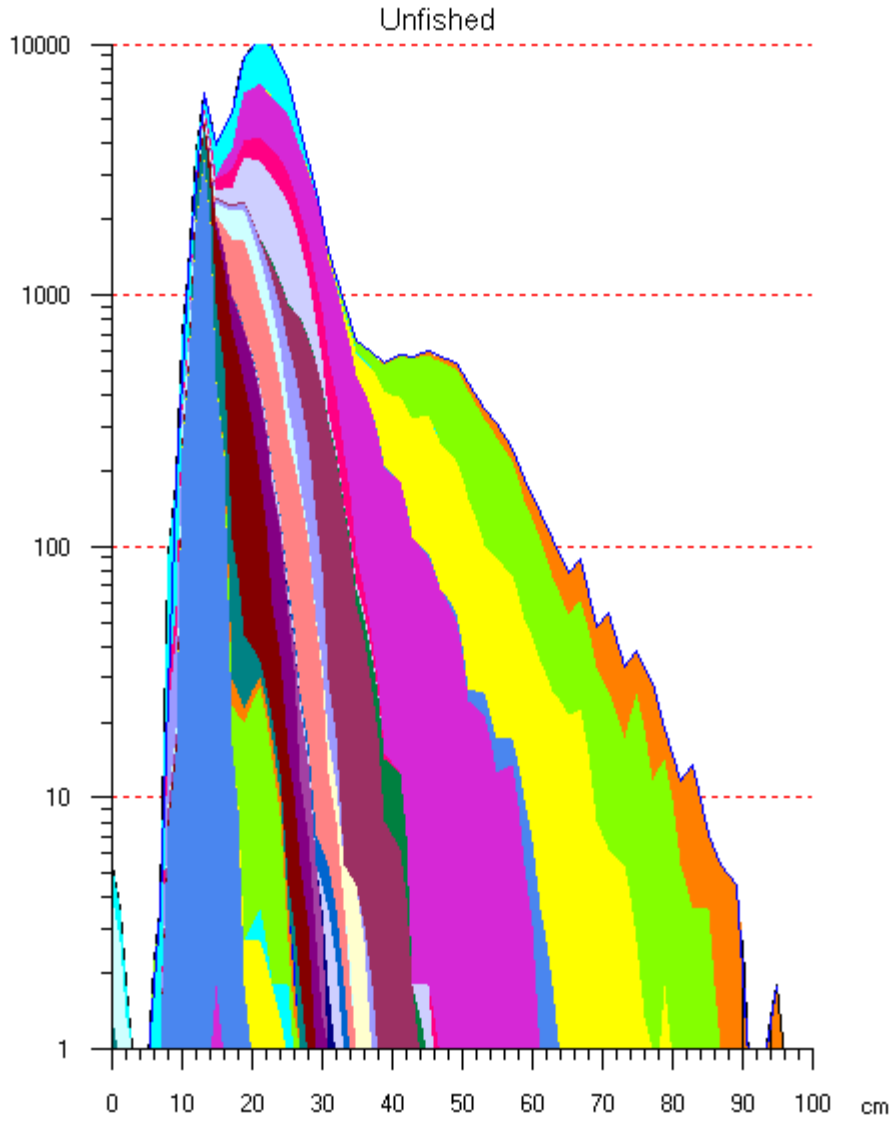
Mesh size distributions and catch rates (Zambia)

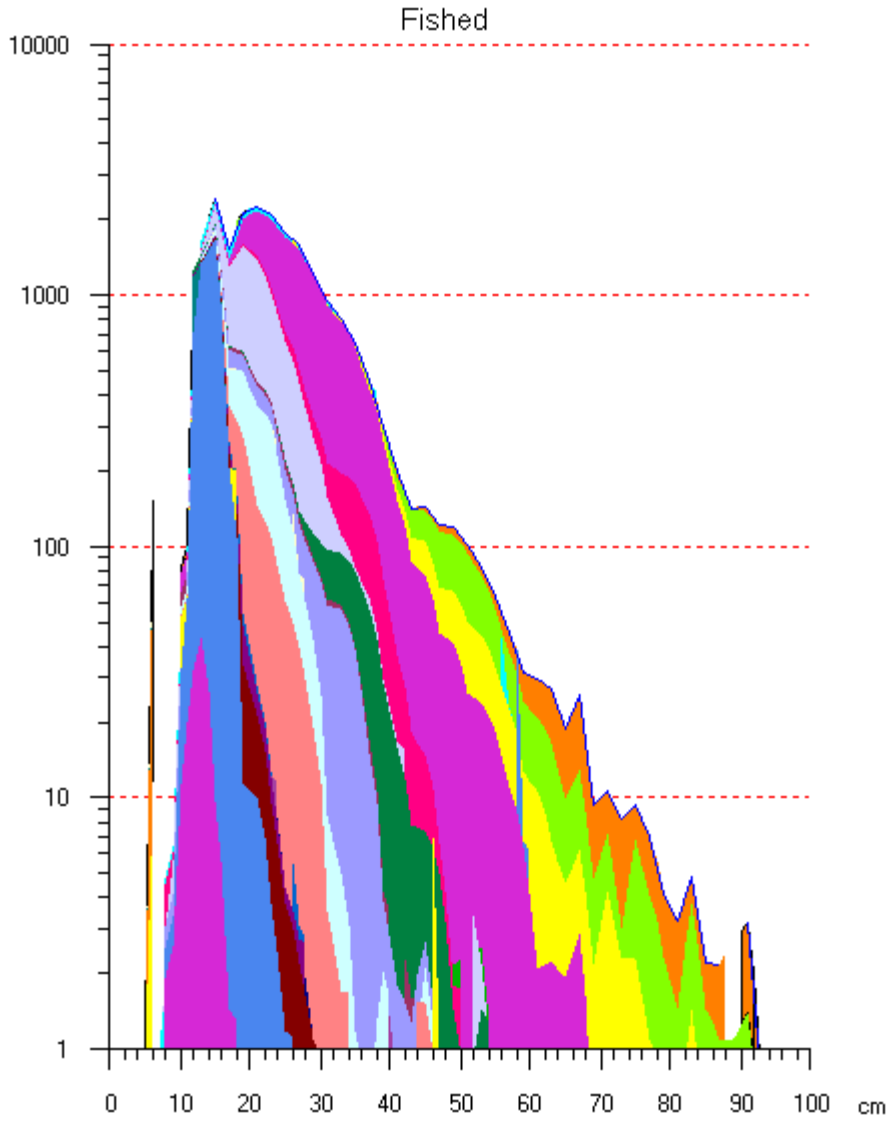


Comparison between unfished and heavily fished areas in Lake Kariba



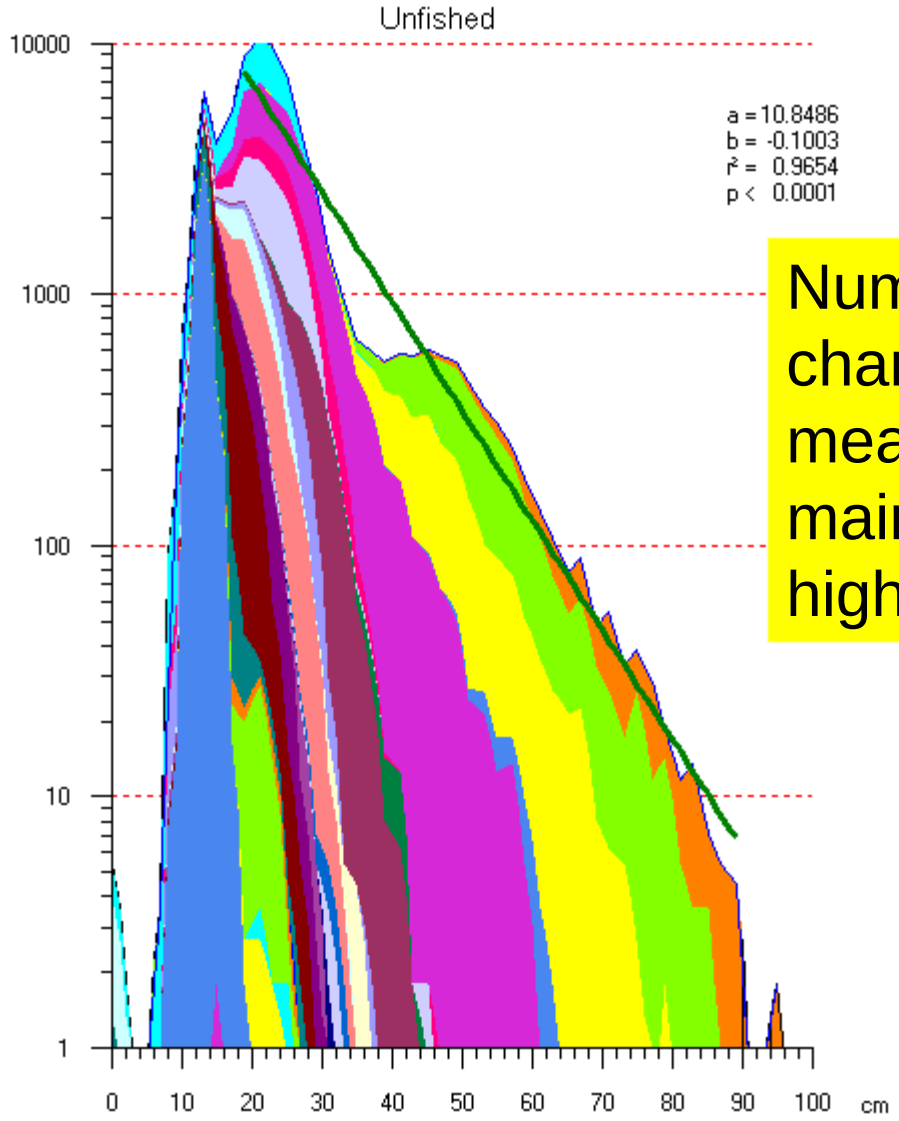
Comparison between unfished and heavily fished areas in Lake Kariba

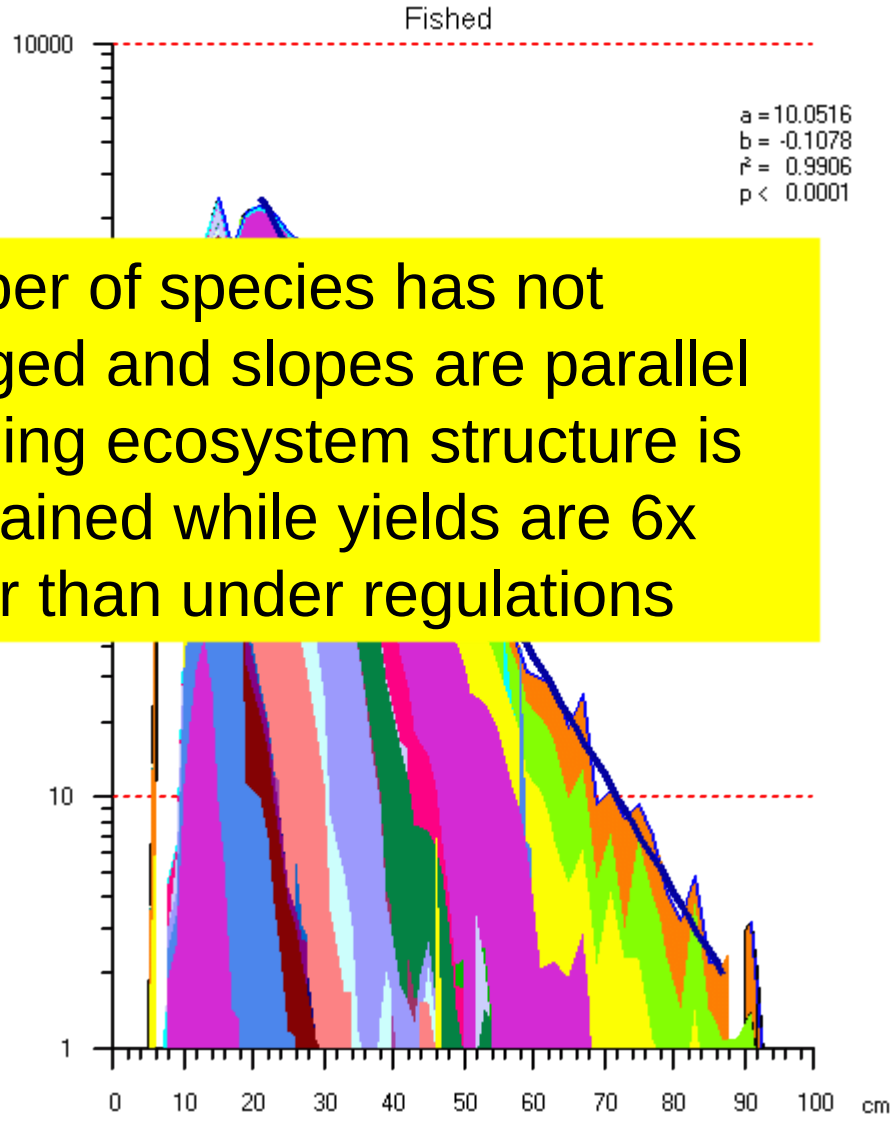




Kolding et al. 2015

Comparison between unfished and heavily fished areas in Lake Kariba

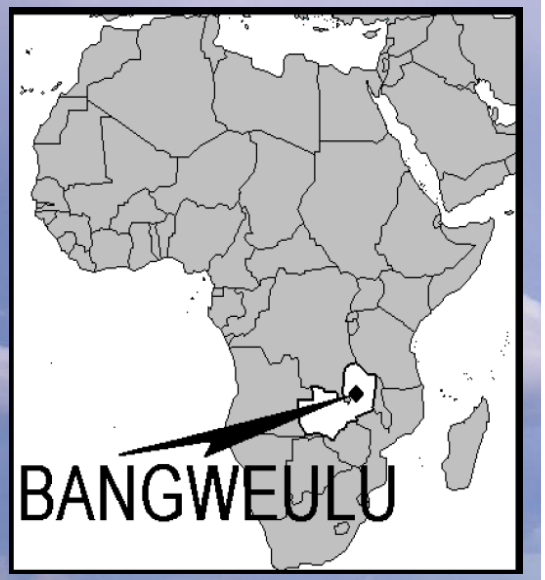


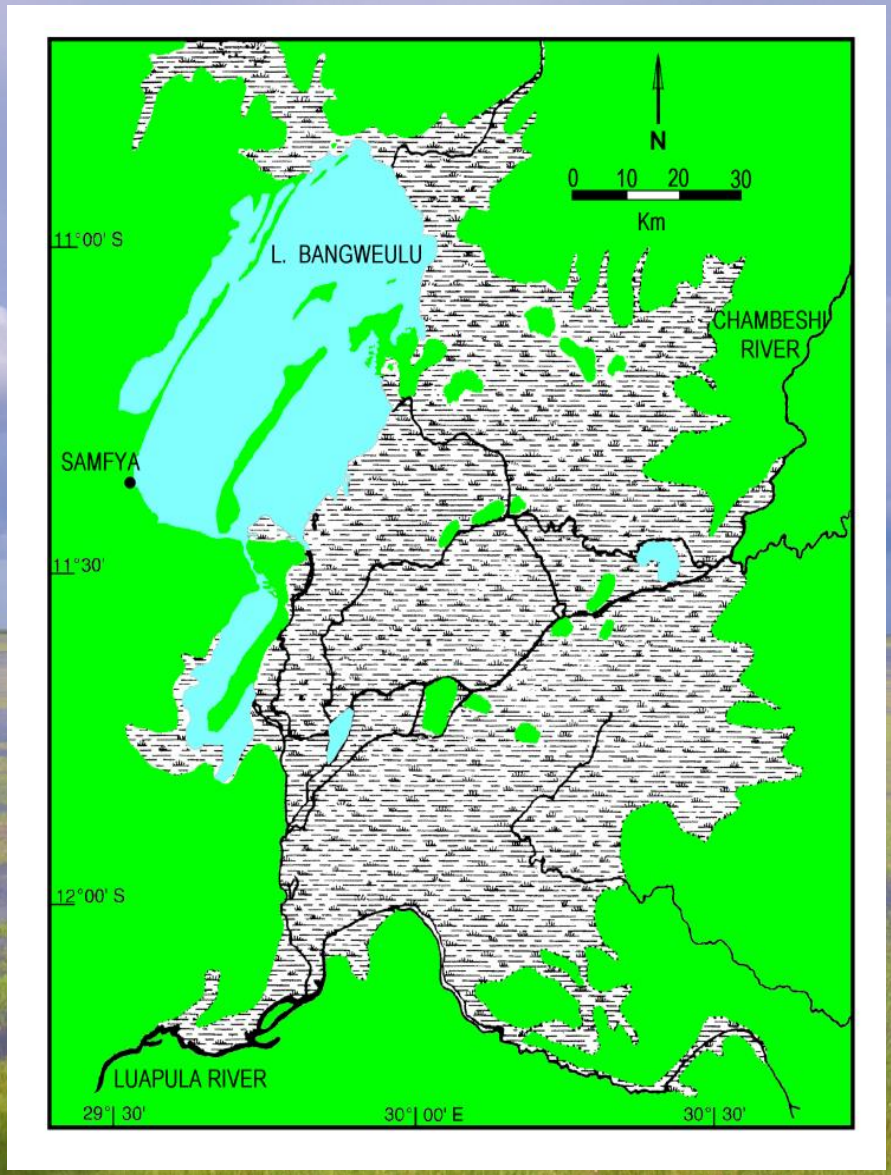


Number of species has not changed and slopes are parallel meaning ecosystem structure is maintained while yields are 6x higher than under regulations

Kolding et al. 2015

Bangweulu swamps Northern Zambia






Carl Huchzermeyer

Bangweulu swamps

- Fish are getting smaller
- Rampant use of illegal gears

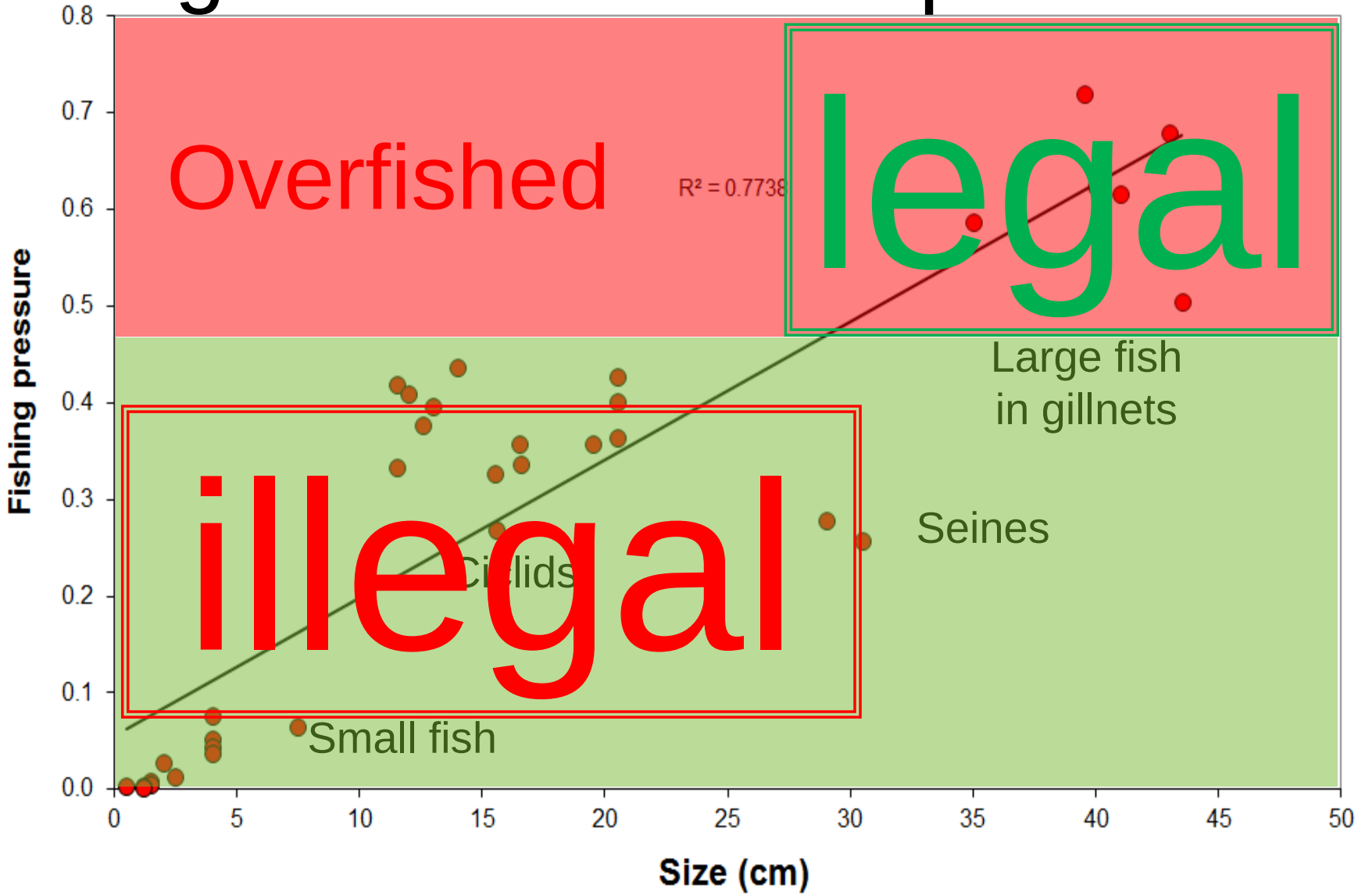
Bangweulu swamps Northern Zambia

Mesh size (mm)	Total number of gear by type				Mesh size cum %
	gillnets	kusikila	seines	weir traps	
3				3,869	13
4				8,358	41
6				2,32[illegible]	49
8				[illegible]87	50
10					
25	534	17	53	Ndang	52
38	6,719	68	17[illegible]	a	75
50	4,233	135	49		90
63	1,260	64[illegible]			97
76	554	[illegible]4			99
89	136	-			99
102	-				
114	-				
127	255				100
140	-				
Total:	13,691	937	280	14,936	29,844
%	46	3	1	50	100
% legal	22				

illegal

Species and size composition by gear

Only largest species in legal Fishing pressure versus size gillnets are overexploited



two multispecies fisheries

Celtic Sea (EU)

major commercial fishery

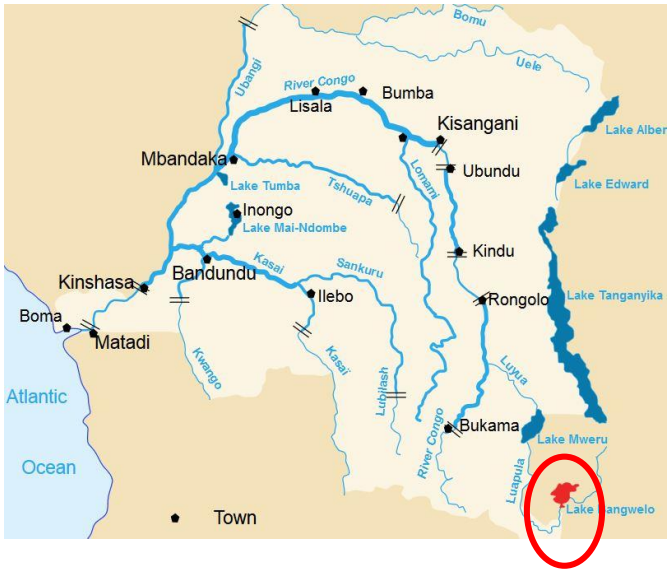
demersal, ~15 spp, trawls

quotas, minimum landing sizes

100,000 to 150,000 tonnes yr^{-1}

>1000 vessels

Bangweulu Swamps (Zambia)



small-scale artisanal fishery

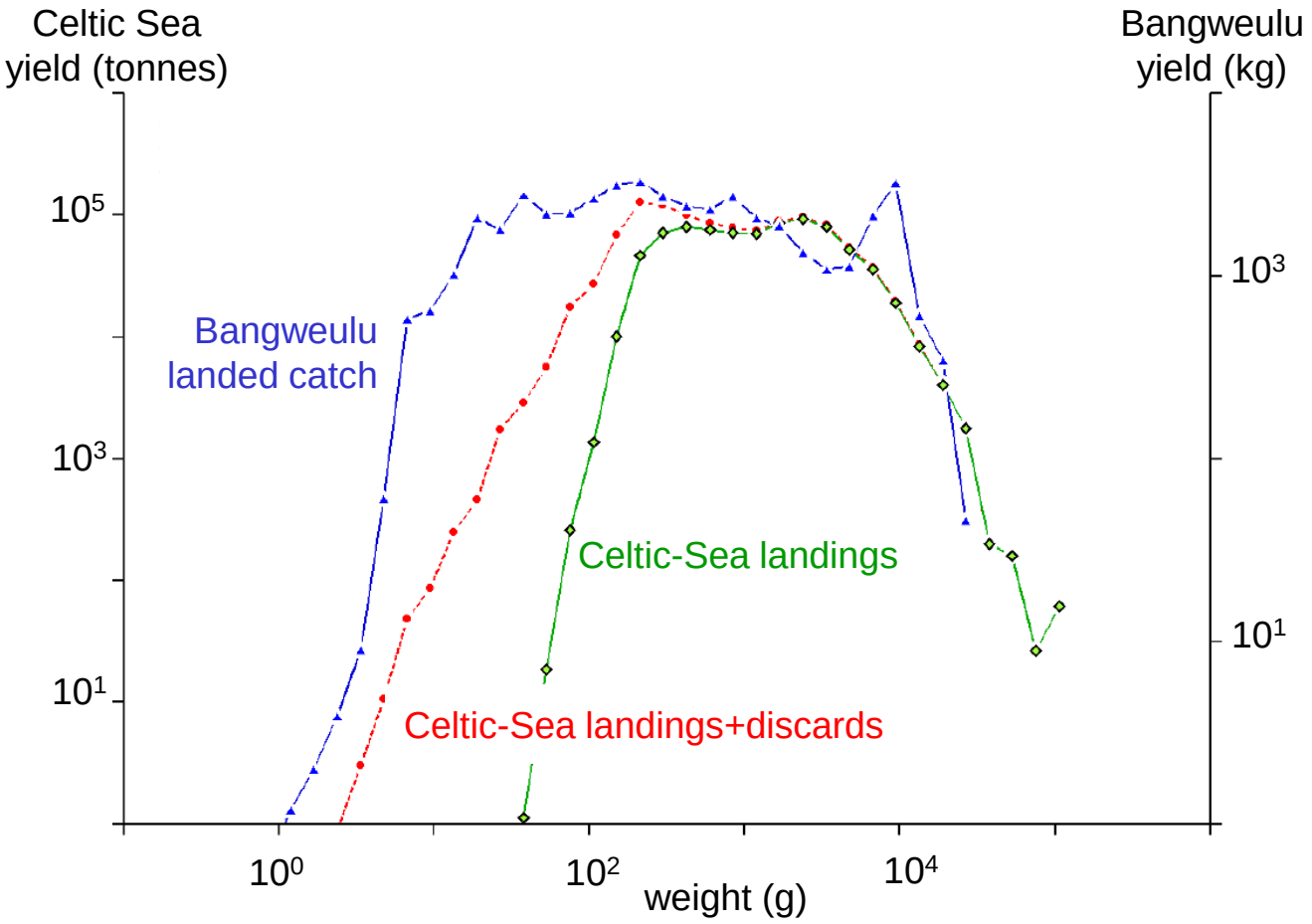
>30 spp, gillnets, seines, traps

largely unregulated

~15,000 tonnes yr^{-1}

~5000 fishers

size distributions of yield



biomass yields as a function over body mass
(aggregated over species)

Plank et al. 2016

size distributions of catch

smallest fish:

~250 g

~10 g

size limits not operating in Bangweulu

largest fish

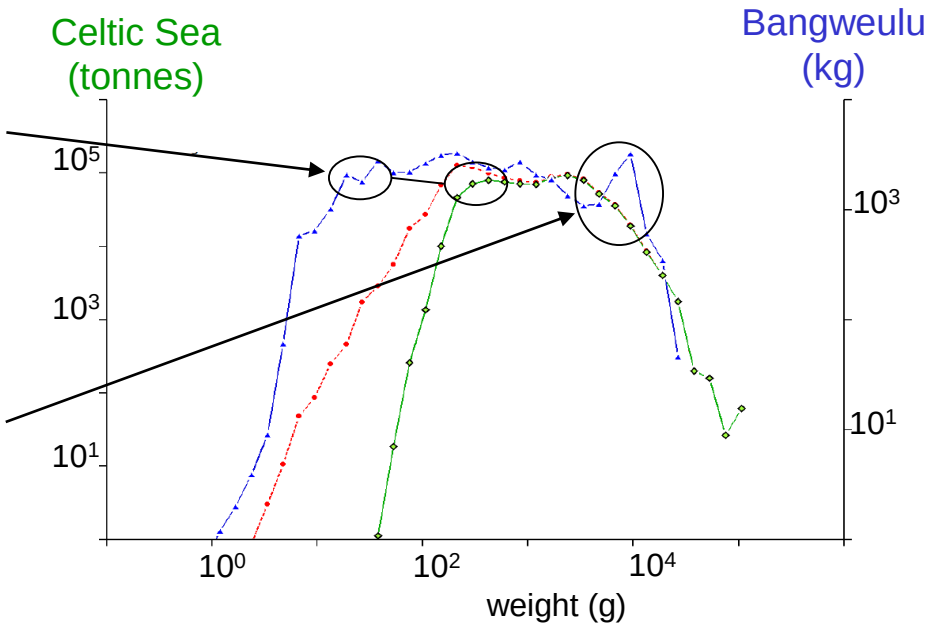
~5 kg (fish caught when smaller)

~10 kg (upper limits to growth)

range of body sizes

~20-fold

~1000-fold



both fisheries are sustainable

how is this possible?

model of an unregulated fishery:

fishers share an aquatic ecosystem (commons)

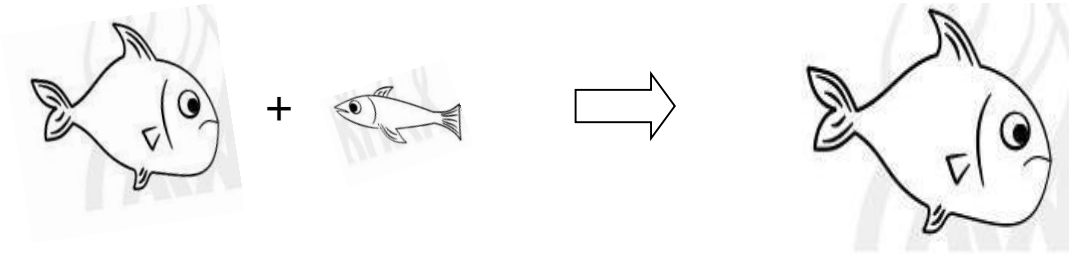
each fisher decides what **size** of fish to catch

what happens to the fish stock and catch?

how does fishing mortality $F(x)$, aggregated over fishers, get distributed over over fish body size x?

Dynamic size-spectrum model a different ecological model:

stochastic event

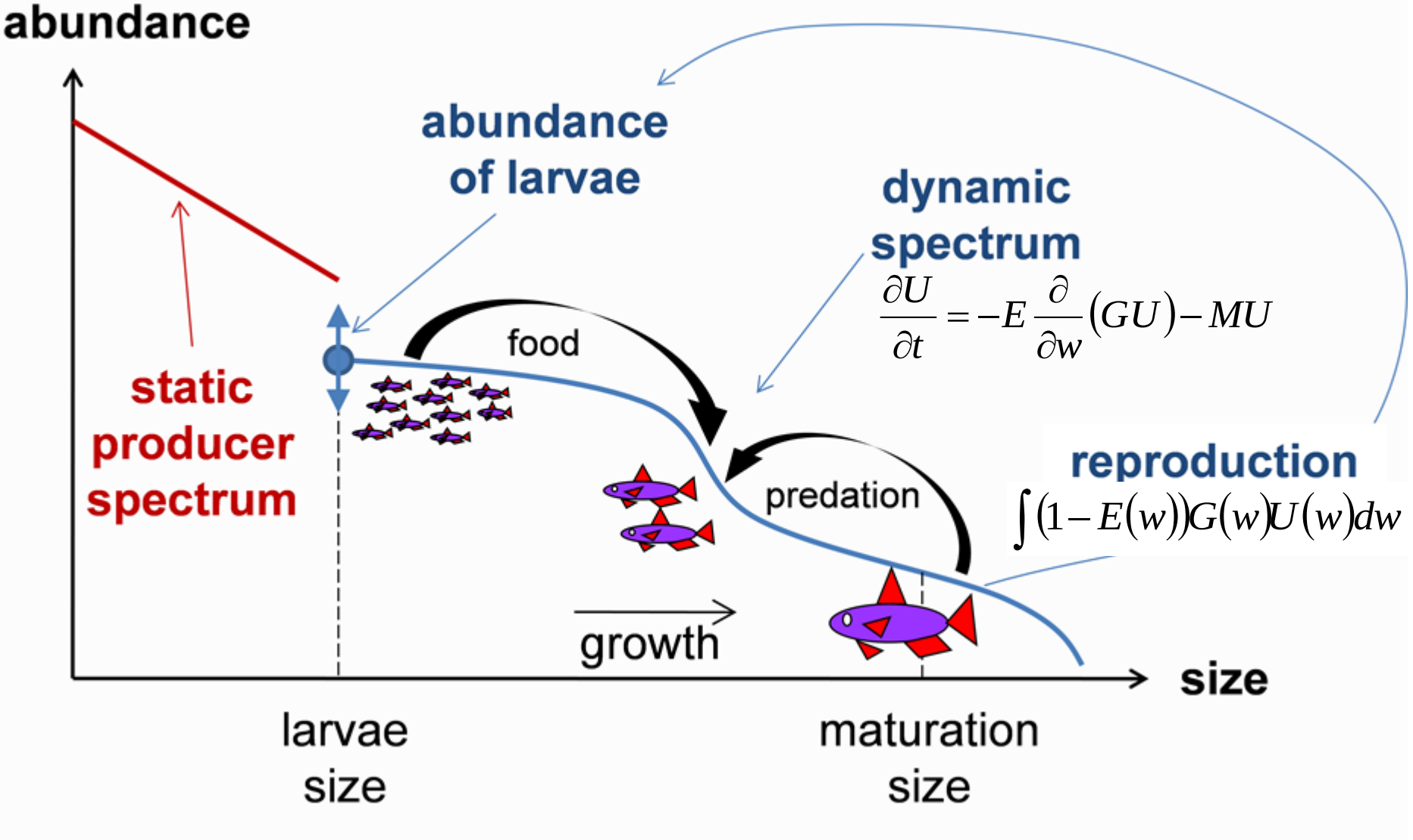


bookkeeping of biomass

w_a w_b ⇨ $w_c = w_a + Kw_b$

Model overview (Law et al. 2015)

1. The fish population

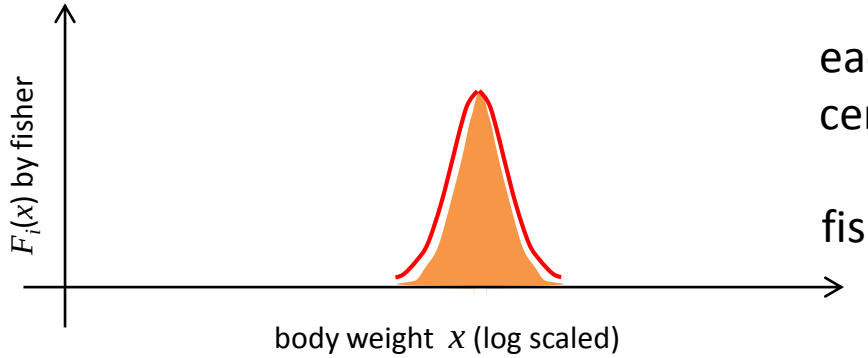


2. The fishers

- know nothing about ecology or size-spectrum dynamics
- do know their own catch, and the catch obtained by their neighbours – and their gears

From time to time he will evaluate his own catch (and gears) compared to those of his neighbours. If he catches less, he will tend to shift gear

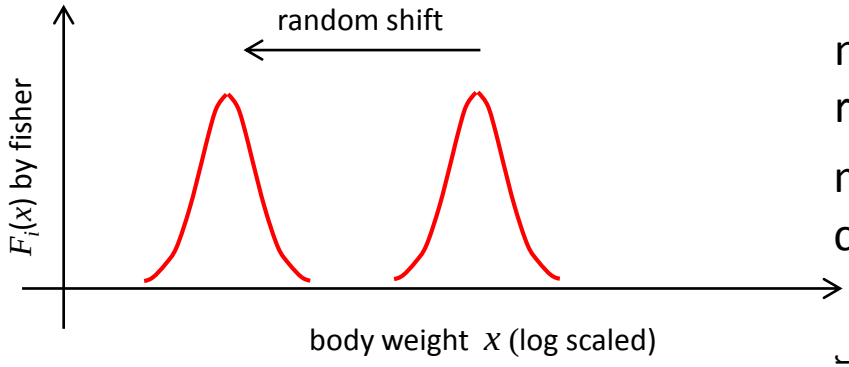
rule for each individual fisher



each fisher i chooses a net mesh centred on an arbitrary fish size

fishing effort is area under curve

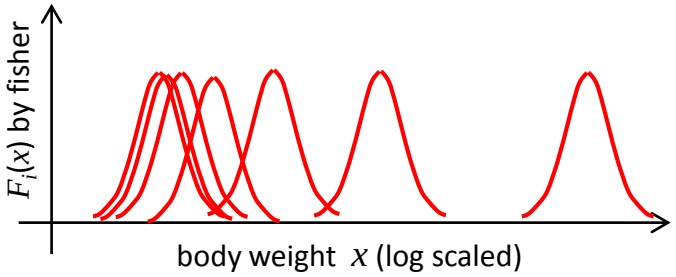
update net mesh from time to time



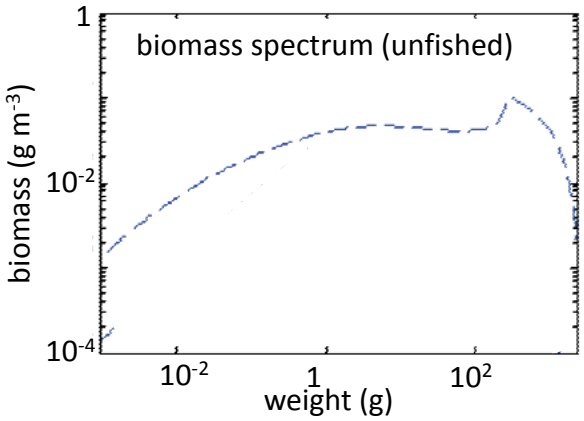
new net mesh size chosen uniformly at random on range of body sizes

more likely to move if his yield (cpue) is small compared to others: $1 - Y_i/\max(Y_j)$.

aggregate fishing mortality $F(x)$ sums over all fishers (simple SEES model)



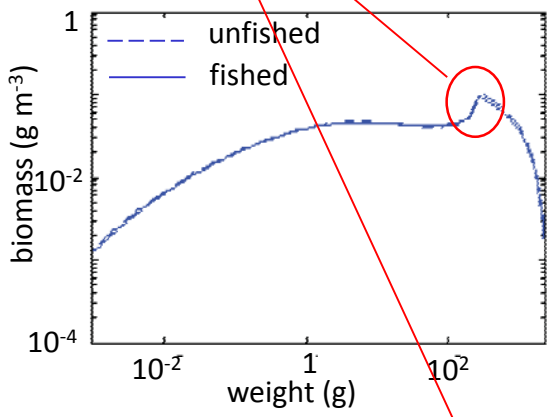
emergent aggregated $F(x)$

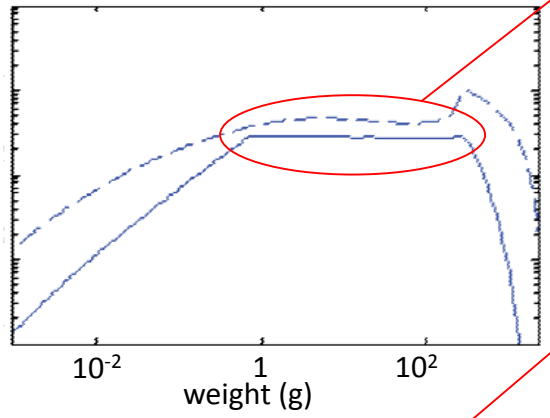


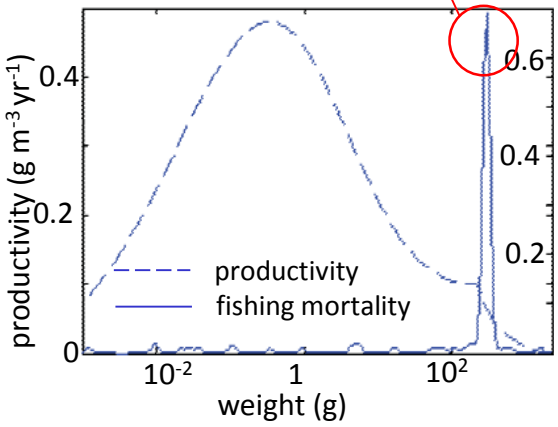
$F(x)$ aggregated close to biomass peak

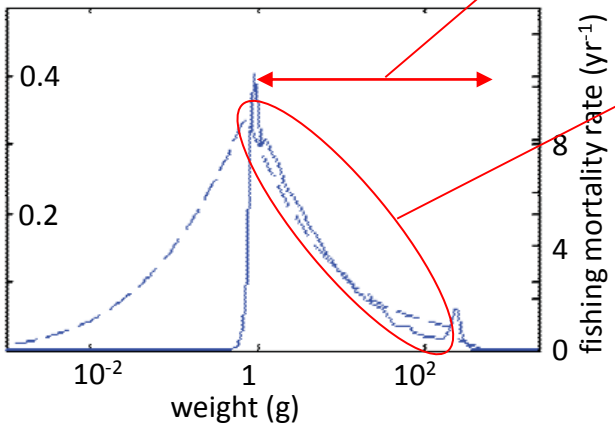
few fishers (100)

many fishers (8000)









fishers remove biomass peak: flat 'Sheldon' biomass spectrum

(constant biomass on log-scaled intervals of body mass)

$F(x)$ spreads out over body size x on RHS of productivity peak

$F(x)$ ~proportional to productivity

Result = emergence of balanced harvesting

constant biomass $\Longrightarrow$ all fishers get equal biomass yield

a fisher cannot increase yield by a change in gear

Nash equilibrium: No fisher has an incentive to change fishing strategy, given the strategies of all other fishers

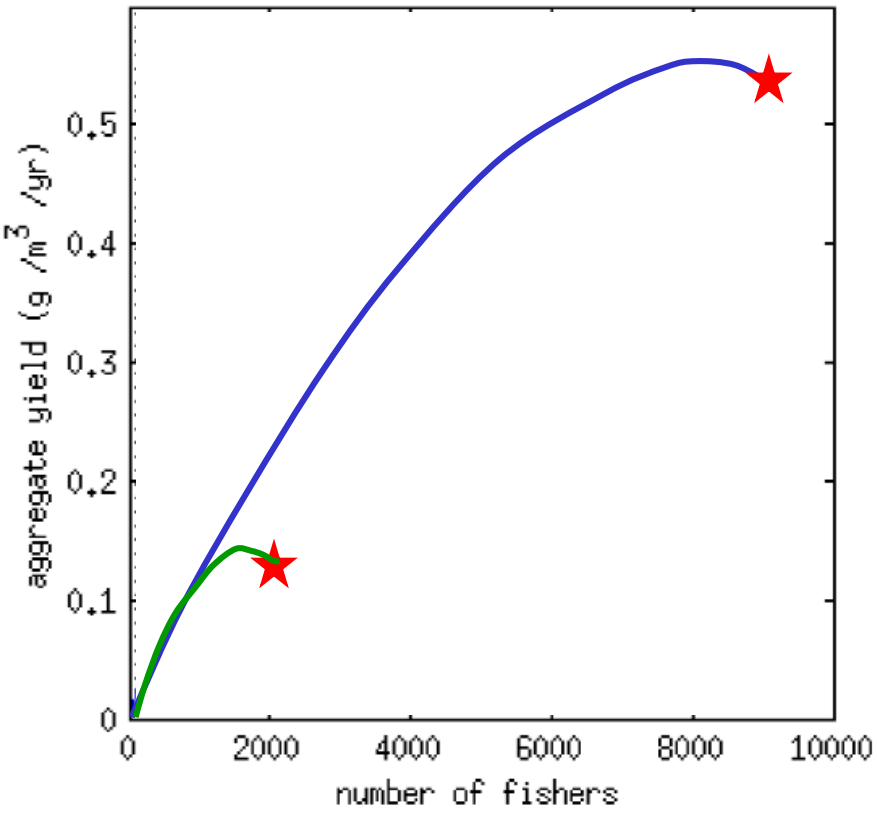
$F(x)$ proportional to productivity $\Rightarrow$ balanced harvesting

aggregate biomass yield

BH gives much greater biomass yield

balanced harvesting without min. landing weight regulation
'Bangweulu-like'

100 g min. landing weight regulation
'Celtic-Sea-like'



★ = collapse of stock and fishery

caveats:

total fishing effort must still be controlled

biomass yield and profit are very different things

Conclusions

- Mesh size regulations in small-scale fisheries are impeding maximum yield and healthy resilient ecosystems
- When food security (biomass) is more important than commercial value, then catch-rates (CPUE) will regulate the fishing pattern towards a Balanced harvest regime.
- For co-management to work the State will have to abandon size and gear regulations.


Thank you for your attention