POPULATION DYNAMICS OF RASTRINEOBOLA ARGENTEA (PELLEGRIN) 1904 (PISCES: CYPRINIDAE) IN THE WINAM GULF OF LAKE VICTORIA, KENYA.

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DECLARATION

This thesis is my original work and has not been presented for any degree in any other University.

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LIST OF SYMBOLS USED

A	$(L_\infty - L_c)/(L_\infty - L_r)$.
a	intercept in linear regression, constant in length - weight relationship.
ANOVA	analysis of variance.
ANCOVA	analysis of covariance.
a1,a2	width of length-group 1,2,...
b	slope in linear regression
$\bar{B}/R$	average biomass per recruit
c	L_c/L_∞
C(j)	catch in numbers in length-group j
dL	interval size of length
dt	interval time
dt(j)	time it takes to grow through length-group j
e	base of natural logarithm
E	exploitation rate
$E_{F0.1}$	exploitation rate at $F_{0.1}$.
E_{CUR}	current exploitation rate
E_{MEY}	exploitation rate at maximum economic yield
E_{MSY}	exploitation rate at maximum sustainable yield
E_{opt}	optimum exploitation rate
exp	exponent to base of natural logarithm
F	fishing mortality coefficient per unit time; females; calculated value of F - distribution in ANOVA
$F_{0.1}$	fishing mortality at which the tangent to the

	yield curve is 10% of that at the origin.
FL	fork length
F_{max}	maximum fishing mortality
frq.(s.j)	frequency of length group j in sample s
I	immature
K	curvature of growth, growth constant; Fultons condition factor
L	length
$\bar{L}$	mean length computed from L' upwards
L'	smallest length fully represented
L_∞	L infinity, asymptotic length.
L_1-L_2	length-classes.
L_c	Length at first capture
L_{c50}	50% retention length
ln	natural logarithm
log	logarithm to base 10
L_r	length at recruitment into the exploited phase
L(j)	lower length of length-group j
L_{mean}	mean length of a cohort
M	natural mortality coefficient per unit time; males.
MEY	maximum economic yield
MSY	maximum sustainable yield
n	integers 0, 1, 2, 3 in Beverton & Holt yield equation
N	numbers in a cohort

N(j)	number in length group j
ns	not significant at α = 0.05 in ANOVA
N1-N2..	total number of fish belonging to group 1,2,..
ø'	growth performance index, log K + 2log L_∞
q	exponent in length-weight relationship
R	annual recruitment (at age t_r)
SD	standard deviation
SE	standard error
SI	separation index
SL	standard length
T	mean annual water temperature (^oC)
t_c	age at first capture
TL	total length
t	relative age, - 1/K.ln (1-Lj/L_∞)
t_o	t-zero, initial condition parameter, age at which the length would be zero
t_r	age at recruitment into the exploited phase
U	(1-L_c/L_∞)
W	weight, predicted weight
W_∞	W infinity, asymptotic weight
W_o	observed weight
Y	steady state annual yield in weight
Y/R'	relative yield per recruit
Z	total mortality coefficient
z	Z/K
*	significantly different at α = 0.05
π	pi = 3.142
Σ	summation sign

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ABSTRACT

Fish stock assessment of *R. argentea* (Pellegrin) was carried out for the first time in the Winam Gulf of Lake Victoria in 1989/90 using Length-based Fish Stock Assessment (LFSA) methods. Correlation between total length (TL), fork length (FL) and standard length (SL) were derived. Length-weight relationship were derived for juveniles, males and females by logarithmic transformation of the raw data.

The Fultons condition factor (K) was highest in December and March /April but lowest in June for all stations. The asymptotic length (L_∞) for the whole Gulf was 67.8 ± 4.3mm TL while the mean growth curvature (K) was 0.576 ± 0.070 yr^{-1} . Growth performance index (ϕ') was determined to be 3.40 ± 0.07. Mortality rates were quite high with a range of total mortality coefficient (Z) of 1.766 - 2.860 yr^{-1} while the fishing mortality coefficient (F) was 0.966 - 1.984 yr^{-1}. Mean Z/K value was 3.749 ± 1.104. F_{max} was 0.82 ± 0.13 yr^{-1} while $F_{0.1}$ was 0.51 ± 0.07 yr^{-1}. The range of selection length (L_c) for fully recruited fish was 45 - 50 mm TL.

The current exploitation rate (E_{CUR}) was 0.551 - 0.653 which was above the maximum sustainable yield

(E_{MSY} = 0.460 - 0.483), maximum economic yield ($E_{F0.1}$ = 0.348 - 0.365) and optimum exploitation rate (E_{opt} = 0.5) by 5.1 - 74%. Two-way analysis of variance (ANOVA) revealed no significant differences between stations nor sexes in 90% of the population parameters. A general reduction in asymptotic length (L_∞) of R. argentea was realized in the Winam Gulf while the stock is currently overexploited.

"Dagaa" fishery in the Winam Gulf of Lake Victoria is commercially important as a source of poultry feed, fish feed, cattle feed and human food. Rational exploitation of this fishery could be possibly achieved through correct management policies including the fisheries cooperative societies, licencing of nets in addition to registration of boats and strict observation of closed seasons.

CHAPTER 1

1. INTRODUCTION

1.1. Taxonomy

The family Cyprinidae are known as typical marine family. However, several members of the family are lake inhabitants. Some of these lacustrine cyprinids have not only adopted a pelagic way of life, but also their shape and silvery camouflage (Greenwood, 1966; Wanink, 1989) resemble marine pelagic fish such as herring (Clupea sp.). The pelagic cyprinids endemic to some East and Central African lakes were previously placed in one genus, Engraulicypris, until a revision by Howes (1980). In Lakes Victoria, Kyoga and Nabugabo, this group of fishes is represented by Rastrineobola argentea (Pellegrin) according to the current classification by Howes (op. cit.) and Chelaethiops sp. in Lake Tanganyika which is of no economic value (Okedi, 1981b; Wanink, 1989). R. argentea is locally known as "omena" in Kenya, "mukene" in Uganda and "nsalali" in Tanzania (Graham, 1929; Greenwood, 1966). The name "dagaa" became popular in the early 1970s when a light fishery for this species reached commercial significance. The fishermen of Lake Victoria adopted this name from the clupeids of Lake Tanganyika which were also caught by light attraction (Okedi, 1981a; 1981b; Wanink, 1989)

1.2. "Dagaa" fishing methods

All methods used in Lake Victoria "dagaa" fishery are based on night light attraction using kerosene pressure lamps with a reflector to concentrate the fish.

Present knowledge of "dagaa" in Lake Victoria is mainly based on the works of Okedi (1973; 1981a; 1981b), Ogari (1985), Chitamwebwa (1988) and Wanink (1989). Fishing takes place for 14 to 16 days during the dark nights of each new moon and the last quarter of each month. The lamps are anchored with a sinker and after some time they are moved slowly towards the beach, bringing the fish within the reach of a beach/mosquito seine. Beach seines (up to 100m) are made of nylon (ply 4 to 6) having a stretched mesh size of 8-12 mm. Before 1970 a beach seine used to be a mosquito net of 30 to 60 m long. In the early 1980s, mosquito seines of stretched mesh sizes 4-8 mm became common in the Winam Gulf of Lake Victoria. Recently, some Kigoma fishermen introduced the lift net to the Mwanza region. Lift netting is conducted from catamarans powered by outboard engines, which can make the fishery offshore and truly pelagic (Chitamwebwa, 1988; Wanink, 1989).

1.3. Trends in "dagaa" fishery

Catches of "dagaa" have undergone explosive changes in the last 15-20 years in Lake Victoria. In the Kenyan portion of the lake, <u>Rastrineobola</u> landing increased to 29.2% of the total fish landings by weight in 1985 as compared to 4.5% in 1969 (Ogari, 1985; CIFA, 1988). Catches in the Tanzanian waters rose from 5.3% in 1981 to 8% in 1985 (Bwathondi, 1988) while in

Uganda, fish landings at Jinja (Masese) indicated an increase from 2.8% in 1979 to 58.6% in 1985 (Acere, 1988). This latter figure only refers to the local situation at Jinja. For the Ugandan waters as a whole, the percent increase is less dramatic (see table 1.3.1.)

Wanink (1989) has quoted the total "dagaa" catch for the complete Tanzanian sector of the lake as 2748-3287 metric tonnes wet fish per year for the period 1978-1984. Okedi (1981b) estimated a total catch of 3828 metric tonnes wet fish from the Ukerewe Island complex of Tanzania during 1978 or 1722 metric tonnes of dried "dagaa". Total catches in Kenya increased steadily from 16357 metric tonnes in 1968 to 89589 metric tonnes wet fish in 1985. No data from Uganda are known. According to Wanink (1989), too little data are available up to date for reliable estimation of maximum sustainable yield (MSY) and fishing mortality (F).

1.4. Biology

Okedi (1973) analyzed 604 specimens from Nyanza Gulf, Mwanza, Bukoba and Musoma and found a sex ratio of 53:34 (females:males). The size at maturity was 6.3 cm TL for males and 5.4 cm TL for females. The largest number of breeding individuals were found in June, July, August and October and fewest in December. The mean fecundity was 2292 ova (range 582-4771). The species is pelagic and its spawn planktonic (Graham, 1929).

Table 1.3.1. Trends of "dagaa" fishery in Lake Victoria

	Kenya		Uganda		Tanzania	
	total catch	dagaa	total catch	dagaa	total catch	dagaa
Year	(m.t)	%	(m.t)	%	(m.t)	%
1968	16357	4.5				
1969	17442	2.9				
1970	16400	3.2				
1971	14918	5.1				
1972	15989	7.8				
1973	16797	10.5				
1974	17175	21.8				
1975	16581	27.4				
1976	18680	30.3				
1977	19332	34.7				
1978	23856	36.5				
1979	30592	30.5	327.7	2.8		
1980	26914	35.1	289.8			
1981	45667	20.0	9104.9	0.5	70620.1	5.3
1982	60958	17.1	2158.9	2.2	63996.1	3.5
1983	71854	21.3	1728.8	2.2	72585.7	4.3
1984	78420	27.1	1226.6	6.5	97790.1	1.6
1985	89589	29.2	2814.6	58.6	98971.4	8.0

Source: Ogari (1985); Acere (1988); Bwathondi (1988)

1.5. Literature review

Fish stock assessment has been carried out in the Winam Gulf of Lake Victoria using bottom trawls (Kudhongania & Cordone, 1974; Marten _et al_., 1976; Benda, 1981; Muller & Benda, 1981), a catch assessment survey on the artisanal fishery (Rabuor, 1988) and length-frequency analysis (Getabu, 1988; Asila & Ogari, 1988). Age data in conjunction with length and weight measurements can give important information on stock composition, life span, mortality rate, age at recruitment into the exploited phase and production under different patterns of fishing (Bagenal & Tesch, 1978; Gulland, 1983; Vibhasiri, 1988). Length - frequency analysis has yielded three year-classes in the common bully (_Gobiomorphus cotidianus_ Mc Dowell) in New Zealand (Stephens, 1982), trout (_Salmo trutta_ L.) in Windermere (Craig, 1982) and yellowfin bream (_Acanthopagrus australis_ Gunther) in Australia (Pollock, 1982), which are progeny from successive peak spawning activity. Gibson & Ezzi (1981) found only two year-classes in the Norway gobby (_Pomatoschistus norvegicus_ Collett) from the West coast of Scotland. Mann (1971) and Pollock (1981) were unable to determine growth in the bullhead (_Cottus gobio_ L.) in southern Scotland and the luderick (_Girella tricuspidata_ Quay and Gaimard) in Australia respectively, from length-frequency distribution due to overlap of the different age groups. Growth in both length and weight in the above cases were found to fit the von Bertalanffy (1938) growth model. The von Bertalanffy (1938) model has the following form:

$$L_t = L_\infty (1 - \exp(-K(t-t_o)))$$

where

L_t = length at age t

L_∞ = asymptotic length

K = growth curvature

t = age in years

t_o = initial condition parameter; starting time at which the fish would have been zero sized if they had always grown according to the von Bertalanffy equation.

In the above equation, the length at age t+1 (L_{t+1}) is a function of length at age t (L_t). The exponential and von Bertalanffy growth models are particularly useful for fitting growth curves from which the asymptotic length (L_∞) and the growth constant (K) can be obtained by well known graphical methods of Gulland & Holt (1959), Bhattacharya (1967) or Wetherall (1986). Successful use of these graphical methods have been demonstrated in the pike (Esox lucius L.) (Frost & Kipling, 1967), thread bream, Dentex spp. (Jones & Jones, 1988), longneck croacker (Pseudotolithus typus Blkr.)(Djama, 1988), Russells scad (Decapterus ruselli Ruppell) (Widodo, 1988) and muckerel (Scomberomorus brasilensis Collette, Russo and Zavalla-Carmin)(Julien-Flus, 1988).

Several research workers using length-frequency analysis have found no significant differences between growth rate of males and females in the bream, Abramis brama (Goldspink, 1978), trout (Craig, 1982) and the common bully (Stephens, 1982). Length-frequency analysis gives better resolution in growth studies than the use of scales. However, Pollock (1981; 1982) and Stephens (1982) have pointed out that, for the former method to be useful, the difference in mean length of adjacent age-classes should be more than the sum of their standard deviations. Le Cren (1947; 1958), Kipling & Frost (1970), Mann (1971) and Craig (1982) have recommended the use of additional methods of age determination for length-frequency analysis like opercular bone, scales and otoliths. Age structure of a population showing many large old fish indicate a well established unfished stock while, with variable recruitment, length-frequency distribution still shows strong year-class profiles (Gibson & Ezzi, 1981; Goldspink,1981). Better methods of resolving length frequency modes which lead to better estimates of L_∞ and K have been given by Harding (1949), Cassie (1954), Bhattacharya (1967) and Pauly (1985; 1986) while much simpler methods have been given by Pauly (1980a) and Jones (1984). The use of length-frequency data for the estimation of L_∞ and K (Ricker, 1977; Gulland, 1983; Samb, 1988, Vibhasiri, 1988) assumes that:

1. the length-frequency data are representative of the population
2. the growth patterns are repeated each year
3. the von Bertalanffy Growth Formula (VBGF) describes the mean growth in the population
4. all samples have the same growth parameters.

The graphical methods for resolving mixed length-frequency distribution into normally distributed components (Harding, 1949; Cassie, 1954; Tanaka, 1956; Bhattacharya, 1967) assumes that certain length intervals are only affected by one and only one peak (Lassen, 1988), called a "clean class". The "clean classes" are found by either:

(i) plotting the data on probability paper (Cassie's method)

(ii) taking logarithms and plotting on a graph paper (Tanaka's method)

(iii) taking the differences of logarithms and plotting on a graph paper (Bhattacharya's method).

The crux of these methods is the concept of the "clean class" (Lassen, 1988), a length where only one peak (age group) contributes to the length distribution. No objective method is available for automatically obtaining the "clean classes" but all the methods available are approximations to one model:

$$n(L) = N1 \frac{dL}{\sqrt{2\pi . a1}} \exp\left[\frac{-1}{2}\frac{(\bar{L}_2-\bar{L}_1)^2}{a1}\right] + N2 \frac{dL}{\sqrt{2\pi . a2}} \exp\left[\frac{-1}{2}\frac{(\bar{L}_3-\bar{L}_2)^2}{a2}\right] + \ldots$$

where

n(L) = the number of fish in length class 1 (mid-length)

dL = interval size of length

N1,N2..= total number of fish belonging to group 1,2,.....

$\bar{L}_1,\bar{L}_2$..= mean length of group 1,2,..

a1,a2..= width interval of group 1,2,..

Data on length-weight relationship are essential for the assessment of any given fish stock. The basic formula for this relationship is used in its logarithmic form:

$$\text{Log } W = \text{Log } a + q \text{ Log } L,$$

where W is the weight of the fish, L are the length while a and q are constants which are empirically determined by least square regression as outlined by Weatherly (1972), Bagenal & Tesch (1978), Welcomme (1979), Pollock (1981) , Craig (1982) and Gulland (1983). The same basic relationship is used to calculate the Fultons condition factor (K), since W/a L^q is a ratio. An alternative expression for the condition factor is:

$$K = W_o/W,$$

has also been used (Mann, 1976; Pollock, 1981; Stephens, 1982); in this case, W_o is the observed weight and W is the weight predicted from the length-weight relationship.

The total mortality coefficient (Z) of a population can be determined from representative samples from the relationship of lengths, numbers in the population at different times as well as age. It is computed, according to Wetherall's (1986) equation, from the relationship:

$$Z = K\ (L_\infty - \bar{L})\ /\ (\bar{L} - L'),$$

where $\bar{L}$ is the mean length computed from L' upwards (L' is the smallest length fully represented in the sample), K and L_∞ are the von Bertalanffy growth constants. The equation has been successfully used (Ahmad, 1988, Djama, 1988; Jones & Jones, 1988) for fish stock assessment in the tropics. Another common method for the estimation of Z based on length-frequency analysis is the length-converted catch-curve (Pauly, 1983; 1984a; 1984b). The decline in numbers with time is a linear function of age. The linear regression fitted to this relationship gives a good estimate of the total mortality coefficient (Z). The problems associated with length-converted catch-curve for the estimation of total mortality coefficient (Z) has been discussed by Pauly (1983, 1984a; 1984b). The pile up effect, where larger size groups contain more age-groups than the smaller size group is overcome by dividing the number (N) in that length-group by the time (dt) it takes to grow through that length group, before plotting the length-converted catch-curve. The use of relative age is employed because using t- zero (t_0) (which leads to absolute ages) is not necessary in conjunction with catch-curves where Z is estimated from a slope. Length-converted catch -curve assumes that:

(i) Z is the same in all age groups included in the plot

(ii) all age groups used in the plot were recruited with the same abundance

(iii) all age groups used for the computation of Z are equally vulnerable to the gear used for sampling.

(iv) samples are large enough to cover enough age groups and effectively represent the average population structure over the time considered.

The use of length-converted catch-curve has been discussed in details by Sparre (1987) and its use demonstrated in the Nile perch (*Lates niloticus* L.) (Asila & Ogari, 1988), emperor red snapper (*Lutjanus sebae* Cuvier) (Lablache & Carrara, 1988) and the sardine (*Sardinella maderensis* Lowe.) (Samb, 1988). According to Sumiono (1988), the length-converted catch-curve refers only to the largest specimens in the sample and is dependent on recruitment to the fishing ground rather than selectivity of the gear. The Wetherall *et al.* (1987) method gives an estimate of

Z/K from which Z can be calculated from known values of K. Due to the frequent occurrence of this method in the text, it will be referred to as the Wetherall et al. method throughout the text without reference to the year of publication. The natural mortality coefficient (M) may be computed from known values of M/K from other estimates. To separate the components of total mortality coefficient (Z) into natural mortality coefficient (M) and fishing mortality coefficient (F), Pauly's (1980b) empirical formula has often been employed to estimate M, then F is computed from the difference between Z and M. This method has given reliable results with both fish species (Djama, 1988; Jones & Jones, 1988; Julien-Flus, 1988, Widodo, 1988) and commercial invertebrates (Agasen & Del Mundo, 1988; Gabral-Llana, 1988; Vibhasiri, 1988) in the tropics. Although Pauly's (1980b) empirical formula for the estimation of natural mortality coefficient (M) is quite popular, a more robust alternative method was given by Munro (1984) and modified by Moreau (1988). These alternative methods can be used to estimate natural mortality coefficient (M) and fishing mortality coefficient (F) simultaneously by using probability of capture by length-group. The choice of method for M thus depends largely on individuals.

Given the estimates of fishing mortality coefficient, natural mortality coefficient and growth constant, the yield in weight and numbers can be calculated for a given cohort of fish reaching catchable size. The expression for yield in weight is the sum, over all time intervals of the products of fishing mortality, the numbers of fish present, their mean weight and the duration of the time interval (Allen, 1969; Gulland, 1977; 1983). The generalized yield equation (Beverton & Holt, 1966; Allen, 1969; Gulland, 1977; 1983) incorporates the von Bertalanffy growth equation with the assumption that there is no upper limit to the life span:

$$Y = F\,R\,W_{\infty} \quad e^{-M(tc-tr)} \sum_{n=o}^{n=3} \frac{Un\ e^{-nK(tc-to)}}{F + M + nK},$$

where

Y = Steady state annual yield in weight

R = Annual recruitment (at age t_r)

t_c = Age at entry into the exploited phase (at first capture)

F = Fishing mortality coefficient

M = Natural mortality coefficient

W_{∞}, K, t_o = Parameters of von Bertalanffy growth equation

Un= Summation variable taking values 1, -3, +3, -1 for n= 0, 1, 2, 3 respectively.

The yield per recruit and biomass per recruit has been calculated by various workers using the exploitation rate (E). Exploitation rate is given as

F/(F+M) (Ahmad, 1988; Cheunpan, 1988; Mohd.Isa, 1988; Widodo, 1988). The modified by Beverton & Holt (1966) yield equation (Allen, 1969; Gulland, 1977; 1983) incorporate the exploitation rate and the age which appears explicitly in the generalized yield equation has been replaced by the corresponding size (length or weight) of the fish as given by the von Bertalanffy growth equation. The generalized yield equation, modified by Beverton & Holt (1966) is given as follows:

$$Y/R' = W_{\infty} \; E \; (1-c)^{M/K} \sum_{n=0}^{n=3} (Un \; (1-c))^{n} / (1 + n \frac{K}{M} (1-E)).$$

The modified equation contains only three variables, E, c and M/K. Although this equation contain several other factors, they only appear as parameters. The principal concern is the relative yield per recruit (or average biomass per recruit) at different levels of fishing mortality or age at first capture. Yield per recruit is described by one characteristic of the fish (M/K) and two characteristics of the fishery (E and c). M/K is the ratio of the coefficients determining, in effect, the relative rate of natural change in numbers and length with age. E defines the numbers or fraction of a year-class which will be caught during its fished life span while c expresses the mean selection length as a fraction of the asymptotic length. To allow calculations of yield per recruit based on average biomass, c can be converted to weight ratios from the length-weight relationship as outlined by Beverton & Holt (1966), Allen (1969), Gulland (1977; 1983).

A number of computer programs exist (Sims, 1985; Pauly, 1985; Thiam, 1986; Vakily et al., 1986) for these and similar expressions and their use has been demonstrated in several tropical fish species (Boonraksa, 1988; Dy-Ali, 1988; Supongpan, 1988; Widodo, 1988).

There is lack of knowledge and information in respect of the present investigations against all this background. The economic importance of "dagaa" as poultry feed, cattle feed, fish feed and human food warrants the acquisition of biological data which can be used as management tools for its rational exploitation.

1.6. Objectives of this study

The major objectives of this study were as follows:

1. To derive linear equations for interconversion of standard length (SL), fork length (FL) and total length (TL).
2. To determine the length-weight relationship.
3. To study the seasonal variation in Fultons

condition factor.

4. To analyze the length-frequency distribution.
5. To estimate growth parameters.
6. To estimate total, natural and fishing mortality coefficients.
7. To determine exploitation rate and patterns of expected yields.

CHAPTER 2

2. MATERIALS AND METHODS

2.1 Study area

The major portion of Kenyan waters of Lake Victoria (fig.2.1), is a narrow gulf, known to various authors by several names. The Victoria Nyanza (Graham, 1929), Kavirondo Gulf (Copley, 1953; Muller & Benda, 1981), Nyanza Gulf (Rinne & Wanjala 1982; Ogari & Dadzie, 1988) and the Winam Gulf (Okach, 1982) are all one and the same place. The Winam Gulf has an area of approximately 1920 Km^2 with a length of about 60 km and width varying between 6 to 30 km. A short description of Winam Gulf has been given by Rinne & Wanjala (1982), Ogari & Dadzie (1988) and Okach & Dadzie (1988), while a detailed description was given by Ogari (1984). The Winam Gulf lies between 34^o 13′ and 34^o 52′ east of latitude 0^o, $0^o4'$ and 0^o 32′ south of the equator. The gulf has a mean depth of 6m and a maximum depth of 43m while its surface is at an elevation of 1136m above sea level. Its irregular shoreline is about 300 km, with several large bays. The major affluent rivers include the Kibos and Nyando to the east and Sondu, Awach, Mogus and Lambwe to the South. Water exchange with the rest of the lake takes place through the Mbita channel while the major outflow from the lake is the river Nile.

Bottom deposits found within Winam Gulf include hard substrates of sand, gravel and bedrock in

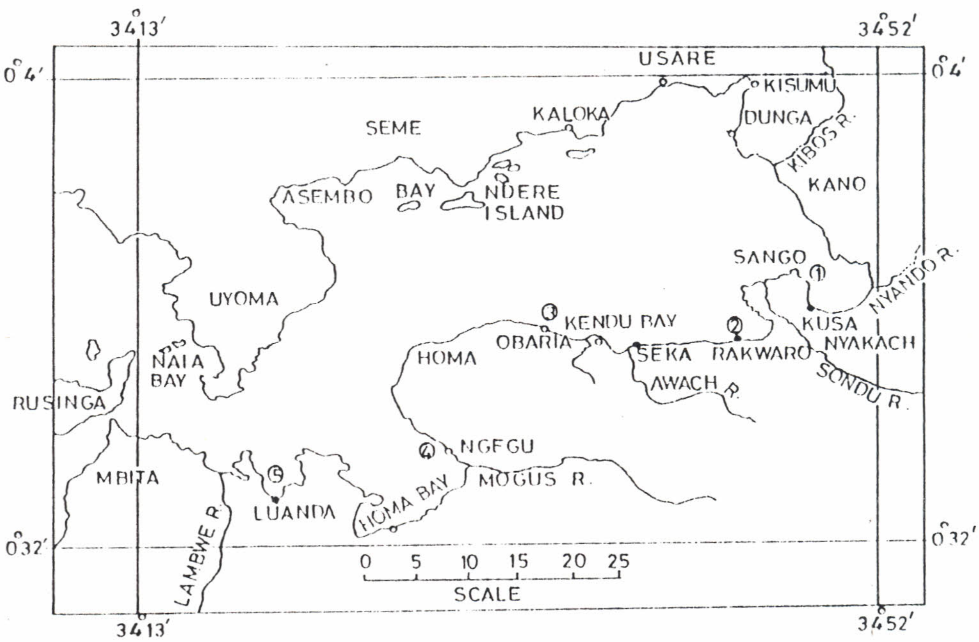

Fig. 2.1.1. Map of Winam Gulf of Lake Victoria showing sampling points.

exposed areas and mud, silt and clay deposits in areas adjacent to the river mouths. Large quantities of both living and dead gastropods and bivalves are common in sheltered bays. Beaches consisting of pebbles, sand or floating aquatic macrophytes are common. The most common emergent macrophytes are papyrus (Cyperus papyrus L.) and the common reed (Phragmites australis Cav.) while submerged macrophytes include the pond weed (Potamogeton), hornwort (Ceratophyllum) and the eelgrass Valisneria. C. papyrus sometimes form large swamps in sheltered bays commonly called "floating islands". Large floating mats of the water cabbage (Pistia stratiotes L.) covering upto 5 Km^2 can be seen in protected bays during the wet season.

The Gulf lies within the equatorial region. The water temperature and solar radiation are relatively constant throughout the year (mean values are 22±3 °C and 1200±140 mε m^{-1} s^{-1} respectively) (Ochumba & Kibaara, 1989).

2.2. Sampling technique

Samples of R. argentea were obtained from five stations on the southern zone of the Winam Gulf of Lake Victoria (fig.2.1.) as representatives of the stock from the outer, mid and inner Gulf, viz:

1. Sango
2. Rakwaro
3. Obaria

4. Ngegu

5. Luanda

Random samples were taken from the commercial artisanal fishermen once every month from each station. Standard length (SL), fork length (FL) and total length (TL) of each individual were measured to the nearest mm using a fish measuring board, in the first sampling month (August). Only TL was measured for subsequent months. Weight of all fish were taken to the nearest 0.1g using a trip pan balance. Each individual was dissected from the ventral side and sex determined according to the subjective methods of Bagenal & Braum (1971), Hopson (1972) and Hopson (1975). The females were identified as having thin flat brown to golden brown gonads embedded in the ventral cavity, sometimes swollen and yellow with clearly discernible eggs (Hopson, 1972; 1975). The males were identified as having thin strands of translucent to white gonadal material embedded in the ventral cavity but never flat, according to the same author. The rest of the individuals were classified as immature. The surface water temperature was recorded for each station every month for the purpose of estimating natural mortality coefficient. Field data were collected for a period of 12 months (from August, 1989 to July 1990). Data on length, weight and sex were used to perform regression analyses and length-frequency analysis of stocks from different portions of the Gulf.

2.3. Data analysis

Methods of data analysis were based on length-frequency analysis (Sims, 1985; Thiam, 1986; Vakily et al., 1986; Sparre, 1987). Specific analysis procedures followed the outline appended to Sparre (1987) and Sparre et al. (1989).

(i) Regression analyses

Regression of different length measurements (SL, FL and TL) was done by least square method while length-weight regression was obtained by log L - log W regression the by least square method. The Fultons condition factor (K) was calculated from the relationship:

$$K = W_o/W$$

where

W_o = observed weight

W = predicted weight

(ii) Asymptotic length (L_∞) and growth curvature (K)

A first estimate of L_∞ was obtained from the longevity relationships:-

$$L_\infty = L_{max}/0.95 \quad \text{(Pauly, 1980a)}$$

where

L_{max} = Maximum length observed in the sample

0.95 = 95% survival before natural death or fishing mortality.

Detailed analysis of L_∞ and K was done using the log-difference or Bhattacharya method (Bhattacharya, 1967). This involved resolving the monthly length-frequency distribution into normally distributed components. The log-differences of frequency between consecutive length-groups were plotted against the length intervals. A sequence of points corresponding to a straight line with a negative slope was identified and a regression analysis performed on this portion of the scatter plot to estimate the mean length of the component (or cohort), the standard deviation of the length distribution and the number of cohort members in the sample. Several components (or cohorts) were identified using the same procedure as above. The mean length (L_{mean}) of each cohort was calculated as follows:

$$L_{mean} = \text{intercept} / \text{slope}.$$

The standard deviation (SD) was calculated from the relationship:

$$SD = \sqrt{-dL/\text{slope}},$$

where

dL = length interval size.

The total cohort number was computed by first calculating the numbers by length-group (N(j)) for the cohort as follows:

$$N(j) = (dL/\sqrt{(2\pi\ SD)}\ .\exp\ (-0.5(Lj + dL/2 - L_{mean}/SD)^2)$$

where

Lj = the lower limit of length-group L(j).

The total cohort number (cal. N) was then estimated from the equation:

$$cal.\ N = (\sum_j frq(s.j))/(\sum_j N(j))$$

where

frq (s.j) = frequency of length-group j in sample s

N(j) = the number in length-group j.

Separation index (SI) was used to check the degree of resolution of each cohort. Separation index values less than 2 were rejected. SI was computed for all adjacent cohorts from the equation:

$$SI = 2(\bar{L}_2 - \bar{L}_1)/(SD2 + SD1)$$

where

$\bar{L}_1$ = mean length of cohort 1

$\bar{L}_2$ = mean length of cohort 2

SD1 = standard deviation in length of cohort 1.

SD2 = standard deviation in length of cohort 2.

The results of Bhattacharya analysis were used to plot the mean length of each cohort from each sample against the time of sample collection for a period of twelve months. The components which appear to belong to the same cohort were then selected and a modal progression performed to obtain L_∞ and K based on all cohorts, calculated by the Gulland & Holt plot (Sparre et al., 1989) (a plot of dL/dt against mean length of each component or cohort).

iii) Growth performance index (ϕ')

The growth performance index was computed from the relationship:

$$\phi' = \text{Log } K + 2\text{Log } L_\infty,$$

according to Munro & Pauly (1983) and Pauly & Munro (1984).

iv) Total mortality coefficient (Z)

The total mortality coefficient was estimated using two methods:

a) Length-converted catch-curve

b) Wetherall et al. (1987) method.

Length-converted catch-curve:

Input data for this analysis were the weighted sum of all length-frequency samples over a period of twelve months. L_∞ and K from Bhattacharya analysis and other estimates were used as input parameters for this analysis. The length-converted catch-curve analysis is a regression analysis on the descending right hand arm of the catch-curve:

$$Y(j) = a + b.X(j),$$

where

$X(j)$ = relative age at length $L(j)$

$= -1/K. \ln (1-(L(j)+dL/2)/L_\infty)$

and $Y(j) = \ln (C(j)/dt(j))$

where

$L(j)$ = lower limit of length - group j

dL = length interval size

K = von Bertalanffy parameter (curvature parameter)

L_∞ = von Bertalanffy parameter (asymptotic length)

$dt(j)$ = the time it takes to grow from length $L(j)$ to $L(j+1)$

$= 1/K. \ln (L_\infty - L(j))/(L_\infty - L(j+1))$.

$C(j)$ = numbers caught in length group j

The total mortality coefficient was estimated from the slope as follows:

$$Z = -b.$$

Wetherall *et al.* analysis:

Wetherall *et al.* (1987) method is also a regression analysis based on the Beverton & Holt (1956) Z-equation:

$$Z = K (L_\infty - \bar{L})/(\bar{L} - L')$$

where

$\bar{L}$ = mean length of fish of L' and longer

L' = some length for which all fish are under full exploitation

L_∞ = von Bertalanffy parameter (asymptotic length)

K = von Bertalanffy parameter (curvature parameter).

By a series of algebraic expressions, the above equation was transformed into a regression equation of the form:

$$\bar{L} - L' = a + b.L',$$

to estimate Z/K and L_∞ as follows:

$$Z/K = -(1+b)/b$$

$$L_\infty = -a/b$$

v) Natural mortality coefficient (M)

Natural mortality coefficient was computed from the empirical formula of Pauly (1980b). Estimates of L_∞ and K were used as inputs for a mean annual temperature of 22 °C for Lake Victoria:

$$\ln M = -0.0152 - 0.279 \ln L_\infty + 0.6543 \ln K + 0.463 \ln T,$$

where

T = mean annual temperature for Lake Victoria (degrees Celcius) and other symbols have their usual meaning

vi) Fishing mortality coefficient (F) and exploitation rate (E)

Fishing mortality coefficient was computed from the relationship:

$$F = Z - M,$$

while the exploitation rate was computed from the relationship:

$$E = F/Z = F/(F+M).$$

vii) Beverton and Holt relative yield per recruit (Y/R') and average biomass per recruit (B/R)

The Y/R' and B/R for an array of fishing mortality coefficients and a fixed natural mortality coefficient was computed from the yield equation:

$$Y/R' = F/K.\ A.\ W_{\infty} \left[\frac{1}{z} - \frac{3U}{z+1} + \frac{3U^2}{z+2} - \frac{U3^3}{z+3} \right]$$

where

$U = 1 - L_{c50}/L_{\infty}$

L_{c50} = length at which probability of capture is 0.5

L_{∞} = von Bertalanffy parameter (asymptotic length)

$A = ((L_{\infty}-L_{c50})/(L_{\infty}-L_r))^{M/K}$

L_r = length at entry into the exploited phase

M = natural mortality coefficient

K = von Bertalanffy parameter (curvature parameter)

F = fishing mortality coefficient

$z = Z/K$

Z = total mortality coefficient

W_{∞} = von Bertalanffy parameter (asymptotic weight)

The average biomass per recruit was calculated from the relationship:

$$\bar{B}/R = 1/F \cdot Y/R.$$

The results of these calculations were used to construct the yield curves in order to obtain the predicted changes in the stock under different fishing patterns and the corresponding exploitation rates.

The results of all these analyses were subjected to statistical tests of significance using one-way and/or two-way analysis of variance (ANOVA) between sexes and stations (Zar, 1984).

CHAPTER 3

3. RESULTS

3.1 Regression analyses

3.1.1 Length regressions

The different forms of length measurements were found to be related to each other by the following linear equation:

$$FL = 0.92\ TL - 0.74$$

$$SL = 0.90\ TL - 1.74$$

$$SL = 0.94\ FL - 1.16.$$

The correlation between the different forms of length measurements are shown in fig. 3.1.1 while the details of these regression analyses are given in table 3.1.1. The correlation coefficients in all the analyses were very high ($r^2 = 0.90 - 0.99$) while the standard error of each coefficient was very low (0.01).

3.1.2 Length-weight relationship

The mean length-weight relationship for each of the five stations could be best described by the logarithmic relationships shown in table 3.1.2. The graphical representation of length-weight relationship is shown in fig. 3.1.2 before any transformation and fig. 3.1.3 after log-log transformation. An analysis of covariance (ANCOVA) revealed significant differences between the slopes of the regression lines (table 3.1.2) while multiple range test, Student Newman-Keuls (SNK) test indicated that there were significant differences between the slopes for juveniles, males and females but no differences within sexes from different

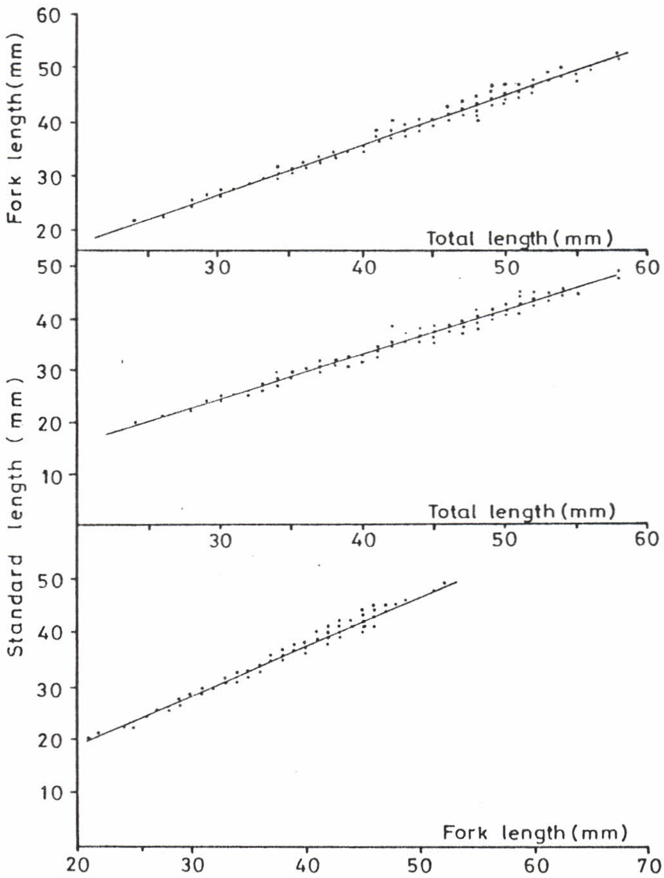

Fig. 3.1.1. Correlation between total length (TL), fork length (FL) and standard length (SL) of R. argentea in the Winam Gulf.

Table 3.1.1. Correlation between total length (TL), fork length (FL) and standard length (SL) of R. argentea in the Winam Gulf of Lake Victoria.

Station	Indep. variable	Dependent variable	Coeff. ± SE	Const	r^2	n
Sango	TL	FL	0.9±0	-0.2	0.90	249
	TL	SL	0.8±0	-0.3	0.90	249
	FL	SL	0.9±0	-0.4	0.90	249
Rakwaro	TL	FL	0.9±0,01	-0.8	0.96	285
	TL	SL	0.9±0.01	-0.8	0.96	285
	FL	SL	0.9±0.01	-0.5	0.96	285
Obaria	TL	FL	0.9±0	-1.0	0.99	238
	TL	SL	0.9±0	-4.0	0.99	238
	FL	SL	0.9±0	-2.0	0.99	238
Ngegu	TL	FL	0.9±0.01	-1.3	0.98	239
	TL	SL	0.9±0.01	-1.3	0.98	239
	FL	SL	0.9±0.01	-0.2	0.99	239
Luanda	TL	FL	0.9±0.01	-0.6	0.98	220
	TL	SL	0.9±0.01	-2.4	0.98	220
	FL	SL	0.9±0.01	-2.7	0.98	220

Table 3.1.2. Correlation between Log TL and Log W of *R. argentea* in the Winam Gulf. Similar superscripts indicate no significant differences

Station	Length-weight relationship	n	r^2
	Juveniles:		
Sango[1]	Log W = 3.06 Log TL - 5.42	732	0.60
Rakwaro[1]	Log W = 3.12 Log TL - 5.60	708	0.68
Obaria[1]	Log W = 3.10 Log TL - 5.50	663	0.72
Ngegu[1]	Log W = 3.20 Log TL - 5.84	479	0.66
Luanda[1]	Log W = 3.22 Log TL - 6.00	456	0.84
	Males:		
Sango[2]	Log W = 2.70 Log TL - 4.69	754	0.60
Rakwaro[2]	Log W = 2.81 Log TL - 4.70	977	0.69
Obaria[2]	Log W = 3.05 Log TL - 4.90	815	0.64
Ngegu[2]	Log W = 2.94 Log TL - 5.00	822	0.67
Luanda[2]	Log W = 2.75 Log TL - 4.76	985	0.70
	Females:		
Sango[3]	Log W = 3.60 Log TL - 6.20	1266	0.66
Rakwaro[3]	Log W = 3.65 Log TL - 6.41	1348	0.72
Obaria[3]	Log W = 3.71 Log TL - 6.50	1144	0.68
Ngegu[3]	Log W = 3.40 Log TL - 5.60	1219	0.68
Luanda[3]	Log W = 3.24 Log TL - 5.45	1337	0.61

$F_{(14,13675)}$ 6.324 *

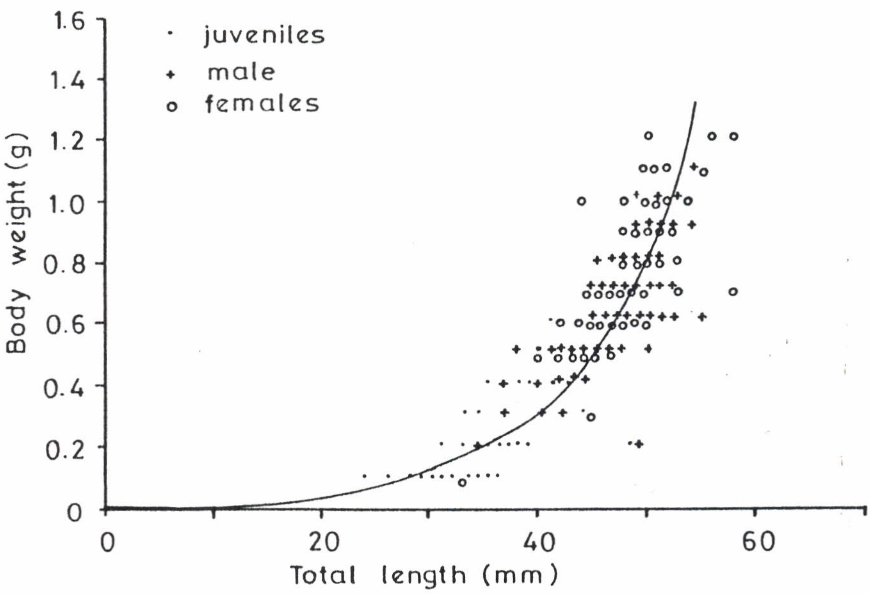

Fig. 3.1.2. An example of length-weight relationship of

R. argentea in the Winam Gulf from Sango.

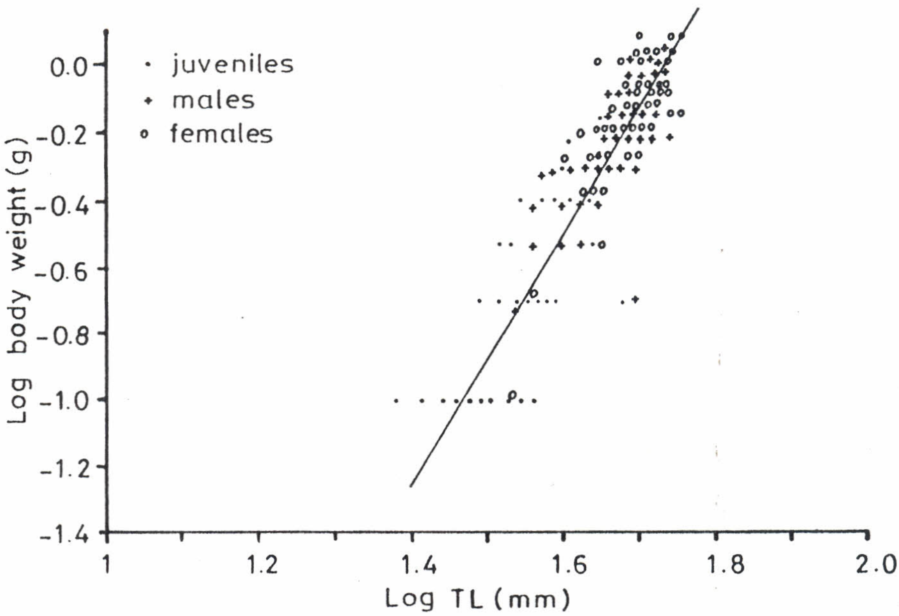

Fig. 3.1.3. Correlation between Log L and Log W of R. argentea in the Winam Gulf for samples taken from Sango.

sampling stations.

3.1.3 Fultons condition factor (K)

There was an initial gain in condition, reaching a peak in December followed by a decline up to February. This decline was followed by a second gain in condition reaching a peak in March/April. Thereafter, there was a general decline in condition up to July. Maximum K value recorded in December was 1.074 while that of March was 1.052. The lowest condition recorded in June was 1.000 and July was 1.006. All stations showed a similar pattern of relative condition factor by months as shown in fig. 3.1.4 . Analysis of variance indicated real differences in the Fultons condition factor (K) in different months but there were no significant differences between stations (table 3.1.3). Differences in K could be attributed to accumulation of gonadal material prior to spawning. K varies considerably between species and the mean value is not always around unity. Weight measurements could not be taken from September to December.

3.2 Growth

3.2.1 Asymptotic length (L_∞)

The asymptotic length (L_∞) determined by Bhattacharya analysis (Gulland & Holt plot), Wetherall et al. method and 95% longevity are shown in table 3.2.1 while the graphical plots of these analyses are shown in figs. 3.2.1 and 3.2.2. The mean values for all the methods combined (table 3.2.2) were 65.1±3.1,

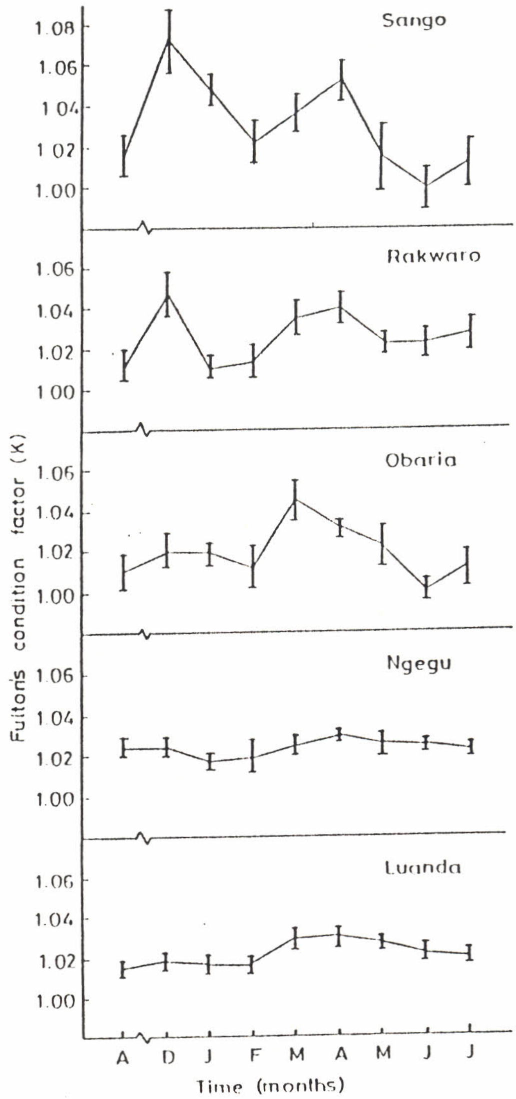

Fig. 3.1.4. Fultons condition factor (K) of R. argentea in the Winam Gulf excluding the months of September, November and December. Vertical bars shows 2SD.

Table 3.1.3. ANOVA of Fultons condition factor of *R. argentea* in the Winam Gulf of Lake Victoria

Month	Sango	Rakwaro	Obaria	Ngegu	Luanda
August	1.015	1.011	1.011	1.024	1.015
December	1.073	1.048	1.020	1.024	1.019
January	1.048	1.011	1.019	1.017	1.017
February	1.021	1.013	1.011	1.019	1.016
March	1.036	1.035	1.045	1.025	1.028
April	1.015	1.023	1.024	1.030	1.029
May	1.015	1.023	1.024	1.025	1.027
June	1.000	1.023	1.002	1.025	1.022
July	1.013	1.028	1.013	1.022	1.020

$F(4,32)$ 0.113 ns stations

$F(8,32)$ 4.323 * months

Table 3.2.1. Asymptotic length (L_{∞} of R. argentea in mm determined by three independent methods in the Winam Gulf.

Station	95% Longevity method	Bhattacharya analysis	Wetherall et al.	Sex
Sango	65.3	59.9	60.0	M
	64.2	60.9	64.6	F
	65.3	68.8	67.1	M+F+I
Rakwaro	63.2	69.8	61.1	M
	65.3	60.8	63.3	F
	65.3	69.2	63.0	M+F+I
Obaria	63.2	68.2	61.9	M
	65.3	71.8	71.6	F
	65.3	78.5	64.5	M+F+I
Ngegu	66.3	66.1	65.0	M
	64.2	62.6	63.3	F
	66.3	63.4	65.1	M+F+I
Luanda	69.5	62.9	68.7	M
	73.7	73.1	72.3	F
	73.7	70.9	70.9	M+F+I
$F(4,8)$	1.206 ns	3.418 ns	4.235 *	stations
$F(2,8)$	0.307 ns	1.313 ns	1.177 ns	sexes

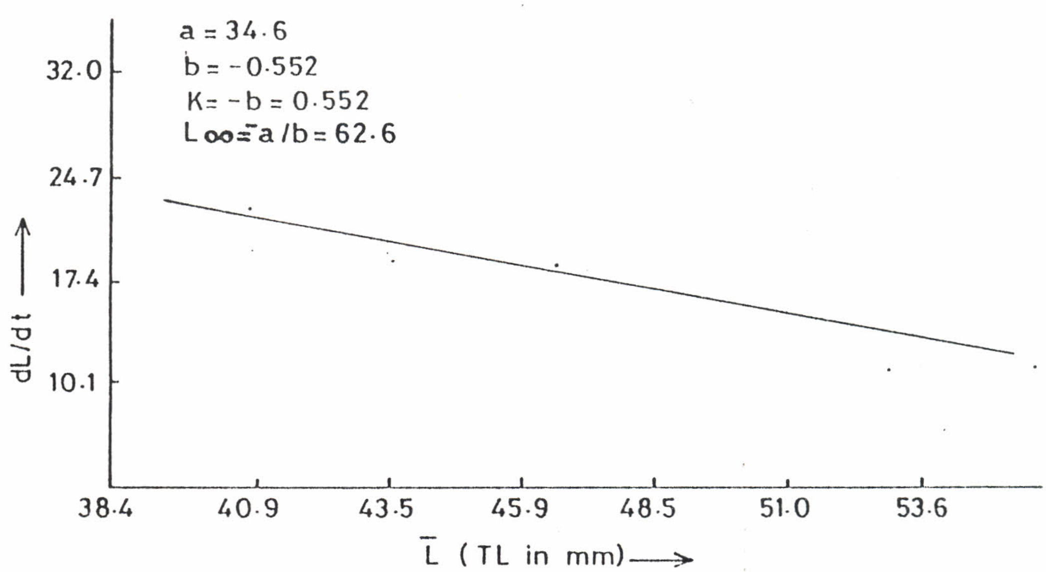

Fig. 3.2.1. Gulland and Holt plot for the estimation of asymptotic length (L_∞) and curvature of growth (K) of *R. argentea* in the Winam Gulf

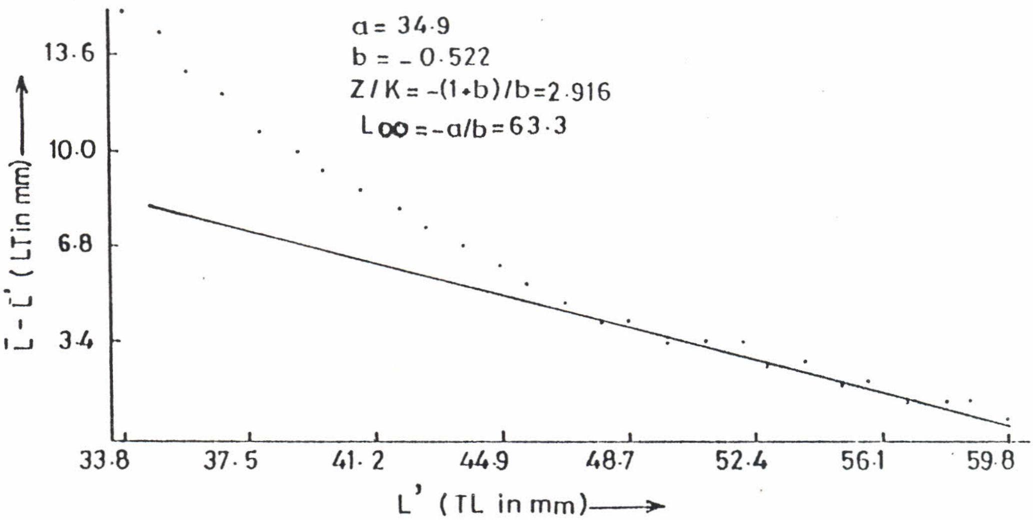

Fig. 3.2.2. Wetherall _et al_. plot for the estimation of L_{∞} and Z/K of _R_. _argentea_ in the Winam Gulf

Table 3.2.2. Mean asymptotic length (L_∞) for three independent methods and all methods combined for *R. argentea* in the Winam Gulf.

Method	Mean ± SD	Sex
95% Longevity method	65.5 ± 2.6	M
	66.5 ± 4.0	F
	67.2 ± 3.7	M+F+I
Bhattacharya analysis	65.4 ± 4.0	M
(Gulland & Holt plot)	65.8 ± 6.1	F
	70.2 ± 5.4	M+F+I
Wetherall *et al.* method	64.5 ± 2.6	M
	66.5 ± 4.0	F
	67.2 ± 3.7	M+F+I
Mean of all three methods	65.1	M
	66.5	F
	67.8	M+F+I
$F(2,4)$	0.115 ns	M
$F(2,4)$	0.068 ns	F
$F(2,4)$	0.538 ns	M+F+I

66.5±4.6 and 67.8±4.3 for males, females and the combined sexes (including immature specimens) respectively. One-way analysis of variance (ANOVA) revealed no significant differences between the methods used for males, females and the combined sexes while two-way ANOVA also revealed no significant differences between stations and sexes except for the Wetherall et al. method which had a significant difference between stations at 0.05 level of significance. There was a general trend of increasing values of L_∞ from the inner to the outer Gulf as shown in table 3.2.1.

3.2.2 Curvature of growth (K)

Growth curvature (K) determined by Bhattacharya analysis (Gulland & Holt plot) were 0.375-0.599 yr^{-1} for males, 0.423-0.552 yr^{-1} for females and 0.467-0.660 yr^{-1} for the combined sexes (including immature specimens). An indirect method for determination of K based on Z/K values (Wetherall et al. method) and Z (linearized catch-curve) gave values of 0.308-0.694, 0.301-0.875 and 0.488-1.142 for males, females and the combined sexes respectively (table 3.2.3) while the mean values were 0.509±0.084, 0.486±0.049 and 0.576±0.070 respectively. Two-way ANOVA revealed no significant differences between stations and sexes at 0.05 level of significance. Significant differences in the indirect method shows that this is not a reliable estimator of K, besides, it is not a standard procedure in length-frequency analysis.

Table 3.2.3. Growth curvature (K) of R. argentea determined by two methods in the Winam Gulf.

Station	K(Gulland & Holt plot)	K(Z/(Z/K))	Sex
Sango	0.558	0.308	M
	0.423	0.301	F
	0.587	0.685	M+F+I
Rakwaro	0.503	0.664	M
	0.482	0.875	F
	0.660	1.142	M+F+I
Obaria	0.375	0.693	M
	0.460	0.344	F
	0.467	0.998	M+F+I
Ngegu	0.508	0.539	M
	0.552	0.554	F
	0.567	0.488	M+F+I
Luanda	0.599	0.422	M
	0.511	0.556	F
	0.600	0.595	M+F+I
Mean ± SD	0.509 ± 0.084	0.525 ± 0.162	M
	0.486 ± 0.049	0.526 ± 0.128	F
	0.576 ± 0.070	0.782 ±0.277	M+F+I
F(4,8)	2.729 ns	35.9 *	stations
F(2,8)	3.611 ns	38.8 *	sexes

3.2.3 Growth performance index (ø')

The growth performance indices of males, females and the combined sexes are shown in table 3.2.4, while the mean values were 3.32±0.12, 3.33±0.07 and 3.40±0.07 respectively. Two-way ANOVA revealed no significant differences between stations and sexes. The ø' values of the combined sexes were always higher than those of males or females in all stations.

3.3. Mortality and exploitation rates

3.3.1 Total mortality coefficient (Z)

Total mortality coefficient (Z) and corresponding Z/K values for males, females and the combined sexes (including immature specimens) are shown in table 3.3.1, while Wetherall et al. plot for estimation of Z/K and length-converted catch-curve for estimation of Z are shown in figs. 3.2.2 and 3.2.3 respectively. The mean values of Z were 1.929±0.322, 1.766±0.392 and 2.860±1.008 and Z/K were 3.914±1.228, 3.737±1.459 and 3.749±1.104 for males, females and the combined sexes respectively. The range of Z values was 1.269 to 3.865 while that of Z/K was 2.551-6.086. The total mortality coefficient (Z) was higher when both sexes were considered than when each sex was taken individually in all stations except at Ngegu. Two-way ANOVA showed a significant difference between sexes for Z values at 0.05 level but not between stations.

Table 3.2.4. Growth performance index (ø') of *R. argentea* in the Winam Gulf.

Station	Growth performance index (ø')	Sex
Sango	3.39	M
	3.25	F
	3.42	M+F+I
Rakwaro	3.27	M
	3.28	F
	3.42	M+F+I
Obaria	3.15	M
	3.37	F
	3.29	M+F+I
Ngegu	3.34	M
	3.34	F
	3.38	M+F+I
Luanda	3.45	M
	3.43	F
	3.48	M+F+I
Mean ± SD	3.32 ± 0.12	M
	3.33 ± 0.07	F
	3.40 ± 0.07	M+F+I
F(4,8)	0.0001 ns	stations
F(2,8)	0.00002 ns	sexes

Table 3.3.1. Total mortality coefficient (Z) and corresponding Z/K values for *R. argentea* in the Winam Gulf.

Station	Total mortality coefficient (Z)	Z/K	Sex
Sango	1.860	6.048	M
	1.269	4.220	F
	3.865	5.641	M+F+I
Rakwaro	2.239	3.372	M
	2.232	2.551	F
	3.241	2.838	M+F+I
Obaria	2.080	3.002	M
	2.092	6.086	F
	3.625	3.632	M+F+I
Ngegu	2.059	3.818	M
	1.634	2.916	F
	1.718	3.519	M+F+I
Luanda	1.406	3.329	M
	1.602	2.879	F
	1.852	3.114	M+F+I
Mean ± SD	1.929 ± 0.322	3.914 ± 1.228	M
	1.766 ± 0.392	3.737 ± 1.459	F
	2.860 ± 1.008	3.749 ± 1.104	M+F+I
F(4,8)	2.435 ns	2.944 ns	stations
F(2,8)	6.608 *	0.051 ns	sexes

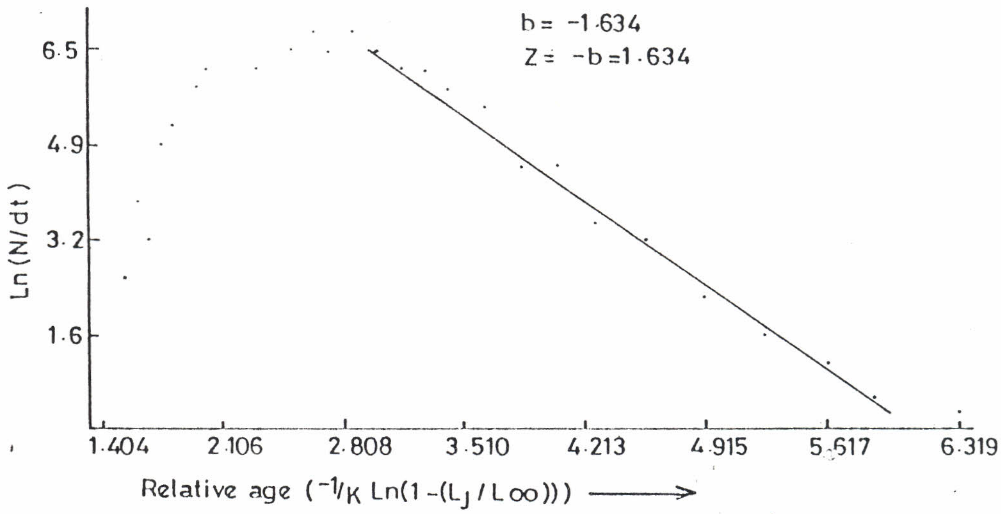

Fig. 3.2.3. Length-converted catch-curve for the estimation of total mortality coefficient (Z) of *R. argentea* in the Winam Gulf.

3.3.2. Natural mortality coefficient (M)

The mean values of natural mortality coefficient (M) (table 3.3.2) were 0.82±0.10, 0.80±0.05 and 0.88±0.08 for males, females and the combined sexes (including immature specimens). Two-way ANOVA showed a significant difference in M values between stations and sexes at 0.05 level of significance.

3.3.3. Fishing mortality coefficient (F) and exploitation rate (E)

The men fishing mortality coefficient (F) was highest for the combined sexes (1.984 ± 1.035) followed by the males (1.107 ± 0.394) and females (0.966 ± 0.392) for the range of M values shown in table 3.3.2. Corresponding mean values of exploitation rate were 0.551 ± 0.136 (males), 0.565 ± 0.081 (females) and 0.653 ± 0.146 (combined sexes including immature specimens). The exploitation rates were general high for the inner Gulf but relatively low for the outer Gulf. Two-way ANOVA revealed a significant difference in F values between stations but not sexes while there was no significant differences in E values between stations and sexes.

3.4. Relative yield per recruit (Y/R') and average biomass per recruit ($\bar{B}$/R)

The Beverton & Holt yield per recruit (Y/R') and average biomass per recruit ($\bar{B}$/R) (fig. 3.4.1) shows that the mean current exploitation rate (E_{CUR}) of

Table 3.3.2. Natural mortality coefficient (M), fishing mortality coefficient (F) and exploitation rate (E) of R. argentea in the Winam Gulf. The confidence intervals for M are shown in parenthesis.

Station	M	F	E_{CUR}	Sex
Sango	0.90(0.80-1.00)	0.960	0.484	M
	0.75(0.68-0.82)	0.519	0.519	F
	0.89(0.81-0.98)	2.975)	0.770	M+F+I
Rakwaro	0.80(0.71-0.90)	1.439	0.637	M
	0.81(0.74-0.88)	1.422	0.637	F
	0.96(0.88-1.04)	2.281	0.704	M+F+I
Obaria	0.67(0.56-0.77)	1.410	0.678	M
	0.76(0.69-0.82)	1.332	0.637	F
	0.74(0.66-0.82)	2.885	0.796	M+F+I
Ngegu	0.82(0.72-0.92)	1.239	0.602	M
	0.88(0.81-0.95)	0.754	0.461	F
	0.89(0.81-0.98)	0.828	0.482	M+F+I
Luanda	0.92(0.81-1.00)	0.486	0.346	M
	0.80(0.74-0.86)	0.802	0.501	F
	0.90(0.82-0.98)	0.952	0.514	M+F+I
Mean ± SD	0.82±0.10	1.107±0.396	0.551±0.136	M
	0.80±0.05	0.966±0.392	0.565±0.081	F
	0.88±0.08	1.984±1.035	0.653±0.146	M+F+I
$F(4,8)$	5.000 *	6.000 *	1.238 ns	stations
$F(2,8)$	4.000 *	3.000 ns	0.571 ns	sexes

0.551±0.136 (males), 0.565±0.081 (females) and 0.653±0.146 (combined sexes including immature specimens) is 5.1-74% above the exploitation rate at maximum sustainable yield (E_{MSY}). The maximum fishing mortality coefficient at which the tangent to the yield curve is 10% of that at the origin ($F_{0.1}$) (table 3.4.1) and the corresponding exploitation rates (E_{MSY}) and ($E_{F0.1}$) generated by the Beverton & Holt yield model are shown in table 3.4.2 with corresponding current exploitation rates (E_{CUR}) for males, females and the combined sexes for different parts of the the Gulf. Over 70% of the values of current exploitation rate (E_{CUR}) show overexploitation while the remaining are close to the optimum exploitation rate (E_{opt} = 0.500).

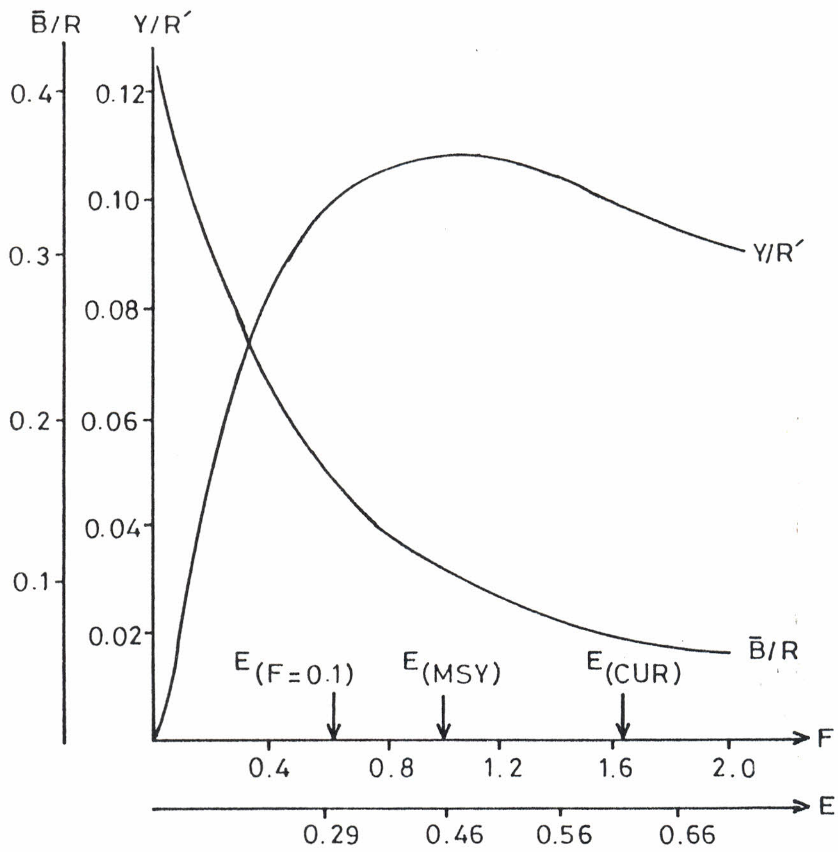

Fig. 3.4.1. Relative yield per recruit (Y/R') and average biomass per recruit ($\bar{B}$/R) of R. argentea in the Winam Gulf obtained with the parameters W_∞ = 1.8, K = 0.66, t_o = 0, M = 0.96, t_c = 0.6, L_∞ = 69.9, a = 0.000001, q = 3.4, L_c = 22.9 and t_r = 0.3.

Table 3.4.1. Predicted fishing pattern and yield of *R. argentea* in the Winam Gulf.

Station	F_{max}	MSY/R	$F_{0.1}$	Y/R($F_{0.1}$)	Sex
Sango	0.82	0.048	0.51	0.045	M
	0.60	0.039	0.38	0.037	F
	0.84	0.065	0.52	0.061	M+F+I
Rakwaro	0.69	0.071	0.44	0.067	M
	0.69	0.047	0.43	0.038	F
	0.97	0.088	0.58	0.083	M+F+I
Obaria	0.51	0.050	0.33	0.047	M
	0.63	0.072	0.40	0.068	F
	0.62	0.103	0.40	0.098	M+F+I
Ngegu	0.71	0.061	0.45	0.058	M
	0.80	0.053	0.50	0.050	F
	0.82	0.057	0.51	0.054	M+F+I
Luanda	0.88	0.045	0.54	0.042	M
	0.70	0.073	0.44	0.069	F
	0.86	0.074	0.52	0.070	M+F+I
Mean±SD	0.72±0.14	0.055±0.011	0.45±0.08	0.052±0.010	M
	0.68±0.08	0.057±0.015	0.43±0.05	0.052±0.016	F
	0.82±0.13	0.077±0.018	0.51±0.07	0.073±0.073	M+F+I
F(4,8)	0.150 ns		2.947 ns		stations
F(2,8)	0.640 ns		2.662 ns		sexes

Table 3.4.2. Predicted exploitation pattern of R. argentea in the Winam Gulf.

Station	E_{CUR}	E_{MSY}	$E_{F0.1}$	Sex
Sango	0.484	0.477	0.462	M
	0.591	0.444	0.336	F
	0.770	0.486	0.369	M+F+I
Rakwaro	0.643	0.463	0.335	M
	0.637	0.460	0.347	F
	0.704	0.503	0.477	M+F+I
Obaria	0.678	0.432	0.330	M
	0.637	0.453	0.345	F
	0.796	0.456	0.351	M+F+I
Ngegu	0.603	0.464	0.354	M
	0.461	0.476	0.362	F
	0.482	0.480	0.364	M+F+I
Luanda	0.346	0.489	0.370	M
	0.501	0.467	0.350	F
	0.514	0.489	0.366	M+F+I
Mean±SD	0.551±0.136	0.465±0.021	0.350±0.017	M
	0.565±0.081	0.460±0.012	0.348±0.010	F
	0.653±0.146	0.483±0.017	0.365±0.009	M+F+I
$F(4,8)$	1.238 ns			stations
$F(2,8)$	0.571 ns			sexes

CHAPTER 4

4. DISCUSSION AND CONCLUSION

4.1. Regression analyses

The linear equations for the interconversion of different forms of length measurements determined by this study are close to those of Wanink (1989) in the Mwanza Gulf of Lake Victoria and had very high correlation coefficients. The sample size for the Mwanza Gulf was relatively small (45-52) while the large sample size for this study (220-285) confirms these previous results. These values can thus be used to convert one form of length measurement to the other for comparison due to individual preferences in the form of length measurements.

Although no values are available for direct comparison, the length-weight relationships derived by this study can form the basis of future work on this species. The exponent in the length-weight relationship seemed to be quite high in this study although the growth of R. argentea was assumed to be isometric by Wanink (1989). Such a parallel relationship could be attributed to sampling errors in this study. Since weight of the specimens were not recorded from September to November, the observed changes only indicate a general trend in the Fultons condition factor. The observed changes in Fultons condition factor could however be attributed to development of the gonadal material during or just prior to the peak breeding seasons. Maximum condition factor incidentally fell within the established rainy seasons for the region and other fish species in Lake Victoria have been established to breed during the same time of the year.

4.2. Length-frequency analysis

the circumstances where methodologies such as length-frequency analysis might apply are, for example, the preliminary stages of development of an assessment programme or for a resource on which investigation is just beginning (Csirke & Caddy, 1987). The main possible source of bias is introduced by the selective capture of the larger sizes of younger groups due to gear selectivity and removal of the larger sizes of older age groups due to fishing mortality, thereby reducing the average length corresponding to a given age. Population parameters derived from length-frequency distribution of R. argentea are subject to sampling errors and bias due to the particular properties of the sampled population, sampling procedure and the characteristics of the fishing gear i.e gear selectivity. For example, variation in recruitment strength may seriously bias F values when these are expressed in terms of length. Parameters estimation and hypothesis testing in length-frequency analysis are facilitated by adopting structural assumptions on the underlying processes and then maximizing likelihood functions or fitting model expectations to the observed length - classes by least square or other criteria. Solutions are then found by iterative search techniques which take advantage of and indeed require the numerical power of computers. For developing countries, the collection of a large number of independent data sets like total catch, landings, catch rate and sizes may be prohibitive in cost and manpower. The price to pay in exchange for this is to accept some risk by using length-frequency analysis and to buffer the risk by cautious management advice. The potential gain in the long term is enormous as this process might finally start development of a more relevant tropical fisheries science.

4.3. Growth

Considering the difficulty of resolving length-frequency distribution into components, the growth parameters derived by this study (L_∞, K and ø') using the Bhattacharya analysis could be said to be subjective. However, the Wetherall et al. and longevity methods could provide independent checks on these values. However, the longevity method of Pauly (1980a) has recently met with some criticism from Mathews & Samwel (1990). The authors state explicitly that this is not a reliable estimator of L_∞ regardless of the definition attached to L_{max}. This technique was thus only used as a guess-timate to the value of L_∞. Since one-way analysis of variance (ANOVA) revealed no significant differences between the three methods used and two-way ANOVA revealed a significant difference in the Wetherall et al. analysis for L_∞ between stations and not between sexes, then the estimates could be the most probable values for R. argentea in the Winam Gulf of Lake Victoria. The differences in principles and procedures behind these three methods augments the fact that any of these methods gives a reliable estimate of the growth parameter L_∞ for the species. Whereas the Bhattacharya analysis (Gulland & Holt plot) relies on resolving the length-frequency into normally distributed components, the other two methods (Wetherall et al. analysis and longevity method) do not and hence the subjectiveness of the Bhattacharya analysis could be reduced to a mere confirmation by the Wetherall et al. analysis.

The tendency of L_∞ to be larger towards the outer Winam Gulf could be attributed to fishing pattern in the Gulf. The popular information given by Okedi (1973; 1981a; 1981b) and Wanink (1989) that all "dagaa" fishery is based on night light attraction is not true for the whole of Winam Gulf. The fishing pattern is such that at Sango and Rakwaro, no lights are used at all for the "dagaa" fishery probably due to the shallow depths of about 6 m and fishing takes place throughout the month; at Obaria and Ngegu, light attraction is used only during the dark phase of the moon and no lights are used during the bright phase; at Luanda and towards the the open waters, fishing takes place during the the dark phase of the lunar cycle by light attraction and no fishing takes place at all during the bright phase. Such a fishing pattern could mean that during the non fishing period of every lunar cycle, there is a reduced fishing pressure to allow substantial growth and this could explain the larger L_∞ values towards the outer Winam Gulf. The diel vertical migration of "dagaa" reported by Wanink (1989) in the Mwanza Gulf of Lake Victoria could could only have an impact on recruitment into the fishery in waters of greater depth where light attraction must be used but samples collected from Luanda had specimens of up to 18 mm TL while those from other places had specimens of up to 15 mm TL indicating a more or less similar age of recruitment into the fishery from all parts of the Gulf. This phenomenon of diel vertical migration does not therefore play an important role in the "dagaa" fishery of Winam Gulf where fishermen are more concerned with the total weight of the catch and not individual specimens due to the small size of "dagaa". The L_∞ values obtained by this study indicate a great reduction in the size as compared to values cited by Wanink (1989) of 103 mm TL in the Kenyan portion of Lake Victoria in the 1970s and 105 mm FL for the Ugandan portion of the Lake. Such a great reduction in L_∞ could be an indication of overexploitation

Wanink (1989) determined a growth curvature (K) of 1.14 yr^{-1} for R. argentea in the Mwanza Gulf of Lake Victoria. This K value is probably an overestimation since his L_∞ was only 52 mm SL while specimens of up to 62 mm SL were collected in the same region in 1986-88. The K value determined by this study is close to that determined by Getabu (1988) of 0.46 yr^{-1} for the characid, Alestes sadleri (Blgr.), a small species that grows to about 14 cm while Asila & Ogari (1988) found a value of 0.19 yr^{-1} for L. niloticus growing to 205 cm in the Winam Gulf.

4.4. Mortality and exploitation rates

In this study, the total mortality coefficient (Z), natural mortality coefficient (M) and the fishing mortality coefficient (F) seem to be quite high by all standards. The significant differences (ANOVA) observed for both Z and M between sexes could arise from the fact that both the analyses use L_∞ and K as inputs. Differences in M between stations could introduce differences in F between stations which is obtained by simple substraction of M from Z while the E values obtained from division of F by Z indicate no significant differences between stations and sexes. This could suggest some linear relationship between F and Z which is actually the basis of Munro's (1984) method for the estimation of M from the linear equation:

$$Z = M + PF,$$

where

intercept = parameter (M)

slope = variable (F)

P = parameter (probability of capture)

The exploitation rate of R. argentea in the Winam Gulf seems to be rather uniform while differences in F and M between stations could be interactive in nature and counterbalancing to produce the more or less uniform exploitation rate observed in the population. As suggested by Wanink (1989), natural mortality may be age specific for R. argentea. The predation by Nile perch (Ogari, 1984), regular infestation by plerocecoid larvae of cestode, probably Ligula intestinalis (L.) (Wanink, 1989) and avarian predation by pied kingfisher (Ceryle rudus L.), and cormorants (Phalacrocorax carbo L., P. africanus Gmelin) probably contribute to the high natural mortality of "dagaa" in the Winam Gulf of Lake Victoria. The high natural mortality coupled with a high fishing mortality coefficient could explain the general reduction in length observed in the population. This general reduction in size can not be taken as a reduction in the standing stock, in fact, standing stock can increase even with reduction in size as observed for Nile perch in Lake Victoria (IFIP, 1990). The fishing pattern and exploitation rate for the Winam Gulf indicate that 80% of the F values determined were above the critical value of exploitation (E) where a theoretical maximum sustainable yield (MSY) indicating a gross overexploitation of R. argentea in the Gulf.

4.5. Relative yield per recruit (Y/R') and average biomass per recruit ($\bar{B}$/R)

Beverton & Holt's (1966) yield model indicated that that the exploitation rate at maximum sustainable (E_{MSY}) was 0.432-0.503 and 87% of the current exploitation rate (E_{CUR}) values were above E_{MSY} while all the values were above E_{MEY} with 73% falling above the optimum exploitation rate (E_{opt} = 0.5), indicating a gross overexploitation of "dagaa" in the Winam Gulf. Although fisheries managers are interested in actual yields, it is true that the yield per recruit as a function of fishing mortality gives an indication of the exploitation pattern and needs some modification for policy formulation and implementation. Gulland (1984) discussed the use of such models with respect to target fisheries. If fisheries managers are looking at a given stock in terms of national economy, whole national fishery or national nutritional demands, then achieving something like MEY is likely to result in a higher total food supply than achieving MSY. Such an objective would strive towards achieving economic targets rather than purely biological ones, which is a proper objective in developed countries but can also apply to developing countries. It may be possible to determine the greatest catch that can be taken from a stock using such analytical models but not the amount of fishing effort required for such a yield. The maximum sustainable yield (MSY) will occure at the fishing mortality F_{max} corresponding to the maximum yield per recruit only if the average recruitment does not change with the adult stock size, at least at stocks corresponding to that level of fishing but this is unlikely, since at F_{max}, the stock will be moderately heavily fished and this is likely to have at least some effect on recruitment. A popular target, that of $F_{0.1}$ is quite arbitrary but has given useful results. In the case of R. argentea in the Winam Gulf, there is no significant difference in the predicted F_{max} and $F_{0.1}$ values between sexes or stations. It is evident from this study that R. argentea is overexploited in the Winam Gulf of Lake Victoria. Dagaa fishery in the Winam Gulf of Lake Victoria could be possibly controlled by:

i) strict observance of the closed season or its extension in some years following very heavy fishing in the previous years.

ii) sale of all landed fish through fisheries cooperative societies.

iii) licencing of mosquito and beach seines in addition to registration of boats to help in monitoring the effort exerted on the fishery.

The current regulation require the purchase of a fishing permit on an annual basis but has no restrictions on the type of gear to be used in Lake Victoria. This permit could modified to serve as a gear licence as well to control the number of mosquito seine nets.

REFERENCES

ACERE, T. (1980). Recent trends in the fisheries of Lake Victoria (Uganda and northern part). FAO Fish. Rep. 388: 36-41.

AGASEN, E. V. AND C. M. DEL MUNDO (1988). Growth, mortality and exploitation rate of Panaeus indicus in Manila Bay, Phillipines and southeast India. FAO Fish. Rep. 389: 89-100.

AHMAD, D. T. B. (1988). Population dynamics big-eye croacker (Pennahia macrophthalmus) off Kedah, Penang and Perak States, Malaysia. FAO Fish. Rep. 389: 141-153.

ALLEN , K. R. (1969). Application of the Bertalanffy growth equation to problems of fisheries management: a review. J. Fish Res. Bd Canada 26:2267-2281.

ASILA, A. A. AND J. OGARI (1988). Growth parameters and mortality of Nile perch (Lates niloticus) estimated from length-frequency in the Nyanza Gulf (Lake Victoria). FAO Fish. Rep. 389:272-287.

BAGENAL, T. B. AND E. BRAUM (1971). Egg and early life history. In. Methods of assessment of fish production in fresh waters. E. W. Ricker (ed.). 2nd. edition, IBP handbook No. 3.

BAGENAL, T. B. AND F. W. TESCH (1978). Age and growth. In. Methods of assessment of fish production in fresh water. T. B. Bagenal (ed.). 3rd. edition, IBP handbook No. 3.

BENDA, R. S. (1981). A comparison of bottom trawl catch rates in the Kenyan waters of Lake Victoria. J. Fish Biol. 18:13-24.

BERTALANFFY, L. von. (1938). A quantitative theory of organic growth (inquiries on growth and laws II). Hum. Biol. 10(2):181-213

BEVERTON, R. J. H. AND S. J. HOLT (1956). A review of methods for estimating mortality rate of exploited populations, with special reference to source of bias in catch sampling. Rapp. P.-V. Reun. Cons. Int. Explor. Mer 140(1): 67-83.

BEVERTON, R. J. H. AND S. J. HOLT (1966). Manual of methods for fish stock assessment part 2. FAO Fish. Tech. Pap. 38. Rev. 1: 67 pp.

BHATTACHARYA, C. G. (1967). A simple method of resolution of a distribution into Gaussian components. Biometrics 23: 115-135.

BOONRAKSA, V. (1988). Growth, mortality and maximum sustainable yield of Indo-Pacific mackerel (Rastrelliger brachysoma) off the southwest coast of Thailand. FAO Fish. Rep. 389: 356-371.

BWATHONDI, P. O. J. (1988). State of Lake Victoria fisheries, Tanzanian sector. FAO Fish. Rep. 388:29-35.

CASSIE, R. M. (1954). Some uses of probability paper in the analysis of size frequency distribution. Aust. J. Mar. Freshwat. Res. 5:513-522.

CHEUNPAN, A. (1988). An assessment of king mackerel (Scomberomorus commerson) in the inner Gulf of Thailand. FAO Fish. Rep. 389: 401-410.

CHITAMWEBWA, D. B. R. (1988). Historical development of dagaa fishery policy and planning. Seminar paper, University of Dar-es-salam, 2-4 May 1988. 11pp.

CIFA (COMMITTEE FOR INLAND FISHERIES OF AFRICA) (1988). Report of the fourth session of the sub-committee for the development and management of Lake Victoria. Kisumu, Kenya, 6-10 April 1987. FAO Fish. Rep. 388:112p.

COPLEY, H. (1953). The tilapia fishery of the Kavirondo Gulf. Jl. E. African Nat. Hist. Soc. 94: 1-5.

CRAIG, J. F. (1982). A study on growth and mortality of trout (Salmo trutta) in afferent streams of Windermere. J. Fish Biol. 20: 423-430.

CIRKE, J. AND J. F. CADDY (1987). Methods of size-frequency analysis and their incorporation in programmes for fish stock assessment in developing countries. FAO interest in recieving advice. In. D. Pauly and G. R. Morgan (eds.). Proceedings of the international conference on the theory and application of length-based methods for stock assessment. 11-16 February 1985, Mazzara del Vallo, Sicily, Italy.

DJAMA, T. (1988). Estimation of growth parameters and mortality of longneck croacker (Pseudotolithus typus) in Cameroon. FAO Fish. Rep. 389: 153-170.

DY-ALI, E. (1988). Growth, mortality, recruitment and exploitation rate of Selar boops in Davao Gulf, Phillipines. FAO Fish. Rep. 389: 346-355.

FROST, W. E. AND C. KIPLING (1967). A study of reproduction, early life, weight-length relationship and growth of pike, Esox lucius L., in Windermere. J. Anim. Ecol. 36: 651-693.

GABRAL-LLANA, MA. E. (1988). Growth, mortality and recruitment of Asian moon scallop (Amusium pleuronectes) in the Visayan Sea, Phillipines. FAO Fish. Rep. 389: 16-24.

GETABU, A. (1988). Aspects of the Lake Victoria fisheries, with emphasis on Oreochromis niloticus and Alestes sadleri from the Nyanza Gulf. FAO Fish. Rep. 389: 416-431.

GIBSON, R. N. AND I. A. EZZI (1981). The biology of the Norway gobby, Pomatoschistus norvegicus (Collett.), on the west coast of Scotland. J. Fish Biol. 19: 697-714.

GRAHAM, M. (1929). The Victoria Nyanza and its fisheries. Crown agents, London.

GREENWOOD, P. H. (1966). The fishes of Uganda. 2nd. Ed. The Uganda Society, Kampala.

GOLDSPINK, C. R. (1978). The population dynamics, growth rate and reproduction of bream, <u>Abramis brama</u>, in Tjeulemeer, the Netherlands. J. Fish Biol. 13: 499-517.

GOLDSPINK, C. R. (1981). A note on growth and year-class strength of bream, <u>Abramis brama</u> (L.) in three eutrophic lakes, England. J. Fish Biol. 19: 665-673.

GULLAND, J. A. (1977). The analysis of data and development of models. In Fish population dynamics. J. A. Gulland (ed.). Wiley Interscience Publication. New York, Sydney, Toronto.

GULLAND, J. A. (1983). Fish stock assessment: a manual of basic methods. Vol. I. FAO/Wiley series on food and agriculture, pp xii + 223.

GULLAND, J. A. (1984). Advice on target fishing rate. ICLARM Fishbyte 2(1): 8-11.

GULLAND, J. A. AND S. J. HOLT (1959). Estimation of growth parameters for data at unequal time intervals. J. Cons. Int. Explor. Mer. 25(2): 215-222.

HARDING, J. P. (1949). The use of probability paper for the graphical analysis of polymodal frequency distribution. J. Mar. Biol. Ass. U.K 28: 141-153.

HOPSON, J. (1972). breeding and growth in two populations of <u>Alestes baremose</u> (Joannis.) (Pisces: Characidae) from the northern basin of

Lake Chad. Overseas research publication No. 22: 50 pp. HMSO London.

HOPSON, J. (1975). Preliminary observations on the biology of Alestes baremose (Joannis.) in Lake Rudolf. Symp. Hydrobiol. Fish. of L. Rudolf, Molo, 25-29 May 1975.

HOWES, G. (1980). The anatomy, phylogeny and classification of bariliine cyprinid fishes. Bull. Brit. Mus. Nat. Hist. (Zool.) 37: 129-198.

IFIP (REGIONAL PROJECT FOR INLAND FISHERIES PLANNING, DEVELOPMENT AND MANAGEMENT IN EASTERN/CENTRAL/SOUTHERN AFRICA) (1990). Symposium on socio-economic aspects of Lake Victoria fisheries. UNDP/FAO 24-27 April 1990, Kisumu, Kenya.

JONES. R. (1984). Assessing the effect of change in exploitation pattern using length composition data (with notes on VPA and cohort analysis). FAO Fish. Tech. Pap. 256: 118 pp.

JONES. A. B. C. AND R. P. JONES (1988). Estimation of growth, biomass and mortality parameters of Dentex spp (Sparidae) in Sierra Leonean waters. FAO Fish. Rep. 389: 229-245.

JULIEN-FLUS, M. (1988). A study of growth parameters and mortality rates of Scomberomorus brasiliensis from the coastal areas of Trinidad, West Indies. FAO Fish. Rep. 389: 385-400.

KIPLING, C. AND W. E. FROST (1970). A study of the mortality, population numbers, year-class strength, production and food consumption of pike, <u>Esox lucius</u> L. in Windermere from 1944-1962. J. Anim. Ecol. 39: 115-157.

KUDHONGANIA, A. W. AND A. J. CORDONE (1974). Bathospatial distribution pattern and biomass estimates of major demersal fishes in Lake Victoria, J. Trop. Hydrobiol. Fish. 3: 15-31.

LABLACHE, G. AND G. CARRARA (1988). Population dynamics of emperor red snapper (<u>Lutjanus sebae</u>) with notes on the demersal fishery of the Mahe plateau, Seychelles. FAO Fish Rep. 389: 171-192.

LASSEN, H. (1988). Splitting length distribution into peaks and the clean class concept. ICLARM Fishbyte 6(1): 11-14.

Le CREN, E. D. (1947). Determination of age and growth of perch (<u>Perca fluviatilis</u>) from the opercular bone. J. Anim. Ecol. 16: 188-204.

Le CREN, E. D. (1958). Observations on the growth of perch (<u>Perca fluviatilis</u>) over twenty four years with special reference to the effect of temperature and change in population density. J. Anim. Ecol. 27: 287-334.

MANN, R. H. K. (1971). The population, growth and reproduction of fish in four small streams in southern England. J. Anim. Ecol. 40: 155-190.

MANN, R. H. K. (1976). Observations on age, growth, reproduction and food of the chubb, Squalis cephalus L. in river Stor, Dorset. J. Fish Biol. 8: 265-288.

MARTEN, G. G., B. WANJALA AND L. T. GALUKA (1976). Exploratory trawling of the Lake Victoria fishery in Kenya during 1975. EAFFRO manuscript, 19 pp.

MATHEWS, C. P. AND M. SAMWEL (1990). The relationship between maximum and asymptotic length in fishes. ICLARM Fishbyte 8(2): 14-16.

MOHD-ISA, M. B. (1988). Population dynamics of Nemipterus japonicus (Pisces: Nemipteridae) off Kedah State, Malaysia. FAO Fish. Rep. 389: 126-140.

MOREAU, J. (1988). Estimation of natural mortality from selection and catch length-frequency data: a modification of Munro' method and an application example. ICLARM Fishbyte 6(2): 10-12.

MULLER, R. G. AND R. S. BENDA (1981(. A comparison of bottom trawl stock densities in the inner Kavirondo Gulf of Lake Victoria. J. Fish Biol. 19: 339-401.

MUNRO, J. L. (1984). Estimation of natural mortality rates from selectivity and catch length-frequency data. ICLARM Fishbyte 2(1): 11-14.

MUNRO, J. L. AND D. PAULY (1983). A simple method for comparing the growth of fishes and invertebrates. ICLARM Fishbyte 1(1): 5-6.

OCHUMBA, P. B. O. AND D. I. KIBAARA (1989). Observations on blue-green algal blooms in the open waters of Lake Victoria, Kenya. Afr. J. Ecol. 27: 23-34

OGARI, J. (1984). The biology of Lates niloticus (Linn.) in the Nyanza Gulf of Lake Victoria (Kenya) with special reference to the food and feeding habits. M. Sc. Thesis, University of Nairobi, 1984.

OGARI, J. (1985). Distribution, food and feeding habits of Lates niloticus (L.) in Nyanza Gulf of Lake Victoria (Kenya). FAO Fish. Rep. 335: 68-80.

OGARI, J. AND S. DADZIE (1988). The food of the Nile perch, Lates niloticus (L.), after the disappearance of the haplochromine cichlids in the Nyanza Gulf of Lake Victoria (Kenya). J. Fish Biol. 32: 571-577.

OKACH, J. I. O. (1982). Reproductive biology and feeding ecology of siluroid catfish, Bagrus docmac Forskal. (Pisces: Bagridae) in Winam Gulf of Lake Victoria, E. Africa. M. Sc. Thesis, University of Nairobi, 1982.

OKACH, J. I. O. AND S. DADZIE (1988). The food, feeding habits and distribution of a siluroid catfish, Bagrus docmac (Forskal) in Kenyan waters of Lake Victoria. J. Fish Biol. 32: 21-26.

OKEDI, J. (1973). Preliminary observations on Engraulicypris argentea from Lake Victoria. EAFFRO annual report (1973).

OKEDI, J. (1981a). Integrated management of the "dagaa" fishery of Lake Victoria. In. Proceedings of the workshop of the Kenya Marine and Fisheries Research Institute on aquatic resources of Kenya. 13-19 July 1981.

OKEDI, J. (1981b). The Engraulicypris "dagaa" fishery of Lake Victoria: with special reference to the southern waters of the Lake. In. Proceedings of the workshop of the Kenya Marine and Fisheries Research Institute on aquatic resources of Kenya. 13-19 July 1981.

PAULY, D. (1980a). A selection of simple methods for the assessment of tropical fish stocks. FAO Fish. Circ. No. 729.

PAULY, D. (1980b). On the interrelationship between natural mortality, growth parameters and mean environmental temperature in 175 fish stocks. J. Cons. Int. Explor. Mer. 39(3): 175-192.

PAULY, D. (1983). Length-converted catch-curve. A powerful tool for fisheries research in the tropics (part 1). ICLARM Fishbyte 1(2): 9-13.

PAULY, D. (1984a). Length-converted catch-curve. A powerful tool for fisheries research in the tropics (part 2). ICLARM Fishbyte 2(1): 17-19.

PAULY, D. (1984b). Length-converted catch-curve. A powerful tool for fisheries research in the tropics (part 3). ICLARM Fishbyte 2(3): 9-10.

PAULY, D. (1985). On improving operation and use of ELEFAN programmes. Part I. Avoiding "drift" of K towards low values. ICLARM Fishbyte 3(3): 13-14

PAULY, D. (1986). On improving operation and use of ELEFAN programmes. Part II. Improving the estimation of L_{∞}. ICLARM Fishbyte 4(1): 18-20.

PAULY, D. AND J. L. MUNRO (1984). Once more on the comparison of growth in fish and invertebrates. ICLARM Fishbyte 2(1): 21.

POLLOCK, B. R. (1981). Age determination and growth of luderick, Girella tricuspidata (Quay and Gaimard.) taken from Moreton Bay, Australia. J. Fish Biol. 19: 475-485

POLLOCK, B. R. (1982). Spawning period and growth of yellowfin bream, Acanthopagrus australis (Gunther), in Moreton Bay, Australia. J. Fish Biol. 21: 349-355.

RABUOR, C. O. (1988). First report of the fish stock assessment on artisanal fishery of the Winam Gulf of Lake Victoria (Kenya). K.M.F.R.I. Tech. Rep. 20 February 1988.

RICKER, W. E. (1977). The historical development. In. Fish population dynamics. J. A. Gulland (ed.). London, Wiley.

RINNE, J. AND B. WANJALA (1982). Observations on movement patterns of Tilapia spp. in Nyanza Gulf, Lake Victoria, East Africa. J. Fish Biol. 20: 317-332.

SAMB, B. (1988). Seasonal growth, mortality and recruitment pattern of Sardinella maderensis off Senegal. FAO Fish. Rep. 389: 257-271.

SIMS, S. E. (1985). Selected computer programmes in FORTRAN for fish stock assessment. FAO Fish. Tech. Pap. 259: 183 pp.

SPARRE, P. (1987). Computer programmes for fish stock assessment: length based fish stock assessment for Apple II computers. FAO Fish. Tech. Pap. 101, suppl. 2.

SPARRE, P., E. URSIN AND S. C. VENEMA (1989). Introduction to tropical fish stock assessment. Part 1. Manual. FAO Fish. Tech. Pap. No. 306.1.

STEPHENS, R. T. T. (1982). Reproduction, growth and mortality of common bully, Gobiomorphus cotidianus (Mc Dowell), in a eutrophic New Zealand lake. J. Fish Biol. 20: 259-270.

SUMIONO, B. (1988). Estimation of growth and mortality in banana prawn (Penaeus merguiensis) from the southern coast of Java. FAO Fish. Rep. 389: 69-88.

SUPONGPAN, M. (1988). Assessment of Indian squid (Loligo duvauceli) and mitre squid (L. chinensis) in the Gulf of Thailand. FAO Fish. Rep. 389: 25-41.

TANAKA, S. (1956). A method for analyzing the polynomial frequency distribution and its application to the length distribution of porgy, Taitus tumifrons (T & S). Bull. Tokai Reg. Res. 14: (Abstract).

THIAM, S. E. (1986). Some improvements and corrections to Sim's version of ELEFAN I. ICLARM Fishbyte 4(3): 6-10.

VAKILY, J. M., M. L. PALMORES AND D. PAULY (1986). Computer programmes for fish stock assessment: HP 41 CV calculator. Produced with the co-operation of ICLARM. FAO Fish. Tech. Pap. 101 suppl. 1: 155 pp.

VIBHASIRI, A. (1988). An assessment of jinga shrimp, Metapenaeus affinis (Penaeidae) in Ban Don Bay, Gulf of Thailand. FAO Fish. Rep. 389: 101-116.

WANINK, J. H. (1989). The ecology of dagaa, Rastrineobola argentea (Pellegrin) 1904. Report of the Haplochromis Ecology Survey Team (HEST) operating in Lake Victoria. HEST/TAFIRI/FAO/DANIDA workshop on the fish stock in Lake Victoria. January/February 1989, Mwanza, Tanzania.

WEATHERLY, A. H. (1972). Growth and ecology of fish populations. New York and London. Academic Press, 293 pp.

WELCOMME, R. L. (1979). Fisheries ecology of floodplain rivers. Longman Group. pp vii + 317.

WETHERALL, J. A. (1986). A new method for estimating growth and mortality parameters from length-frequency data. ICLARM Fishbyte 4(1): 12-14.

WETHERALL, J. A., J. J. POLOVINA AND S. RALTON (1987). Estimating growth and mortality in steady-state fish stocks from length-frequency data. ICLARM Conf. Proc. (13): 53-74.

WIDODO, J. (1988). Population biology of Russells scad (_Decapterus ruselli_) in the Java Sea, Indonesia. FAO Fish. Rep. 389: 308-323.

ZAR, J. H. (1984). Biostatistical analysis. Prentice-Hall International, Inc., Englewood Cliffs, New Jersey. 718 pp.

APPENDIX IA

Length-frequency distribution of R. argentea from

Sango, males

year	1989	1989	1989	1989	1989	1990	1990	1990	1990	1990
month	8	9	10	11	12	1	2	3	4	5
day	15	15	15	15	15	15	15	15	15	15
34.00- 35.00	0	0	0	0	0	0	0	0	0	0
35.00- 36.00	1	0	0	0	0	0	0	0	0	0
36.00- 37.00	0	0	0	0	0	0	0	0	0	0
37.00- 38.00	2	0	0	0	0	0	0	0	0	0
38.00- 39.00	3	1	0	0	0	0	0	0	0	0
39.00- 40.00	1	2	0	0	0	0	1	0	1	0
40.00- 41.00	6	0	0	0	0	0	2	0	10	0
41.00- 42.00	5	0	2	0	0	2	3	0	4	0
42.00- 43.00	5	0	6	0	1	5	2	0	2	4
43.00- 44.00	3	1	2	1	3	2	4	6	6	9
44.00- 45.00	6	1	1	1	6	1	2	5	4	9
45.00- 46.00	5	4	5	6	9	14	6	7	11	11
46.00- 47.00	5	9	4	6	9	6	6	14	6	7
47.00- 48.00	8	4	10	12	10	15	8	16	4	5
48.00- 49.00	7	12	9	5	11	17	9	15	9	4
49.00- 50.00	7	14	10	12	9	14	10	4	5	6
50.00- 51.00	6	11	20	9	7	30	12	14	5	3
51.00- 52.00	11	5	8	9	3	11	15	7	1	2
52.00- 53.00	4	3	4	3	2	8	5	5	1	4
53.00- 54.00	1	2	3	3	4	6	2	3	0	3
54.00- 55.00	2	5	1	1	9	0	2	6	0	0
55.00- 56.00	1	1	1	3	4	1	1	4	0	0
56.00- 57.00	0	1	0	1	5	0	0	2	0	0
57.00- 58.00	0	0	0	0	3	0	0	0	0	1
58.00- 59.00	0	0	0	0	1	0	0	1	0	0
59.00- 60.00	0	0	0	0	0	0	0	0	0	1
60.00- 61.00	0	0	0	0	0	0	0	0	0	0
61.00- 62.00	0	0	0	0	0	0	0	0	0	0
62.00- 63.00	0	0	0	1	0	0	0	0	0	0
Total	89	76	86	73	96	132	90	109	69	69

APPENDIX IA (CONTD.)

Length-frequency distribution of R. *argentea* from

Sango, males

year	1990	1990	
month	6	7	
day	15	15	Total
34.00- 35.00	0	0	0
35.00- 36.00	0	0	1
36.00- 37.00	0	0	0
37.00- 38.00	0	0	2
38.00- 39.00	0	0	4
39.00- 40.00	0	1	6
40.00- 41.00	2	0	20
41.00- 42.00	3	2	21
42.00- 43.00	1	2	28
43.00- 44.00	1	3	41
44.00- 45.00	2	1	39
45.00- 46.00	0	6	84
46.00- 47.00	6	7	85
47.00- 48.00	5	7	104
48.00- 49.00	5	7	110
49.00- 50.00	10	7	108
50.00- 51.00	6	3	126
51.00- 52.00	6	1	79
52.00- 53.00	2	1	42
53.00- 54.00	2	0	29
54.00- 55.00	1	0	27
55.00- 56.00	0	0	16
56.00- 57.00	0	0	9
57.00- 58.00	0	0	4
58.00- 59.00	0	0	2
59.00- 60.00	0	0	1
60.00- 61.00	0	0	0
61.00- 62.00	0	0	0
62.00- 63.00	0	0	1
Total	52	48	989

APPENDIX IB

Length-frequency distribution of R. argentea from Sango, females

year	1989	1989	1989	1989	1989	1990	1990	1990
month	8	9	10	11	12	1	2	3
day	15	15	15	15	15	15	15	15
34.00- 35.00	1	0	0	0	0	0	0	0
35.00- 36.00	1	3	0	0	0	0	2	0
36.00- 37.00	0	9	0	0	0	0	1	0
37.00- 38.00	1	4	0	5	0	0	2	3
38.00- 39.00	0	0	3	1	0	2	4	0
39.00- 40.00	0	8	2	1	0	1	3	1
40.00- 41.00	2	4	8	1	2	1	8	7
41.00- 42.00	0	4	3	5	3	1	6	9
42.00- 43.00	3	7	2	5	3	2	4	7
43.00- 44.00	3	2	1	0	6	3	8	5
44.00- 45.00	10	7	5	6	8	3	6	11
45.00- 46.00	7	9	13	12	10	21	14	12
46.00- 47.00	13	18	15	9	10	13	15	17
47.00- 48.00	9	9	20	12	7	14	13	9
48.00- 49.00	17	11	19	15	0	21	13	11
49.00- 50.00	10	25	20	15	0	26	14	9
50.00- 51.00	20	20	30	25	1	29	18	8
51.00- 52.00	12	20	8	8	2	15	20	1
52.00- 53.00	9	14	9	5	3	9	14	1
53.00- 54.00	4	7	4	3	11	8	8	2
54.00- 55.00	1	2	3	2	11	1	4	3
55.00- 56.00	1	4	2	2	15	4	3	1
56.00- 57.00	1	2	1	4	17	0	1	1
57.00- 58.00	0	1	0	0	10	0	0	0
58.00- 59.00	2	1	0	1	3	0	1	0
59.00- 60.00	0	1	0	0	6	0	2	0
60.00- 61.00	0	0	0	0	2	0	0	0
61.00- 62.00	0	0	0	0	1	0	0	0
Total	127	192	168	137	131	174	184	118

APPENDIX IB (CONTD.)

Length-frequency distribution of R. argentea from Sango, females

year	1990	1990	1990	1990	
month	4	5	6	7	
day	15	15	15	15	Total
34.00- 35.00	0	0	0	0	1
35.00- 36.00	0	0	2	2	10
36.00- 37.00	0	0	2	1	13
37.00- 38.00	0	0	2	0	17
38.00- 39.00	0	0	4	4	18
39.00- 40.00	2	0	4	3	25
40.00- 41.00	13	4	7	7	64
41.00- 42.00	18	4	6	5	64
42.00- 43.00	21	5	3	3	65
43.00- 44.00	9	8	4	4	53
44.00- 45.00	14	9	6	6	91
45.00- 46.00	15	15	4	5	137
46.00- 47.00	8	17	11	9	155
47.00- 48.00	13	10	14	14	144
48.00- 49.00	9	12	12	13	153
49.00- 50.00	9	10	9	10	157
50.00- 51.00	5	9	13	12	190
51.00- 52.00	4	3	19	19	131
52.00- 53.00	3	3	7	5	82
53.00- 54.00	3	3	4	4	61
54.00- 55.00	2	1	3	3	36
55.00- 56.00	0	1	0	0	33
56.00- 57.00	2	1	0	0	30
57.00- 58.00	1	0	0	0	12
58.00- 59.00	0	0	1	0	9
59.00- 60.00	0	0	0	0	9
60.00- 61.00	0	0	0	0	2
61.00- 62.00	0	0	0	0	1
Total	151	115	137	129	1763

APPENDIX IC

Length-frequency distribution of _R._ <u>argentea</u> from Sango, males, females, immature

year	1989	1989	1989	1989	1989	1990	1990	1990
month	8	9	10	11	12	1	2	3
day	15	15	15	15	15	15	15	15
15.00- 16.00	0	0	0	3	0	0	0	0
16.00- 17.00	0	0	1	5	0	0	0	4
17.00- 18.00	0	0	0	13	0	0	0	5
18.00- 19.00	0	0	1	24	0	2	0	18
19.00- 20.00	0	0	1	14	2	0	0	8
20.00- 21.00	0	4	2	41	2	1	0	32
21.00- 22.00	0	1	1	15	1	1	0	11
22.00- 23.00	0	3	2	34	2	0	1	12
23.00- 24.00	0	6	2	17	5	0	0	7
24.00- 25.00	0	3	2	27	5	0	1	11
25.00- 26.00	0	2	0	25	9	0	2	20
26.00- 27.00	0	3	0	16	4	1	2	7
27.00- 28.00	0	3	2	10	2	1	8	13
28.00- 29.00	2	6	1	7	3	1	4	7
29.00- 30.00	1	4	1	15	6	0	12	7
30.00- 31.00	3	10	0	20	8	1	11	16
31.00- 32.00	4	5	0	12	2	0	7	8
32.00- 33.00	1	5	0	17	3	1	4	3
33.00- 34.00	3	9	2	8	4	1	6	9
34.00- 35.00	5	14	2	19	14	1	4	10
35.00- 36.00	4	7	1	19	19	1	6	10
36.00- 37.00	4	12	0	8	19	0	7	15
37.00- 38.00	6	5	0	10	18	2	11	3
38.00- 39.00	4	4	3	4	8	5	8	1
39.00- 40.00	2	13	2	6	3	2	10	3
40.00- 41.00	8	6	9	2	2	1	14	18
41.00- 42.00	6	7	5	5	3	3	9	14
42.00- 43.00	7	7	8	5	4	7	7	10
43.00- 44.00	6	3	3	1	9	5	12	11
44.00- 45.00	16	10	6	7	14	35	8	15
45.00- 46.00	14	13	18	18	19	19	20	33
46.00- 47.00	18	27	19	15	19	30	21	23
47.00- 48.00	20	13	30	24	17	38	21	13
48.00- 49.00	25	22	28	20	11	40	22	20
49.00- 50.00	17	39	30	27	9	59	24	14
50.00- 51.00	26	31	50	34	8	26	30	14
51.00- 52.00	22	19	16	17	5	17	35	2
52.00- 53.00	12	10	13	8	5	14	19	2
53.00- 54.00	5	3	7	6	15	1	10	3
54.00- 55.00	3	9	4	3	20	5	6	3
55.00- 56.00	2	3	3	5	19	0	4	2
56.00- 57.00	1	2	1	5	22	0	1	1
57.00- 58.00	0	1	0	0	13	0	1	0
58.00- 59.00	2	1	0	1	4	0	2	0
59.00- 60.00	0	0	0	0	6	0	0	0
60.00- 61.00	0	0	0	0	2	0	0	0
61.00- 62.00	0	0	0	0	1	0	0	0
62.00- 63.00	0	0	0	1	0	0	0	0
Total	249	345	276	593	366	321	370	438

APPENDIX IC (CONTD.)

Length-frequency distribution of *R. argentea* from

Sango, males, females, immature

year	1990	1990	1990	1990	
month	4	5	6	7	
day	15	15	15	15	Total
15.00- 16.00	0	0	0	0	3
16.00- 17.00	0	0	0	0	10
17.00- 18.00	0	0	0	0	18
18.00- 19.00	4	0	0	0	49
19.00- 20.00	4	0	0	0	29
20.00- 21.00	2	0	0	0	84
21.00- 22.00	2	0	0	0	32
22.00- 23.00	6	0	0	0	60
23.00- 24.00	8	0	0	0	45
24.00- 25.00	3	0	0	0	52
25.00- 26.00	3	1	0	0	62
26.00- 27.00	6	1	0	0	40
27.00- 28.00	9	1	0	0	49
28.00- 29.00	16	2	0	0	49
29.00- 30.00	10	1	0	0	57
30.00- 31.00	8	7	0	0	84
31.00- 32.00	7	7	0	0	52
32.00- 33.00	13	8	4	4	63
33.00- 34.00	8	7	5	8	70
34.00- 35.00	16	5	3	8	101
35.00- 36.00	16	8	6	10	107
36.00- 37.00	15	7	5	8	100
37.00- 38.00	17	5	7	0	84
38.00- 39.00	15	2	9	10	73
39.00- 40.00	7	3	7	11	69
40.00- 41.00	13	12	9	7	101
41.00- 42.00	18	5	9	7	91
42.00- 43.00	25	5	4	5	94
43.00- 44.00	18	13	5	7	93
44.00- 45.00	23	14	8	7	163
45.00- 46.00	26	22	4	11	217
46.00- 47.00	22	31	17	14	256
47.00- 48.00	13	26	19	20	254
48.00- 49.00	17	27	17	20	269
49.00- 50.00	15	14	19	17	284
50.00- 51.00	12	23	19	19	292
51.00- 52.00	7	10	25	26	201
52.00- 53.00	8	8	9	8	116
53.00- 54.00	6	6	6	5	73
54.00- 55.00	3	7	4	4	71
55.00- 56.00	2	5	0	0	45
56.00- 57.00	0	3	0	0	36
57.00- 58.00	3	0	0	0	18
58.00- 59.00	1	0	1	0	12
59.00- 60.00	1	0	0	0	7
60.00- 61.00	0	0	0	0	2
61.00- 62.00	0	0	0	0	1
62.00- 63.00	0	0	0	0	1
Total	428	276	221	236	4139

APPENDIX IIA

Length-frequency distribution of R. argentea from

Rakwaro, males

year	1989	1989	1989	1989	1989	1990	1990	1990
month	8	9	10	11	12	1	2	3
day	16	16	16	16	16	16	16	16
34.00- 35.00	0	1	0	0	0	0	0	0
35.00- 36.00	0	0	1	0	0	0	0	0
36.00- 37.00	0	1	0	0	0	0	0	0
37.00- 38.00	1	2	1	0	0	0	1	0
38.00- 39.00	0	2	0	0	0	0	1	0
39.00- 40.00	1	3	0	0	0	0	3	1
40.00- 41.00	2	8	1	0	0	1	7	15
41.00- 42.00	0	5	1	0	0	1	11	7
42.00- 43.00	3	6	2	0	2	3	6	4
43.00- 44.00	2	3	1	0	4	0	7	10
44.00- 45.00	1	9	3	0	1	11	1	4
45.00- 46.00	3	10	7	7	11	5	2	18
46.00- 47.00	9	9	5	10	6	13	2	10
47.00- 48.00	13	4	9	11	6	13	4	7
48.00- 49.00	26	4	10	8	10	10	14	12
49.00- 50.00	20	7	13	7	11	28	1	3
50.00- 51.00	23	10	17	12	9	8	6	8
51.00- 52.00	21	4	4	11	12	10	10	2
52.00- 53.00	16	2	4	12	8	5	4	1
53.00- 54.00	11	1	3	6	6	0	6	0
54.00- 55.00	4	1	4	6	7	1	6	0
55.00- 56.00	3	1	6	2	3	0	14	1
56.00- 57.00	1	0	1	0	3	0	5	0
57.00- 58.00	1	0	0	0	1	0	6	0
58.00- 59.00	0	0	0	0	2	0	5	0
59.00- 60.00	0	0	0	0	1	0	1	0
60.00- 61.00	0	0	0	1	0	0	1	0
Total	161	93	93	93	103	109	124	103

APPENDIX IIA (CONTD.)

Length-frequency distribution of *R. argentea* from Rakwaro, males

year	1990	1990	1990	1990	
month	4	5	6	7	
day	16	16	16	16	Total
34.00- 35.00	0	0	0	0	1
35.00- 36.00	0	0	0	0	1
36.00- 37.00	0	0	0	0	1
37.00- 38.00	0	0	1	1	7
38.00- 39.00	0	0	1	1	5
39.00- 40.00	0	0	3	3	14
40.00- 41.00	1	0	3	3	41
41.00- 42.00	1	0	3	7	36
42.00- 43.00	4	0	6	6	42
43.00- 44.00	7	3	6	8	51
44.00- 45.00	16	5	1	1	53
45.00- 46.00	13	4	1	2	83
46.00- 47.00	6	8	2	2	82
47.00- 48.00	6	12	2	4	91
48.00- 49.00	7	12	9	12	134
49.00- 50.00	6	3	4	4	107
50.00- 51.00	2	11	8	6	120
51.00- 52.00	3	6	5	7	95
52.00- 53.00	5	4	4	5	70
53.00- 54.00	5	1	6	5	50
54.00- 55.00	3	5	6	5	48
55.00- 56.00	0	3	11	14	58
56.00- 57.00	0	1	3	4	18
57.00- 58.00	2	0	5	7	22
58.00- 59.00	2	1	6	5	21
59.00- 60.00	1	0	0	0	3
60.00- 61.00	0	0	0	0	2
Total	90	79	96	112	1256

APPENDIX IIB

Length-frequency distribution of R. argentea from Rakwaro, females

year	1989	1989	1989	1989	1989	1990	1990	1990
month	8	9	10	11	12	1	2	3
day	16	16	16	16	16	16	16	16
34.00- 35.00	0	0	0	0	0	0	1	0
35.00- 36.00	0	4	1	0	0	0	1	0
36.00- 37.00	0	1	1	2	0	0	3	0
37.00- 38.00	0	3	5	2	0	0	5	3
38.00- 39.00	0	5	1	0	0	0	6	1
39.00- 40.00	0	9	4	0	1	0	7	1
40.00- 41.00	0	7	12	2	13	1	10	14
41.00- 42.00	0	6	2	0	10	0	13	6
42.00- 43.00	3	10	9	0	8	1	14	8
43.00- 44.00	2	4	6	2	5	3	10	9
44.00- 45.00	6	24	15	1	6	1	9	11
45.00- 46.00	2	22	12	4	5	19	12	26
46.00- 47.00	5	19	8	5	4	9	14	21
47.00- 48.00	11	10	14	7	2	12	6	4
48.00- 49.00	9	16	22	12	8	13	5	13
49.00- 50.00	10	19	12	17	11	26	6	10
50.00- 51.00	19	39	23	25	14	30	10	13
51.00- 52.00	9	12	6	6	6	16	7	1
52.00- 53.00	11	9	10	11	6	8	9	5
53.00- 54.00	7	9	5	9	9	7	11	2
54.00- 55.00	8	5	1	3	7	3	17	1
55.00- 56.00	3	2	5	1	8	2	24	1
56.00- 57.00	2	2	2	0	8	1	15	1
57.00- 58.00	6	0	0	0	7	0	10	0
58.00- 59.00	1	1	0	0	3	0	15	0
59.00- 60.00	0	0	0	0	2	0	7	0
60.00- 61.00	0	0	0	0	0	0	3	0
61.00- 62.00	0	0	0	0	0	0	2	0
62.00- 63.00	0	0	0	0	0	0	1	0
Total	114	238	176	109	143	152	253	151

APPENDIX IIB (CONTD.)

Length-frequency distribution of R. argentea from Rakwaro, females

year	1990	1990	1990	1990	
month	4	5	6	7	
day	16	16	16	16	Total
34.00- 35.00	0	0	0	0	1
35.00- 36.00	0	0	0	0	6
36.00- 37.00	0	0	0	0	7
37.00- 38.00	0	0	3	3	24
38.00- 39.00	0	0	3	4	20
39.00- 40.00	0	1	0	2	25
40.00- 41.00	11	3	2	3	78
41.00- 42.00	14	4	13	11	79
42.00- 43.00	12	6	12	15	98
43.00- 44.00	12	9	7	9	78
44.00- 45.00	19	9	3	4	108
45.00- 46.00	12	15	0	0	129
46.00- 47.00	14	19	0	0	118
47.00- 48.00	7	14	0	0	87
48.00- 49.00	8	14	0	0	120
49.00- 50.00	8	16	0	0	135
50.00- 51.00	10	15	0	0	198
51.00- 52.00	4	6	0	0	73
52.00- 53.00	5	4	0	1	79
53.00- 54.00	6	5	2	4	76
54.00- 55.00	3	2	16	16	82
55.00- 56.00	2	2	15	21	86
56.00- 57.00	3	3	4	8	49
57.00- 58.00	4	0	8	9	44
58.00- 59.00	1	1	8	11	41
59.00- 60.00	1	0	4	5	19
60.00- 61.00	0	0	1	1	5
61.00- 62.00	0	0	0	2	4
62.00- 63.00	0	0	0	1	2
Total	156	148	101	130	1871

APPENDIX IIC

Length-frequency distribution of *R. argentea* from

Rakwaro, males, females, immature

year	1989	1989	1989	1989	1989	1990	1990	1990
month	8	9	10	11	12	1	2	3
day	16	16	16	16	16	16	16	16
14.00- 15.00	0	0	0	0	0	0	0	3
15.00- 16.00	0	0	3	0	0	2	0	7
16.00- 17.00	0	0	1	0	0	3	0	8
17.00- 18.00	0	0	0	0	0	2	0	8
18.00- 19.00	0	0	2	0	0	1	0	10
19.00- 20.00	0	0	4	0	0	0	0	11
20.00- 21.00	0	5	6	0	0	0	0	22
21.00- 22.00	0	1	5	0	0	1	0	7
22.00- 23.00	0	2	7	0	0	0	0	4
23.00- 24.00	0	0	11	0	0	1	0	11
24.00- 25.00	0	0	7	1	0	1	0	5
25.00- 26.00	0	0	15	1	0	0	0	17
26.00- 27.00	0	0	8	2	0	0	0	5
27.00- 28.00	0	1	5	6	1	1	0	8
28.00- 29.00	1	1	6	3	3	0	0	11
29.00- 30.00	1	1	7	1	3	0	1	8
30.00- 31.00	2	2	9	1	4	0	3	16
31.00- 32.00	0	0	10	0	13	0	8	8
32.00- 33.00	0	2	8	1	15	0	6	5
33.00- 34.00	2	2	4	2	10	0	1	7
34.00- 35.00	0	3	5	5	5	0	2	15
35.00- 36.00	0	5	3	3	3	0	4	16
36.00- 37.00	2	2	4	2	2	0	8	12
37.00- 38.00	4	5	0	1	1	0	7	5
38.00- 39.00	0	7	3	0	0	5	10	2
39.00- 40.00	1	12	4	0	1	0	14	4
40.00- 41.00	2	15	13	1	13	1	17	32
41.00- 42.00	0	11	3	0	10	1	24	13
42.00- 43.00	6	16	11	0	10	2	20	12
43.00- 44.00	4	7	7	2	9	6	17	19
44.00- 45.00	7	33	18	1	7	1	10	15
45.00- 46.00	5	32	19	11	16	30	14	44
46.00- 47.00	14	28	13	15	10	14	16	31
47.00- 48.00	23	14	23	18	8	25	10	11
48.00- 49.00	36	20	32	20	13	26	19	25
49.00- 50.00	30	26	25	24	22	36	10	13
50.00- 51.00	42	49	40	37	23	58	16	21
51.00- 52.00	30	16	10	17	18	24	17	3
52.00- 53.00	27	11	14	23	14	18	13	6
53.00- 54.00	18	10	8	15	15	12	17	2
54.00- 55.00	12	6	5	9	14	3	23	1
55.00- 56.00	6	3	11	3	11	3	38	2
56.00- 57.00	3	2	3	0	11	1	20	1
57.00- 58.00	6	0	0	0	8	0	16	0
58.00- 59.00	2	1	0	0	5	0	20	0
59.00- 60.00	0	0	0	0	3	0	8	0
60.00- 61.00	0	0	0	1	0	0	4	0
61.00- 62.00	0	0	0	0	0	0	2	0
62.00- 63.00	0	0	0	0	0	0	1	0
Total	286	351	392	226	301	278	416	486

APPENDIX IIC (CONTD.)

Length-frequency distribution of R. argentea from

Rakwaro, males, females, immature

year	1990	1990	1990	1990	
month	4	5	6	7	
day	16	16	16	16	Total
14.00- 15.00	0	0	0	0	3
15.00- 16.00	0	0	0	0	12
16.00- 17.00	0	0	0	0	12
17.00- 18.00	0	0	0	0	10
18.00- 19.00	0	0	0	0	13
19.00- 20.00	2	0	0	0	17
20.00- 21.00	2	0	0	0	35
21.00- 22.00	2	0	0	0	16
22.00- 23.00	2	0	0	0	15
23.00- 24.00	5	0	0	0	28
24.00- 25.00	7	0	0	0	21
25.00- 26.00	5	3	0	0	41
26.00- 27.00	6	2	0	0	23
27.00- 28.00	5	1	0	0	28
28.00- 29.00	12	6	0	0	43
29.00- 30.00	12	1	0	0	35
30.00- 31.00	9	9	0	0	55
31.00- 32.00	8	12	0	0	57
32.00- 33.00	12	11	0	0	60
33.00- 34.00	9	7	0	0	44
34.00- 35.00	9	8	0	0	52
35.00- 36.00	6	13	0	0	53
36.00- 37.00	10	11	0	0	53
37.00- 38.00	15	7	4	6	55
38.00- 39.00	10	4	3	5	49
39.00- 40.00	5	6	3	3	53
40.00- 41.00	14	8	5	18	139
41.00- 42.00	15	7	16	21	121
42.00- 43.00	16	6	18	17	134
43.00- 44.00	19	12	13	5	120
44.00- 45.00	35	14	4	2	147
45.00- 46.00	25	19	1	2	218
46.00- 47.00	20	27	2	3	193
47.00- 48.00	13	26	2	12	185
48.00- 49.00	15	26	9	4	245
49.00- 50.00	14	19	4	6	229
50.00- 51.00	12	26	8	7	339
51.00- 52.00	7	12	5	6	165
52.00- 53.00	10	8	4	9	157
53.00- 54.00	11	6	8	21	143
54.00- 55.00	6	7	22	35	143
55.00- 56.00	2	5	26	12	122
56.00- 57.00	3	4	7	16	71
57.00- 58.00	5	0	13	16	64
58.00- 59.00	3	1	14	5	51
59.00- 60.00	2	1	4	1	19
60.00- 61.00	0	0	1	2	8
61.00- 62.00	0	0	0	1	3
62.00- 63.00	0	0	0	0	1
Total	400	335	196	235	3902

APPENDIX IIIA

Length-frequency distribution of R. argentea from

Obaria, males

year	1989	1989	1989	1989	1989	1990	1990	1990
month	8	9	10	11	12	1	2	3
day	17	17	17	17	17	17	17	17
34.00- 35.00	0	1	0	0	0	0	0	0
35.00- 36.00	0	2	0	1	0	0	0	0
36.00- 37.00	1	0	0	0	0	0	0	0
37.00- 38.00	1	2	1	2	0	0	0	0
38.00- 39.00	0	12	1	2	0	1	1	0
39.00- 40.00	1	7	2	0	1	0	2	0
40.00- 41.00	8	3	1	0	3	1	4	9
41.00- 42.00	0	2	0	4	4	4	3	6
42.00- 43.00	2	5	2	9	2	2	4	6
43.00- 44.00	6	8	0	11	2	9	7	6
44.00- 45.00	7	3	4	13	9	0	10	4
45.00- 46.00	15	3	8	14	12	2	12	12
46.00- 47.00	8	3	5	4	6	9	8	13
47.00- 48.00	11	11	8	15	2	5	4	4
48.00- 49.00	13	19	8	4	4	7	7	4
49.00- 50.00	9	8	6	7	4	9	6	2
50.00- 51.00	5	6	17	9	9	13	10	6
51.00- 52.00	4	6	4	3	11	13	14	1
52.00- 53.00	1	1	5	1	2	4	2	2
53.00- 54.00	3	1	6	1	3	1	2	0
54.00- 55.00	0	1	4	0	9	1	1	0
55.00- 56.00	0	0	2	0	8	2	4	0
56.00- 57.00	0	0	1	0	3	5	1	0
57.00- 58.00	0	0	1	0	1	0	2	0
58.00- 59.00	0	0	0	0	0	0	1	0
59.00- 60.00	0	0	0	0	0	0	0	0
60.00- 61.00	0	0	0	0	0	0	0	0
Total	95	104	86	100	95	88	105	75

APPENDIX IIIA (CONTD.)

Length-frequency distribution of R. argentea from

Obaria, males

year month day	1990 4 17	1990 5 17	1990 6 17	1990 7 17	Total
34.00- 35.00	0	0	0	0	1
35.00- 36.00	0	0	0	0	3
36.00- 37.00	0	0	0	0	1
37.00- 38.00	0	0	0	0	6
38.00- 39.00	0	0	0	0	17
39.00- 40.00	0	0	0	0	13
40.00- 41.00	0	0	0	0	29
41.00- 42.00	1	1	1	0	26
42.00- 43.00	6	0	0	6	44
43.00- 44.00	5	9	9	5	77
44.00- 45.00	5	5	6	0	66
45.00- 46.00	14	7	7	10	116
46.00- 47.00	6	12	12	6	92
47.00- 48.00	8	10	5	9	92
48.00- 49.00	3	15	9	2	95
49.00- 50.00	6	12	12	3	84
50.00- 51.00	6	8	5	6	100
51.00- 52.00	5	7	5	3	76
52.00- 53.00	3	7	6	4	38
53.00- 54.00	5	0	4	5	31
54.00- 55.00	5	3	3	2	29
55.00- 56.00	3	5	4	2	30
56.00- 57.00	2	2	2	2	18
57.00- 58.00	2	2	2	1	11
58.00- 59.00	1	2	2	0	6
59.00- 60.00	1	0	1	1	3
60.00- 61.00	1	0	0	0	1
Total	88	107	95	67	1105

APPENDIX IIIB

Length-frequency distribution of R. *argentea* from Obaria, females

year	1989	1989	1989	1989	1989	1990	1990	1990
month	8	9	10	11	12	1	2	3
day	17	17	17	17	17	17	17	17
34.00- 35.00	0	1	0	0	0	0	0	0
35.00- 36.00	0	2	1	2	1	0	0	0
36.00- 37.00	0	0	0	3	1	0	1	0
37.00- 38.00	0	4	2	3	0	0	3	2
38.00- 39.00	0	5	3	10	1	1	6	2
39.00- 40.00	0	0	9	13	3	1	7	0
40.00- 41.00	0	7	14	32	16	7	6	6
41.00- 42.00	3	13	7	26	5	3	6	3
42.00- 43.00	3	2	3	20	4	6	7	3
43.00- 44.00	5	8	10	17	3	4	10	8
44.00- 45.00	9	13	10	26	9	9	25	9
45.00- 46.00	2	8	19	24	18	18	20	17
46.00- 47.00	13	13	12	9	9	4	10	8
47.00- 48.00	14	15	11	11	4	18	6	4
48.00- 49.00	17	29	16	9	5	8	7	7
49.00- 50.00	11	20	12	11	2	12	10	9
50.00- 51.00	17	17	17	12	12	14	11	7
51.00- 52.00	15	12	7	5	2	10	10	2
52.00- 53.00	9	7	9	4	3	4	8	1
53.00- 54.00	4	7	3	1	3	7	7	0
54.00- 55.00	1	2	3	1	3	1	9	1
55.00- 56.00	0	2	3	1	9	3	2	0
56.00- 57.00	1	1	2	0	0	1	4	0
57.00- 58.00	4	0	1	1	0	1	5	0
58.00- 59.00	1	0	1	0	0	0	7	0
59.00- 60.00	0	0	0	0	0	0	2	0
60.00- 61.00	0	0	1	0	0	0	1	0
61.00- 62.00	0	0	0	0	0	0	2	0
62.00- 63.00	0	0	0	0	0	0	1	0
Total	129	188	176	241	113	132	193	89

APPENDIX IIIB (CONTD.)

• Length-frequency distribution of R. argentea from Obaria, females

year	1990	1990	1990	1990	
month	4	5	6	7	
day	17	17	17	17	Total
34.00- 35.00	0	0	0	0	1
35.00- 36.00	0	0	0	0	6
36.00- 37.00	0	0	0	0	5
37.00- 38.00	0	0	0	0	14
38.00- 39.00	0	0	0	0	28
39.00- 40.00	0	2	2	0	37
40.00- 41.00	2	7	7	1	105
41.00- 42.00	13	6	6	9	100
42.00- 43.00	11	8	8	10	85
43.00- 44.00	8	5	4	8	90
44.00- 45.00	13	8	7	2	140
45.00- 46.00	21	14	12	15	188
46.00- 47.00	17	11	11	17	134
47.00- 48.00	13	12	11	10	129
48.00- 49.00	9	11	10	7	135
49.00- 50.00	9	8	7	3	114
50.00- 51.00	9	5	5	5	131
51.00- 52.00	7	7	5	5	87
52.00- 53.00	4	2	1	3	55
53.00- 54.00	5	0	1	6	44
54.00- 55.00	4	1	1	4	31
55.00- 56.00	4	3	2	4	33
56.00- 57.00	2	0	1	1	13
57.00- 58.00	1	0	0	1	14
58.00- 59.00	4	0	0	3	16
59.00- 60.00	3	0	0	1	6
60.00- 61.00	1	0	0	1	4
61.00- 62.00	0	0	0	0	2
62.00- 63.00	0	0	0	0	1
Total	160	110	101	116	1748

APPENDIX IIIC

Length-frequency distribution of *R. argentea* from Obaria, males, females, immature

year	1989	1989	1989	1989	1989	1990	1990	1990
month	8	9	10	11	12	1	2	3
day	17	17	17	17	17	17	17	17
18.00- 19.00	0	0	0	0	0	0	0	21
19.00- 20.00	0	0	0	0	1	0	0	10
20.00- 21.00	0	2	0	0	2	0	0	25
21.00- 22.00	0	0	0	0	1	0	0	9
22.00- 23.00	0	0	1	0	0	0	0	6
23.00- 24.00	0	0	3	0	0	0	0	9
24.00- 25.00	0	4	2	1	3	0	0	4
25.00- 26.00	0	1	3	0	2	0	1	15
26.00- 27.00	0	5	0	1	0	0	2	5
27.00- 28.00	0	3	3	3	0	2	0	7
28.00- 29.00	0	0	4	0	1	0	5	12
29.00- 30.00	0	3	2	7	2	1	4	7
30.00- 31.00	0	3	3	11	1	0	9	19
31.00- 32.00	0	2	0	8	5	0	6	11
32.00- 33.00	0	6	2	10	3	0	5	7
33.00- 34.00	0	4	3	16	1	0	1	6
34.00- 35.00	0	5	5	22	5	3	4	17
35.00- 36.00	0	8	10	40	9	6	18	7
36.00- 37.00	2	1	4	33	11	4	11	10
37.00- 38.00	2	10	1	40	7	3	6	3
38.00- 39.00	2	18	8	34	1	2	8	4
39.00- 40.00	1	7	12	24	4	2	9	1
40.00- 41.00	9	12	16	37	5	12	10	18
41.00- 42.00	3	16	7	31	20	5	9	9
42.00- 43.00	5	7	5	30	9	16	11	9
43.00- 44.00	11	16	10	30	6	3	17	14
44.00- 45.00	16	16	14	39	5	11	35	14
45.00- 46.00	17	11	27	39	18	27	22	29
46.00- 47.00	21	16	17	13	30	9	18	21
47.00- 48.00	26	27	14	26	15	25	10	8
48.00- 49.00	29	48	24	13	6	17	14	11
49.00- 50.00	20	28	18	18	9	25	16	11
50.00- 51.00	28	23	34	21	6	27	21	13
51.00- 52.00	20	18	11	8	21	14	24	3
52.00- 53.00	13	8	14	5	12	5	10	3
53.00- 54.00	5	8	8	2	5	8	9	0
54.00- 55.00	4	3	7	1	6	3	10	1
55.00- 56.00	0	2	5	1	12	9	6	0
56.00- 57.00	1	1	3	0	17	1	5	0
57.00- 58.00	4	0	2	1	3	1	7	0
58.00- 59.00	1	0	1	0	1	0	8	0
59.00- 60.00	0	0	1	0	0	0	2	0
60.00- 61.00	0	0	1	0	0	0	1	0
61.00- 62.00	0	0	0	0	0	0	2	0
62.00- 63.00	0	0	0	0	0	0	1	0
Total	240	342	305	565	265	241	357	379

APPENDIX IIIC (CONTD.)

Length-frequency distribution of _R. argentea_ from

Obaria, males, females, immature

year	1990	1990	1990	1990	
month	4	5	6	7	
day	17	17	17	17	Total
18.00- 19.00	2	0	0	0	23
19.00- 20.00	4	0	0	0	15
20.00- 21.00	6	0	0	0	35
21.00- 22.00	6	0	0	0	16
22.00- 23.00	3	0	0	0	10
23.00- 24.00	2	0	0	0	14
24.00- 25.00	3	0	0	0	17
25.00- 26.00	6	0	0	0	28
26.00- 27.00	5	0	0	0	18
27.00- 28.00	7	1	1	0	27
28.00- 29.00	5	1	1	0	29
29.00- 30.00	12	1	1	0	40
30.00- 31.00	14	2	2	0	64
31.00- 32.00	7	1	1	0	41
32.00- 33.00	8	8	8	0	57
33.00- 34.00	9	5	5	1	51
34.00- 35.00	10	5	6	3	85
35.00- 36.00	8	3	8	2	119
36.00- 37.00	9	5	6	3	99
37.00- 38.00	7	2	4	2	87
38.00- 39.00	17	4	5	2	105
39.00- 40.00	12	3	5	12	92
40.00- 41.00	6	11	10	3	149
41.00- 42.00	14	10	14	8	146
42.00- 43.00	17	8	8	16	141
43.00- 44.00	13	14	13	13	160
44.00- 45.00	18	13	13	2	196
45.00- 46.00	35	21	19	25	290
46.00- 47.00	23	23	24	28	243
47.00- 48.00	21	22	16	19	229
48.00- 49.00	12	26	19	8	227
49.00- 50.00	15	20	19	6	205
50.00- 51.00	15	13	10	11	222
51.00- 52.00	12	14	10	8	163
52.00- 53.00	7	8	7	6	98
53.00- 54.00	10	0	0	10	65
54.00- 55.00	8	4	4	8	59
55.00- 56.00	7	8	6	6	62
56.00- 57.00	3	2	2	3	38
57.00- 58.00	3	2	2	3	28
58.00- 59.00	5	2	2	4	24
59.00- 60.00	4	0	0	1	8
60.00- 61.00	2	0	0	2	6
61.00- 62.00	0	0	0	0	2
62.00- 63.00	0	0	0	0	1
Total	412	262	251	215	3034

APPENDIX IVA

Length-frequency distribution of R. argentea from

Ngegu, males

year	1989	1989	1989	1989	1989	1990	1990	1990
month	8	9	10	11	12	1	2	3
day	18	18	18	18	18	18	18	18
34.00- 35.00	0	0	0	0	0	0	0	0
35.00- 36.00	1	0	0	0	0	0	0	0
36.00- 37.00	0	2	0	0	0	0	1	0
37.00- 38.00	0	0	1	0	0	0	1	0
38.00- 39.00	0	5	2	0	0	0	2	0
39.00- 40.00	0	5	5	0	0	1	4	0
40.00- 41.00	0	1	7	0	1	6	5	8
41.00- 42.00	1	10	3	1	2	4	8	1
42.00- 43.00	2	5	12	3	3	9	4	2
43.00- 44.00	4	2	10	1	3	4	5	2
44.00- 45.00	2	4	8	2	7	6	7	4
45.00- 46.00	0	2	3	1	5	5	6	13
46.00- 47.00	1	1	5	0	4	14	2	4
47.00- 48.00	7	9	8	3	6	8	4	8
48.00- 49.00	12	12	8	11	6	10	12	6
49.00- 50.00	10	9	10	25	5	7	3	1
50.00- 51.00	18	5	17	17	8	7	2	7
51.00- 52.00	14	5	7	13	9	5	8	1
52.00- 53.00	9	8	8	8	9	2	10	1
53.00- 54.00	13	2	10	7	8	0	12	0
54.00- 55.00	2	1	12	6	11	3	2	0
55.00- 56.00	4	0	2	0	11	1	2	1
56.00- 57.00	0	0	3	1	7	4	1	0
57.00- 58.00	1	0	5	0	1	1	2	0
58.00- 59.00	0	0	2	0	3	0	1	0
59.00- 60.00	0	0	1	0	3	0	3	0
60.00- 61.00	0	0	0	0	1	0	1	0
61.00- 62.00	0	0	0	0	0	2	0	0
62.00- 63.00	0	0	0	0	0	0	0	0
63.00- 64.00	0	0	0	0	0	0	0	0
Total	101	88	149	99	113	99	108	59

APPENDIX IVA -(CONTD.)

Length-frequency distribution of R. argentea from Ngegu, males

year	1990	1990	1990	1990	
month	4	5	6	7	
day	18	18	18	18	Total
34.00- 35.00	0	0	0	0	0
35.00- 36.00	0	0	0	0	1
36.00- 37.00	0	0	0	0	3
37.00- 38.00	0	0	0	0	2
38.00- 39.00	0	0	0	0	9
39.00- 40.00	0	0	0	0	15
40.00- 41.00	0	0	0	0	28
41.00- 42.00	0	0	0	2	32
42.00- 43.00	0	0	0	2	42
43.00- 44.00	8	4	0	2	45
44.00- 45.00	2	7	0	3	52
45.00- 46.00	4	5	0	2	46
46.00- 47.00	13	11	0	4	59
47.00- 48.00	6	10	6	5	80
48.00- 49.00	8	9	8	5	107
49.00- 50.00	6	3	7	4	90
50.00- 51.00	5	10	14	3	113
51.00- 52.00	6	11	12	8	99
52.00- 53.00	4	6	7	6	78
53.00- 54.00	9	2	9	7	79
54.00- 55.00	7	6	2	10	62
55.00- 56.00	4	5	4	10	44
56.00- 57.00	1	1	0	5	23
57.00- 58.00	3	1	1	7	22
58.00- 59.00	2	1	0	2	11
59.00- 60.00	0	0	0	2	9
60.00- 61.00	2	0	0	0	4
61.00- 62.00	0	0	0	0	2
62.00- 63.00	0	0	0	0	0
63.00- 64.00	1	0	0	0	1
Total	91	92	70	89	1158

APPENDIX IVB

Length-frequency distribution of R. argentea from Ngegu, females

year	1989	1989	1989	1989	1989	1990	1990	1990
month	8	9	10	11	12	1	2	3
day	18	18	18	18	18	18	18	18
34.00- 35.00	0	0	0	0	0	0	0	0
35.00- 36.00	1	0	0	0	0	0	1	0
36.00- 37.00	0	1	1	0	0	1	1	0
37.00- 38.00	3	1	2	0	2	1	1	0
38.00- 39.00	0	4	3	1	2	5	2	2
39.00- 40.00	0	1	7	1	4	3	6	3
40.00- 41.00	0	5	6	4	2	10	9	7
41.00- 42.00	0	7	10	4	7	1	10	9
42.00- 43.00	0	6	10	2	7	11	15	2
43.00- 44.00	0	9	12	4	9	10	6	5
44.00- 45.00	0	9	12	2	9	12	8	13
45.00- 46.00	2	4	17	3	1	16	10	11
46.00- 47.00	2	7	26	7	6	17	16	8
47.00- 48.00	5	7	17	5	0	11	18	9
48.00- 49.00	12	11	20	21	5	11	16	8
49.00- 50.00	14	17	10	38	8	10	10	8
50.00- 51.00	14	18	4	17	3	8	8	8
51.00- 52.00	21	23	7	18	5	13	4	10
52.00- 53.00	18	15	8	23	7	4	6	10
53.00- 54.00	12	11	3	13	6	10	8	5
54.00- 55.00	15	20	3	12	12	4	9	6
55.00- 56.00	4	7	4	6	12	1	7	5
56.00- 57.00	1	5	1	1	14	3	4	3
57.00- 58.00	0	1	2	0	7	0	1	2
58.00- 59.00	0	0	1	0	7	1	0	1
59.00- 60.00	1	0	0	0	3	3	1	0
60.00- 61.00	1	0	0	0	1	0	0	0
61.00- 62.00	0	0	0	0	2	0	0	0
Total	126	189	186	182	141	166	177	135

APPENDIX IVB (CONTD.)

Length-frequency distribution of R. argentea from Ngegu, females

year	1990	1990	1990	1990	
month	4	5	6	7	
day	18	18	18	18	Total
34.00- 35.00	0	0	0	0	0
35.00- 36.00	0	0	0	0	2
36.00- 37.00	0	0	0	0	4
37.00- 38.00	0	0	0	2	12
38.00- 39.00	0	0	0	2	21
39.00- 40.00	0	0	0	1	26
40.00- 41.00	7	4	0	2	56
41.00- 42.00	15	2	0	7	72
42.00- 43.00	12	5	0	7	77
43.00- 44.00	5	7	0	7	74
44.00- 45.00	9	6	0	7	87
45.00- 46.00	17	9	3	1	94
46.00- 47.00	15	14	2	4	124
47.00- 48.00	6	11	5	0	94
48.00- 49.00	4	12	7	6	133
49.00- 50.00	10	12	11	6	154
50.00- 51.00	11	6	13	2	112
51.00- 52.00	7	2	19	2	131
52.00- 53.00	8	4	12	5	120
53.00- 54.00	5	1	9	5	88
54.00- 55.00	10	1	15	12	119
55.00- 56.00	0	0	3	8	57
56.00- 57.00	3	0	1	15	51
57.00- 58.00	3	1	0	7	24
58.00- 59.00	2	0	0	7	19
59.00- 60.00	3	0	1	1	13
60.00- 61.00	3	0	1	1	7
61.00- 62.00	1	0	0	2	5
Total	156	97	102	119	1776

APPENDIX IVC

Length-frequency distribution of *R. argentea* from Ngegu, males, females, immature

year	1989	1989	1989	1989	1989	1990	1990	1990
month	8	9	10	11	12	1	2	3
day	18	18	18	18	18	18	18	18
19.00- 20.00	0	0	3	0	0	0	0	0
20.00- 21.00	0	0	2	0	0	0	0	1
21.00- 22.00	0	0	4	0	0	0	1	1
22.00- 23.00	0	0	1	0	0	0	2	1
23.00- 24.00	0	1	0	0	0	0	1	0
24.00- 25.00	0	3	4	0	0	0	0	0
25.00- 26.00	0	1	7	0	0	2	4	2
26.00- 27.00	0	2	4	0	0	1	2	4
27.00- 28.00	0	0	5	0	0	0	6	2
28.00- 29.00	1	4	2	0	2	0	1	2
29.00- 30.00	2	4	1	0	1	0	0	2
30.00- 31.00	3	2	3	5	1	2	3	1
31.00- 32.00	2	4	2	4	3	2	5	3
32.00- 33.00	0	2	2	1	3	0	8	2
33.00- 34.00	3	5	0	1	5	1	7	3
34.00- 35.00	0	0	2	4	2	3	11	4
35.00- 36.00	3	3	4	1	5	4	6	7
36.00- 37.00	1	3	3	6	9	3	2	15
37.00- 38.00	4	1	3	7	9	2	13	13
38.00- 39.00	0	9	5	5	9	12	12	6
39.00- 40.00	1	6	12	4	3	8	10	5
40.00- 41.00	0	7	13	2	5	17	14	12
41.00- 42.00	1	17	13	5	3	5	18	11
42.00- 43.00	2	11	22	5	9	20	19	8
43.00- 44.00	4	11	22	5	10	14	11	10
44.00- 45.00	2	13	18	4	12	18	15	18
45.00- 46.00	2	6	13	4	16	21	16	22
46.00- 47.00	3	8	12	4	6	31	18	19
47.00- 48.00	12	16	20	10	10	19	22	15
48.00- 49.00	17	23	20	16	6	21	28	13
49.00- 50.00	21	26	25	29	11	17	13	15
50.00- 51.00	31	23	43	63	13	15	10	15
51.00- 52.00	35	28	20	34	11	18	14	18
52.00- 53.00	26	23	28	31	14	6	16	13
53.00- 54.00	25	13	18	31	16	10	20	5
54.00- 55.00	17	21	15	20	14	7	11	8
55.00- 56.00	8	7	9	18	23	2	9	7
56.00- 57.00	1	5	11	6	23	7	5	3
57.00- 58.00	1	1	8	2	21	1	3	2
58.00- 59.00	0	0	5	0	14	1	1	1
59.00- 60.00	1	0	5	0	10	3	4	0
60.00- 61.00	1	0	1	0	6	0	1	0
61.00- 62.00	0	0	2	0	2	0	0	0
62.00- 63.00	0	0	1	0	2	0	0	0
63.00- 64.00	0	0	0	0	0	0	0	0
Total	230	309	413	327	309	293	362	289

APPENDIX IVC (CONTD.)

Length-frequency distribution of *R. argentea* from

Ngegu, males, females, immature

year	1990	1990	1990	1990	
month	4	5	6	7	
day	18	18	18	18	Total
19.00- 20.00	0	0	0	0	3
20.00- 21.00	2	0	0	0	5
21.00- 22.00	2	0	1	0	9
22.00- 23.00	2	0	0	0	6
23.00- 24.00	3	0	0	0	5
24.00- 25.00	2	0	0	0	9
25.00 26.00	0	1	3	0	20
26.00- 27.00	0	1	1	0	15
27.00- 28.00	1	0	0	0	14
28.00- 29.00	0	0	1	0	13
29.00- 30.00	1	2	2	0	15
30.00- 31.00	6	4	3	2	35
31.00- 32.00	8	4	1	2	40
32.00- 33.00	8	5	1	4	36
33.00- 34.00	12	3	3	2	45
34.00- 35.00	10	2	0	5	43
35.00- 36.00	6	1	1	3	44
36.00- 37.00	11	6	1	2	62
37.00- 38.00	5	4	3	8	72
38.00- 39.00	11	2	0	2	73
39.00- 40.00	17	2	1	2	71
40.00- 41.00	10	10	0	2	92
41.00- 42.00	22	4	2	9	110
42.00- 43.00	12	5	1	9	123
43.00- 44.00	10	11	2	9	119
44.00- 45.00	27	15	1	10	153
45.00- 46.00	25	17	3	3	148
46.00- 47.00	25	28	3	8	165
47.00- 48.00	9	24	12	5	174
48.00- 49.00	9	20	15	11	199
49.00- 50.00	20	19	18	10	224
50.00- 51.00	13	15	27	5	273
51.00- 52.00	15	12	31	10	246
52.00- 53.00	13	9	19	11	209
53.00- 54.00	8	3	18	12	179
54.00- 55.00	13	5	17	22	170
55.00- 56.00	2	2	7	18	112
56.00- 57.00	2	2	1	20	86
57.00- 58.00	1	2	1	13	56
58.00- 59.00	4	1	0	8	35
59.00 - 60.00	3	0	1	3	30
60.00- 61.00	6	0	1	1	17
61.00- 62.00	3	0	0	2	9
62.00- 63.00	1	0	0	0	4
63.00- 64.00	1	0	0	0	1
Total	361	241	202	233	3569

APPENDIX VA

Length-frequency distribution of *R. argentea* from Luanda, males

year	1989	1989	1989	1989	1989	1990	1990	1990
month	8	9	10	11	12	1	2	3
day	19	19	19	19	19	19	19	19
34.00- 35.00	0	0	0	0	0	0	0	0
35.00- 36.00	0	0	0	0	0	0	0	0
36.00- 37.00	0	0	1	0	0	0	1	0
37.00- 38.00	0	0	2	1	0	0	2	0
38.00- 39.00	0	1	1	5	2	0	6	0
39.00- 40.00	0	2	3	3	5	1	5	2
40.00- 41.00	0	2	6	2	8	6	8	5
41.00- 42.00	0	1	7	3	8	4	9	2
42.00- 43.00	0	1	5	4	2	7	7	6
43.00- 44.00	1	3	4	10	4	4	5	5
44.00- 45.00	3	4	7	12	3	4	5	5
45.00- 46.00	2	7	11	10	5	6	10	11
46.00- 47.00	3	2	12	7	5	13	11	11
47.00- 48.00	3	4	8	4	7	7	10	6
48.00- 49.00	9	1	4	5	15	8	14	5
49.00- 50.00	3	3	5	3	13	7	16	7
50.00- 51.00	5	5	3	6	14	5	7	7
51.00- 52.00	8	14	3	8	12	6	4	8
52.00- 53.00	9	12	5	11	10	1	8	3
53.00- 54.00	4	7	8	10	0	0	10	0
54.00- 55.00	4	2	8	8	5	3	11	2
55.00- 56.00	2	5	7	3	4	1	5	2
56.00- 57.00	3	8	5	4	2	5	5	0
57.00- 58.00	2	3	3	5	2	1	4	0
58.00- 59.00	4	1	3	7	6	0	1	0
59.00- 60.00	1	0	4	2	6	1	0	0
60.00- 61.00	0	1	3	3	2	1	1	0
61.00- 62.00	1	1	1	1	1	0	0	0
62.00- 63.00	2	1	2	0	2	0	1	0
63.00- 64.00	1	1	1	2	1	0	0	0
64.00- 65.00	0	1	0	0	0	0	0	0
65.00- 66.00	2	0	0	0	0	0	0	0
66.00- 67.00	0	1	0	0	0	0	0	0
Total	72	94	132	139	144	91	166	87

APPENDIX VA (CONTD.)

Length-frequency distribution of *R. argentea* from

Luanda, males

year month day	1990 4 19	1990 5 19	1990 6 19	1990 7 19	Total
34.00- 35.00	0	0	0	0	0
35.00- 36.00	0	0	0	0	0
36.00- 37.00	0	0	0	0	2
37.00- 38.00	0	0	0	0	5
38.00- 39.00	0	0	0	2	17
39.00- 40.00	0	0	1	5	27
40.00- 41.00	0	0	0	5	42
41.00- 42.00	2	1	1	6	44
42.00- 43.00	0	0	1	1	34
43.00- 44.00	5	4	1	4	50
44.00- 45.00	18	9	5	3	78
45.00- 46.00	8	8	6	5	89
46.00- 47.00	10	14	3	5	96
47.00- 48.00	3	13	8	6	79
48.00- 49.00	5	8	13	15	102
49.00- 50.00	10	7	2	10	86
50.00- 51.00	2	9	8	13	84
51.00- 52.00	8	10	11	10	102
52.00- 53.00	5	5	8	8	85
53.00- 54.00	3	2	2	0	46
54.00- 55.00	3	4	6	5	61
55.00- 56.00	2	2	1	4	38
56.00- 57.00	0	2	2	1	37
57.00- 58.00	0	1	2	1	24
58.00- 59.00	1	1	2	6	32
59.00- 60.00	1	0	0	5	20
60.00- 61.00	3	0	2	1	17
61.00- 62.00	0	0	0	0	5
62.00- 63.00	0	0	0	1	9
63.00- 64.00	1	0	1	0	8
64.00- 65.00	0	0	0	0	1
65.00- 66.00	0	0	0	0	2
66.00- 67.00	0	0	0	0	1
Total	90	100	86	122	1323

APPENDIX VB

Length-frequency distribution of R. argentea from

Luanda, females

year	1989	1989	1989	1989	1989	1990	1990	1990
month	8	9	10	11	12	1	2	3
day	19	19	19	19	19	19	19	19
34.00- 35.00	0	0	0	0	0	0	0	0
35.00- 36.00	0	0	0	0	0	0	1	0
36.00- 37.00	0	0	2	0	4	0	3	0
37.00- 38.00	0	1	4	2	3	0	8	0
38.00- 39.00	0	7	2	2	3	1	12	4
39.00- 40.00	0	5	3	4	5	2	15	9
40.00- 41.00	0	2	8	6	4	9	10	23
41.00- 42.00	0	6	12	5	3	1	11	12
42.00- 43.00	0	3	10	8	5	16	10	6
43.00- 44.00	0	4	4	7	7	9	11	4
44.00- 45.00	0	5	3	15	9	13	10	11
45.00- 46.00	4	5	6	12	10	18	6	13
46.00- 47.00	4	11	9	10	15	17	3	8
47.00- 48.00	4	5	14	5	17	10	6	6
48.00- 49.00	11	9	13	5	11	12	10	4
49.00- 50.00	8	19	10	6	11	8	10	7
50.00- 51.00	9	8	3	10	8	16	20	10
51.00- 52.00	12	16	4	12	6	11	10	7
52.00- 53.00	12	14	7	14	7	4	9	5
53.00- 54.00	10	10	15	15	5	12	8	3
54.00- 55.00	9	10	20	10	5	3	10	2
55.00- 56.00	3	3	19	10	6	2	6	0
56.00- 57.00	4	3	13	5	8	2	5	2
57.00- 58.00	3	3	9	5	4	0	6	0
58.00- 59.00	3	3	10	9	6	1	4	0
59.00- 60.00	2	5	5	14	5	3	0	0
60.00- 61.00	1	3	7	13	4	0	1	0
61.00- 62.00	4	2	3	9	10	2	0	0
62.00- 63.00	4	1	3	5	3	0	0	0
63.00- 64.00	0	4	3	2	2	1	1	0
64.00- 65.00	3	0	2	3	0	0	1	0
65.00- 66.00	0	1	3	5	1	0	2	0
66.00- 67.00	0	0	2	3	1	0	0	0
67.00- 68.00	0	1	1	1	0	0	0	0
68.00- 69.00	0	0	2	2	0	0	0	0
69.00- 70.00	0	0	0	0	0	1	0	0
70.00- 71.00	1	0	0	0	0	0	0	0
Total	111	169	231	234	188	174	207	136

APPENDIX VB (CONTD.)

Length-frequency distribution of R. argentea from Luanda, females

year	1990	1990	1990	1990	
month	4	5	6	7	
day	19	19	19	19	Total
34.00- 35.00	0	0	0	0	0
35.00- 36.00	0	0	0	0	1
36.00- 37.00	0	0	0	4	13
37.00- 38.00	0	0	0	3	21
38.00- 39.00	0	0	0	3	34
39.00- 40.00	0	0	0	3	46
40.00- 41.00	3	2	1	4	72
41.00- 42.00	12	2	0	3	67
42.00- 43.00	5	4	1	5	73
43.00- 44.00	8	8	3	7	72
44.00- 45.00	9	4	2	8	89
45.00- 46.00	6	10	6	12	108
46.00- 47.00	9	14	5	17	122
47.00- 48.00	13	13	4	10	107
48.00- 49.00	18	9	9	10	121
49.00- 50.00	11	13	8	7	118
50.00- 51.00	4	5	4	7	104
51.00- 52.00	9	3	10	6	106
52.00- 53.00	8	4	12	5	101
53.00- 54.00	7	5	11	4	105
54.00- 55.00	6	2	5	6	88
55.00- 56.00	6	0	3	6	64
56.00- 57.00	2	1	3	4	52
57.00- 58.00	1	0	3	6	40
58.00- 59.00	2	1	5	5	49
59.00- 60.00	5	1	1	3	44
60.00- 61.00	1	0	0	8	38
61.00- 62.00	4	0	2	3	39
62.00- 63.00	0	0	2	3	21
63.00- 64.00	1	0	0	0	14
64.00- 65.00	0	0	2	1	12
65.00- 66.00	0	0	1	0	13
66.00- 67.00	0	0	0	0	6
67.00- 68.00	0	0	0	0	3
68.00- 69.00	0	0	0	0	4
69.00- 70.00	0	0	2	0	3
70.00- 71.00	0	0	0	0	1
Total	150	101	105	163	1971

APPENDIX VC

Length-frequency distribution of *R. argentea* from-

Luanda, males, females, immature

year	1989	1989	1989	1989	1989	1990	1990	1990
month	8	9	10	11	12	1	2	3
day	19	19	19	19	19	19	19	19
20.00- 21.00	0	0	1	0	0	0	0	0
21.00- 22.00	0	0	2	0	0	0	0	1
22.00- 23.00	0	0	1	0	0	0	1	1
23.00- 24.00	0	0	4	0	0	0	2	0
24.00- 25.00	0	0	2	0	0	0	1	2
25.00- 26.00	0	0	3	0	0	2	0	1
26.00- 27.00	0	0	5	1	0	1	1	3
27.00- 28.00	0	0	7	2	0	0	5	4
28.00- 29.00	0	0	3	1	0	1	6	6
29.00- 30.00	0	0	2	5	1	0	2	5
30.00- 31.00	0	0	0	3	2	2	2	7
31.00- 32.00	0	0	4	8	4	2	8	5
32.00- 33.00	0	0	3	12	3	0	4	5
33.00- 34.00	0	0	2	11	4	1	5	8
34.00- 35.00	0	0	0	10	8	2	10	10
35.00- 36.00	0	0	3	8	11	3	11	22
36.00- 37.00	0	1	4	4	8	3	5	21
37.00- 38.00	0	8	6	4	5	3	10	12
38.00- 39.00	0	7	3	7	5	8	18	7
39.00- 40.00	1	4	6	6	10	16	20	12
40.00- 41.00	0	7	14	8	12	5	18	35
41.00- 42.00	2	4	19	10	11	23	20	13
42.00- 43.00	2	7	22	12	7	13	17	8
43.00- 44.00	6	9	9	11	11	17	16	6
44.00- 45.00	6	12	7	25	12	24	15	15
45.00- 46.00	14	13	13	22	15	30	16	26
46.00- 47.00	8	9	20	20	20	17	14	12
47.00- 48.00	12	10	26	12	24	20	18	14
48.00- 49.00	23	22	21	9	26	15	24	10
49.00- 50.00	11	13	14	11	24	21	26	8
50.00- 51.00	16	30	8	13	22	17	27	17
51.00- 52.00	20	26	7	18	18	5	14	8
52.00- 53.00	23	17	10	22	17	12	17	6
53.00- 54.00	14	12	18	21	5	6	18	3
54.00- 55.00	12	8	26	20	10	3	21	2
55.00- 56.00	5	11	25	18	10	7	11	1
56.00- 57.00	7	6	20	8	10	1	10	2
57.00- 58.00	5	4	14	9	6	1	9	0
58.00- 59.00	7	5	11	14	12	4	5	0
59.00- 60.00	3	4	8	20	11	0	0	0
60.00- 61.00	1	3	11	15	6	3	2	0
61.00- 62.00	5	3	5	12	11	1	0	0
62.00- 63.00	6	2	4	6	0	1	1	0
63.00- 64.00	1	5	5	2	1	0	1	0
64.00- 65.00	3	0	3	5	1	0	2	0
65.00- 66.00	2	2	3	5	0	0	0	0
66.00- 67.00	0	0	2	3	0	0	0	0
67.00- 68.00	0	1	1	1	0	0	0	0
68.00- 69.00	0	1	2	2	0	0	0	0
Total	215	266	409	436	363	290	433	318