Nile Perch Fishery in Lake Victoria

Biological and Exploitation Reference Points

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Abstract

The abstract of the report will go here.

Preface

This book is about checking data with the validate package for R.

This version of the book was rendered with `validate` version 1.1.1. The latest release of `validate` can be installed from CRAN as follows.

```
install.packages("validate")
```

The purposes of this book include demonstrating the main tools and workflows of the `validate` package, giving examples of common data validation tasks, and showing how to analyze data validation results.

The book is organized as follows. Chapter 1 discusses the bare necessities to be able to follow the rest of the book. Chapters 2 to 3 form the 'cookbook' part of the book and discuss many different ways to check your data by example. Chapter 4 is devoted to deriving plausibility measures with the `validate` package. Chapters ?? and ?? treat working with validate in-depth. Chapter ?? discusses how to compare two or more versions of a dataset, possibly automated through the lumberjack package. The section with Biblographical Notes lists some references and points out some literature for further reading.

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Citing this work

To cite the `validate` package please use the following citation.

> MPJ van der Loo and E de Jonge (2020). Data Validation Infrastructure for R. *Journal of Statistical Software*, Accepted for publication. `https://arxiv.org/abs/1912.09759`
> To cite this cookbook, please use the following citation.

> MPJ van der Loo (2022) *The Data Validation Cookbook* version 1.1.1. https://data-cleaning.github.io/valid

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Acknowledgements

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Contributing

If you find a mistake, or have some suggestions, please file an issue or a pull request on the github page of the package: https://github.com/data-cleaning/validate. If you do not have or want a github account, you can contact the author via the e-mail address that is listed with the package.

License

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1 Introduction

Lake Victoria is the world's second-largest lake and the largest tropical lake with a surface area of 68,800 km^2. The lake has a maximum depth of between 80 and 84 m and an average depth of 40 m (Wikipedia contributors, 2022). The lake has a shoreline of 7,142 km with islands constituting 3.7% of this length.The lake's area is divided among three countries: Kenya occupies 6% (4,100 km2, Uganda 45% (31,000 km2), and Tanzania 49% (33,700 km2).

In addition to its size, the lake is unique in several ways. It supports one of the world's biggest inland fisheries aimed at both domestic consumption and international export (Kolding et al., 2014). It has an approximately equal to one million tons. Lake Victoria Nile perch fishery is the most valuable freshwater fishery in Africa and it has supported an extremely valuable export-oriented fishery that generates a significant source of revenue for the East African countries.

Nyamweya et al. (2020) investigated the impacts of fishing using catch and effort data that have been consistently recorded for the past two decades and found that water transparency in the offshore decreased from close to 8m in late 1920s to less than 2m in the 1990s before improving to about 4m in the 2010s, a reflection of change in ecosystem functioning. Catches in Lake Victoria increase with increasing fishing effort but catch composition has shifted to one dominated by small pelagic species (Nyamweya et al., 2020).

Although different management options for Nile perch management in Lake Victoria, including slot size management and species-specific management have been placed, the stock of nile perch has been declining over the years. The size and biomass of nile perch has shown a significant decrease (Kayanda et al., 2009; Natugonza et al., 2022).

The fishery of Lake Victoria became a major commercial fishery with the introduction of Nile perch in 1950s and 1960s. Biological and population characteristics point to a fishery under intense fishing pressure attributed to increased capacity and use of illegal fishing gears. Studies conducted between 1998 to 2000 suggested capture of fish between slot size of 50 to 85 cm TL to sustain the fishery (Njiru et al., 2009).

1.1 Food and feeding habits of Nile perch

A predatory freshwater fish, Nile perch (*Lates niloticus*), widely distributed in Africa and native in the Niger, Senegal, Volta, DRC and Nile River Basins including Lakes Chad, Albert, and Turkana (Balirwa, 1995). The species was introduced into Lake Victoria from lakes Turkana (Kenya) and Albert (Uganda) in 1950s and early 1960s (Pringle, 2005).

In Lake Victoria, haplochromines were the main component of the diet up to the 1970s (Balirwa, 2007). After declining of haplochromine from the lake in the 1980s, Nile perch shifted its diet to shrimps (*Caridina nilotica*), dagaa (*Rastrineobola argentea*), tilapiines, anisopteran nymphs and Nile perch juveniles (Katunzi et al., 2006; Mkumbo and Ligtvoet, 1992; Ogutu-Ohwayo, 1990)

Between 1995 and 2000 shifted mainly to Rastrineobola after its booming following a decline in Haplochromine. But still Caridina nilotica, anisopteran nymphs, Nile perch juveniles, tilapiines remained to be major prey with proportion increase of haplochromines. Nile perch were later reverted to haplochromine after its increase in the lake (Mkumbo, 2002). up to 2020, diet of Nile perch is dominated by Caridina niloticus, Haplochromines, and followed by Dagaa. Insects, Molluscs, barbus, and Synodontis contributed the least to Nile perch diet (LVFO, 2020).

Fish plays a role as a nutritional security and income to hundreds of million people in the rural household (Welcomme et al., 2010, Balirwa, 2007). In Africa, inland fisheries are utilised the same way like any other continent despite the fact that are characterized by patterns of overexploitation, environmental degradation and exotic species introduction (Balirwa, 2007). One of the major Bassa et al.: Stock Assessment of Lates niloticus in Upper Victoria Nile 12 fish species that is highly utilised is the Lates niloticus, Nile perch. The Nile perch (Centropomidae: Lates niloticus L., 1758) was introduced in Lake Victoria in mid-1950s whose population exploration was realized in 1980s.

Nile perch, like other fishes in the world is an important source of high quality proteins and a wide variety of essential micronutrients, trace minerals, vitamins and fatty acids (Kalhoro et al., 2017; Abowei et al., 2010). The species is an economically important commodity with various products and by-products such as the fillets, fish maws, fish oils, fish bones and skin that support many fisher communities in Uganda and the region at large. In spite of the decline attributed to overfishing due to the species high demand (Balirwa 2008; Ogutu-Ohwayo et al, 2013; Balirwa 2007; Yongo et al., 2018). However, with the new fishing regimes that included the use of lucrative illegal gears have led to the stock decline of the native fishery including the Nile perch from all lakes and the rivers. The decline of the Nile perch in the lakes has led the riparian people to exploit the riverine system including the upper Victoria Nile in order to meet the demand and supply.

Several studies have reported that fish growth, mortality and recruitment parameters are important for assessment and management of fish stocks population (Kalhoro et al., 2017; Abowei et al, 2010). This study utilised both total catches and length frequency data to determine the population structure, exploitation rate and fishing efforts of the Nile perch in UVN. The main aim was to assess the trends and fishing pressures of Nile perch in the UVN Bujagali area with a view of obtaining information to guide management for sustainable use and conservation of the species.

2 Methods

2.1 Study area

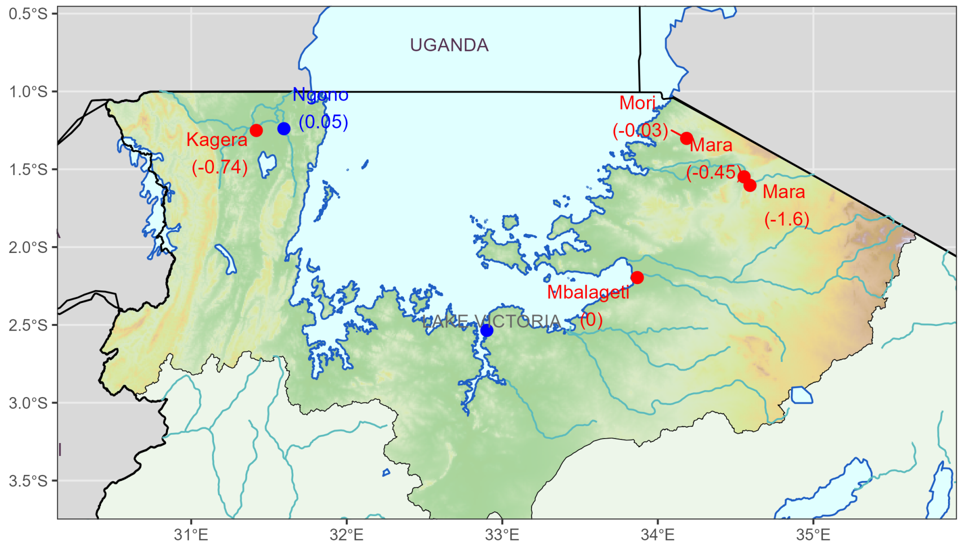

Figure 2.1: Map of Lake Victoria in the Tanzania Side

2.2 Scope of study

The study was conducted in Lake Victoria located between longitude 31.603°E and 34.092°E and latitude 1.002°S and 3.093°S (Figure xxxx) with a width of about 243.89 km and a maximum depth of about 80 m (mean depth of 40m).

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2.3 Data

The study used existing biometric and length frequency data of nile perch in lake victoria. The data is fishery independent that were collected between 2003 to 2021 and covers the Tanzania waters. The data was sampled during hydroacoustic survey in which some stations were selected for bottom trawling. The trawling was conducted for thirty minutes each and sampled for length and weight was based on standard operating procedure described (LVFO, 2005). Total length (TL) was taken to the nearest cm for all fish and total weight (TW) of individual fish to nearest 0.01 kg was measured. Gonadal maturity stage of male and female individual fish was determined based on (Hopson and Kitching, 1972) (Table 1).

Table 1: Maturity stages and sex of nile perch

Sex	Maturity Stages: Stage	Maturity Stages: Maturity	Descriptions
Male	I	Immature	Testes a pair of thin transparent strands running longitudinally along the dorsal wall of the body cavity; sexes indistinguishable macroscopically
	II	Early developing	Testes transparent greyish-white, occasionally pinkish; narrow and flattened
	III	Late developing	Testes semi-transparent, greyish-white or pinkish; often well-vascularized; more or less flattened in transverse section; no milt
	IV	Mature/resting	Testes opaque, whitish or pinkish; often well-vascularized; firm, triangular in section; slight milt exudes from lumen when cut
	V	Mature/ripe	Testes opaque, ivory white or pinkish; soft; triangular in section; lying in the longitudinal groove on ventral surface; copious milt when cut
	VI	Ripe/running	Similar in appearance to stage V but milt running freely from the vent when slight external pressure is applied to fish
Female	I	Immature	Appearance alike testes; sexes indistinguishable macroscopically
	II	Resting	Ovary grayish-white, or pinkish, transparent, smooth and cylindrical, circular in transverse section; eggs not visible macroscopically; only slightly vascularized
	III	Early maturing	Ovary pinkish or reddish, semi-transparent; pear-shaped in section; eggs not visible macroscopically, tissue well vascularized
	IV	Late maturing	Ovary pinkish or reddish with small opaque yolky ova, clearly visible; pear-shaped in section
	V	Ripe	Ovary yellowish-buff, opaque due to presence of large yolky ova visible through the superficial membrane; pear-shaped in section; large blood vessels on the surface
	VI	Running	Ova yellow-brown in colour, oil globule present; slight external pressure causes ripe ova to be extruded from the vent
	VII	Spent	Ovaries loose and flabby, containing torn follicular tissue rich in blood with a few residual stage V ova

$$W = aL^b \tag{1}$$

2.3.1 Catch

2.3.2 Timeline

The sequence of major events and management regulations were extracted from reviews of journal papers, books and unpublished technical reports.

2.3.3 Estimate the Stock

The Length-Based Spawning Potential Ratio (LBSPR) model was used to assess the stock status based on length frequency data of Kawakawa in the territorial water. The LBSPR was chosen for this analysis because is able to estimate fisheries stock from limited data— a situation where few data are available. This technique is an equilibrium based, and assume that the length composition data is a representative of the exploited population at steady state. The method is able to simulate and estimate the exploitation reference points from biological reference points. The LBSPR model requires biological and exploitation parameters to simulate length frequency data and predict an equilibrium size composition and the resulting level of Spawning potential ratio (SPR).

2.3.4 Estimate size at first maturity

Size at first maturity (L_{50}) describe the length at which 50 percent of the individuals fish caught are adults or with mature gonads. The size at 50% maturity (L_{50}) was estimated as the length at which a randomly chosen specimen has a 50% chance of being mature (Torrejon-Magallanes, 2020). We used a morphometric instead of gonado somatic technique to estimate L_{50} of Kawakawa because is robust in assessing the stock using the length-based-spawning potential ratio (LBSPR). In the regression analysis, the fork length is denoted as the explanatory variable and the classification of maturity (*juveniles* versus *adults*) is considered the response variable (*binomial*). The variables are fitted to a logit function in equation (2):

$$P_{CS} = \frac{1}{1 + e^{-(\hat{\beta}_0 + \hat{\beta}_1 \times X)}} \tag{2}$$

where PCS is the probability of an individual of being mature at a determinate X length. β_0 (intercept) and β_1 (slope) are parameters estimated. The L_{50} is calculated in equation (3):

$$L_{50} = -\frac{\hat{\beta}_0}{\hat{\beta}_1} \tag{3}$$

2.3.5 Catch Converted Curve

Life history parameters were determined from growth parameters (length asymptotic and growth coefficient), mortality and size at first maturity. Total mortality was estimated using the length–converted catch curve model. The selectivity parameters were estimated by the length-converted catch curve analysis with simultaneous estimation of the selection ogive. The construction of the catch curves requires information about growth parameters to estimate the relative age of the individuals. Here, growth parameters (L_∞ and K) of the von Bertlanffy growth equation (VBGE) were computed. Based on the growth parameters, the instantaneous natural mortality rate (M) were approximated by means of the empirical formula in equation (4):

$$M = 4.118K^{0.73}L_\infty - 0.33 \tag{4}$$

where K and L∞ are the growth parameters of the VBGE. By subtraction of M from Z, an estimate of the instantaneous fishing mortality rate (F) was estimated and an indicator of the exploitation rate was estimated as ($E = \frac{F}{Z}$).

A *Powell-Wetherall* method was used to estimate the instantaneous total mortality rate (Z) and the infinite length (L_∞) of the von Bertalanffy growth equation (Powell, 1979; Wetherall et al., 1987). The Electronic LEngth Frequency ANalysis (ELEFAN) method was used to fitting the best growth curve, which allows the fitted curve through the maximum number of peaks of the length frequency distribution.With the aid of the best growth curve, the growth constant and asymptotic length (L_∞) were estimated. The von Bertalanffy growth equation was defined in equation (5)

$$L_t = L_\infty[1 - exp(-K(t - t_0))] \tag{5}$$

Where L_t is length at time t, L_∞, the asymptotic length, K, the growth coefficient and t_0, is the hypothetical time at which length is equal to zero. The t_0 value estimated using the empirical equation (6)

$$Log_{10}(-t_0) = -0.3922 - 0.2752 \times Log_{10} \times L_\infty - 1.038 \times Log_10 \times K \tag{6}$$

2.4 Data Analysis and Packages

We used R–a language and environment for statistical computing version 4.2 (R Core Team, 2020) to process, analyse, and visualize, plot graphs and maps. Wilcoxon test was used to test whether the length at maturity was significant difference from the median total length of Nile perch. Several packages were used to create length frequency distribution, compute biological references points and estimate exploitation parameters. These packages include TropFishR (Mildenberger et al., 2017), sizeMat (Torrejon-Magallanes, 2020) and LBSPR (Hordyk, 2019). We also used **readr** (Wickham and Hester, 2020) package for reading comma–separated files, **readxl** for importing Excel spreadsheets into R sessions (Wickham and Bryan, 2019), **ncdf4**

(Pierce, 2019) for importing satellite data stored in NECDF file format and **sf** (Pebesma, 2018) for reading, processing and analysis of spatial data.

The **lubridate** (Grolemund and Wickham, 2011) was used to seprate time into monsoon seasons, **wior** Semba and Peter (2020) was used to detect and remove outlier observations from the datasets, **dplyr** (Wickham et al., 2021) for manipulating data, and **tidyr** (Wickham, 2021) for organizing the file into a consistent format for subsequent analysis and mapping. The results from the analysis were summarized and presented in tables with **knitr** (Xie, 2014) and **kableExtra** (Zhu, 2021) packages while plotting and mapping was made with the **ggplot2** (Wickham, 2016), and **ggstatsplot** (Patil, 2021) and **metR** (Campitelli, 2021) packages. **patchwork** (Pedersen, 2020) was used to combine plots and export them in both PDF and PNG formats. The **bookdown** (Xie, 2016) and **rmarkdown** (Xie et al., 2020) packages were used to typeset and compile LATEX document of the manuscript an knit with **knitr** package (Xie, 2014) to various format including PDF, tex and word. The script file that can be used to reproduce the analysis and plotting figures used in this study can be accessed from this github link.

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3 Results

The total number of individuals sampled are 12168 shown in Table 2

Table 2: Sampling Individuals of length and weight measurement

	Sampling Quarter				
year	First	Second	Third	Fourth	Total
2003	0.0% (0)	0.6% (77)	0.0% (0)	0.6% (77)	0.0% (0)
2004	0.0% (0)	2.0% (243)	0.0% (0)	2.0% (243)	0.0% (0)
2005	1.3% (158)	3.0% (370)	7.6% (924)	3.0% (370)	6.1% (744)
2006	0.0% (0)	0.0% (0)	3.9% (477)	0.0% (0)	4.0% (483)
2007	0.0% (0)	0.2% (30)	0.0% (0)	0.2% (30)	5.8% (704)
2008	1.2% (150)	0.8% (93)	0.7% (90)	0.8% (93)	1.2% (151)
2013	6.8% (833)	1.9% (226)	0.0% (0)	1.9% (226)	7.8% (944)
2014	4.2% (509)	1.6% (198)	0.7% (88)	1.6% (198)	0.0% (2)
2015	0.0% (0)	0.5% (57)	0.0% (0)	0.5% (57)	4.2% (513)
2016	0.0% (0)	5.1% (621)	0.0% (0)	5.1% (621)	0.0% (2)
2017	0.0% (0)	13.6% (1660)	0.0% (0)	13.6% (1660)	0.6% (71)
2018	0.0% (0)	4.1% (500)	0.0% (0)	4.1% (500)	0.6% (76)
2019	0.0% (0)	2.8% (345)	0.0% (0)	2.8% (345)	0.8% (103)
2020	0.0% (0)	0.4% (48)	0.0% (0)	0.4% (48)	1.3% (163)
2021	0.0% (0)	1.5% (187)	0.0% (0)	1.5% (187)	2.7% (328)
Total	13.6% (1650)	38.3% (4655)	13.0% (1579)	38.3% (4655)	35.2% (4284)

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3.1 Length–Weight Relationship

3.1.1 Fishery Independent

The length and weight relationship of nile perch individual from fishery independent (Surveys) data is shown in figure 3.1.

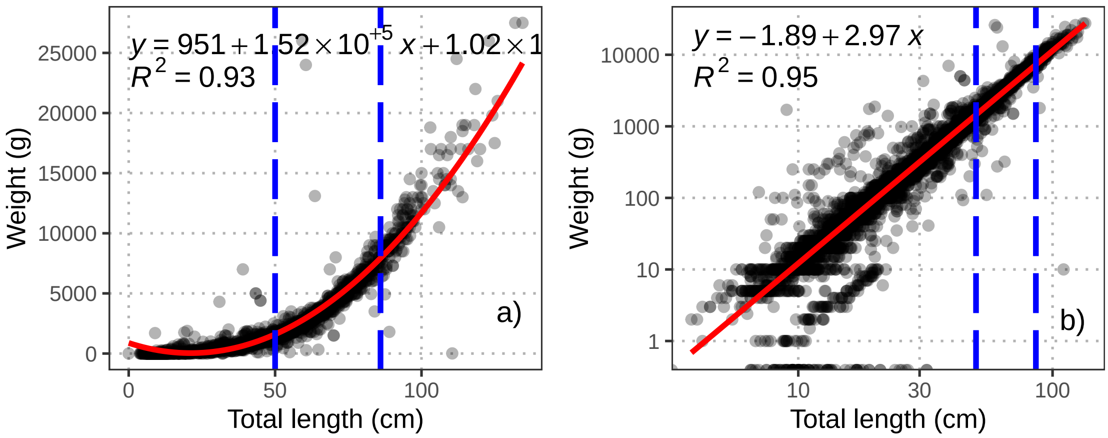

Figure 3.1: Length-Weight relationship of Nile Perch with a) raw data and b) standardized data with logarithmic scale of 10

3.1.2 Fishery Dependent

The length and weight relationship of nile perch individual from fishery independent (Surveys) data is shown in figure 3.2.

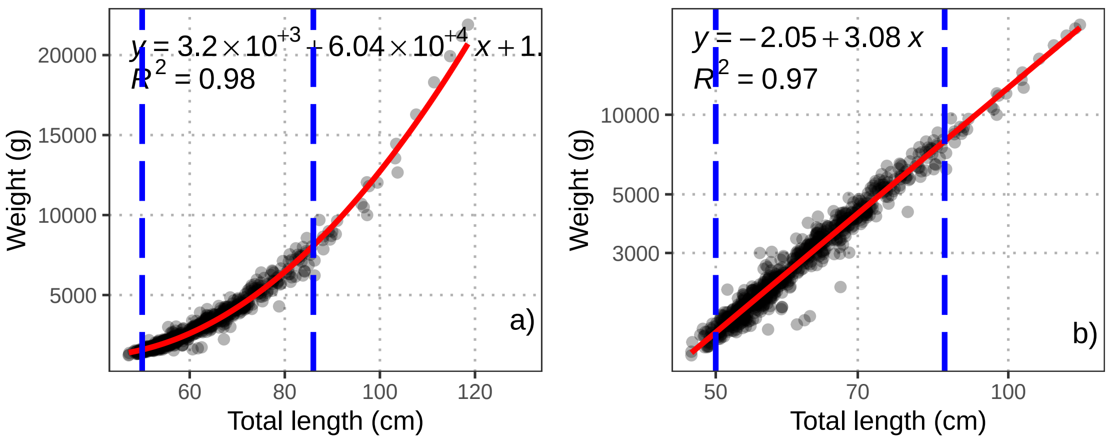

Figure 3.2: Length-Weight relationship of Nile Perch with a) raw data and b) standardized data with logarithmic scale of 10

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3.1.3 Dependent and Independent Fishery Data

The length and weight relationship of nile perch individual from fishery independent (Surveys) and fishery dependent (sampled from fish processing industries) data is shown in figure 3.3.

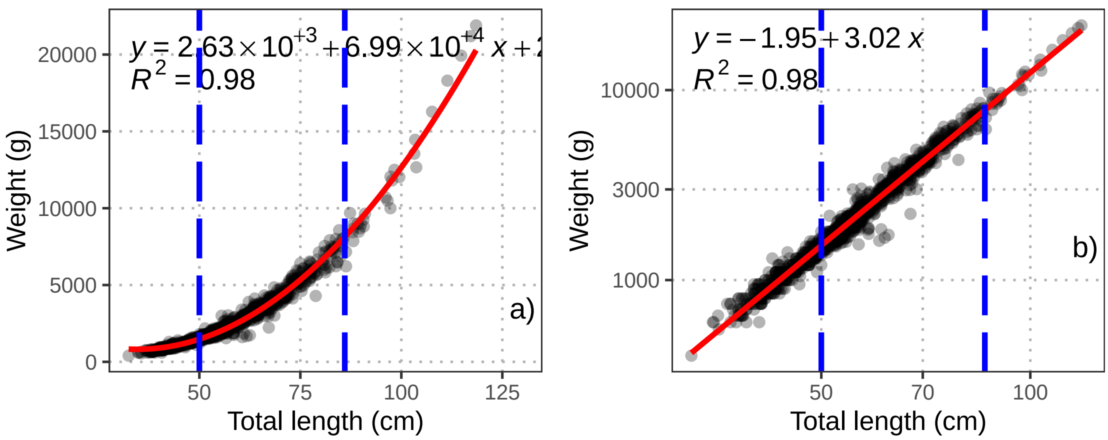

Figure 3.3: Length-Weight relationship of combined independent (survey) and dependent (industrial) Nile Perch with a) raw data and b) standardized data with logarithmic scale of 10

3.2 Using information on Life History relationships

Life history traits include growth rate; age and size at sexual maturity; the temporal pattern or schedule of reproduction; the number, size, and sex ratio of offspring; the distribution of intrinsic or extrinsic mortality rates (e.g., patterns of senescence); and patterns of dormancy and dispersal. These traits contribute directly to age-specific survival and reproductive functions.

These relationships have many uses, for example in age-structured population models, functional relationships for these processes allow the calculation of the population growth rate and have been used to to develop priors in stock assessments and to parameterise ecological models. Table 3 show model coefficients (A and B) and slope of the log-transformed length and weight of nile perch from fishery–independent data sampled between 2003 to 2021 in the Lake Victoria.

Table 3: Length-Weight coefficients of Nile Perch

Year	Count	Coefficients A	Coefficients B	Coefficients R2
2003	77	0.95	2.43	0.76
2004	243	2.11	3.17	0.91
2005	2196	2.07	3.08	0.90
2006	960	1.73	2.87	0.96
2007	734	2.14	3.12	0.99
2008	484	1.88	2.98	0.97
2013	2003	1.85	2.95	0.97
2014	797	1.96	3.02	0.95
2015	570	1.73	2.85	0.98
2016	623	1.82	2.92	0.96
2017	1731	1.76	2.89	0.96
2018	576	1.75	2.88	0.97
2019	448	1.59	2.78	0.97
2020	211	1.74	2.89	0.98
2021	515	1.98	3.02	0.97

3.2.1 Length at first maturity (L50)

At a population level, the removal of larger fish may be reflected in changes in mean length or weight of population i in surveys forumla, and in some index of maximum length Lmax,i. (Because maximum observed length is highly dependent on sample size, upper quartiles such as L90% or L95% may be more robust.) Traditional single-species assessment models account for the reduction in mean size caused by increasing exploitation rate (Beverton and Holt, 1957). Stock indices, such as proportional stock density (PSD) or relative stock density (RSD), which are widely used in freshwater ecosystems, may also account for larger fish forming a smaller proportion of a population. Their calculation is based on reference lengths (Table 1), which have variously been defined as approximate length at maturity, minimum length effectively sampled by traditional fishing gears, or the minimum length of fish having recreational value (Willis et al., 1993). The definition of reference lengths has been set almost exclusively from a recreational point of view, and their use would therefore have to be rigorously expanded in the context of commercial fisheries for stock indices to be useful for EAF.

At the level of a community, the simplest SBI accounting for fish removals is mean length or weight of all individuals therein. It aims at quantifying the combined changes in mean size within each population, and in the relative abundance of small- and large-bodied species. Mean length must be calculated on the basis of the total size distribution, in order to estimate the variance. In contrast, changes in forumla are used to quantify the relative abundance of small and large species, using a fixed maximum length of each species (Jennings et al., 1999), rather than to reflect changes of intra-specific maximum size. For convenience, maximum size is sometimes expressed using the Linf parameter of the von Bertalanffy growth equation (Jennings et al., 2001). Other reported community SBIs refer to mean age and size at maturity (Jennings et al., 1999). However, while these are based upon fixed life history parameters by species, they are not more informative than forumla, because they do not account for phenotypic plasticity, but only for changes in the relative abundance of species with different life history parameters.

Table 4

Table 4: Ogive parameters and length at first maturity for male and female individuals of nile perch in Lake Victoria

	Ogive Parameter		Maturity Length (cm)	
Year	A	B	Male	Female
2003	-35.98	0.77	47.11	49.89
2004	-11.83	0.21	56.96	60.04
2005	-11.31	0.23	48.78	45.58
2006	-10.97	0.26	42.02	44.98
2007	-20.00	0.45	44.47	46.45
2008	-19.84	0.43	46.03	50.82
2013	-18.21	0.47	38.88	40.93
2014	-19.38	0.43	45.23	50.55
2015	-18.00	0.42	42.00	44.58
2016	-23.68	0.54	43.73	45.36
2017	-16.11	0.36	44.36	47.89
2018	-18.01	0.40	44.49	48.04
2019	-30.26	0.71	42.58	45.14
2020	-11.74	0.26	45.54	43.97
2021	-29.93	0.66	45.33	48.10

Figure 3.4

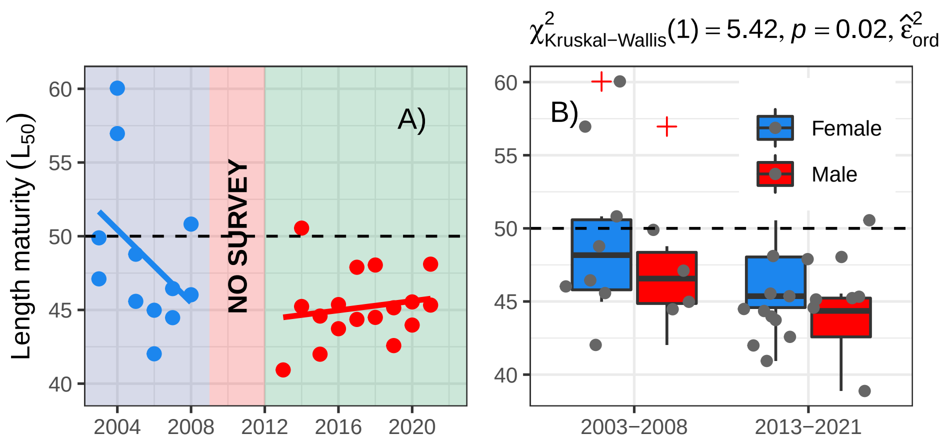

Figure 3.4: The length at maturity of nile perch indicating a) trends during the period between 2003-2008 and 2013-2021 and b) is the median value of L50 for male and female nile perch during the two epoches. The dotted black line mark the the lower size limit allowable for nile perch

3.3 Change in Size

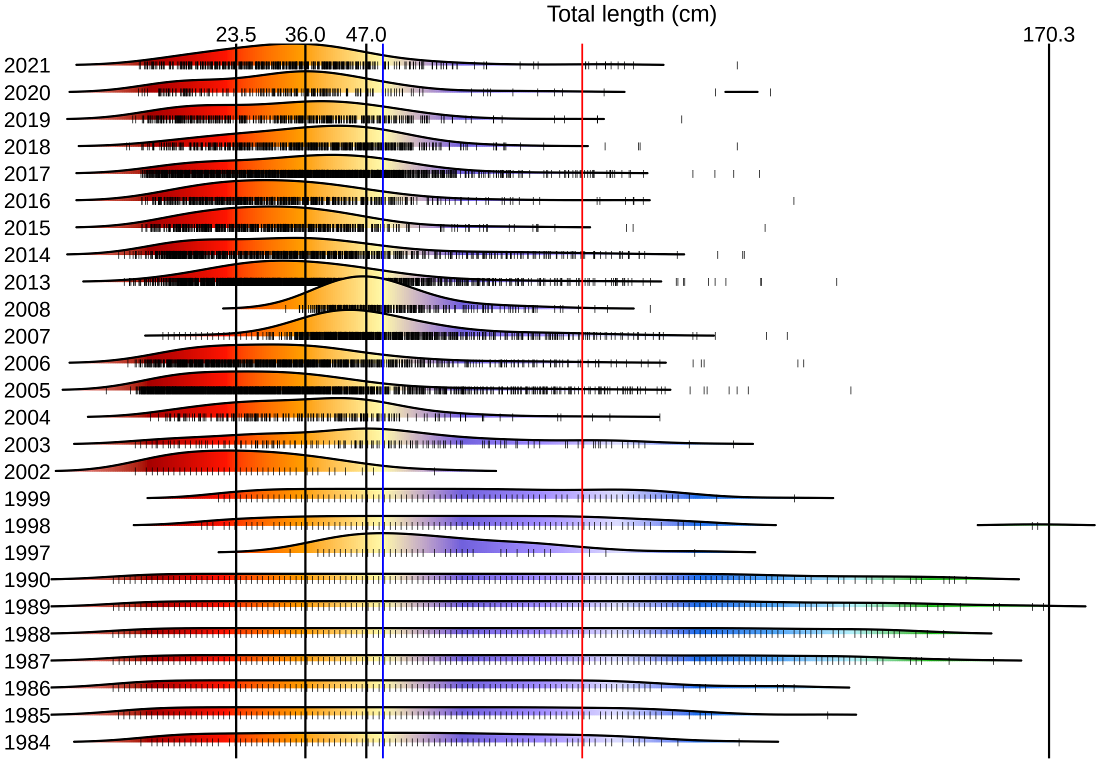

Figure 3.5: Total length density of nile perch in lake Victoria by years. the solid black line are quantiles (25,50,75,99), the dotted blue line is an allowable minimum slot size and the red dotted line is the maximum slot size.The ridges indicate the density of the sampled data points

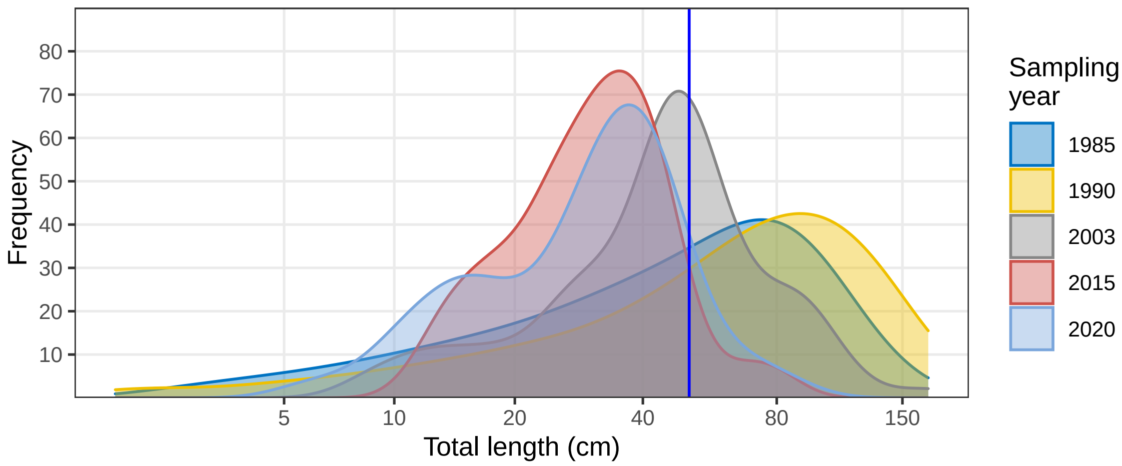

Figure 3.6: Shifting of total length of Nile Perch at over the years.A solid blue line is the minimum slot size

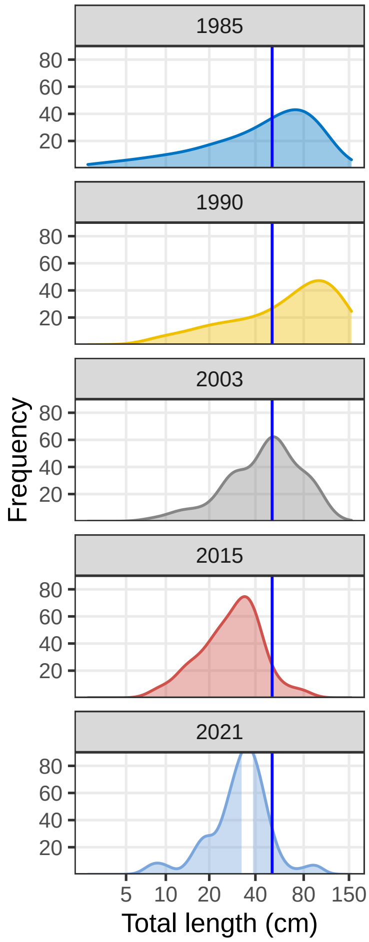

Figure 3.7: Shifting of total length of Nile Perch at over the years.A solid blue line is the minimum slot size

3.4 Empirical evidence of sensitivity to fishing

Changes in the size composition of nile perch in Lake Victoria are well documented. spatial comparisons between areas subject to different fishing intensities, and temporal comparison within areas where fishing effort has increased over time, show responses that are generally consistent with theory. This allows us to look the total length of nile perch at three different epoches. Based on long–term survey data (1978–1993) in Lake Victoria, the mean size of Nile Perch dropped drastically from 57.82cm in 1980-1999s to 38.05cm in 2000-2010 (Figure 3.8). The median size of 57.82cm in 1980-1999s is significant higher than the 38.05cm of 2000-2010 and 31.55cm observed between 2010-2021 (Figure 3.8).

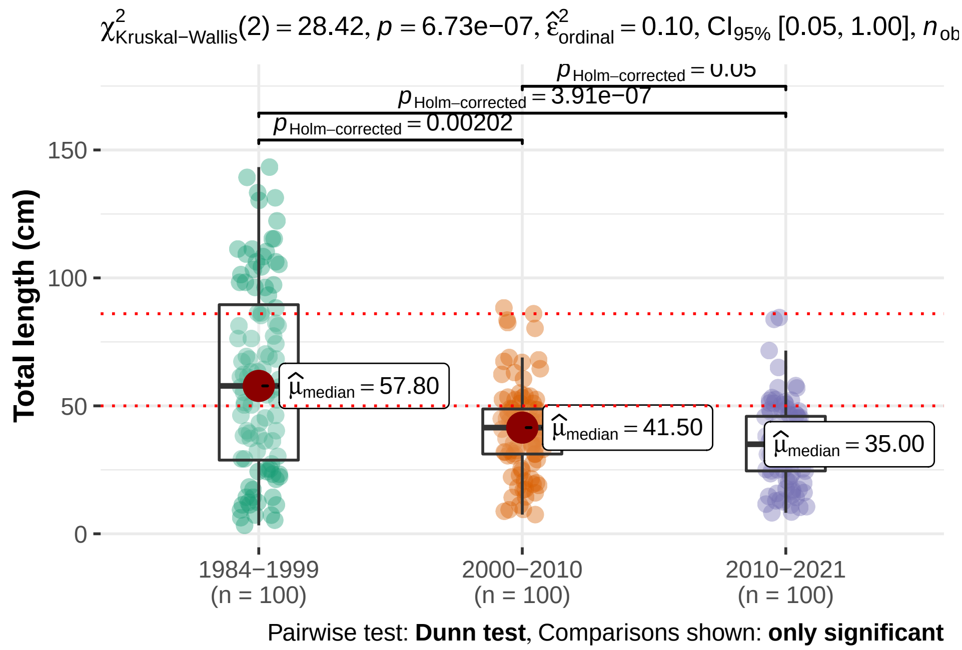

Figure 3.8: The median total length of Nile Perch in Lake Victoria grouped in three different managment regimes. The dotted line is minimum and maximum allowable slot size of Nile Perch

The percentage of adult individuals in nile perch population has decreased over time. The adult population composed more than 70 percent of harvested fishes in 1980s to late 1990 and drastical change in early 2000s dominated with juvenile (Figure 3.9). In recent years the adult population of nile perch landed has shrunk to less than 20 percent (Figure 3.9).

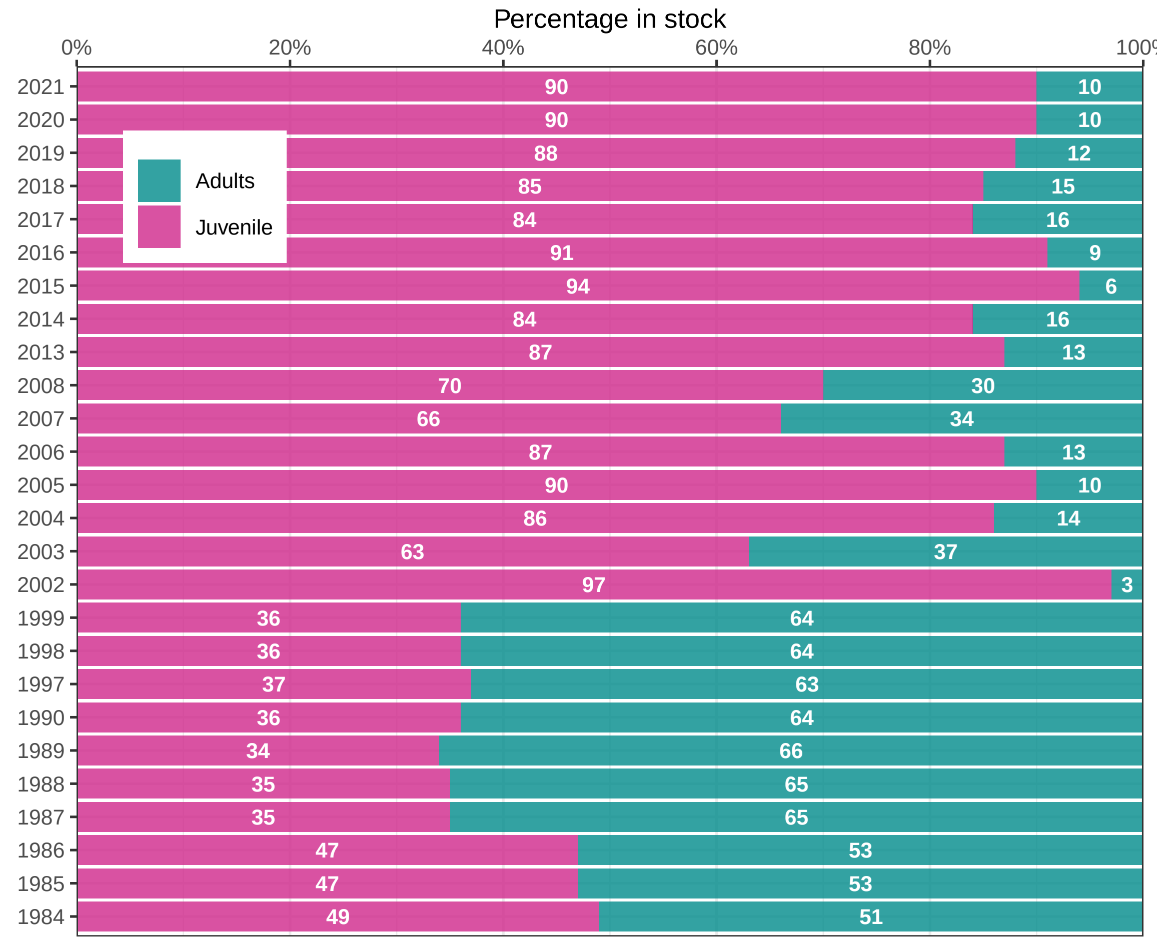

Figure 3.9: Population of adults and juvenile surveyed in the Lake Victoria water from 1984 in Tanzania waters

```
<ggproto object: Class ScaleDiscrete, Scale, gg>
    aesthetics: fill
    axis_order: function
    break_info: function
    break_positions: function
    breaks: waiver
    call: call
    clone: function
    dimension: function
    drop: TRUE
    expand: waiver
    get_breaks: function
    get_breaks_minor: function
    get_labels: function
    get_limits: function
    guide: legend
```


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```
    is_discrete: function
    is_empty: function
    labels: waiver
    limits: NULL
    make_sec_title: function
    make_title: function
    map: function
    map_df: function
    n.breaks.cache: NULL
    na.translate: TRUE
    na.value: grey50
    name: waiver
    palette: function
    palette.cache: NULL
    position: left
    range: <ggproto object: Class RangeDiscrete, Range, gg>
        range: NULL
        reset: function
        train: function
        super:  <ggproto object: Class RangeDiscrete, Range, gg>
    rescale: function
    reset: function
    scale_name: manual
    train: function
    train_df: function
    transform: function
    transform_df: function
    super:  <ggproto object: Class ScaleDiscrete, Scale, gg>
```

3.5 The Nile Perch Stock

An important step in providing management advice for a fish stock is the estimation of current status, past history and stock productivity through an stock assessment (SA) model. The FLStock object we have created contains some of the inputs required for most SA models: catches, natural mortality, and maturity. What is now needed is some indication of changes in abundance over the period of exploitation, an index of abundance, derived from either research surveys or catch-per-unit-effort of commercial fleets.

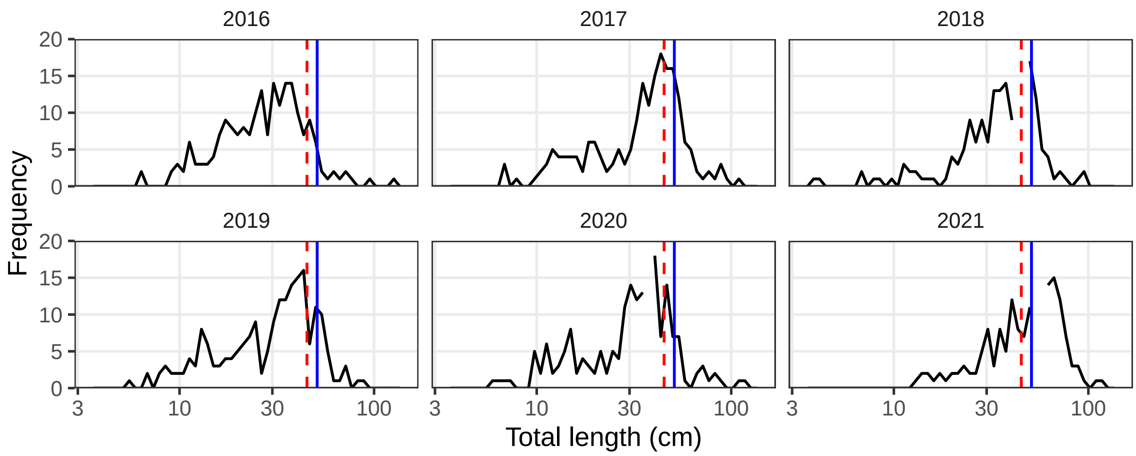

Figure 3.10: Histogram of Nile perch based on survey sampled between 2016 and 2021 in Lake Victoria part of Tanzania

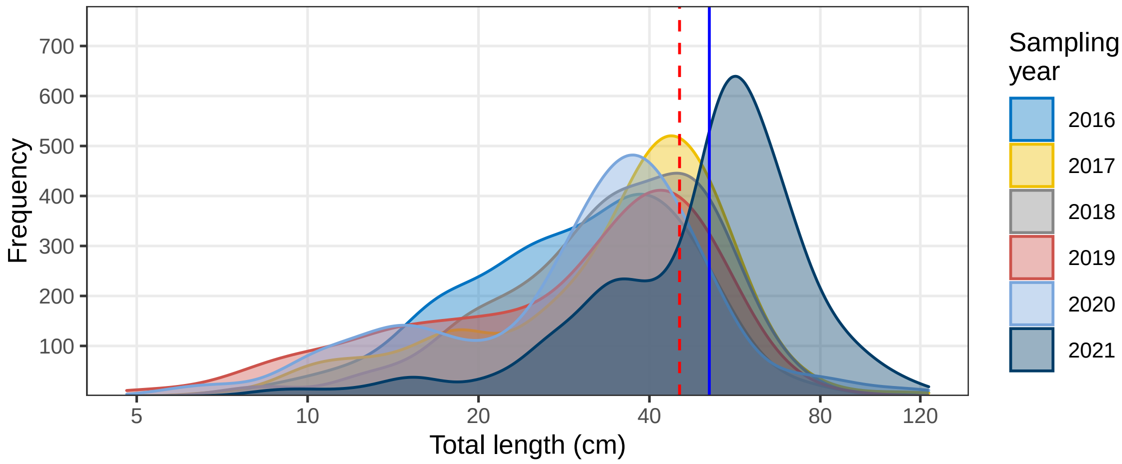

Figure 3.11: Density of Nile perch based on survey sampled between 2016 and 2021 in Lake Victoria part of Tanzania. Dotted red line mark the legngth at maturity and solid blue line is the minimum slot size

The yearly data shown in figure 3.13 were pooled together to have an average median size at first maturity and found that the mean maturation length for Nile Perch, which was 54-74 for male and 62–83 for female in the 1990s, had dropped to approximately 45.3 years by the 2010s (Figure 3.12).

```
formula: Y = 1/1+exp-(A + B*X)

    Original Bootstrap (Median)
A   -15.386  -15.1211
B   0.3395   0.3336
L50 45.3241  45.3124
R2  0.8363   -
```

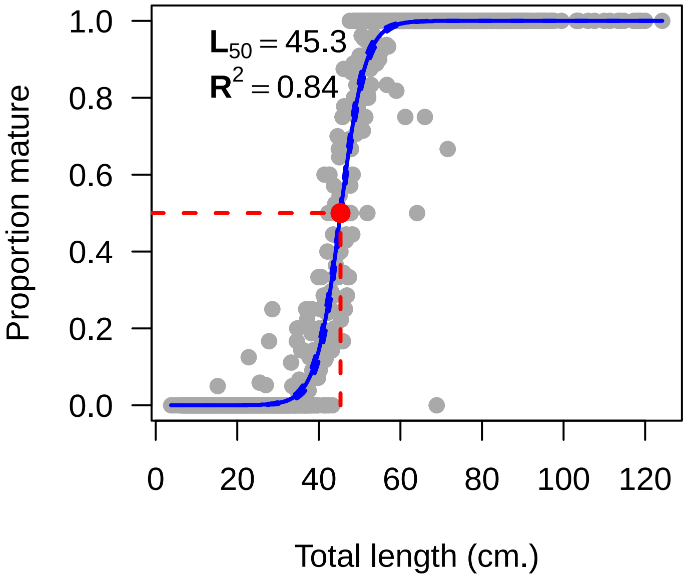

Figure 3.12: Legth at first maturity (L50) for Nile Perch. The ogive fitted well with an R2 of 0.85

```
Size at gonad maturity = 45.3
Confidence intervals = 45.1 - 45.7
Rsquare = 0.84
```


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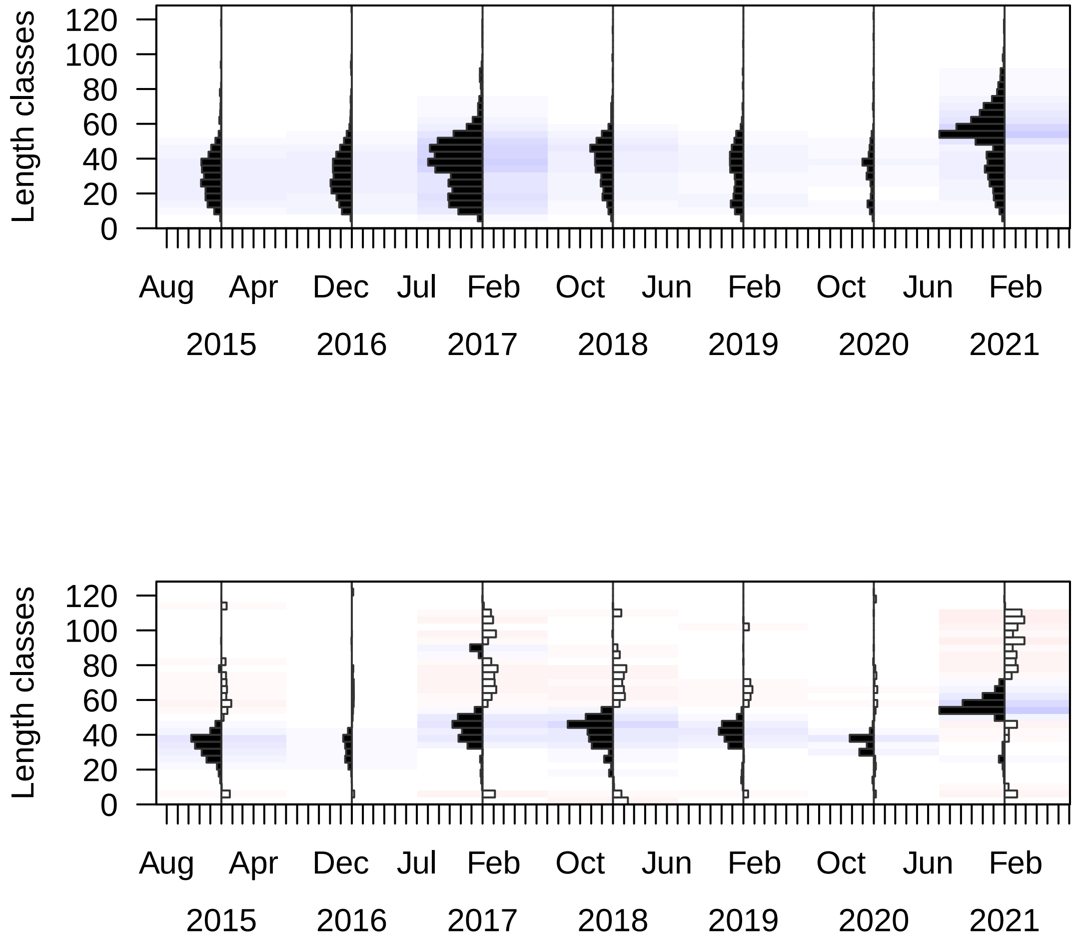

Figure 3.13: Length frequency catch (top panel) and counts (bottom panel) of Nile Perch in Lake Victoria

When the fishery independent (survey samples) and fishery dependent (fish processing samples) where combined, the length values fitted to the maturity by 96 percent with a slight increase of 0.4 cm in maturity from 45.3 to 43.7 (Figure 3.14).

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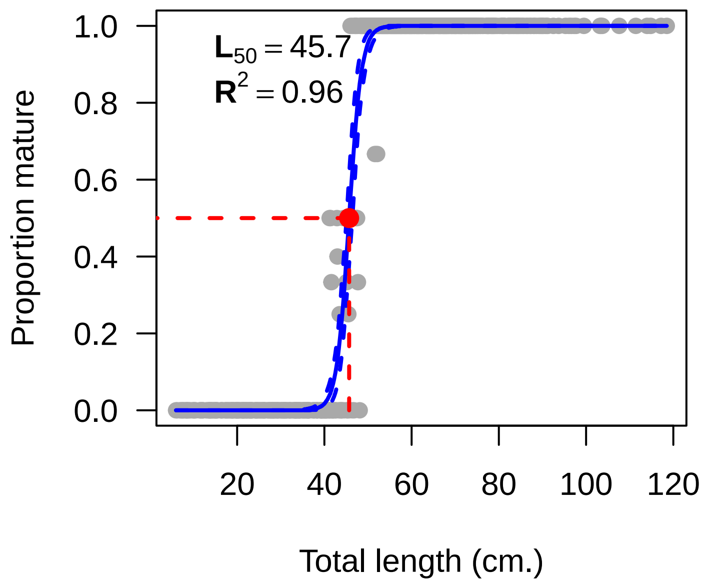
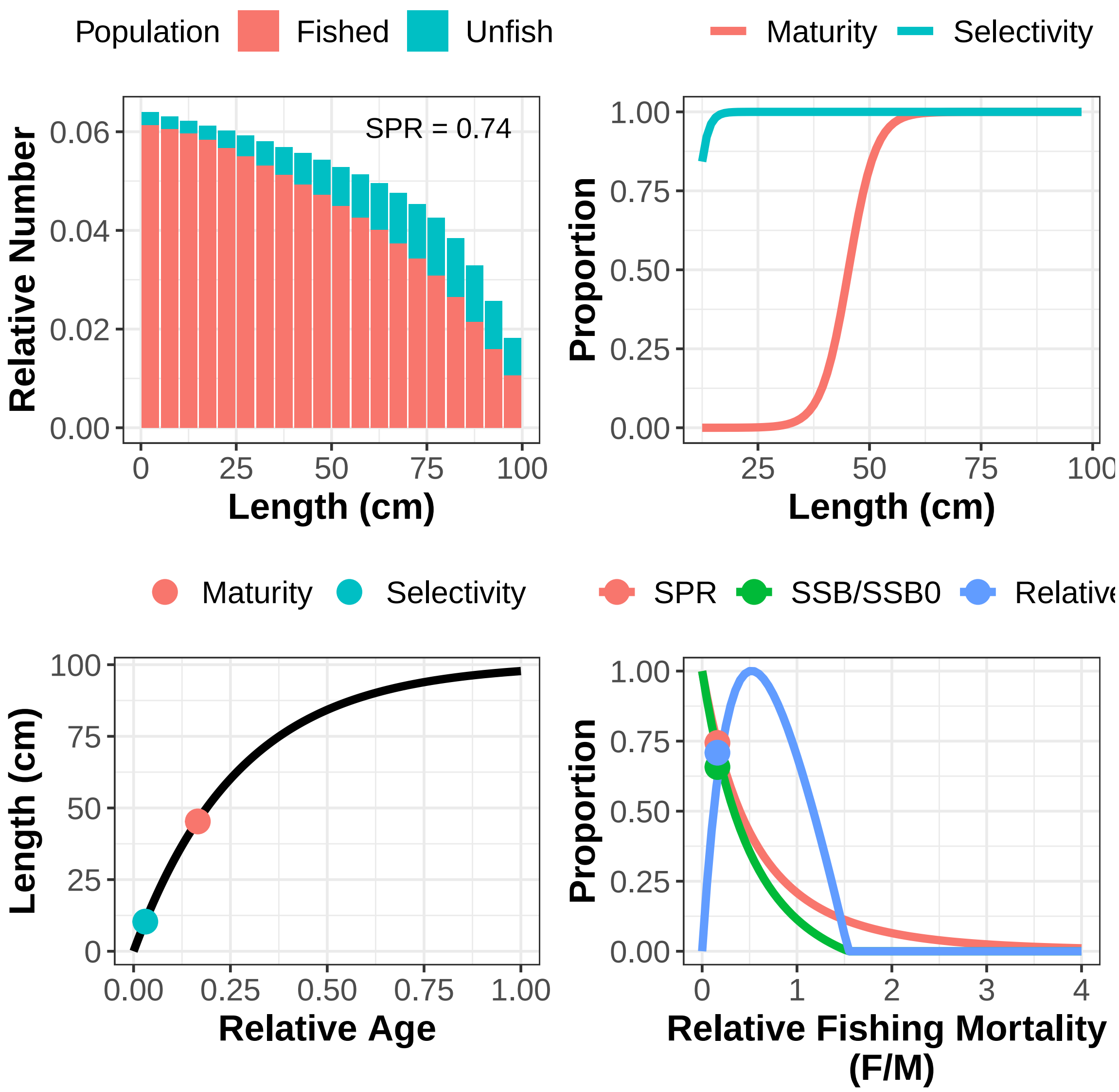
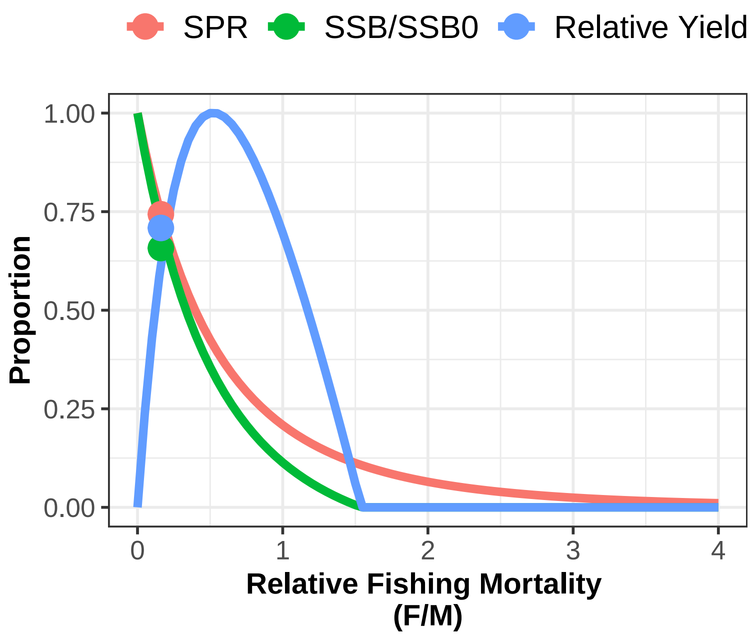


Figure 3.14: Legth at first maturity (L50) for Nile Perch sampled in 2021. The ogive fitted well with an R2 of 0.96

```
Size at gonad maturity = 45.7
Confidence intervals = 45.1 - 46.4
Rsquare = 0.96
```


21


Population
Fished
Unfish
Maturity
Selectivity
SPR = 0.74
Relative Number
0.06
0.04
0.02
0.00
0
25
50
75
100
Length (cm)
Proportion
1.00
0.75
0.50
0.25
0.00
25
50
75
100
Length (cm)
Maturity
Selectivity
SPR
SSB/SSB0
Relative
Length (cm)
100
75
50
25
0
0.00
0.25
0.50
0.75
1.00
Relative Age
Proportion
1.00
0.75
0.50
0.25
0.00
0
1
2
3
4
Relative Fishing Mortality
(F/M)


SPR
SSB/SSB0
Relative Yield
Proportion
1.00
0.75
0.50
0.25
0.00
0
1
2
3
4
Relative Fishing Mortality
(F/M)

22

4 Discussion

Female Nile perch grow to a larger size and mature later than males and up to 2006 males and females reached 50% maturity at 54-64 and 62-85 cm TL respectively (Njiru et al., 2009). the slot size of 50 to 85 cm TL sought to protect immature fish, harvest mature individuals and at the same time protect the larger females which would be expected to replenish the stocks.

While previous studies have shown that nile perch mature at 55 to 110 cm, we found that over the last 20 years the maturity of line perch ranged between 42 and 48cm. The L50 found in this study is below the recommended minimum slot size of 50 cm, which imply that the recommended slot size is ensure the individual caught have matured and contributed to the population. This findings contradict with findings presented in previous studies that found L50 above 50, suggesting that most of the individual that are allowed for catch have not attained maturity have not attained maturity.

In the their study Njiru et al. (2009) reported that male mature at a size between 54–74cm and female 62–85cm, but deliberately set the minimum slot size of 50cm was allowed (Njiru et al., 2007). The minimum slot size recommended is below the L50 reported but is above the L50 found in this study. This imply that the individual fish caught are far below tha reported maturity and regard the fish caught are caught while still immature. On contrast, using the L50 from this study, which is below the minimum slot size, imply that most fish caught have attained mature before they caught.

The slot size is suppose to be above the SL50, for sustainable fishery. However, this findings inform that since the reported SL is above minimum slot size, then the individuals landed are still juvenile yet legally allowed because of the slot size regulation. The L_50 of below slot size found in this study, suggest that despite the fishing pressure and change in ecological functioning and environmental conditions, the nile perch fishery still persist.

> To help preserve Nile perch and other commercial species in Lake Victoria, the board of ministries of the EAC established slot size regulation of 50 cm to 85 cm total length (TL) in early 2000s. This slot size was introduced to protect immature fish and large adults so that the stock could be replaced while mature fish are being harvested
>
> Despite its efforts to manage the fisheries, the TAFIRI overestimated the minimum slot size of 50cm TL of nile perch as well as the stock's growth rate during the late 1990s and assigned minimum slot size that was above the length at first maturity of about 48cm. High fishing effort and demand of fillet by European countries Overexploitation by international fishing fleets forced the species into decline. Between 1962 and 1977, the harvestable biomass of northern cod dropped by 82 per cent, which resulted in a near collapse of the stock and of the industry.

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Fisheries science conducted within the federal Department of Fisheries and Oceans (DFO) contributed to overfishing and stock depletion by consistently providing possible overestimates of the abundance of northern cod from the late 1970s through the 1980s. This in turn allowed policy makers to set quotas that were too high to maintain the stocks. Although the department announced in 1982 that cod stocks were rebuilding and forecast a long-term sustainable yield of 550,000 metric tons, a 1989 internal review revealed DFO had overestimated cod populations by as much as 100 per cent during the decade leading up to the moratorium. A variety of factors contributed to the errors in cod stock assessments.

Fisheries scientists based their stock assessments on data gathered almost exclusively from commercial trawlers, but failed to analyze the impact that increasingly efficient technology had on stock sizes. They also omitted from their calculations the number of undersized cod offshore fishers discarded, which resulted in low estimates of mortality from fishing. Although inshore fishers reported cod were decreasing in both size and number, DFO scientists ignored this information and instead focused on the offshore sector. Nor did they recognize that northern cod are divided into sub-populations that may function differently from one another in the complex environment of the continental shelf. As a result, fisheries scientists based their cod-stock assessments on oversimplified models of population and ecosystem dynamics.

Even after NAFO established lower TACs and Canada ended most foreign fishing within its 200-mile limit, overexploitation of northern cod in offshore waters remained a major problem throughout the 1980s. Many nations feared conservation efforts would result in economic losses – the fishery was one of the world's major employers and a drop in quotas would cause a similar drop in jobs and income. To avoid large-scale unemployment and economic hardships, Canada and other NAFO nations tried to keep quotas as high as possible.

At the same time, Canada and NAFO continued to overestimate the abundance of cod in the Atlantic Ocean and therefore continued to set dangerously high TACs. This was in large part due to the widespread practice of calculating cod populations from catch rates in the commercial fishery – if fishers filled their quotas with ease, then officials believed the stock size was at adequately high levels. However, fishing technology had become so efficient by the 1970s that commercial catch rates remained high even as the cod population dropped to dangerously low levels. Electronic tracking devices could find fish no matter how small their numbers and trawlers could harvest most species with relative ease.

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4.1 Conclusion

A several of factors led to the exploitation of Nile Perch in Lake Victoria. Increasingly efficient technology allowed fishers to find and harvest unprecedented amounts of nile perch, while need of filled in European marked allowed expansion of effort in the regione. At the same time, regulations safeguarding nile perch stocks did not evolve alongside the world's ability to harvest fish, and governments or international bodies assigned slot size that was relatively lower than the length at maturity. Although conservation became an increasing concern after the 1990s, officials consistently overestimated the slot size of nile perch and, as a result, also overestimated the amount of fishers could harvest at sustainable levels. This resulted in the recent observed decrease size of nile perch and decline of landed stock, which ultimately forced fish processing factories along the lakeshore to shutdown operations.

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