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OPTIMIZING FISH HARVESTING IN ETHIOPIA

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***ABSTRACT**: Hawassa Lake and Tana Lake in Bahder are in Ethiopia most important source of inland fishery production. After it was initially fished down in the first half of the 20th century, lakes became home to a series of introduced food fishes. Data on the resurgence of the indigenous species suggest that heavy fishing of lakes may enhance **biodiversity**. This has spawned renewed interest in management options that promote both fishery **Sustainability** and **Biodiversity conservation**.*

*Sustainability in fisheries has over the past decades evaluated from species maximization concepts to covering **ecosystem**. Recently, the idea balanced harvest that is harvesting all components in the ecosystem in proportion their productivity it requires a fundamental change to management. In this paper, we review the objectives of **theoretical background** and **practicalities** of securing high yielding fisheries in inland waters, with empherical examples from lake water (Tropical fresh water) fisheries. These all evaluated through biological modeling with help of **typical dynamic trajectory**, **quantitative to qualitative methods***

***KEY WORDS**: Sustainability Management, Biomanipulation, Balance harvesting, Regression fit line for Biogeography, Optimization of Linear Programming*

I. INTRODUCTION

Fishery resources have long been a crucial source of food for hundreds of millions people worldwide. The food and Agriculture organization (FAO) of the United Nations reported in 2005, fish was the sole source of protein for 80 – 90 million people in developing countries.

Ethiopia has an extensive body of inland waters, comprising eight principal lakes, we concern only two of them Awash and Tana. In Ethiopia total area of lakes is more than 7, 000 $k.m^2$ (FAO). Even despite its large potential, attempt to develop Ethiopia's fishery resources are limited only about 0.45 of expenditure in the agricultural sector is allocated for development of fisheries (FAO draft – 2010). Lake Tana and Awash, Tana is one of the biggest lakes in Amhara region and Awash in Sedamo region.

These lakes are approximately 3200km^2 and 129 km^2. Commonly in both lakes there are three types of fish species, namely **Tilapia, Barbusse and African Cat fish**. Fishery population is affected by many categories. Here we choose, Sustainability Management, Bio Manipulation, Balance harvesting, those three categories first evaluated by in three ways

a. Sustainability Fisheries evaluated by questioner surveys from this we will get sample data.
b. Biomanipulation evaluated by decision question manner, here also we will get some modified data.
c. Finally Balance harvesting new approach to empirical class studies.

From these categories we built an optimization mathematical modeling and we will conclude fish harvesting is optimized in Ethiopia or not.

1.1 Sustainable Fisheries Category I

FAO defined sustainability as "The balance of fishery resource conservation with human needs" (FAO 1999). An important framework for sustainable management of fishery resources in the Code of Conduct for Responsible Fisheries, which emphasizes the balance between the environment and human needs: The main components of the framework are fishery management, fishing operations, aquaculture development, integration of fisheries into lake management, the fishery industry and trade, and also fishery research and also noted that sustainability factors for fisheries include the richness of fishery resources, human well – being, and effective management of fishery resources [1], [2] and [3].

The FAO (2010) summarizes a two – step process for developing indicators.

1. To determine the scope and identify the measured criteria in general terms
2. To develop and apply the indicators

The information used to develop the indicators consists of qualitative and quantitative data from questionnaire surveys, the opinion of experts and stakeholders, and the traditional knowledge of communities.

1.2 Development of Indicators for a Sustainability Fishery

The indicators for a sustainable fishery should demonstrate causes and effects, the fishery status, and the development of the fishery system. They can be used to assess the quality and efficiency of fishery and aquaculture resource management in order to improve policy – making regarding fishery system management [4].

1.3 Selection of Tana and Awash Lake's Indicators

On the basis of development of indicators, together with the weighing criteria for the selection of Tana and Awash Lake's indicators, eight significant indicators were identified. They are:

1.3.1 Ecology

1. Catch per unit effort (CPUE) (S_1)
2. Availability of economic aquatic animals (S_2)
3. Water Quality (S_3)

1.3.2 Economic:

1. Fishery productivity (S_4)

1.3.3 Community:

1. Community Participation (S_5)
2. Attitude to fishing as an occupation (S_6)

1.3.4 Policy and Institution:

1. Control of Religion (S_8)
2. Fish as Diet (S_8)

These indicators will help us to improve the optimization problems.

Table – 1: Proposed Indicators for Sustainability Fishery in Tana – Awash – Lakes – Ethiopia

Sustainability Components	Indicators	Operational Definition and Units of Measurement	Data Sources
Ecology	CPUE S_1	Catch per unit effort by Gillnets with varied mesh sizes (Monofilament & multifilament) $\frac{Kg}{Day \times Unit\ of\ fish\ gear}$	Animal Biology Journal 2012 Direct collected rough data FAO MOA
	Availability of Economic Aquatic fishes (selected three) S_2	Fishermen can catch economic aquatic fishes in Tana, Awash	FAO Fishermen Commercial people
	Water Quality S_3	Standard classification level of water quality from the (MOWR), Ethiopia	Environmental Office , Hawassa and Bahir Dar Fishermen
Economic	Fishery productivity S_4	Production from fishing using all fishing gear $\frac{Kg}{Day \times Household}$	FAO Fishermen
Community	Community Participation S_5	Fishermen participate in restoration of protected in Lake area of Tana and Awash	Fishermen
	Attitude to fishing as an occupation S_6	Fishermen believe that this occupation is good and wants to their families to be fishermen	Fishermen
Policy and Institution	Control of Religion S_7	Orthodox Christians predominate	FAO
	Fish as Diet S_8	Not Recognized by Most Ethiopian	Community & priest Fishermen

II. DATA COLLECTED FROM

FAO means Food and Agriculture Organization of the United Nations – Ethiopia – 2018

MOWR means Ministry of Water Resources of Ethiopia.

Animal Biology Journals – 2015 to 2018 Worldwide

Table – 2: All % convert from enquires of column- 5 – 8 around (1200 in Awash area, 3360 in Bahir Dar)

Data collected from FAO (Ethiopia) - 2018								Remarks
Lake Name	CPUE (Kg)	Water Quality	Fishery Productivity	Community Participation In %	Attitude Occupation In %	Control Religion In %	Fish as diet In %	CPUE and Fishery productivity Calculate from three types of fishes and in three month (Oct, Nov, Dec) average
Awash	16542	Not normal	16542*	43	17	40.22	29.43	
Tana	51846	Normal	51846*	57	23	39.11	31.79	

16542*$= 13915\ (Tilapia) + 1345\ (Barbus) + 1695\ (African\ cat)$

51846**$= 46594\ (Tilapia) + 1849\ (Barbus) + 3403 (African\ cat)$

2.1 Biomanipulation and Lake Management – Category II

Biomanipulation is a widely accepted and frequently applied ecotechnology to improve the environmental quality of standing waters. In this context Biomanipulation refers to reduction of impurity followed by an increase in the abundance of three types of fishes. In addition to graphical representation demonstrating the decision flow, the approach of Welcomme (2011) to formulate the decision questions similar to a faunistic key, with Yes and NO answers guiding to the next questions was followed. For all steps, detailed explanations and reference to the main literature and experience from World – Wide Biomanipulation which lasted at least 5 years are give (Figure – 1).

World Fish Trade Center recommended around thirty categories to optimize harvesting fishing in lakes here we choose six needed categories in Ethiopian lakes especially for Awash and Tana as follows:

1. Are any potential Stakeholders involved in fisheries?

   Fisheries – related stakeholders may be commercial fishermen, anglers or fisheries – related sectors of the principal fishery [5], [6]. It is necessary to develop a detailed management plan with clearly (B_1) Yes $\longrightarrow 2$; No $\longrightarrow 3$

2. Rehabilitate the catchment area

   To decrease external loading, habitat improvement measures in thecatechment area are required. Numerous handbooks and overviews describe approaches for catchment improvement [7] (B_2)

   Yes $\longrightarrow 5$; No $\longrightarrow$ 6

3. Is manual removal of unwanted impurities of fish technology possible?

   Continuously seining and trawling can efficiently remove unwanted impurities [7] .

   To catch a sufficient proportion of three types of fishes he mesh end not exceed 15 mm. Despite progress in the development of fishing gears, the features pointed out above restrict application of active fisheries o lakes with appropriate morphology. Catching efficiency depends on lake size. An optimal catching efficiency for a 15 mm mesh net used in lakes whereas efficacy was below 55% if the lake area increased to more than 17,300km^2 $and\ 250\ km^2$[4].

   In particular, in urban lakes or lakes in forested areas (Awash) and in large lakes (Tana) it is recommended to involve professional, experienced fishermen as they possess the necessary skills for handling fishing and often are in possession of necessary seines or trawls and equipment for transport [8]. Therefore biomass reduction of carp may be required to prevent density Dependent growth [9]: In some countries, the fish which are caught by manipulations can be sold as stocking material to support recreational fisheries e.g. Bream in The Netherlands [10], although this raises problems like spread of disease and genetic contamination [11]. More often, however, in Ethiopia there is no market for fish's to support continuous commercial fisheries. If the quantities are large enough it may be possible to sell the fish to a fishmeal producer or deliver them to a biogas facility (Not available in Ethiopia) (B_3).

Yes $\longrightarrow 4$; No $\longrightarrow 1$

4. Perform maintenance or compensatory stocking if necessary

   If fishes are reproducing naturally, supplementary stocking may be required only after drastic population crashes or in response to heavy exploitation rates [11]. In these cases, stocking with adults fish (For example – African Cat Fish recommended): However, even in these cases stocking may be of little benefit if sufficient recruits are naturally available [12]. Long term success of these measures is currently under evaluation but $\longrightarrow 5$, otherwise$\longrightarrow 1(B_4)$.

5. Commercial Fisheries Dominate

   Usually, commercial fisheries are interested in continuous harvest rates of medium – sized fish which can be better marketed than trophy – sized fish (Large). Therefore, in this case maximum annual harvest rates have to be defined, but minimum size limits can be low, only allowing for first maturation of predators (15cm and above length of Cat and Tilapia fishes). Due to continuous removal of medium – sized fish, large predators are scarce and cannibalism is low, whereas growth and individual consumption rates are high. Normally in Ethiopia one expects full agreement of commercial fishermen with the interest of medium – size fishes. However the aim of the management needs to be communicated to the local fishermen by an educational out reach$\longrightarrow 6$ (B_5).

6. The final stage – Adaptive Management

   Fish biomass and fish community composition have to be controlled annually, and the management (stocking measures and harvest regulation) be adapted to the prevailing situation and the management targets. This kind of continuous evaluation and adaptation of management decisions is called "Adaptive Management" [13]. According to ecosystem theory, strong and intense perturbations are required o shift a system into another stable state, whereas pulsed perturbations are of little impact [12] $\longrightarrow 1$ (B_6).

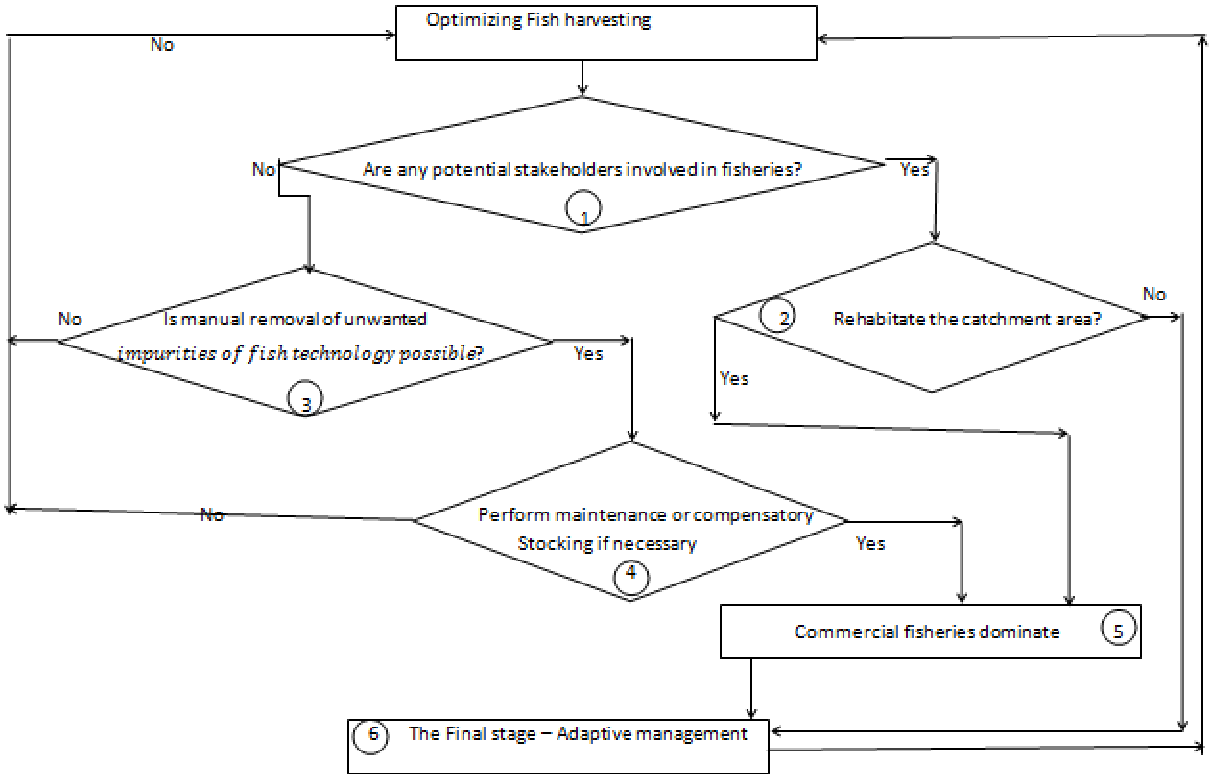


Figure – 1: Decision question flow chart presentation. The numbers on the circle correspond to the numbered question in the six stages

2.2 Balances harvesting – Theory and Application Category III

Recent work on a range of multispecies fisheries, ecosystem and size – spectrum models suggest that fishing patterns operating with moderate mortality in proportion to biological production, and spread across a wide range of sizes all fishes in community, maximize yield while conserving biological diversity and size structure better than conventional selective removal based on single species optimization of yield [14], [15] [16]. Size – spectrum models in particular give rise to a different view on ecosystem and community perturbations due to fishing. Results from this model will be used here to derive a framework of analysis of the sustainability of fished communities in freshwater. As the results from these models are so diverging from traditional single species fisheries models, as for instance the widely applied yield – per – recruit $(YpR)\ models$ [17], a short description is required.

Size – spectrum models have their root in the observation that total biomass per unit volume in aquatic systems in logarithmically – scaled bins of body mass is roughly equal [18], [19], which results in a strongly size structured biomass – size spectrum. This typical demographic structure of aquatic communities comes about as virtually all organisms start ontogeny as tiny larvae, act in their early life as prey for larger predators and grow through a range of tropic levels during their development until adulthood [20]. Unlike terrestrial ecosystems, there are usually neither large herbivores nor large plants in open aquatic environments as most primary production must start in the narrow euphotic surface layer with no foothold and strong turbulence, which require miniscule body sizes to persist. The aquatic food chain must therefore, in general, begin at the microscopic phytoplankton level and most organisms must run the gauntlet of predation which growing to adult size. This, perhaps, can explain the very high fecundity of many aquatic organisms compared to terrestrial equivalents. However, the steady loss of mass due to assimilation efficiencies of around 20 -25%, will – on a logarithmic scale result in the typical triangular shaped biomass – size distribution (Fig 2).

Size – spectrum models keep track of biomass changes in an ecosystem by explicitly linking growth and mortality through predation. Thus fish grow dependent on how much they eat, while most fish die because they are eaten. The flow of biomass from small to large organisms is internally accounted for through feedbacks between growth and available food, between assimilated food and reproduction, and between mortality and predation. The typical triangular biomass – size structure of aquatic communities emerges from these feedback and dissipation processes, while changes in diet and mortality captured through this internal accounting result in changes in the size structure. This is a fundamentally different approach than single species (YpR) models where two independent external growth and decay functions (usually according to von Bertalanffy growth equation and negative exponential mortality function) determine the rates of change in biomass. In these models there is no accounting for food, which is assumed present and for free. As a result of this free lunch assumption, the general recommendation from (YpR) models to optimize yield is to delay fishing mortality (by regulating size – at – entry) until the balance between mortality and growth has peaked. However when accounting for food and assimilation loss (It takes approximately 2 – 3 kg of prey to produce 1 kg predator), the size – based models shifts the whole focus to the productive areas of the ecosystem, which are generated at lower trophic levels and smaller/younger individuals in a population or community (Fig: 2). Then a delayed size – at entry fishing does not produce the highest sustainable yields in contrast to fishing patterns targeting juveniles and producting large mature adults, where a truly balanced harvesting pattern produces the highest sustainable yield [16]. Apart from the criterion of sustainable yield [16], evaluate the impact of different fishing patterns on two additional criteria.

a. The resilience of a system to disturbance and (H_1)
b. The disruption of the natural size structure of system caused by exploitation (H_2)

Again resilience and disruption deviated most at conventional size – at – entry fishing with minimum size limits, while the greatest resilience to disturbances and least disruption of the size structure were obtained by a balanced harvesting pattern. A size based framework of analyzing fisheries derived from similar physiologically structured, size – spectrum models is also proposed by others [21]

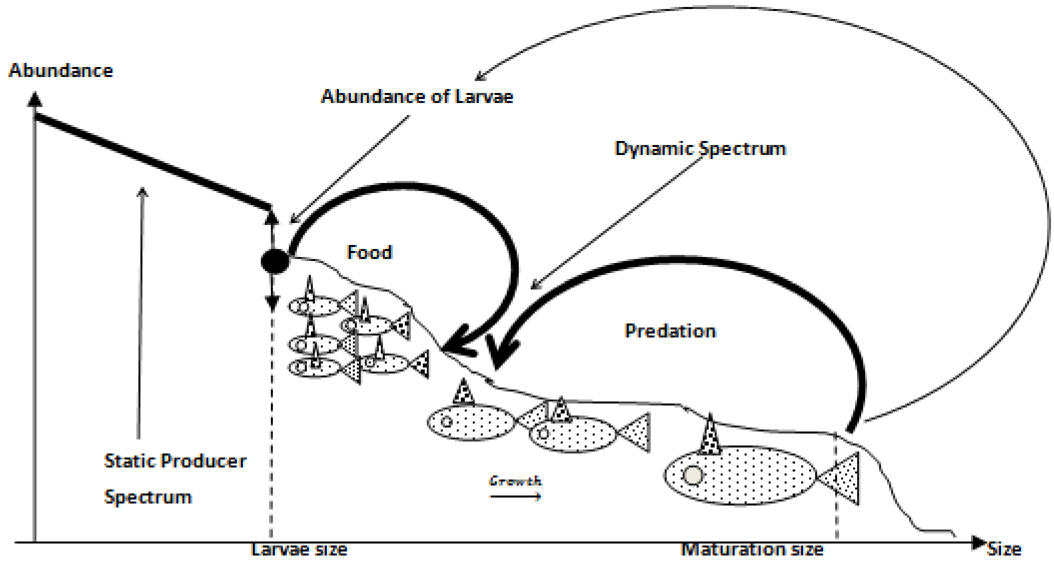


Figure – 2: A dynamic size Spectrum model of abundance as a function of body size, over the course of time in a fish community feeding on itself and on fish larvae delivered by a static producer spectrum

From those above three categories, previously in many papers authors doing simulation or statistical model with selective sample data and they sketch the graphic or phi – chart result. It is a quantitative process it describes a process by developing a model of that process and then conducting a series of organized trial and error experiments to predict the behavior of the process overtime. Then they will get how the real process will react to certain changes in the model and simulate the reaction of the real process to them. In our research, using data, questioners' participations and new balance harvesting choosing disturbance of total catching fishes by the size modified by three types of fishes with Bio geographical manner and form subdivisions from regression fitting finally we built Modeling as optimization.

2.3 Prepare mainland Lakes Biogeography

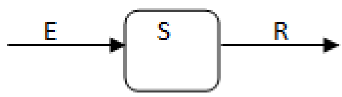
Biogeography is a discipline that combines elements of ecology and geography; its primary objective is to describe and explain the spatial distribution of plants and animals (here we choose fish) on the Earth's surface. The spatial scale for this field is broad: landmass on the order of continents and large islands. Mapping the geographical distributions of species is a major component of biogeography, but it also examines patterns of numbers of species over the geographical space. Inland lakes biogeography is a sub discipline which restricts itself to land.

2.4 Physical Setting

Ecological an inland lake can be true biogeographers are interested in the number of species on the lakes will occur as well as the dynamic s of the build – up species on lakes or the extinction of species as lake conditions change. An impressive field experiment performed by [22] tracked the number of insects on small mangrove islands following complete defaunation. The dynamics of numbers of species is shown in Fig: 3 and 4; the number of species after two years was nearly identical to the pre – defaunation level.

The physical frame work is shown in Fig: 5. Organism from the mainland species disperse randomly. If an individual species not currently on the lake intersects the lake that constitutes a colonization of a new species. If all of the individuals of a species on the lake die, then the species has gone extinct. Consequently the number of species on a lake is the result of two processes:

Colonization and extinction



Type of Problem	Given	To find	Uses of Models
Synthesis	E and R	S	Understand
Analysis	E and S	R	predict
Instrumentation	S and R	E	Control

Figure – 3: Systems and uses of models

First row – A general system represented as a input (E), a system object (S) and the output (R)

Third row: Knowledge needed for models of different uses.

From Karplus 1977 – simulation councils [20]

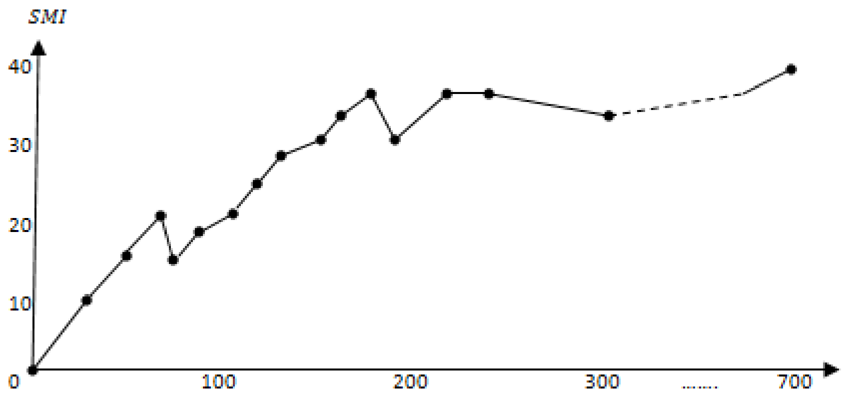


Figure – 4: Numbers of species on a small mangrove island following defaunation (Reprinting permission from Ecological Society of America)

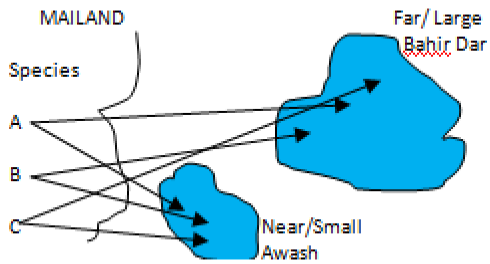


Figure – 5: Physical picture of Lake Biogeography theory. Organisms colonize randomly (Arrows) lake can vary by their distance to the mainland (near or far) and their size (large or small)

III. THEORY

There are many approaches to the problem of describing the numbers of species on lakes.

For example, we could take figure – 5 literally by mathematically creating a two – dimensional picture of a particular mainland and set of lakes. We could then mathematically describe the movement of individuals of all species as the attempt to colonize the lake with random flight paths. This approach could incorporate extensive ecological and behavioral realism. Alternatively, we could simplify the figure by ignoring individual organisms, writing equations or the populations of each species on each lake. [23] However took an even simpler approach. They simplified the problem by abstracting away population's species and considered the system S in figure – 3, to be the number of species on a lake, without regard to the numbers of organisms in the species. Thus, they describe a dynamic theory of biogeography in which the numbers of species is a balance of two processes: Immigration and extinction. The rates of both processes depend on the number of species currently on the lake. The net rate of change of species is the sum of these two forces. When immigrating is greater than extinction, the number of species increases; the number decreases if the opposite is true.

We make two very simple biological hypotheses concerning these processes:

a. Individuals of each species (type of fishes) have a constant probability of arriving at the lake and this probability is identical for all individual and all species (type of fishes). The rate of immigration (I) of new types for example in Tana Lake [1] (more than three types available) of new species only occurs upon the arrival of individual of a species not currently in the lake.
b. The probability of extinction of any single species is constant. Consequently as the number of species on the lake increases. Thus the total rate of extinction (E) increases with (R) (number type of fishes in the lake)

Figure – 6: graphically illustrate these hypotheses. In this figure R, it is the number of type of fishes on the lake, P – it is number of type of fishes in both lakes. We use the equation for the straight line to represent the rate of colonization (in our case the vector constants of constraints) and extinction (CPUE)

(I), it may be decreases because as type of fishes accumulates there are any other types that can be new. In the limit, if a lake has as many species as the whole mainland, the rate of colonization must be zero. Extinction increases because on lake with much type of fishes, the total number of type of fishes going extinct will increase if there is a constant probability (Three categories sub divisions) that any one type of fish goes extinct.

These hypotheses (which might be based on the data and prior knowledge) have simple mathematical expressions. The simple model is a straight line in both cases.

$$I = I_x - \left(\frac{I_x}{P}\right) R \tag{1}$$

$$E = \left(\frac{E_x}{P}\right) R \tag{2}$$

Note that we are not doing colonization and immigration model, it will help us to find optimizing fish harvesting, only we change as colonization as total number of three types of fishes in kilograms and immigration is nothing but all three categories sub divisions, so that

I_x *as maximum weight rate and* E_x *as maximum extinction (sub divisions)rate*

We assemble these hypotheses into a single equation that describes the vector constant columns(c_i, d_j, e_k), in our following model, for simplicity, we will consider time to be discrete, but later we will use continuous time.

$$R_{t+1} = R_t + I_t - E_t = R_t + I_t - \left(\frac{I_x}{p}\right) R_t - \left(\frac{I_x}{p}\right) R_t \qquad (3)$$

Equation (3) mathematically represents our hypothesis that three types of fishes dynamic are based on the relative strength of two processes

I_t *causing numbers to increase the weigth rate*

E_t *causing numbers to decrease (by the sub division applicable or not)*

We conclude that these types of data are difficult to collect in natural field situations, but are possible in laboratory settings figure – 7 is one such data set obtained from physical simulation of the colonization process.

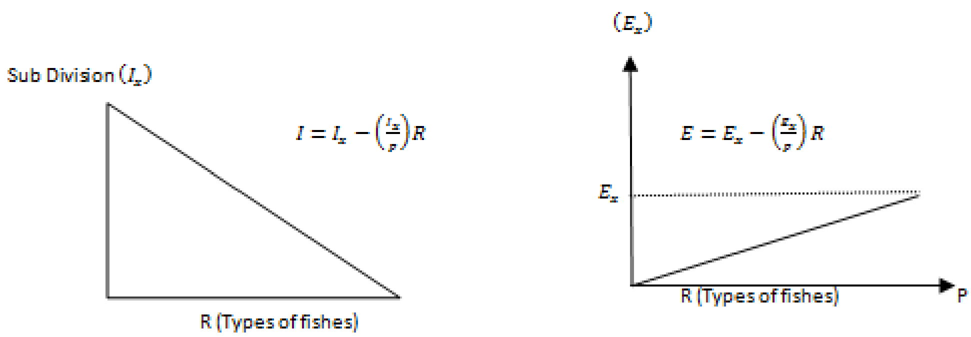
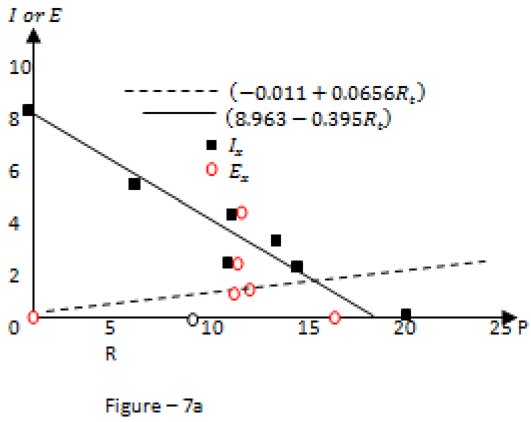


Figure – 6: Quantitative relationships between types of fishes on a lake (R) and rate of subdivisions (I) and extinction (E), it is the types of fishes in Tana Lake



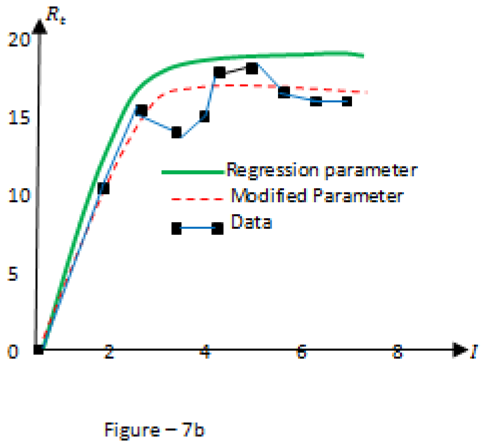


Figure – 7: Data and results from a simulate biogeographically experiment

Figure – 7a: I=Numbers per time, solid diamnods and its best fit regression line (solid line) E numbers per time open circles And its regression line (dashed line)
Figure – 7b: Observed and predicted types of fishes by iterating Regression parameters assigned to c_i, Modified regression parameters assigned to d_i, it obtained from equation (3)

From equation (3) substituting the values of $I_x; \left(\frac{E_x}{P}\right) and \left(\frac{I_x}{P}\right);$, by the simulated biogeographically experiment we get

$$R_{t+1} = R_t + (8.963 - 0.395R_t) - 0.011 + 0.0656R_t \quad (4)$$

3.1 Note:

The use of the regression equations which are strongly influenced by the considerable statistical variation of the data has some implications for this model to find subdivisions values promptly.

In our concepts we use firstly, by the nature of environmental we deterministic and represent to an extent the complexity of the real world and uncertainty prevailing with time and dynamically and we built a function and use convexity and essential aspects from three categories with three types of fishes.

"**Categories mean those are mutually exclusive and its union form whole aspects**" [24]

First we assume that Sustainability management, Biomanipulation and balanced harvesting are three categories. The first and last are dependent and middle one is independent of the others

The sub divisions in Sustainability's are parameters are constants and take them as

$S_1, S_2, \ldots, S_8 \text{ with } S_1 + S_2 + \cdots + S_8 = S$ (5)

The sub divisions in Biomanipulation parameters are constants and take them as

$B_1, B_2, \ldots, B_6 \text{ with } B_1 + B_2 + \cdots + B_8 = B$ (6)

Then lastly we select balance harvesting has two parameters they are also constants and take them as

$H_1, H_2 \text{ with } H_1 + H_2 = H$ (7)

We can form a function $f(x_i) \text{ for } i = 1, 2, 3 \text{ (Three type of fishes)}$

Formulate the objective function

Maximize $f(x_1, x_2, x_3) = \sum_{i=1}^{3} x_i$

With constraints $Sx_i <, >, = c_i$

$Bx_i <, >, = d_i$

$Hx_i <, >, = e_i$

Where $x_1, x_2, x_3 > 0$

By equation (4) and our data table we can calculate

$(c_i \text{ (regreeion parameter)and } d_j \text{ (Modified) we can fix } e_k\text{, becasue not implemented in Ethiopia)}$

By equations (5), (6) and (7)

We get $S, B \text{ and } H \text{ either positive or zero and also}$

$S_i, B_j \text{ and } H_k \text{ for } i = 1,..8; j = 1, \ldots 6 \text{ and } k = 1, 2$, they are any real numbers

Here we have three variables so we can solved graphically also

The best method is Simplex method because all objective and constraints are linear functions

From this optimizing problem we conclude that, we get maximum or least or zero results only (no negative results) by the following approach

Approach – 1:

In Sustainable Management: Note that in the table – 1, in Ethiopia we have the following possibilities

$S_1 \text{ to } S_5$, they are applicable, we get the data from the table – 2

Approach – 2:

$S_6 \text{ to } S_7$, they are rarely applicable, we get the data from the table – 2

Approach – 3:

In Biomanipulation all six sub divisions are needed to implement in Ethiopia

Approach – 4:

New project it must need in future in Ethiopian lakes, already some African countries are adopted this category and succeeded their optimization

Examples:

Tanzania, Kenya and Uganda

IV. RECOMMENDATION AND CONCLUSION

This paper simply explains regarding linear equations optimization for harvesting fishing. If anyone interest in this field, if they will do parameters are variables and prepare non – linear equations with regression parameters convert to variable form they will get more accurate optimization and also that will help to improve our country Ethiopia harvesting fishing is in peak in future.

Secondly in sustainability management and Biomanipulation take more sub divisions the result will be improve by iterations.

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