MODELLING THE IMPACTS OF FISHING ON TROPHIC INTERACTIONS IN LAKE VICTORIA USING ECOTROPH

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Introduction

- Human beings believed that the earth was limitless and its resources infinite
- However the Apollo mission of December 1968, fundamentally changed the mind of the world population


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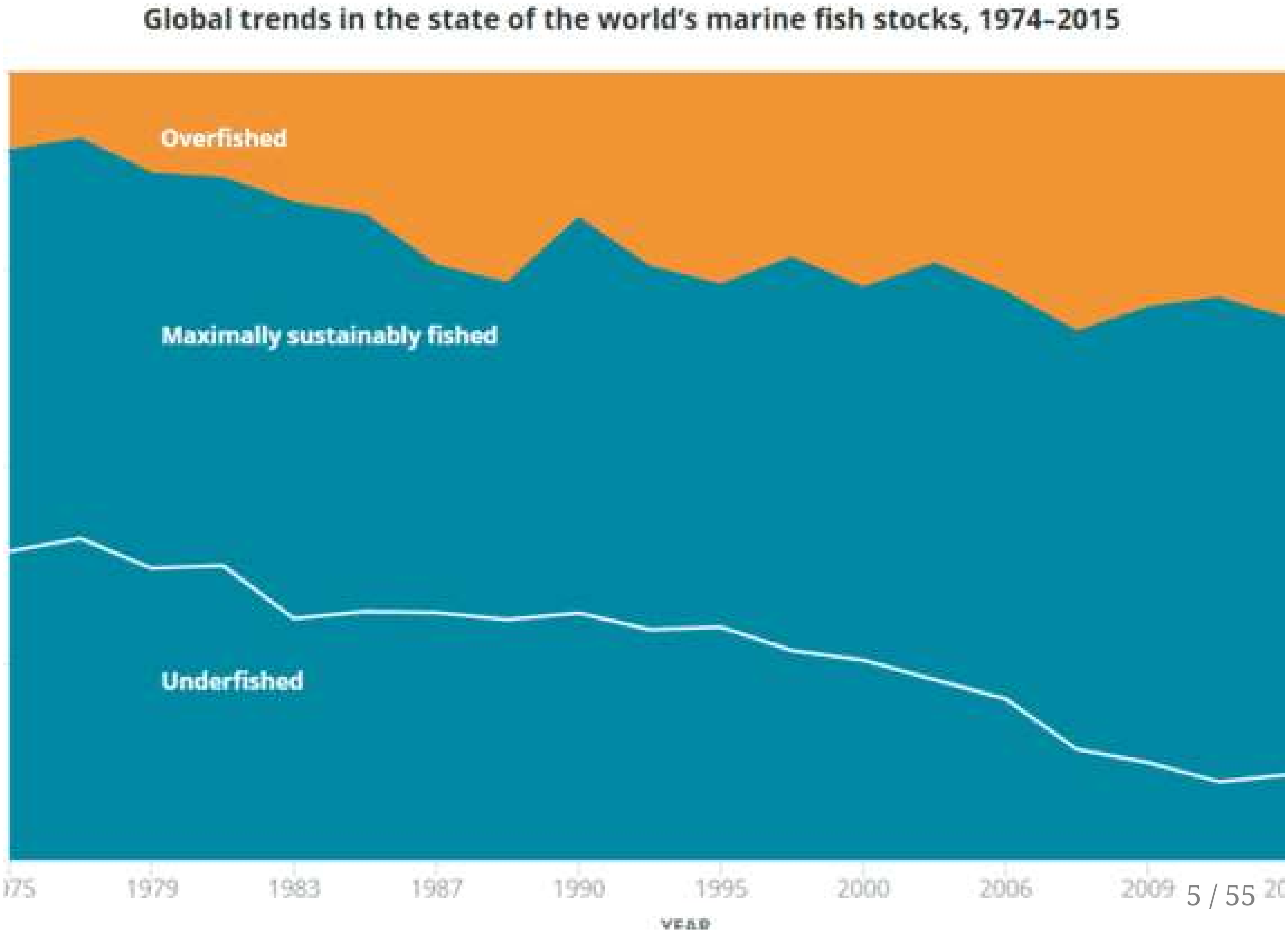
- The world realized that her resources are finite and there exists an edge to our existence
- Marine and Fisheries scientist had earlier claimed that, no matter the effort applied in world oceans, it could never deplete the Ocean's resources
- However, the decline of global catches, extirpation and extinction of commonly fished species in oceans as well changed the minds of fisheries scientists
- They also realized that the ocean resources are finite and need our protection

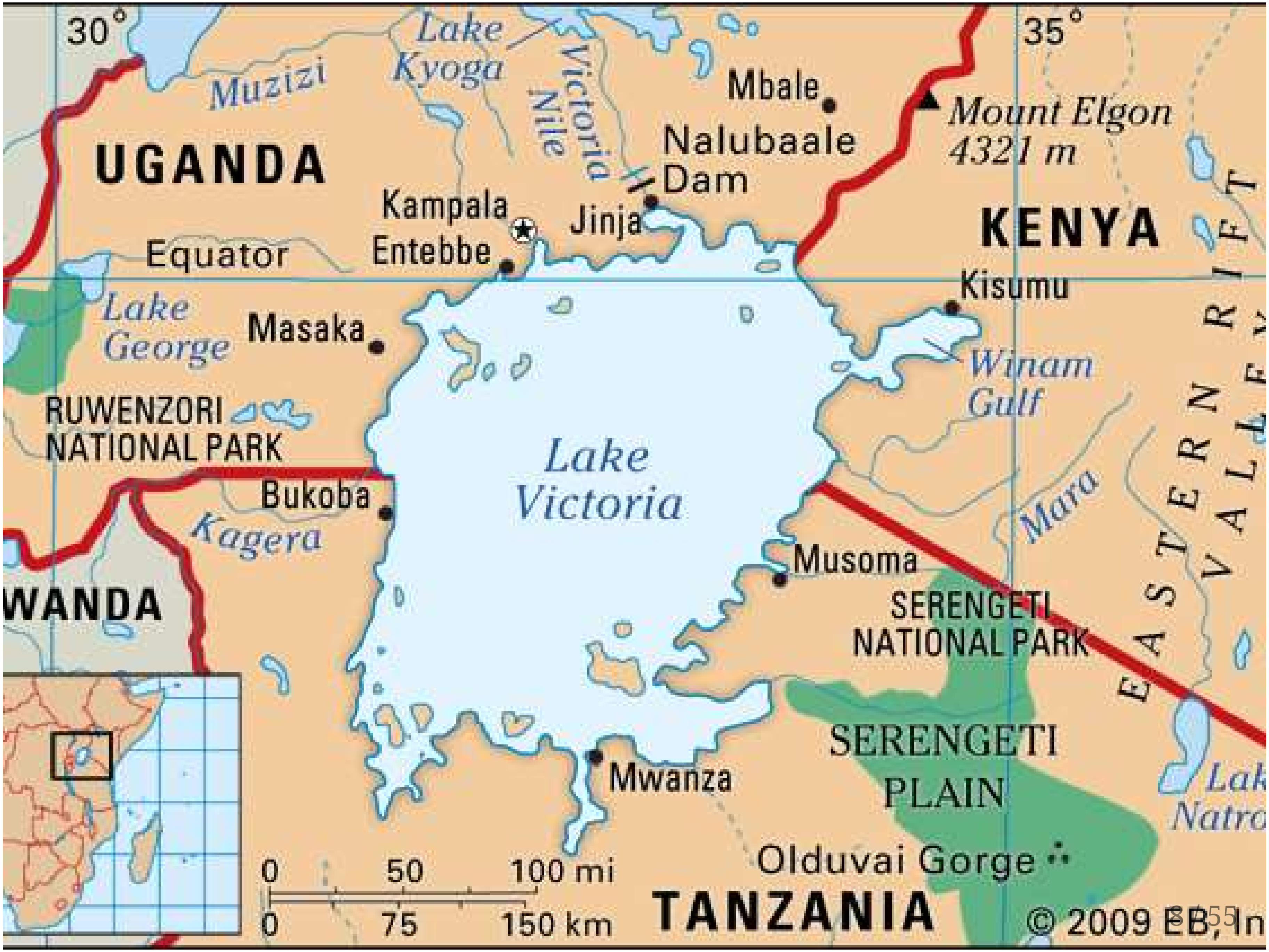

Global trends in the state of the world's marine fish stocks, 1974–2015
Overfished
Maximally sustainably fished
Underfished
1979
1983
1987
1990
1995
2000
2006
2009
YEAR

Aquatic Ecosystems

- The tragedy of our times is still unfolding across the globe barely noticeable
- The loss of our planets Wild Places - its biodiversity
- The living world is a unique and spectacular marvel
- consists of billions of plants and animals - Dazzling in their variety and richness
- Working together to benefit from the energy of the sun and minerals of the earth
- leading lives that interlock in such a way that they sustain each other
- Humans rely entirely on this finely tuned life support system- and each rely on its biodiversity to run smoothly
- the way humans are living in the world is setting biodiversity into a decline
- The natural world is fading thus making the planet uninhabitable due to poor planning and management - basically human error.

Lake Victoria Ecosystem

- Lake Victoria is an iconic East African Lake
- Both for its surface area and fisheries production
- Regarding surface area, is the second largest freshwater lake in the world after lake superior
- It is shared by three east African countries in varying proportions with its catchment area extending beyond Kenya, Uganda and Tanzania to Rwanda and Burundi.
- In terms of production, it produces an annual tonnage of 1M metric tones supporting an approximate 70 million households.

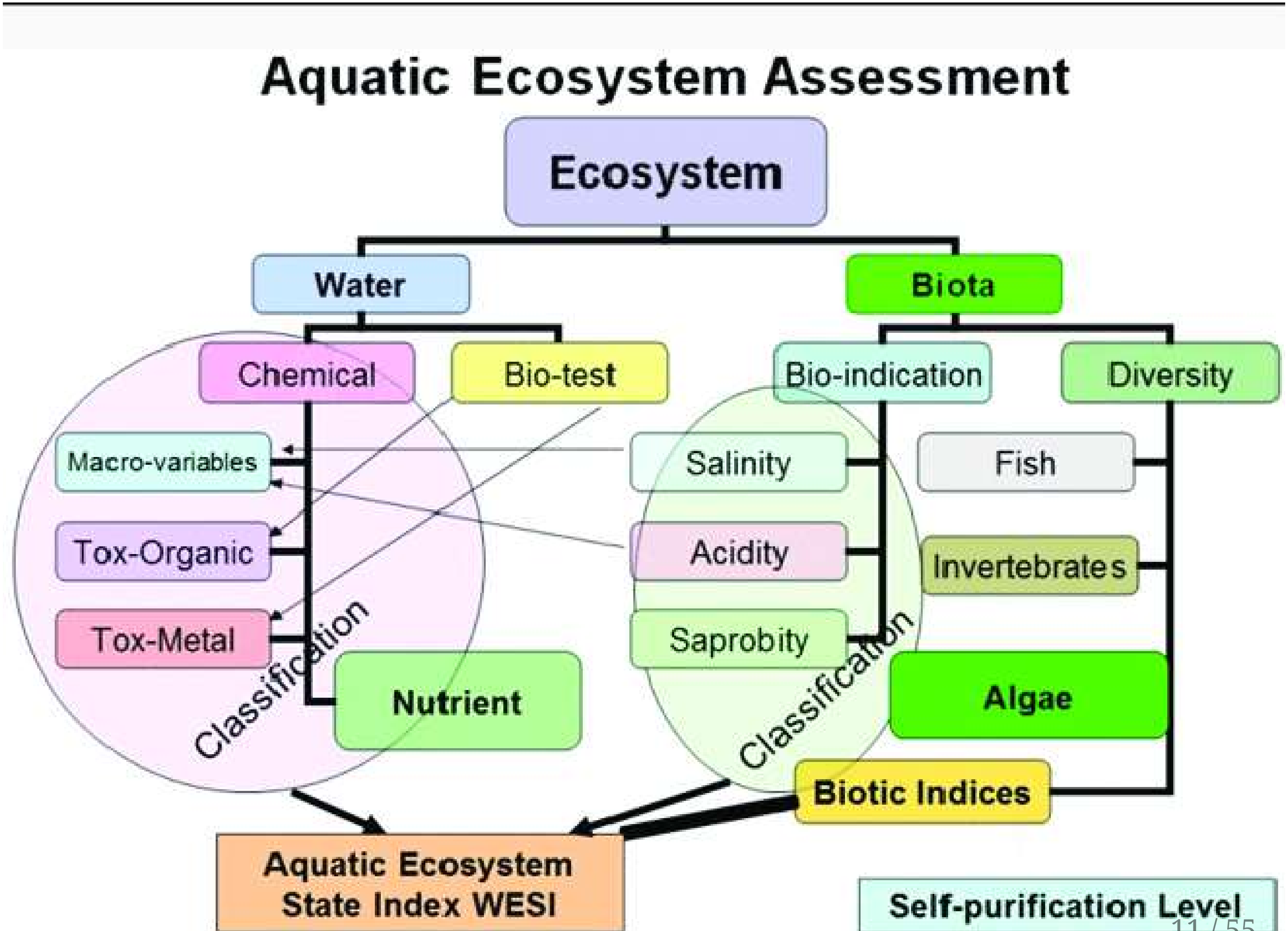

30°
35°
Lake Kyoga
Muzizi
Victoria Nile
Mbale
Mount Elgon
4321 m
Nalubaale Dam
UGANDA
Kampala
Jinja
KENYA
Equator
Entebbe
Kisumu
Lake George
Masaka
Winam Gulf
RUWENZORI NATIONAL PARK
Lake Victoria
Bukoba
Kagera
Mara
EASTERN RIFT VALLEY
Musoma
WANDA
SERENGETI NATIONAL PARK
SERENGETI PLAIN
Mwanza
Olduvai Gorge
0 50 100 mi
0 75 150 km
TANZANIA
© 2009 EB, In

Cont..

- Research conducted in the early 1900s indicated that the lake was composed of multi-genera, multi-species fishery
- However due to overfishing and introduction of exotic species, the fishery of the Lake has been reduced to three species
- The dagaa/omena and reduced species of haplochromines are the only endemic species left
- The majorly composed a Nile perch and Nile tilapia fishery which are exotic species

Ecological Models

- For proper planning and sound management of aquatic ecosystems
- We need to understand the functioning processes of aquatic ecosystems
- Models create a method or an avenue of understanding, describing and interpreting the functioning processes of ecosystems
- Ecological models are thus representations of real ecosystem functioning and processes
- Models are integral data intensive strategies through which available resources are approximated and their exploitation mapped over time
- On the basis on sustainability
- Models are not always correct but provide insights regarding real ecosystems
- Aquatic Ecosystems are complex and no single model is capable of capturing all components of an ecosystem
- Therefore incorporate the components we are interested in and exclude the less important components.



Aquatic Ecosystem Assessment
Ecosystem
Water
Biota
Chemical
Bio-test
Bio-indication
Diversity
Macro-variables
Tox-Organic
Tox-Metal
Nutrient
Salinity
Acidity
Saprobity
Fish
Invertebrates
Algae
Classification
Classification
Biotic Indices
Aquatic Ecosystem State Index WESI
Self-purification Level
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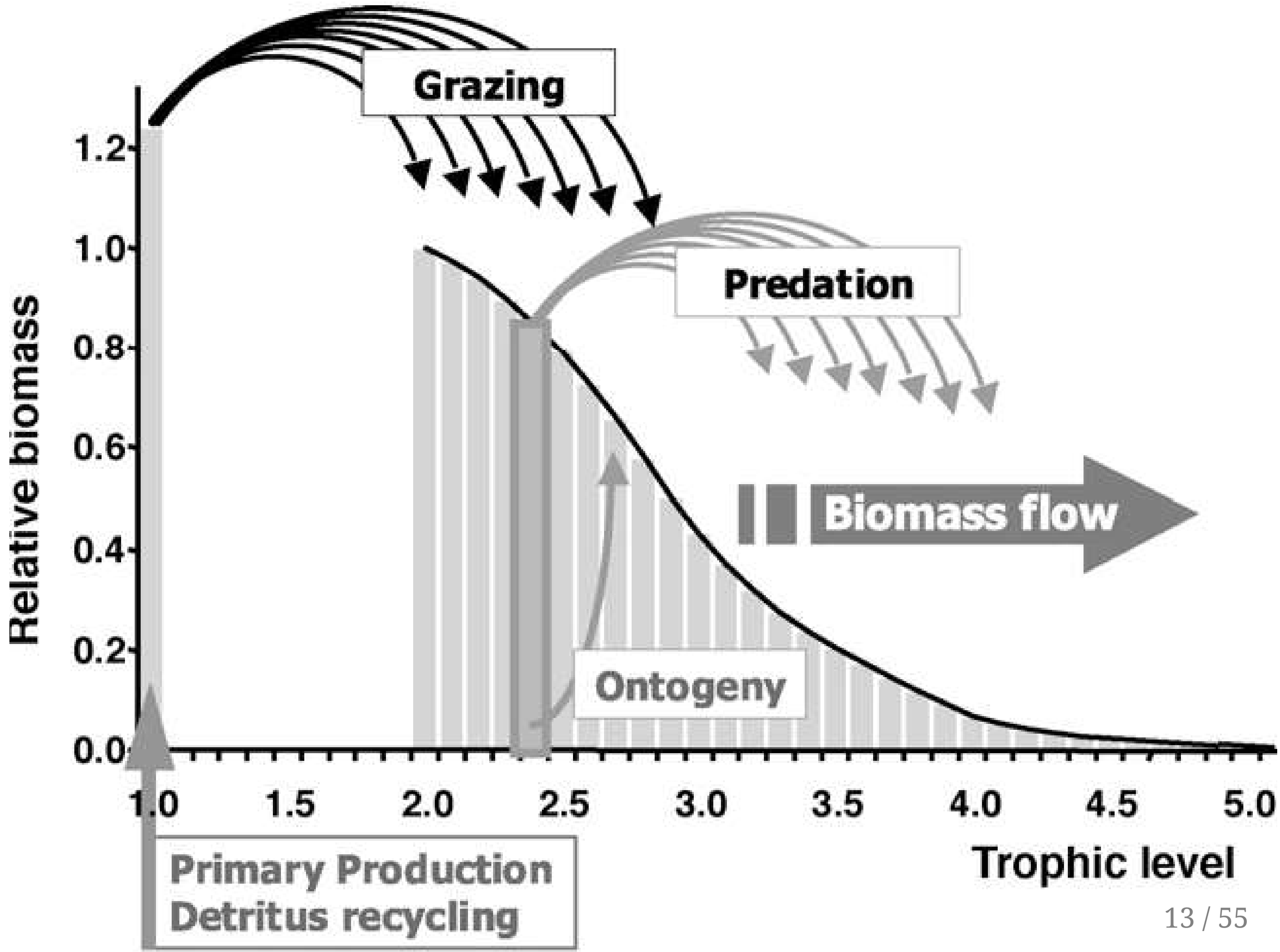
Ecotroph Model

- This model uses trophic spectra to represent the functioning of aquatic ecosystems using the flow of biomass
- The ecosystems are structured as function of transfer of energy from low to high trophic level species through predation and ontogeny
- The flow of energy through each trophic level is influenced by Kinetics and Volume of biomass
- Fishing is the component that interferes with the flow of biomass through the removal of biomass at certain trophic levels
- The effect of fishing is profound in ecosystems due to technological advancements in fishing gears and gear technology
- Whereby if a species becomes our target there is nowhere in the planet it can hide
- The Major components of the Ecotroph model therefore are kinetics, volume of biomass, magnitude and nature of fishing.


Grazing
Predation
Biomass flow
Ontogeny
Relative biomass
1.2
1.0
0.8
0.6
0.4
0.2
0.0
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
Trophic level
Primary Production
Detritus recycling

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Problem Statement

- Overexploitation through overfishing is one of the most apparent reasons for the declines of fishery recorded from Lake Victoria
- The current ecosystem models do not emphasize the importance of trophic interactions in which;
- when some components are destroyed; the whole ecosystem is destabilized
- The decline of the Lake Victoria fishery is attributable to the fishing patterns that do not support sustainability
- All the compartments of ecosystems are potentially affected by fishing activities

Objectives

General Objective

- The study aimed at predicting the Lake Victoria trophic ecosystem response to varied fishing scenarios, with the aim to arrive at the best fishing scenario

Specific Objective

- To determine critical determinants of Lake Victoria trophic functioning.
- To determine the effect of different fishing patterns on trophic functioning.
- To determine a fishing strategy that optimizes production with minimal adverse effects on trophic functioning.

Hypotheses

- There are no significant changes in the trophic functioning given different fishing patterns in Lake Victoria.
- There is no significant difference between fishing at lower and higher trophic levels in Lake Victoria

Expected Outcome

- The determination of the most appropriate or optimal level of fishing and target trophic level that produces highest attainable catch without threatening the trophic interactions in Lake Victoria
- The determination of a fishing strategy that optimizes catch while preserving the natural functioning process of trophic interaction

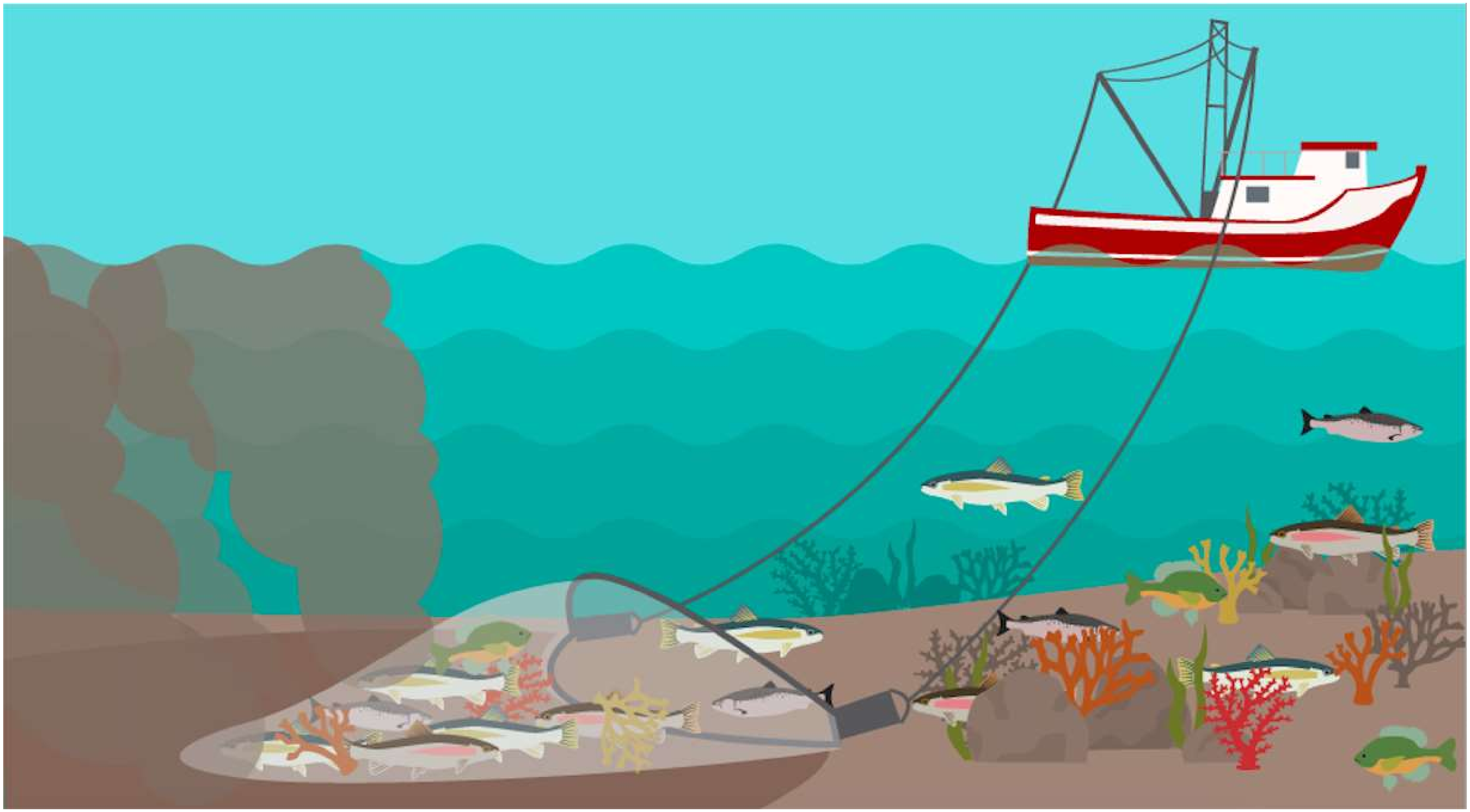
Materials and Methods

Study Area

- An area covering 68900 km2 with a spatial extent of 3.05°S to 0.55°N and 31.5°W to 34.88°E was constructed to represent the Lake Victoria ecosystem

Research Design

- The main method of data collection to determine the biology of Nile perch, Nile tilapia and dagaa was done through bottom trawling.
- The swept area method was used to calculate the biomass Every bottom trawl was done for 30 minutes.
- The fishes caught were sorted according to their species and sizes.
- At least two trawls were done in the sampling sites.



Fish Sampling

- A deck trawl net with an attached small-sized net was used for bottom trawling
- Seine nets were used to catch the small sized species
- Swept area method was used to estimate the biomass
- Every bottom trawl was done between 30 and 45 minutes at speeds of 19 to 20 knots per hour.
- Two hauls were done in every sampling point and expedition

Towing the trawl net on deck

The dagaa and the haplochromines caught in the mosquito net were separated and weighed differently

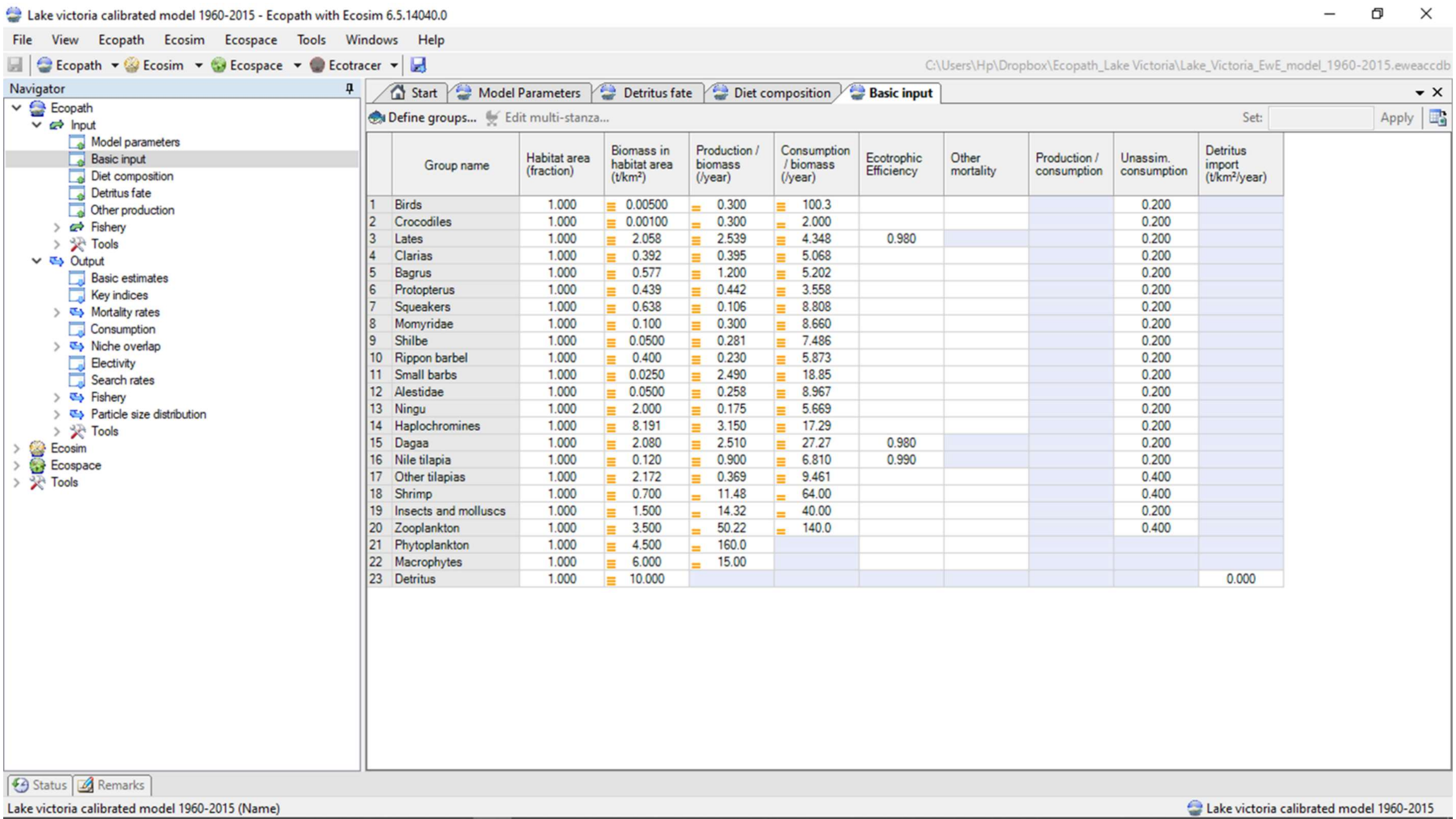
- The larger fishes caught were sorted according to their species and sizes and weighed

- The physical and chemical parameters were taken in-situ using the multiparameter meter, YSI model

Modelling Framework

- The data collected was fitted into Ecopath with Ecosim model created for the whole Lake Victoria
- The ecosystem biomass was partitioned into functional groups, as functions of their roles in ecological feeding interactions
- The functional groups of the model were piscivorous birds, the Nile crocodile,
- 15 fish groups grouped according to feeding similarities, history or habitat
- 3 different invertebrate groups,
- 2 producer groups and a
- detrital group

Ecopath GUI



	Group name	Habitat area (fraction)	Biomass in habitat area (t/km²)	Production / biomass (/year)	Consumption / biomass (/year)	Ecotrophic Efficiency	Other mortality	Production / consumption	Unassim. consumption	Detritus import (t/km²/year)
1	Birds	1.000	0.00500	0.300	100.3				0.200	
2	Crocodiles	1.000	0.00100	0.300	2.000				0.200	
3	Lates	1.000	2.058	2.539	4.348	0.980			0.200	
4	Clarias	1.000	0.392	0.395	5.068				0.200	
5	Bagrus	1.000	0.577	1.200	5.202				0.200	
6	Protopterus	1.000	0.439	0.442	3.558				0.200	
7	Squeakers	1.000	0.638	0.106	8.808				0.200	
8	Momyridae	1.000	0.100	0.300	8.660				0.200	
9	Shilbe	1.000	0.0500	0.281	7.486				0.200	
10	Rippon barbel	1.000	0.400	0.230	5.873				0.200	
11	Small barbs	1.000	0.0250	2.490	18.85				0.200	
12	Alestidae	1.000	0.0500	0.258	8.967				0.200	
13	Ningu	1.000	2.000	0.175	5.669				0.200	
14	Haplochromines	1.000	8.191	3.150	17.29				0.200	
15	Dagaa	1.000	2.080	2.510	27.27	0.980			0.200	
16	Nile tilapia	1.000	0.120	0.900	6.810	0.990			0.200	
17	Other tilapias	1.000	2.172	0.369	9.461				0.400	
18	Shrimp	1.000	0.700	11.48	64.00				0.400	
19	Insects and molluscs	1.000	1.500	14.32	40.00				0.200	
20	Zooplankton	1.000	3.500	50.22	140.0				0.400	
21	Phytoplankton	1.000	4.500	160.0						
22	Macrophytes	1.000	6.000	15.00						
23	Detritus	1.000	10.000							0.000

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Simulating fishing scenarios

- The Ecotroph module was used to simulate different fishing scenarios using the ET-Diagnose routine r package,
- Variations of fishing mortality with common multipliers ranging from 0-5 were used for all trophic levels,
- A value of 0 simulated a virgin ecosystem, 1 and 2 values decreased fishing mortality and values above 2 indicated increased fishing mortality
- Fishing effort multipliers were imposed on haplochromines, Nile perch and the dagaa
- The mean trophic level of biomass and catch change depicted trends

Exploring fishing Scenarios

- Changes in fishing biomass, fishing mortality and catch
- of Nile perch, dagaa, Nile tilapia and haplochromines were used to understand the importance of each to fishing.
- The dagaa, Nile Perch and Nile tilapia were used because they form the commercially important species of Lake Victoria
- while the haplochromines were selected because they are prey for the Nile perch.

Data Analysis

- The model outputs were analyzed using excel 2016 version
- Bar graphs were used to illustrate changes in ecosystem biomass across trophic levels.
- Line graphs were used to illustrate trends in biomass flow across trophic levels.
- Model output was compared with corresponding data sets to check whether simulations were able to preserve both trends and magnitude
- using Pearson's correlation and modelling efficiency (E) as proposed by Olsen et al. (2016).
- A one way ANOVA was used to determine differences in mortality losses and biomass changes within different fishing scenarios
- To determine biomass and catch trend changes in trophic levels, the mean trophic level of biomass and catch was used using the formulae below
- where ti is the trophic level, b is the biomass of that specific trophic level and B is the sum of biomass in all trophic levels.

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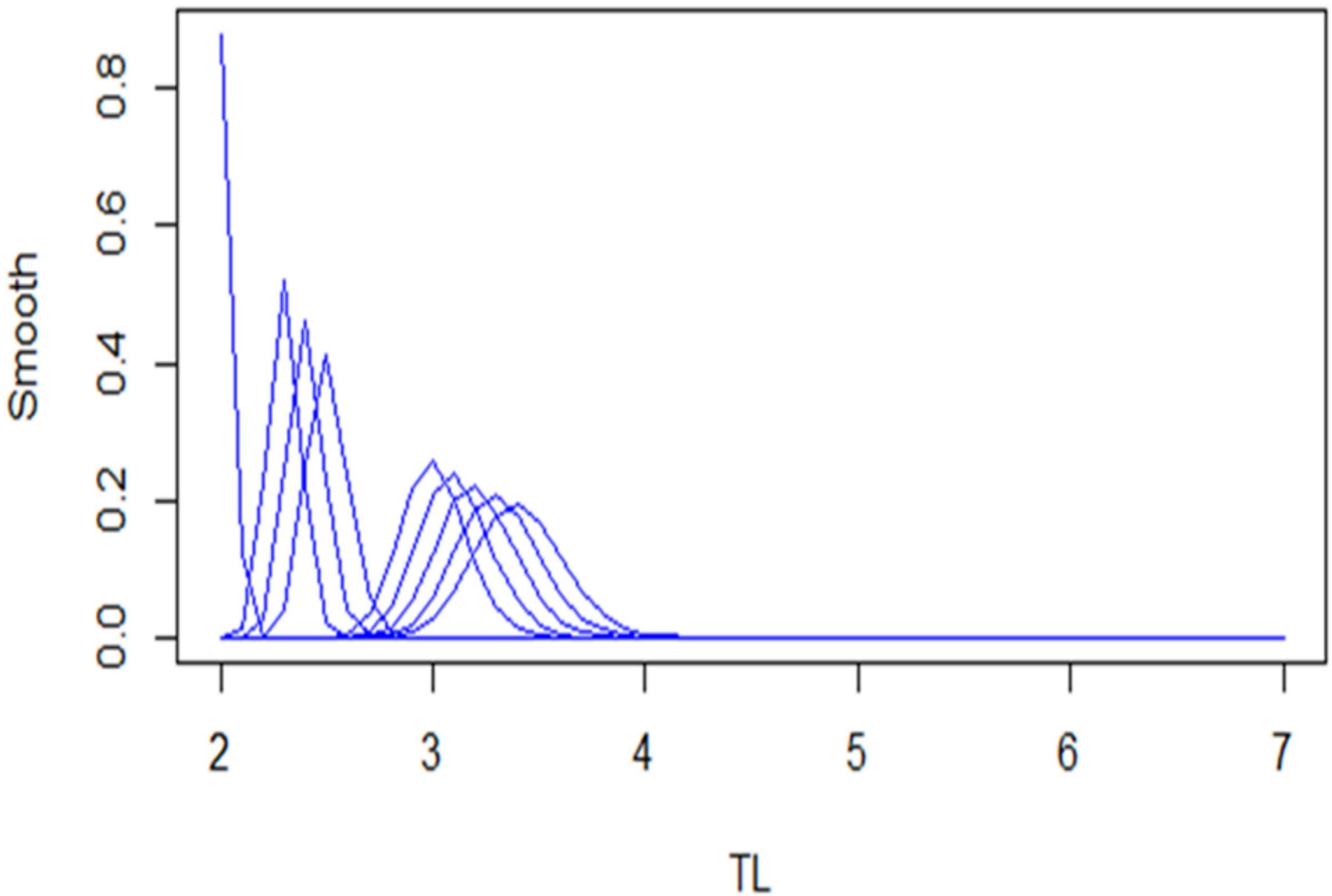
RESULTS AND DISCUSSION

Biomass

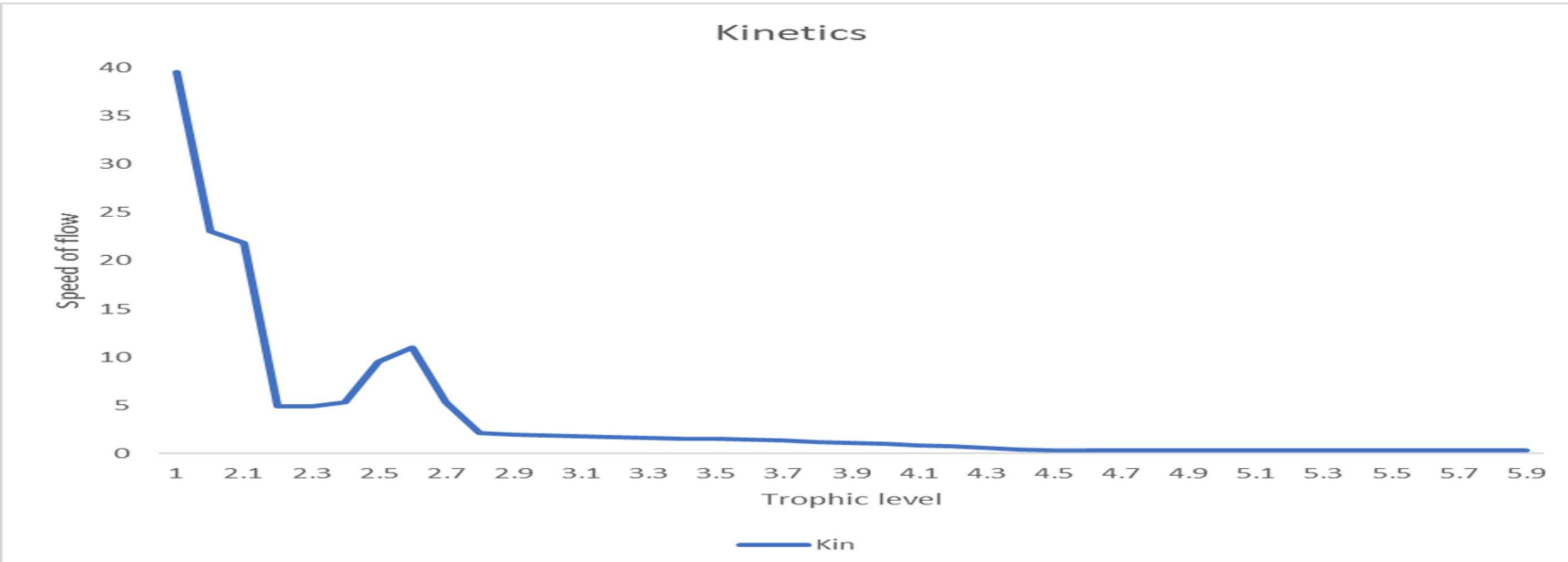
- The total biomass recorded was 274.7147 t km-2 164.7448t km-2 being the accessible biomass.
- The highest biomass that can be extracted from the ecosystem using the highest exploitation effort multiplier of 5 is 8.9316 t km-2

Group name	Trophic Leve	Biomass	P/B	accessibilty	Omnivory index	Others	Small seines	Gill nets	Long lines
Zooplankton	2.052632	3.5	50.21855	0	0.05263158	0	0	0	0
Squeakers	3.451617	0.638	0.106	0.8	0.01401623	0.000214	0	0.010765	8.93E-06
Small barbs	3.052632	0.025	2.49	0	0	0	0	0	0
Shrimp	2.526316	0.7	11.47669	0	0.2770083	0	0	0	0
Shilbe	3.332234	0.05	0.281	0.8	0.004234358	0.004674	0	0.0070116	0
Rippon barbel	3.044787	0.4	0.23	0.8	0.289854	0.003924	0	0.0058866	0
Protopterus	3.104005	0.439	0.442	0.8	0.3463205	0.014516	0	0.0329032	0.01258065
Phytoplankton	1	4.5	160	0	0	0	0	0	0
Other tilapias	2	2.172	0.369	0.8	0	0.112513	0	0.1916229	0.000879
Ningu	2	2	0.175	0.8	0	0.043512	0	0.0652675	0
Nile tilapia	2.45792	0.12	0.9	0.8	0.3950846	0.000401	0	0.0006826	3.13E-06
Momyridae	3.181378	0.1	0.3	0.8	0.2806715	0.000329	0	0.0165178	1.37E-05
Macrophytes	1	6	15	0	0	0	0	0	0
Lates	3.334084	2.0584	2.539	0.8	0.03646339	1.06E-05	2.57E-08	2.40E-05	2.38E-05
Insects and mc	2.31589	1.5	14.32347	0	0.232787	0	0	0	0
Haplochromine	2.300228	8.191396	3.15	0.8	0.228705	0.005478	0.02873407	0.0077877	0.00891562
Detritus	1	10	0	0	0.3917667	0	0	0	0
Dagaa	3.052632	2.08	2.51	0.8	0	0.000104	0.000695605	0	0
Crocodiles	4.091322	0.001	0.3	0	0.30672	0	0	0	0
Clarias	3.324343	0.3918459	0.395	0.8	0.00760397	0.00772	0	0.0145829	0.02573453
Birds	3.533859	0.005	0.3	0	0.1541713	0	0	0	0
Bagrus	3.358609	0.577	1.2	0.8	0.01258661	0.017125	0	0.0323471	0.05708314
Alestidae	3.20002	0.05	0.258	0.8	0.03701294	0.00089	0	0.0013343	0
Total	61.714508	45.498642	266.9637	11.2	3.067637978	0.211411	0.029429701	0.3867333	0.10524251

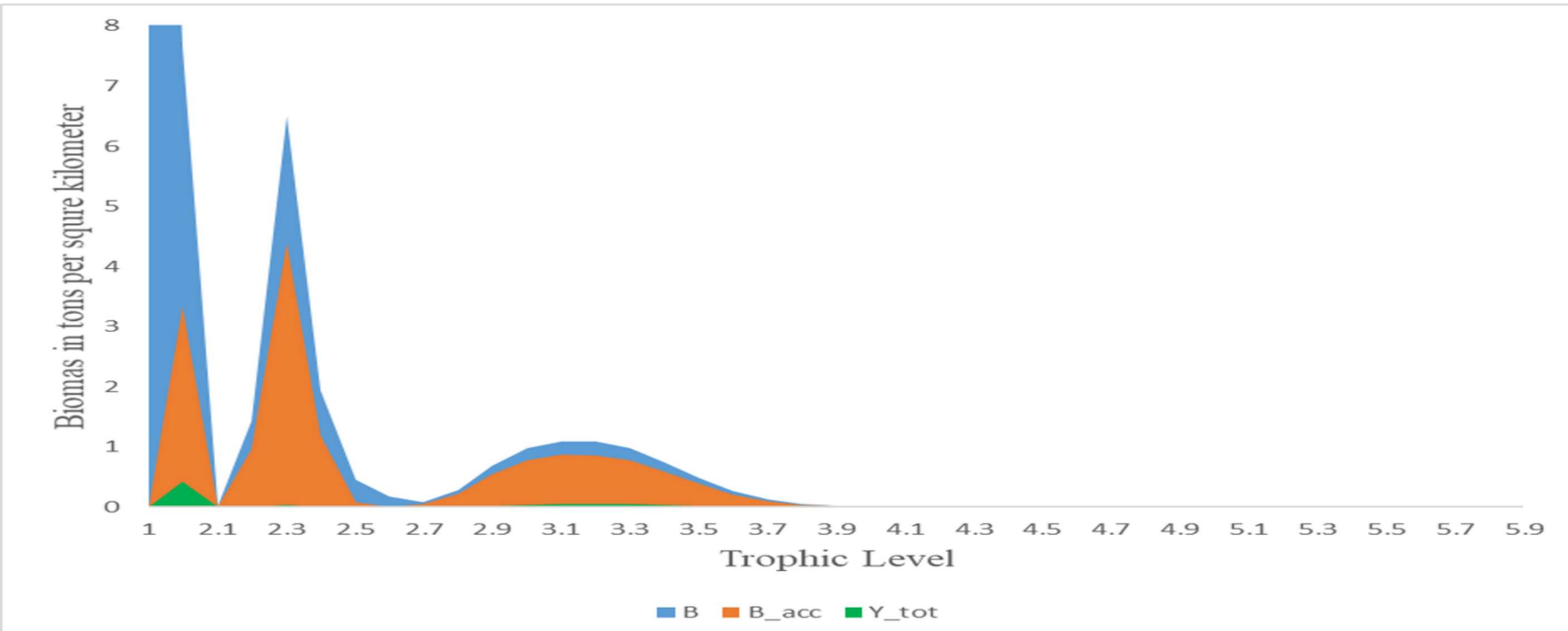
The Flow of Biomass



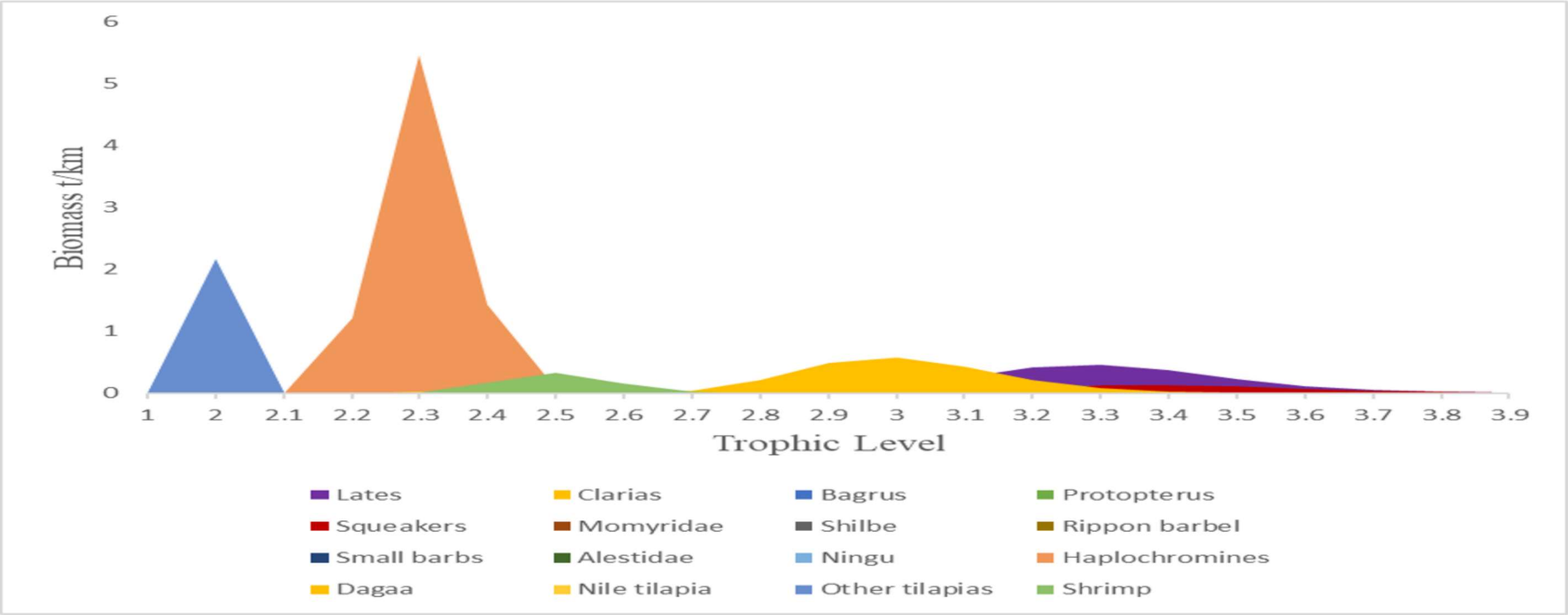
The Kinetics of biomass flow in Lake Victoria

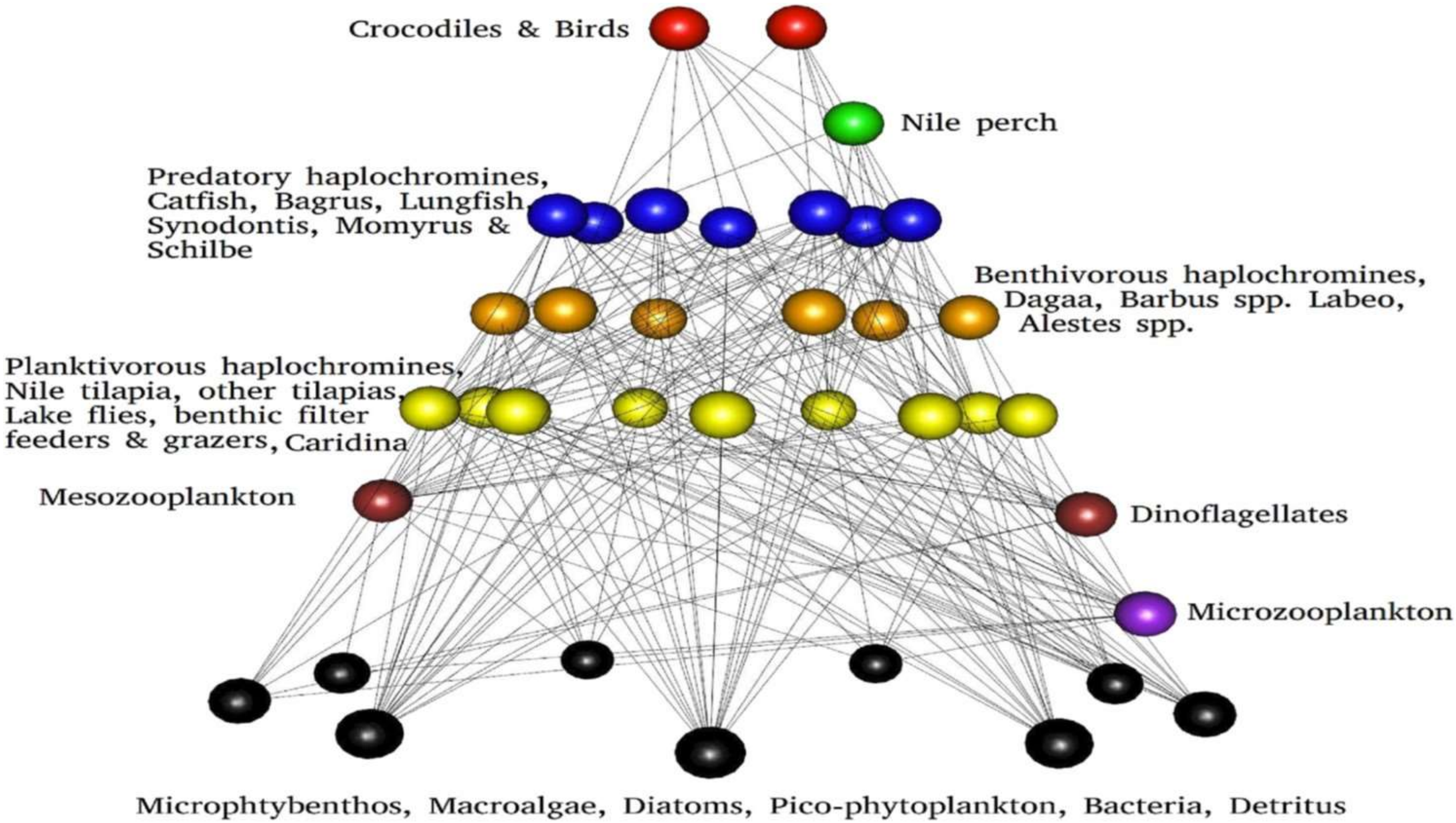


Biomass Distribution Across Trophic Level



Trophic Level Distribution of Species




Crocodiles & Birds
Nile perch
Predatory haplochromines, Catfish, Bagrus, Lungfish, Synodontis, Momyrus & Schilbe
Benthivorous haplochromines, Dagaa, Barbus spp. Labeo, Alestes spp.
Planktivorous haplochromines, Nile tilapia, other tilapias, Lake flies, benthic filter feeders & grazers, Caridina
Mesozooplankton
Dinoflagellates
Microzooplankton
Microphtybenthos, Macroalgae, Diatoms, Pico-phytoplankton, Bacteria, Detritus

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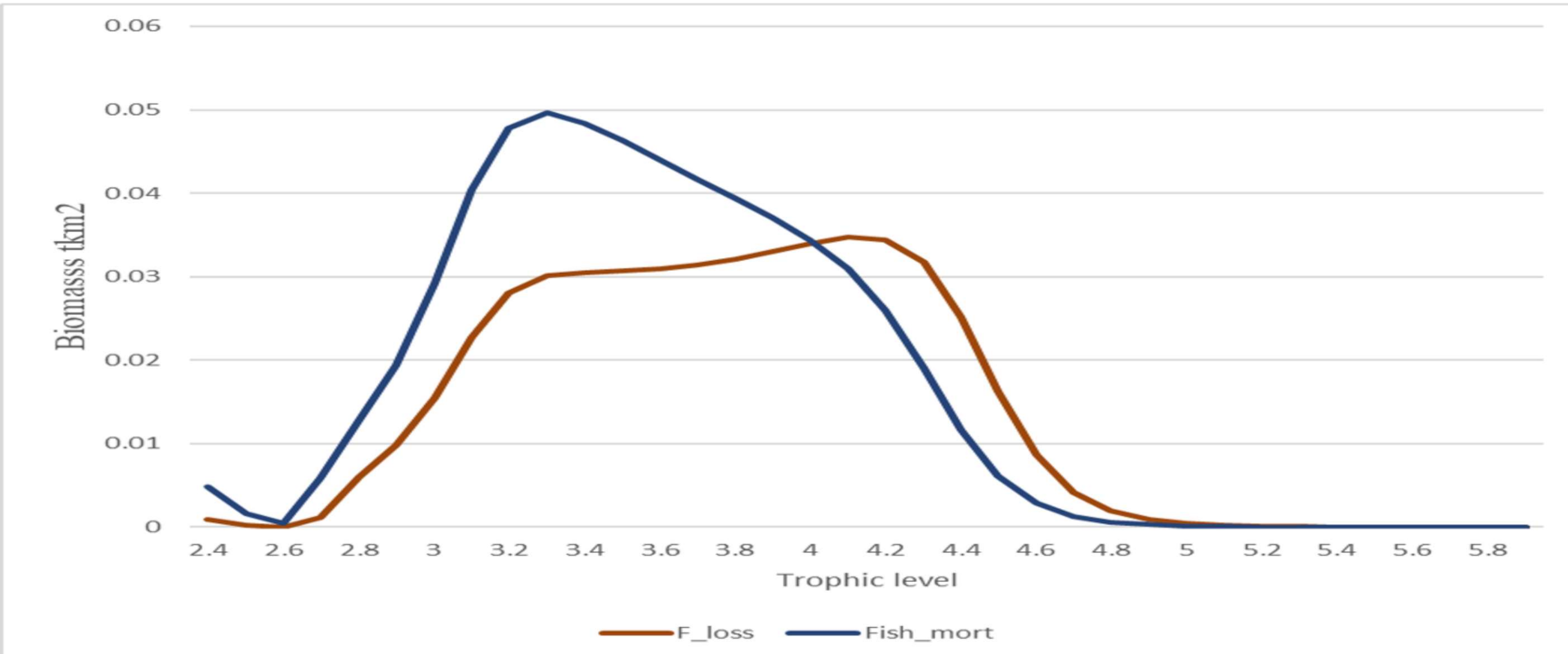
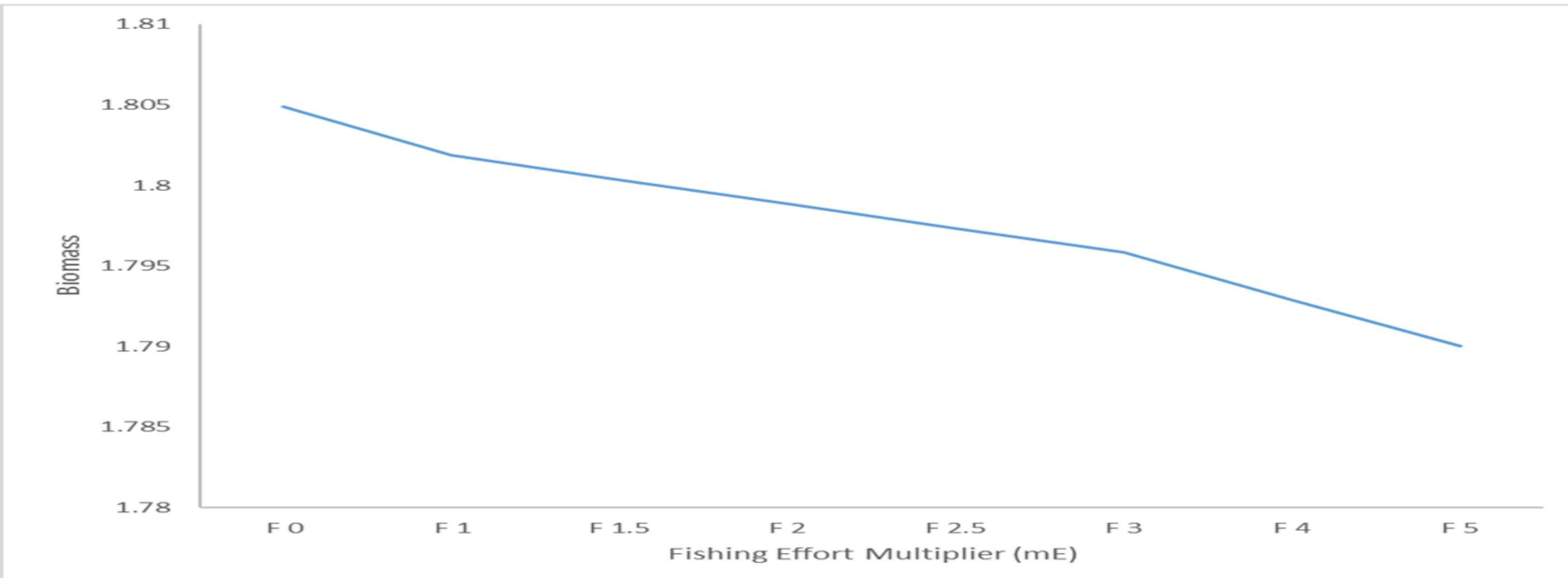
Exploring the Impacts of Fishing

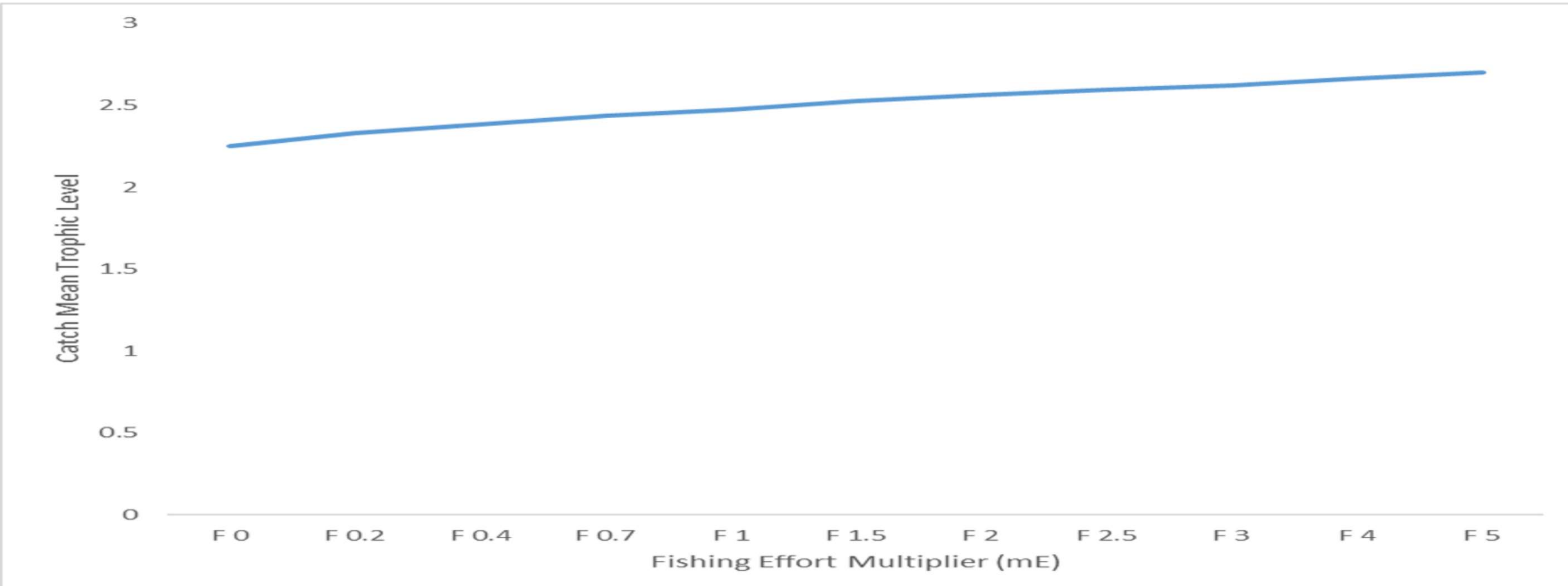


mE	0	0.2	0.4	0.7	1	1.5	2	2.5	3	4	5
1	0	0	0	0	0	0	0	0	0	0	0
2	0.0142	0.0221	0.0301	0.042	0.0539	0.0738	0.0937	0.1136	0.1334	0.1732	0.213
2.1	0.0136	0.021	0.0284	0.0395	0.0506	0.0691	0.0876	0.1061	0.1246	0.1616	0.1987
2.2	0.0053	0.0053	0.0053	0.0053	0.0053	0.0053	0.0053	0.0053	0.0053	0.0053	0.0053
2.3	0.0052	0.0052	0.0052	0.0053	0.0053	0.0053	0.0053	0.0053	0.0053	0.0054	0.0054
2.4	0.0046	0.0047	0.0047	0.0048	0.0049	0.0051	0.0052	0.0054	0.0055	0.0059	0.0062
2.5	0.0011	0.0012	0.0013	0.0014	0.0016	0.0018	0.0021	0.0023	0.0026	0.0031	0.0036
2.6	0.0002	0.0002	0.0003	0.0003	0.0004	0.0004	0.0005	0.0006	0.0007	0.0008	0.001
2.7	0.0056	0.0057	0.0057	0.0058	0.0059	0.006	0.0061	0.0063	0.0064	0.0066	0.0069
2.8	0.0123	0.0124	0.0125	0.0126	0.0128	0.013	0.0133	0.0135	0.0137	0.0142	0.0147
2.9	0.0183	0.0185	0.0187	0.0191	0.0194	0.0199	0.0204	0.0209	0.0214	0.0225	0.0235
3	0.0265	0.0271	0.0276	0.0284	0.0292	0.0305	0.0318	0.0331	0.0344	0.0371	0.0397
3.1	0.0347	0.0358	0.037	0.0387	0.0404	0.0433	0.0461	0.049	0.0519	0.0576	0.0633
3.2	0.0388	0.0406	0.0424	0.0451	0.0478	0.0523	0.0568	0.0614	0.0659	0.0749	0.084
3.3	0.0386	0.0408	0.043	0.0463	0.0496	0.0551	0.0606	0.0661	0.0716	0.0826	0.0936
3.4	0.0368	0.0391	0.0414	0.0449	0.0484	0.0542	0.06	0.0658	0.0716	0.0832	0.0948
3.5	0.0349	0.0372	0.0394	0.0429	0.0463	0.052	0.0577	0.0634	0.0691	0.0805	0.0919
3.6	0.0331	0.0353	0.0375	0.0408	0.044	0.0494	0.0549	0.0603	0.0657	0.0766	0.0874
3.7	0.0316	0.0336	0.0356	0.0387	0.0417	0.0468	0.0519	0.0569	0.062	0.0721	0.0823
3.8	0.0301	0.032	0.0338	0.0366	0.0394	0.0441	0.0488	0.0534	0.0581	0.0674	0.0767
3.9	0.0286	0.0303	0.032	0.0345	0.0371	0.0413	0.0455	0.0497	0.054	0.0624	0.0709
4	0.0269	0.0284	0.0299	0.0321	0.0344	0.0382	0.0419	0.0457	0.0494	0.0569	0.0644
4.1	0.0245	0.0258	0.0271	0.029	0.0309	0.0342	0.0374	0.0406	0.0438	0.0502	0.0566
4.2	0.0209	0.0219	0.0229	0.0244	0.026	0.0285	0.031	0.0336	0.0361	0.0412	0.0463
4.3	0.0156	0.0163	0.017	0.018	0.0191	0.0208	0.0226	0.0244	0.0261	0.0296	0.0332
4.4	0.0097	0.0101	0.0105	0.0111	0.0117	0.0127	0.0137	0.0147	0.0158	0.0178	0.0198
4.5	0.0051	0.0053	0.0055	0.0058	0.0061	0.0066	0.0071	0.0076	0.0081	0.009	0.01
4.6	0.0024	0.0025	0.0026	0.0027	0.0029	0.0031	0.0033	0.0035	0.0037	0.0042	0.0046
4.7	0.0011	0.0012	0.0012	0.0013	0.0013	0.0014	0.0015	0.0016	0.0017	0.0018	0.002
4.8	0.0005	0.0005	0.0005	0.0006	0.0006	0.0006	0.0007	0.0007	0.0007	0.0008	0.0009
4.9	0.0002	0.0002	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0004	0.0004
5	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.0002	0.0002
5.1	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001

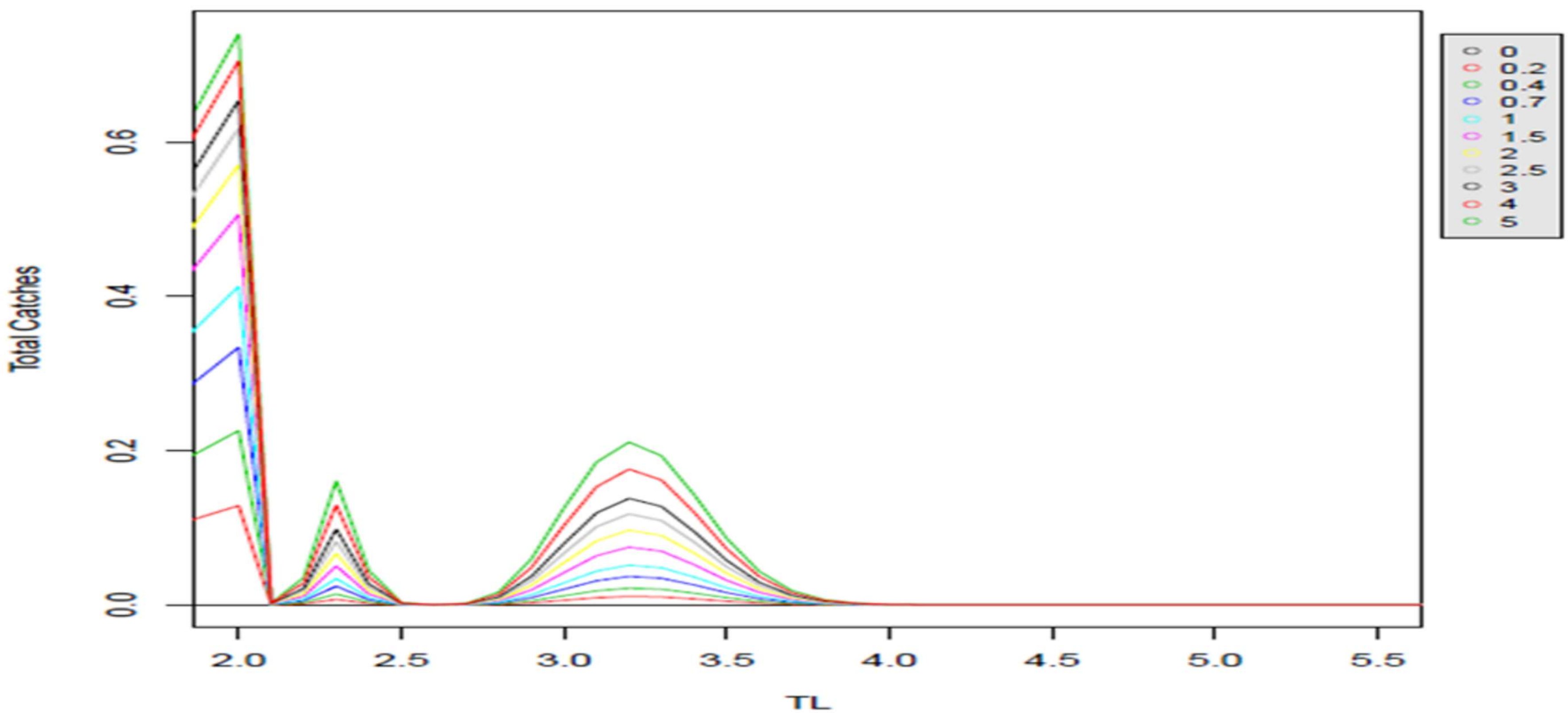
Mean Trophic Level of Biomass for Dagaa and Haplochromines



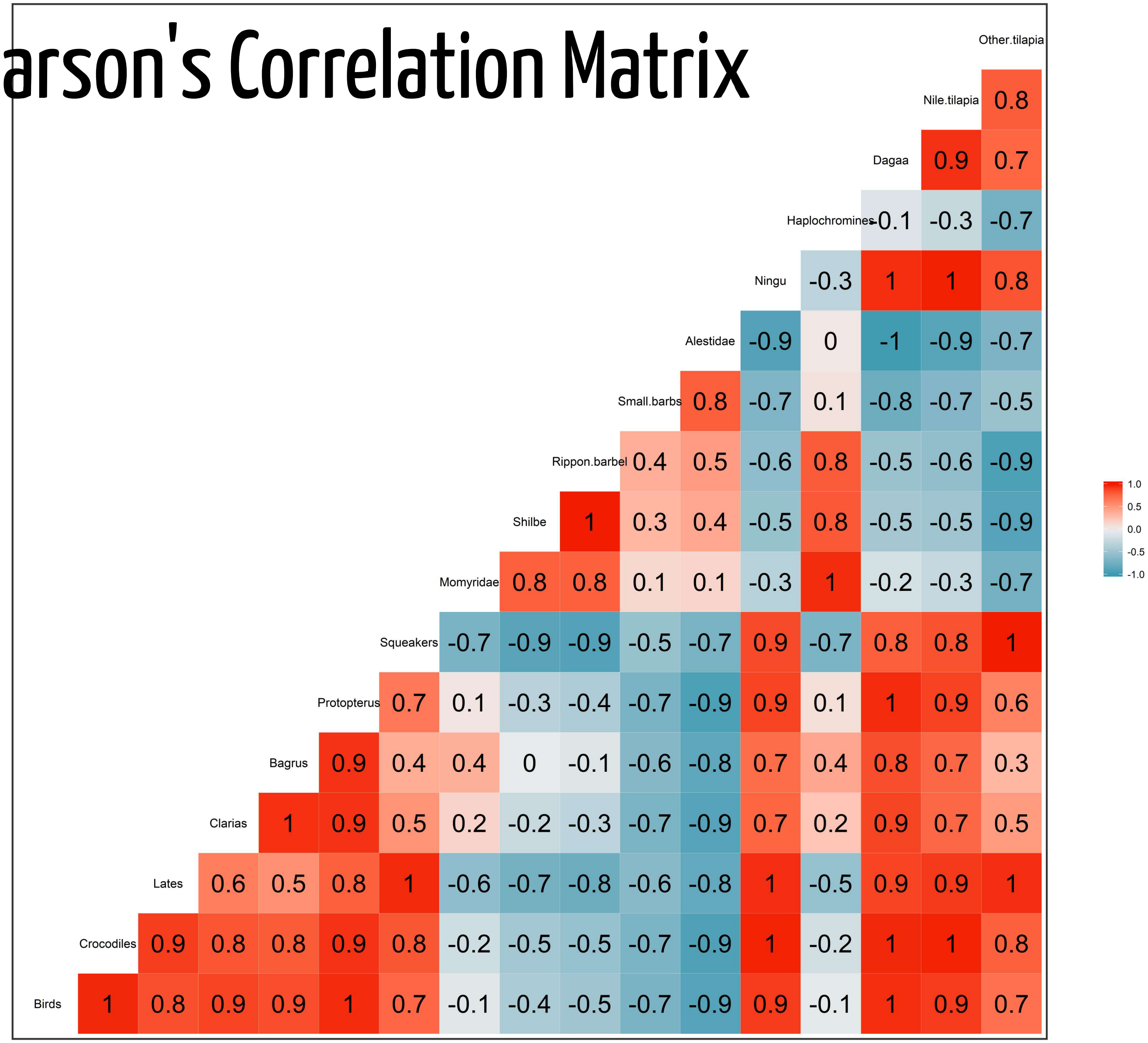
Mean Trophic level for Nile Perch and Nile Tilapia



Trophic Level Variation of Catch



Pearson's Correlation Matrix



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DISCUSSION AND RECCOMENDATION

- In Lake Victoria only, a small proportion of the total biomass is accessible to fishing.
- This, therefore, makes the trophic functioning relatively stable.
- The exploitation of the lake mainly targets the higher trophic level Nile perch species but also mid trophic level species the Dagaa.
- The impact of fishing on Dagaa is compensated by the huge biomass of mid trophic level species the haplochromines.
- The trophic interactions are hugely impacted by exploitation at lower trophic level while impacts are associated with fishing concentrated in higher trophic levels

Cont..

- The high trophic level species are the Nile Perch which due to overfishing are currently at very lower sizes
- The capture at young sizes ensure the Nile perch does not harvest most of lower trophic level species
- Leading to the predatory release phenomenon
- Fishing Haplochromines, tilapia and dagaa hugely interrupts the trophic functioning as the diet of higher trophic level species is depleted by fishing
- The ecosystem biomass decreases significantly when fishing is concentrated at low trophic level species

CONCLUSION

- The determinants of trophic functioning in Lake Victoria are Accessibility of biomass to fishing, the biomass flow kinetics and the fishing loss rate
- Fishing at higher trophic levels improves the trophic interactions of lake Victoria
- Fishing at lower trophic level hugely impacts the trophic functioning of Lake Victoria Negatively
- Therefore fishing at higher trophic level produces large biomass catches while only impacting the trophic functioning of Lake Victoria minimally

Parting Shot

- Our existence is not limitless
- There is an edge to our existence
- we are ultimately bound-by and reliant-upon the finite natural world about us
- Saving, Managing, conserving of certain/individual/groups of species would not be enough to re-wild the world.
- A powerful share of consciousness should be fostered regarding the natural world
- This is a fundamental truth, an objective truth- a fact that is true no matter what.

THANK YOU

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