Chapter 3

Sampling and measuring

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In this chapter some basic information is given on sampling and measuring techniques. These include linear and weight measurements of fishes, techniques for sub-sampling and determination of sex and maturity stages. Attention is paid to stomach content analysis and to the sampling of food sources and some other environmental parameters. Reference is made to important literature for statistics and sampling design.

3.1 Length

Types of length measurements

The length of the fish can be measured as:

- Total length.
- Fork length.
- Standard length.

Definitions are given by Bagenal (1978) and cited here:

- Total length is the greatest length of the fish from its anterior extremity to the end of its tail fin. In fishes having a forked tail, for example, the two lobes are moved to the position which gives the maximum length measurement (whichever may be the longer lobe is used).
- Fork length is the length measured from its anterior extremity to the tip of the median rays of its tail. This measurement is the same as the total length in species in which the tail fin is not notched or forked.
- Standard length is the greatest length of a fish from its anterior extremity to the hidden base of its median tail fin ray (where these meet the median hypural plate).

Fishermen, fisheries administrators and fisheries biologists prefer to express the length of fishes as total length, since this is usually more easily measured than fork length or standard length. Standard length is preferred for taxonomical purposes because the ends of the caudal fin rays are often bent or missing in preserved specimens in laboratories or museums. In *Figures 3.1, 3.2* and *3.3* the three length measurements are presented for the three main species of Lake Victoria. For routine fisheries research, the total length of *Lates*, the tilapiines and *Rastrineobola* is usually measured. Since the tail fin of *Rastrineobola* is very thin, standard length can be measured as easily as total length for this genus.

Length measurements are to be made in metric scales (*e.g.* cm or mm). A common goal is a measurement accurate to 0.5% of the overall length, but anything finer than the nearest millimetre is rarely attempted (Bagenal 1978). Fish can be measured to the nearest cm (or mm) or to the nearest cm below (mostly referred to as 'cm below'). A *Lates* with an actual total length between 48.00 and 48.99 cm will be noted down as 48 cm measured to the nearest cm below. *Lates* with actual lengths of 48.74 and 53.86 cm will be measured to the nearest mm, *i.e.* as 48.7 cm and 53.9 cm respectively. Length is best measured by using a measuring board in which the anterior extremity of the fish is put against a stop at the beginning of the measuring scale *(Figure 3.4)*.

Length-frequency distributions

A common practice in fisheries research is for fish to be grouped in size classes. Remember that, once a wide size class has been used, it is impossible to regroup the data into narrower size classes, but conversely, data first grouped into narrow size classes can be regrouped into wider size classes. As a rule of thumb, the complete size range of a species should be covered by a length-frequency distribution of at least 30 classes. In *Table 3.1* the recommended width of size classes of some fish species from Lake Victoria is presented. The length should be presented as mid-length in calculations which are performed with grouped data (*e.g.* the calculation of the mean length of a length-frequency sample). The mid-length of a size class 1 is the mean length of the smallest fish which could theoretically belong to size class 1 and

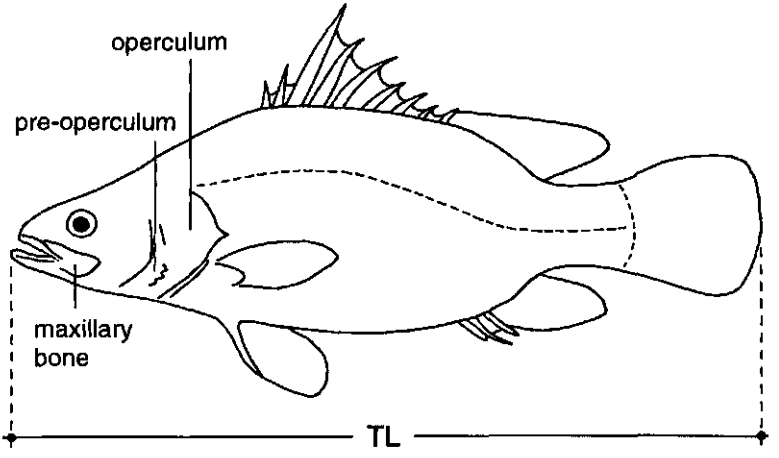

Figure 3.1 Total length (TL) of *Lates*.

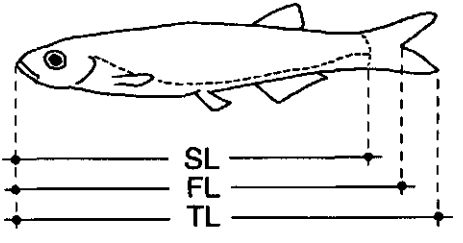

Figure 3.2 Total length (TL), fork length (FL) and standard length (SL) of *Rastrineobola*. If the total length is measured, make sure that the two lobes are moved in a position which gives the maximum length measurement.

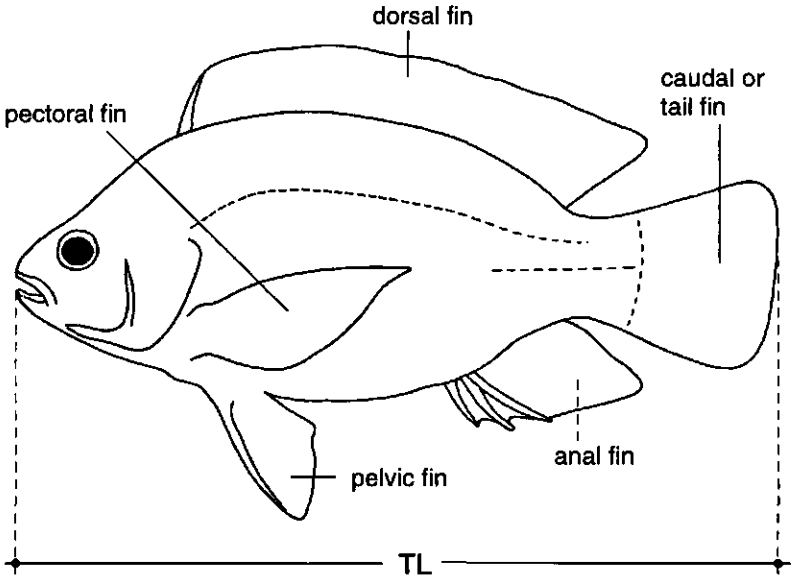

Figure 3.3 Total length (TL) of a tilapiine cichlid.

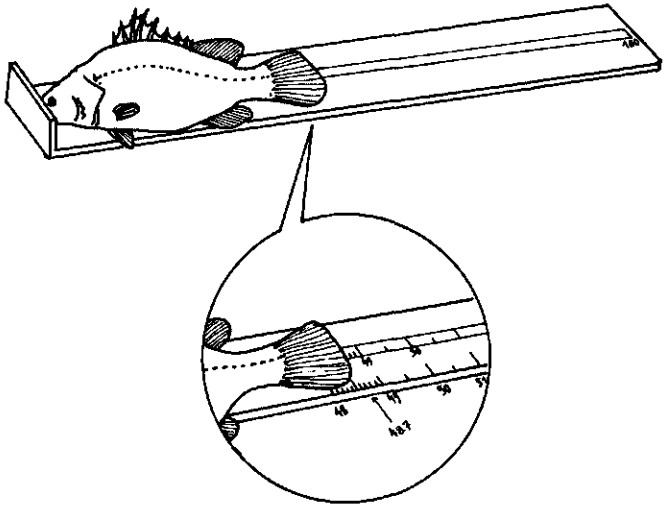

Figure 3.4 A *Lates* of 48.7 cm (measured to the nearest mm) on a measuring board.

Table 3.1 Recommended width of size classes for some fish species from Lake Victoria. These size classes are recommended for use during measuring; size classes can be combined later if necessary.

Species	Recommended width of size class
Lates	1 cm
Oreochromis niloticus	1 cm
Other tilapiines	0.5 cm
Rastrineobola	1 mm
Protopterus	1 cm
Bagrus	1 cm
Clarias	1 cm
Haplochromines	1 mm or 0.5 cm (large specimens)

the largest fish which could theoretically belong to size class 1. In Chapter 6 some examples are given on the calculation of mid-length.

Sub-sampling

Even if data are grouped, it may still not be possible to measure all the fish in a catch *(C)*. In this case only the length-frequency distribution of a sub-sample *(S)* is measured, and the frequencies are multiplied by the ratio of the catch to the sub-sample *(C/S)*. If the catch consisted of *Lates* which varied considerably in length (*e.g.* 0.03-1.0 m total length), and the catch weight was about 300-600 kg, the procedure would be as follows:

1. The larger specimens (greater than about 20 cm total length) are removed from the catch and are all measured.
2. The remainder of the catch is stirred with shovels to give an homogeneous mixture of sizes.
3. If the heap of remaining fishes looks homogeneous, the heap is divided into two equal parts.
4. One half is put into a container, the other half is again divided into two equal parts.
5. Stages 3 and 4 are repeated until the number of fish remaining is about 150; and the number of times that stages 3 and 4 were repeated is counted for the calculation of *C/S*.
6. The fish in the sub-sample are measured.
7. Finally, data of the sub-sample are multiplied by *C/S*.

Example

The length-frequency distribution of a trawl catch of approximately 350 kg is to be established. After sorting out the fish larger than 20 cm in total length, the remainder was homogenised using shovels. The remaining part was then divided into two parts three times. This means that *C/S* for fish smaller than 20 cm total length is:

$$\frac{C}{S} = 2 \times 2 \times 2 = 8$$

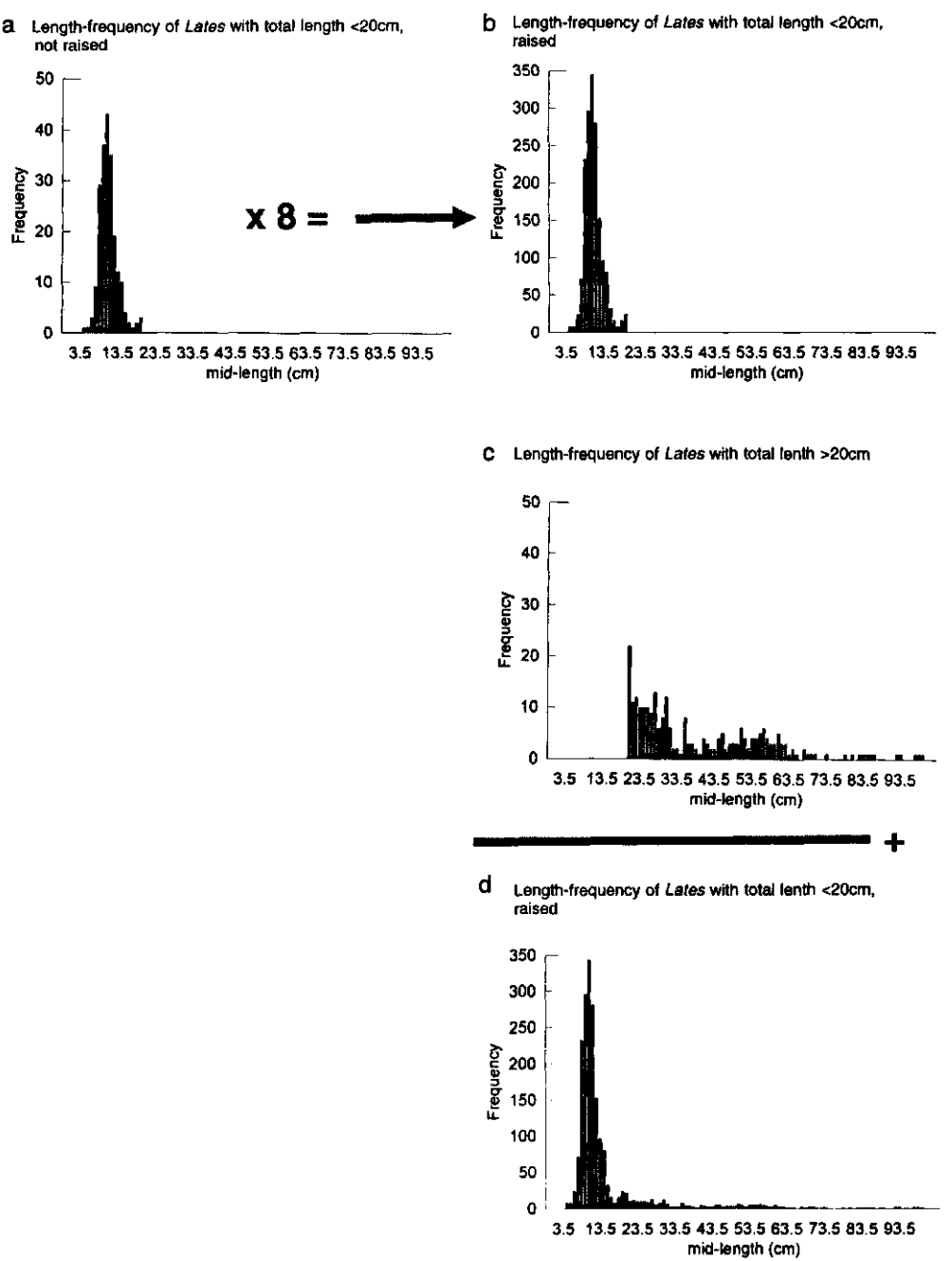

Figure 3.5 Establishing a length-frequency distribution; for explanation see text.

The number of fish in each size class smaller than 20 cm *(Figure 3.5a)* is multiplied with *C/S*. After multiplication *(Figure 3.5b)*, the length-frequency distribution can be established by adding the length-frequency distribution of fish larger than 20 cm *(Figure 3.5c)* to the multiplied length-frequency distribution of fish smaller than 20 cm *(Figure 3.5d)*.

Sources of error

There are several possible sources of error in making measurements of fish, including those cited below, and taken from Bagenal (1978):

- Muscular tension in living fish relaxes after death.
- Fish shrink due to preservation techniques (including freezing).
- Variation in the pressure applied to put the jaws into a normal closed position (at time of measurement) leads to inconsistencies.
- Failure to always squeeze the tail fin, so as to get the maximum total length (in fishes with forked caudal fins), leads to inconsistencies.

These errors can be avoided by a thorough standardization of method.

3.2 Weight

General

Weight can be measured from a number of fishes (*e.g.* all fish in a catch), from the individual fish or from a part of the fish such as the gonads, the liver, the visceral fat etc. The weight of a fish changes as it dries and so weighing should occur as soon as possible after capture. It is important to make measurements at a standard degree of wetness and for this reason fish are sometimes kept wet by pouring water over them, or they are dried with a piece of cloth to make them towel dry. Sometimes preserved fish are weighed. If the weight of preserved fish is to be compared with the weight of fresh fish a correction must be made. The correction factor can be established by weighing and marking a sub-sample before preservation; the sub-sample can be weighed again when the total sample is processed and the weight loss or gain can be determined. In *Table 3.2* some weight changes in haplochromines, tilapiines, *Lates* and *Rastrineobola*, occurring as a result of various preservation methods, (including commercial methods) are presented.

Types of weighing machines

Ideally, a weighing scale should be precise to 1% of the weight of the fish. In Lake Victoria a range of balances of 10, 50, 200 and 1000 grams and 5, 10, 25, 50 and 100 kilograms was sufficient to measure almost all individual fishes and filled fish boxes. For *Rastrineobola*, a weighing scale which is accurate to the nearest 0.01 g over the range 0-5 g is needed.

There are several types of balances. Those used in fisheries research during the HEST/TAFIRI period were:

- Spring balance (*e.g.* Salter, *Figure 3.6a*).
- Weigh-beam (*e.g.* Pessola, *Figure 3.6b*).

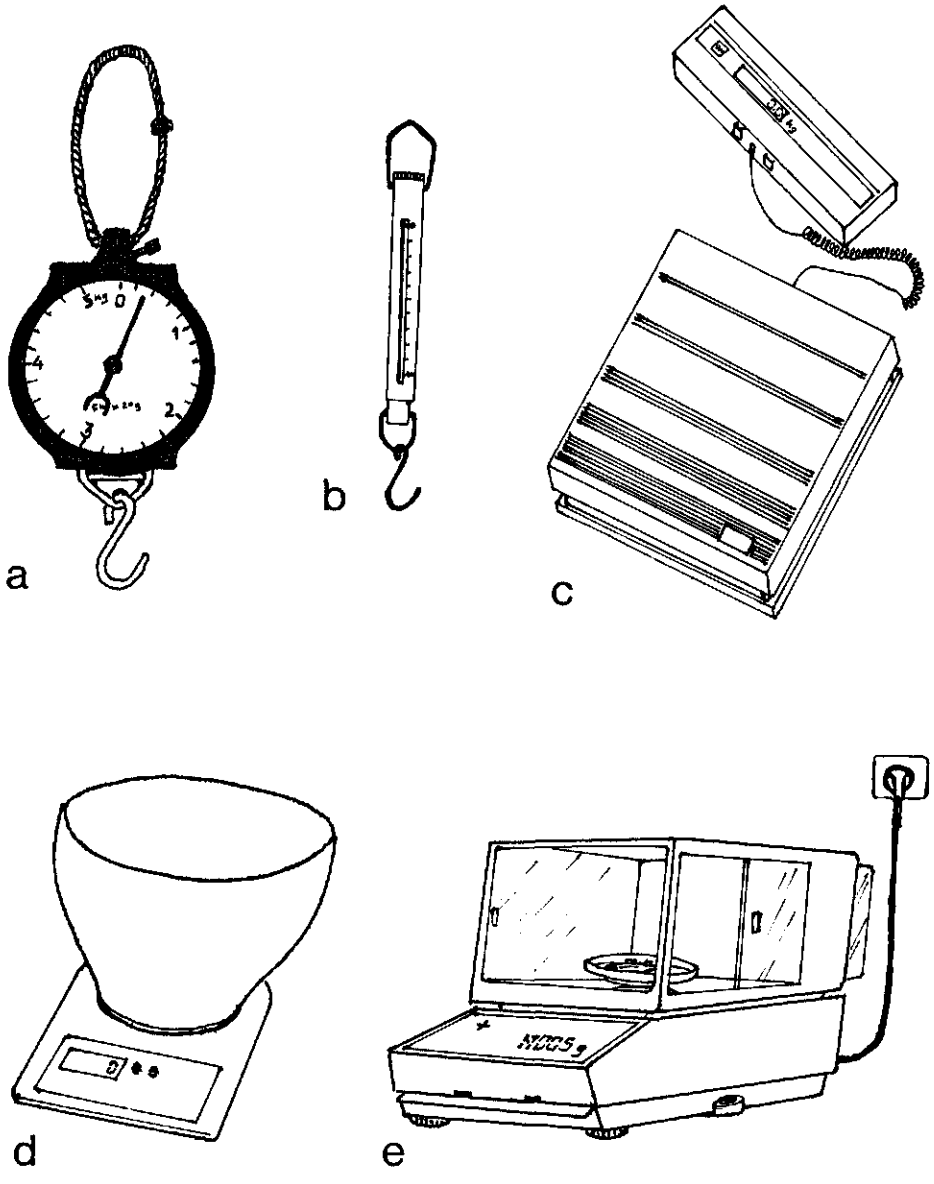

Figure 3.6 Several types of weighing scales: (a) spring balance; (b) weigh-beam; (c) household scale 0-120 kg; (d) household scale 0-2000 g; (e) laboratory scale; for further explanation see text and *Table 3.3.*

Table 3.2 Weight changes (expressed as % from fresh weight) due to preservation methods. Storage time in alcohol and formalin was 2-3 months.

Species	Preservation method					
	Alcohol (40%)	Formalin (10%)	Freezing	Sun drying	Smoking	Fish meal
Lates			0%		-72% to -60% (3)	
Rastrineobola		+8%	(1)	-70% (2)		
Tilapiines	-10%	+2%	0%			
Haplochromines	-10%	+2%				-83%

(1) Considerable weight loss judging from appearance after being frozen.
(2) After 2 days drying in favourable circumstances (sunny weather, on stone).
(3) Weight loss due to removing viscera and smoking.

Table 3.3 Characteristics of several weighing scales used during the HEST/TAFIRI period and their application for research on the three major fish species of Lake Victoria.

Type	Measuring range	Precise to nearest:	Application
Spring balance	0-5 kg	10 g	Weighing individual *Lates* and tilapiines of 2-5 kg total weight
	0-25 kg	100 g	Weighing individual *Lates* of 5-25 kg total weight
	0-50 kg	200 g	Weighing individual *Lates* of 25-50 kg total weight
	0-100 kg	500 g	Weighing filled fish boxes
Weigh-beam	0-10 g	0.1 g	Weighing individuals of fish between 5 and 10 g
	0-50 g	0.5 g	Weighing individuals of fish between 10 and 50 g
	0-200 g	2 g	Weighing individuals of fish between 50 and 200 g
	0-1000 g	10 g	Weighing individuals of fish between 200 and 1000 g
Household scale (with digital display and zero-adjust)	0-2000 g	2 g (in range 0-130 g) 5 g (in range 130-360 g) 10 g (in range 360-2000 g)	Weighing smaller *Lates* and viscera of *Lates*; cannot be used on board ship
Household scale (with digital display and zero-adjust)	0-120 kg	100 g	Weighing larger individual *Lates* and total catches at landing; cannot be used on board ship
Laboratory scale (Mettler AC 100)	0-100 g	0.00001 g	Measuring fresh weight and dry weight of *Rastrineobola*; weighing stomachs and viscera of small fish; cannot be used on board ship

- Battery powered household weighing scales (*e.g.* Tefal or EKS, *Figures 3.6c* and *d).*
- Laboratory weighing scales (*e.g.* Mettler AC 100, *Figure 3.6e).*

For weighing fish on board boats, only spring balances were used. Characteristics of these instruments are listed in *Table 3.3.*

Mechanical weighing scales are more robust than electronic weighing scales, and they require no batteries. For protection against dirt and shocks, weigh-beams can be put in plastic transparent tubes. Zero adjustment of electronic weighing scales after recording each fish weight makes it possible to continue weighing, without removing the previously weighed fishes from the scales *(Figure 8.6).* Electronic weighing scales with LED display (red or green lit characters against a dark background) are less suitable than weighing scales with LCD display (black characters on a grey background) since a LED display is difficult to read in daylight.

Other, less commonly used types are bar equilibrium balances and weighing machines (Bascule). A bar equilibrium balance is not suitable for beach recording or for use on board boats. They are available in several measuring ranges. A weighing machine or Bascule is a machine for rough estimates of weight with low precision. This machine is sometimes used by fishmongers who buy large quantities of fish (*e.g.* bags of dried *Rastrineobola* or baskets of processed *Lates*).

Calibration of weighing machines

Weighing equipment should be calibrated regularly. This is usually done by weighing standard weights and performing a regression analysis of measured weight on actual weight. The regression analysis can be done in Lotus as demonstrated in Section 6.2. The result of the regression analysis can be presented as follows:

$$MW = a \times AW + b$$

where MW is the measured weight, AW is the actual weight and a and b are the calculated parameters. If the weighing scale can be adjusted to 0, the intercept *(b)* has the value 0. The recalculated relationship can be used to correct the measured values for the deviation of the weighing scale:

$$AW = \frac{(MW - b)}{a}$$

If several weighing scales are used, each weighing scale has to be given an identification number. If a fish is weighed, the identification number of the weighing scale with which the fish was measured should be noted, so that the measured value can be corrected using the appropriate relationship.

Weighing a catch

After taking the catch from the water all fishes are sorted out to the species level and stored in separate boxes or heaps. *Protopterus* should be killed first because they bite fiercely. It is convenient to divide the fish of one species into small, medium and large sized animals. Each group is weighed as soon as possible to avoid desiccation and the results are recorded. In case of small fishes like *Rastrineobola* and small *Lates* (below 10 cm length) it is possible to calculate the weight from the volume caught, calculating it from the number of filled fish

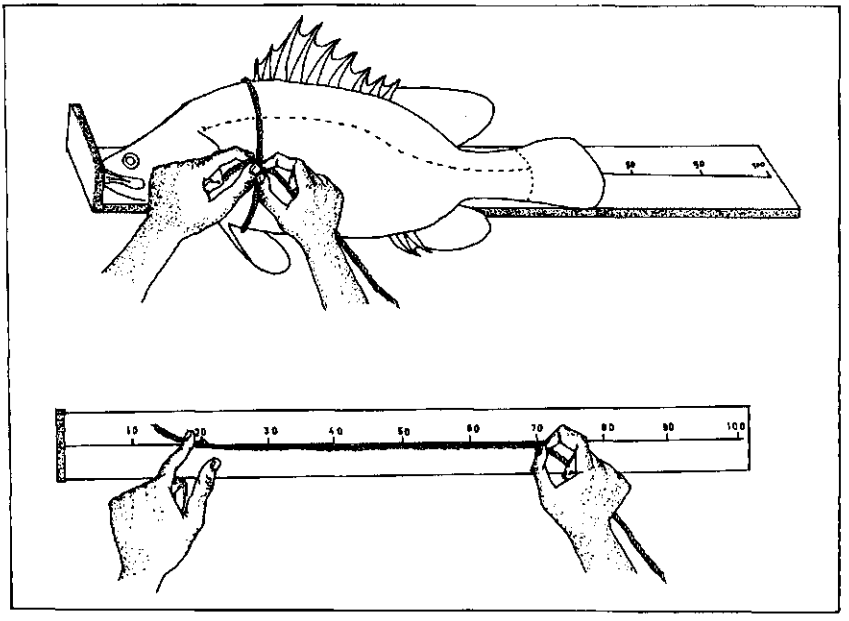

Figure 3.7 Measuring maximum girth of *Lates*. The girth of the *Lates* shown in the illustration is 50 cm.

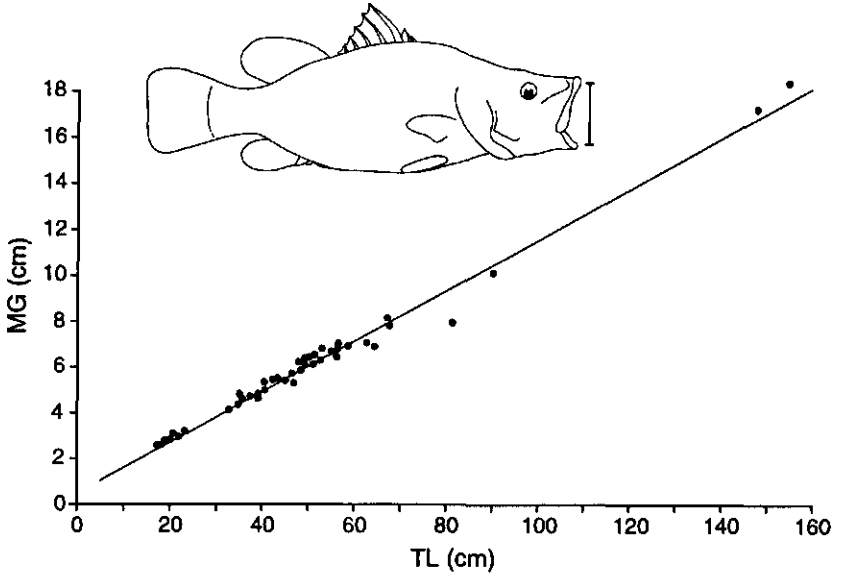

Figure 3.8 Relationship between maximum mouth gape (MG) and total length (TL) in the predator *Lates*. (After Ligtvoet & Mkumbo 1990).

boxes and the average weight of a filled fish box. When this method is applied one should realise that there are considerable differences in the weight of filled fish boxes for different species and different size classes (due to the differential packing of the fish).

Weighing individual fish

The approximate weight of an individual fish can be calculated from a length-weight relationship formula if the length of the fish is known (see Section 6.3). If the precise weight of an individual fish is needed, a correction has to be made for the weight of the stomach contents. This can be done by weighing the stomach contents and subtracting the weight of these from the total weight. This method is time-consuming. It is also possible to index the stomach fullness with a number and then establish the relationship between the length of the fish and the stomach weight for each stomach fullness index. These relationships were established for *Lates*, but not for tilapiines and *Rastrineobola*, during the HEST/TAFIRI research period (see Section 3.5).

3.3 Girth, body depth and mouth gape

Rough estimates of gill net selectivity can be obtained from girth measurements. The maximum girth can also provide information on the condition of the fish. (A fish with a relatively large circumference is in good condition or a female ready to spawn). However, evaluating the results from 12 months research on the reproductive cycle of *Lates*, P. Van de Wateren (pers. comm.) concluded that maximum girth is a poor indicator of condition for this species.

Establishing the relationship between length and body depth for all fish species, together with the establishment of the relationship between length and mouth gape for the most important predators in a system, allows the potential size ranges of their prey species to be determined.

Girth is the circumference of the fish body measured perpendicular to the central body axis. For measuring girth a thin non-elastic thread is laid close around the fish body at the required position. The thread should not be pulled with force and care should be taken that all girths are measured with the thread under the same tension. Remove the thread and measure the length to the nearest mm between the two points held by thumb and finger of each hand *(Figure 3.7)*. Make sure that the pelvic and pectoral fins are consistently included or excluded. If the aim of the girth measurement is to establish a length-girth relationship, fishes should preferably be sampled from comparatively non-selective gear like beach seines and trawls. The selectivity of gill nets probably gives biased results in the length-girth relationship (see Section 5.2).

Girth can be measured at the following positions:

- Position 1: maximum girth. The maximum girth is measured where the circumference is greatest. Normally this is just anterior to the dorsal fin, but in the case of *Clarias* the maximum girth is around the head.
- Position 2: head girth. The circumference is measured over the most posterior end of the operculum.
- Position 3: pre-operculum girth. Circumference is measured over the most posterior end of the pre-operculum.

- Position 4: girth at the eye. Circumference is measured just posterior to the eye.
- Position 5: girth at maxillary bone. Circumference is measured at the posterior end of the maxillary bone.

Measurements of girths at positions 1-5 can be taken on behalf of research on net selectivity (*e.g.* Coulter 1970; Marais 1985).

Maximum body depth of the fish is measured in the dorsal-ventral direction, at right angles to the length axis of the fish at the position where the body depth is greatest. Normally this is just anterior to the dorsal fin. The fish is laid with its back (dorsum) against the raised end of the ruler and with a carpenter's rectangle lightly touching the belly (ventrum) the maximum body depth is read. In smaller fishes (<15 cm TL) dividers or callipers give more precise results.

Maximum mouth gape is the depth in dorsal-ventral direction of the maximum opening of the mouth of a fish. The mouth gape can be measured with dividers or callipers measuring the width from inside, when the mouth is opened with some force to its maximum. It is difficult to give a fixed directive because the resistance in opening the mouth to its maximum differs according to species and size. Practising and comparing results of various researchers may improve the consistency of the measurements. In *Figure 3.8* the mouth gape-total length relationship of *Lates* is shown.

For measuring of other dimensions especially relevant to taxonomical studies, such as head length, eye diameter, spine length, caudal peduncle length, scale counts etc., refer to Barel *et al.* (1977) and Bagenal (1978). Measuring bony elements, otoliths or eye lenses of fish, can provide a key to reconstruct the prey size from the gut contents of a predator. For example, the diameters of the eye lenses of several cichlids, found in the faeces of otters could be used to determine the original length of the fresh fish eaten from Lake Victoria (Kruuk & Goudswaard 1990).

3.4 Sex and maturity

General

Fish become sexually mature at a certain length or age. Once mature the gonads go through a seasonal cycle of stages of ripeness. Scoring maturity stages per size category provides information about length at 50% maturity, a parameter commonly applied in fisheries biology. Information on stages of ripeness can be analysed together with data on seasonal changes in condition and in weight of the viscera, and with data on recruitment patterns. The process of maturing, developing, spawning and recovering is reflected in the appearance of the gonads.

To obtain the length at 50% maturity, the length of each individual in the sample must be measured and the maturity of each individual assessed. The percentage of mature individuals in each size class is described with a logistic curve as a function of the length of the fish *(Figure 3.9)*. See Section 6.3 for an example of the calculation of the length at 50% maturity. For establishing the length at 50% maturity a coding of maturity stages with only two stages (immature, mature) will suffice, provided that the sexes are distinguishable. The best period to take the sample for establishing the length at 50% maturity is just before the spawning period. At that moment the difference in maturity is at its most distinct. If the spawning period is not known, or if there is an extended breeding season, the length at 50% maturity will be more difficult to appraise.

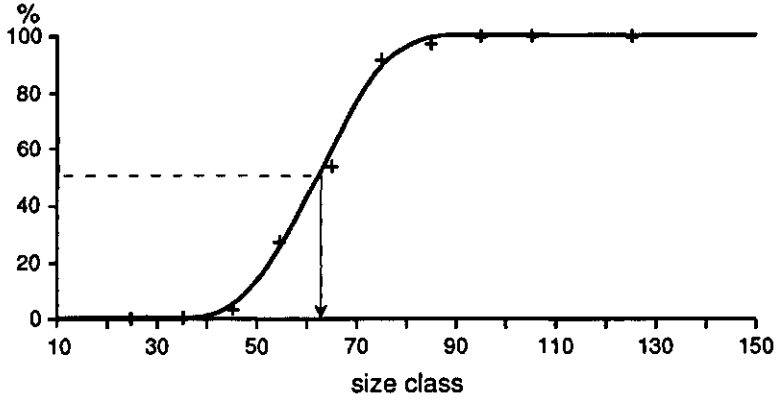

Figure 3.9 Percentage mature male *Lates* of all males. Length at 50% maturity is reached at a total length of *ca.* 60 cm.

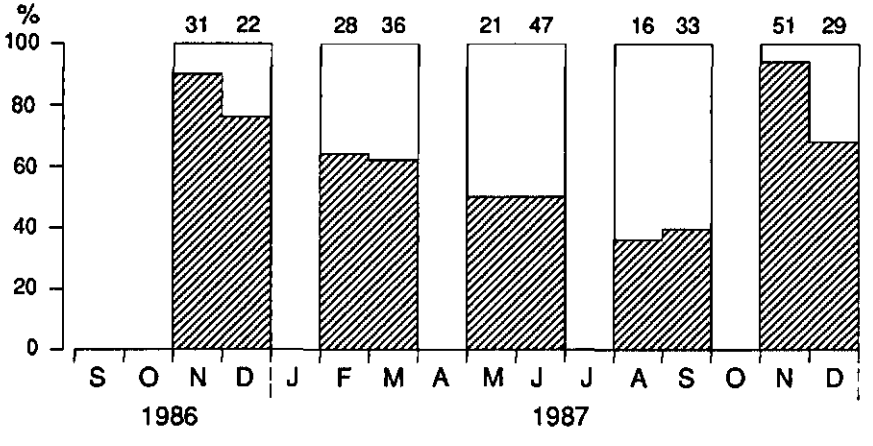

Figure 3.10 Seasonal changes in ripeness of adult male *Lates*. Shaded is the percentage of late mature males (stage V-VI) of all mature males (stage IV, V, VI). Immature *Lates* (stage I, II, III) are not included in this graph. See *Table* 3.4 for a description of the stages. (After Ligtvoet & Mkumbo 1990).

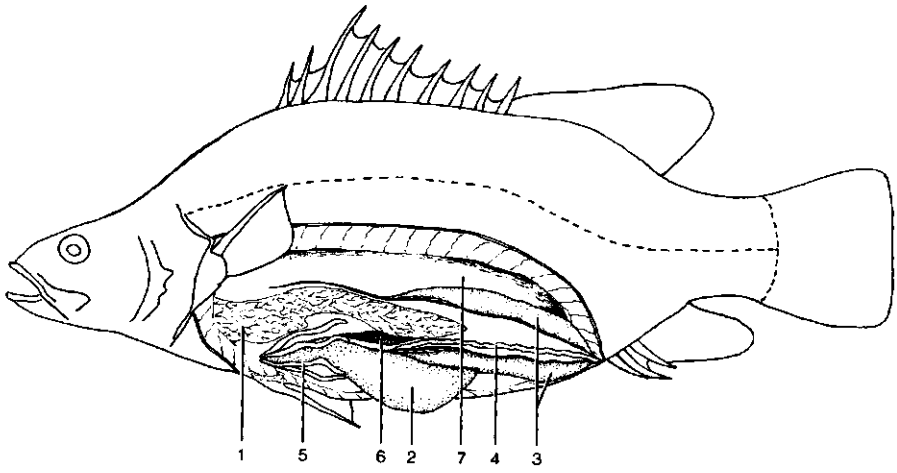

Figure 3.11 Position of the gonads and the other viscera in the body cavity of *Lates*. 1 = liver, 2 = stomach, 3 = gonads, 4 = intestine, 5 = pyloric caecae, 6 = spleen, 7 = swim bladder.

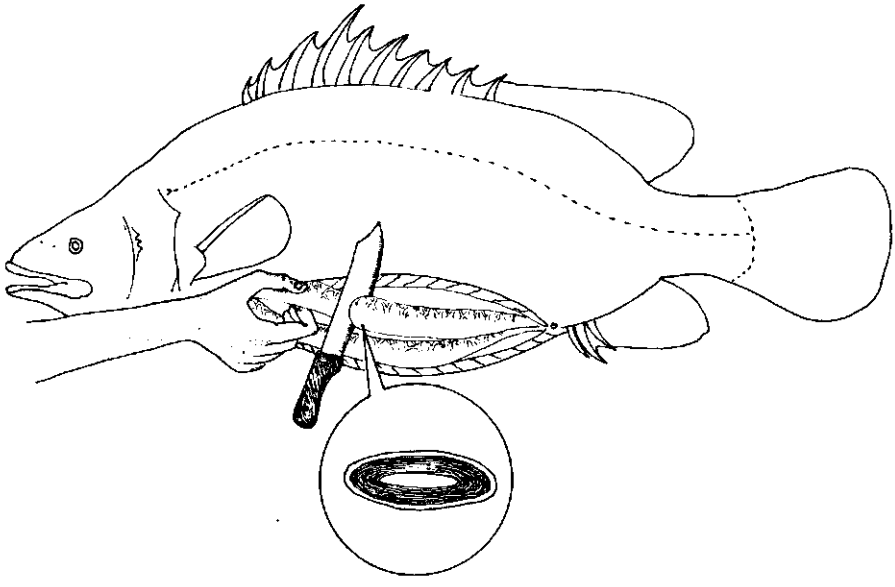

Figure 3.12 Examining a female *Lates*, lateral view. The gonads are in maturity stage VII (see transverse section in the detail).

Table 3.4 Coding of maturity stages of male and female *Lates* in fresh individuals according to Hopson (1972).

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

During a period of increased reproductive behaviour a higher percentage of the adult fish will be in an advanced stage of maturity, and some individuals will have spawned already. Thus, by taking samples each month, and evaluating the ripeness stage of each individual, information about the reproduction cycle will be gained *(Figure 3.10)*. In this case, a division of maturity stages into at least three categories (immature, early maturing, late maturing-spent) is necessary.

Lates

For *Lates* from Lake Chad, a coding of maturity stages has been developed by Hopson (1972) (see *Table 3.4*). This coding has been adopted by HEST/TAFIRI for *Lates* from Lake Victoria. The gonads of *Lates* are easily found if the fish is cut with a knife, from the anus towards a point slightly above the pectoral fin. For a complete overview of the viscera the wall of the body cavity can be totally removed *(Figure 3.11)*. To determine the maturity stage, the gonads can be cut as in *Figure 3.12*. In *Figure 3.13*, female gonads of stages I-V and in male gonads of stages I-V are presented. Note that gonads are paired in fish. Before cutting the fish, slight pressure should be applied to the fish to test if it is in stage VI. During the HEST/TAFIRI research, stage VI females were never encountered.

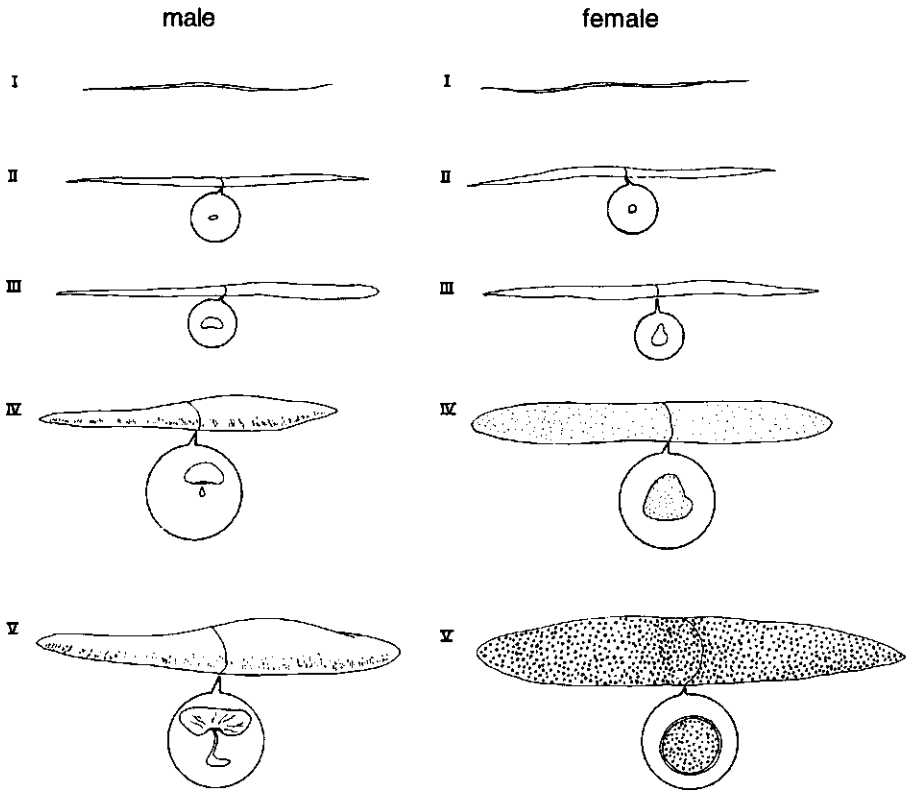

Figure 3.13 Male and female gonads of *Lates* in maturity stage I-V. The details show the transverse sections. For explanation see *Table* 3.4.

According to *Table 3.4*, *Lates* males return to stage IV after spawning, and females return to stage II after spawning. Ogutu-Ohwayo (1988) distinguished between stage III-maturing, and stage III-recovering females, but did not give a description of these stages. This difference was not observed during the HEST/TAFIRI research. Thus, when establishing the length of females at 50% maturity, recovering females cannot be distinguished from virgin females which are maturing for the first time. To overcome this problem, it is better to consider females mature from stage IV onwards. The length at 50% maturity will be somewhat overestimated because recovering stage II and stage III females are left out. Another consequence is that the percentage of mature females will not reach 100 with increasing length.

For research on maturation and on the reproductive cycle of *Lates*, about 150 fish should be sampled monthly. The sample should consist of fish above 30 cm TL. To obtain enough information about female reproductive activity, at least 15 specimens of more than 100 cm TL must be sampled monthly.

During the HEST/TAFIRI research it was found that maturation of males starts at about 35 cm TL for males and 45 cm TL for females. 100% maturity is reached at about 85 cm TL for males, and about 90 cm for females. It is noteworthy that the sex ratio of the *Lates* population of the Mwanza Gulf is skewed; in the lower size classes (TL below 100 cm) males dominate, while in the higher size classes (TL above 100 cm) females dominate (Ligtvoet & Mkumbo 1990).

Rastrineobola

There is no literature available about the coding of maturity stages in *Rastrineobola*. Macroscopically three categories are easily recognized: ripe males, ripe females and an undefined 'others' category. In females earlier stages may be distinguished without the aid of a microscope (J.H. Wanink pers. comm.; Okedi 1974).

To locate the gonads of *Rastrineobola*, the body cavity wall must be removed with a pair of dissecting scissors. Starting at the anus, move laterally along the upper ridge of the body cavity towards the operculum. Cut ventrally along the operculum towards the median of the chest and then towards the anus. The body cavity wall can now be removed and the viscera can be examined *(Figures 3.14* and *3.15)*. However, classification of ripeness stages appeared difficult. In ripe individuals the gonads are conspicuous. In formalin preserved specimens of *Rastrineobola* the visceral fat may be confused with immature gonads.

Tilapiines and haplochromines

All cichlids have a complicated courtship and spawning behaviour and many species in Africa are mouth brooders. *Oreochromis niloticus* is a female mouth brooder. The maturity stages to be discerned in *Oreochromis niloticus* are given in *Table 3.5*. The ripeness stages for *Oreochromis niloticus* are applicable for *Oreochromis leucosticus, Oreochromis variabilis* and also for *Oreochromis esculentus. Tilapia zillii*, however, is a substrate spawner so stage VI of females is not valid for this species. Several cichlid species in Lake Victoria show distinct spawning seasons (Lowe McConnell 1956a; Garrod 1959; Witte 1981; Goldschmidt & Witte 1990).

The gonads of cichlids can be found by cutting the fish with a knife or a pair of scissors. Starting from the anus, proceed towards the pelvic fins and then again from the anus towards a point slightly above the left pectoral fin *(Figure 3.16)*.

Male tilapiines are never seen running sperm when caught and do not release sperm when the belly is squeezed. If a female *Oreochromis* has eggs or juveniles in the mouth when caught, she will often spit them out. For that reason it is worthwhile to check the posterior part of the buccal cavity of females, by looking through the gill opening into the cavity. Often a few eggs or larvae that were not expelled can be found in this part of the buccal cavity.

In general, the classification of *Table 3.5* can also applied to the haplochromines of Lake Victoria. With the exception of some piscivorous haplochromines (van Oijen 1991) mature males and females differ in colouration and can easily be distinguished from each other. Most adult haplochromine males have black pectoral fins and all have egg dummies on the anal fin.

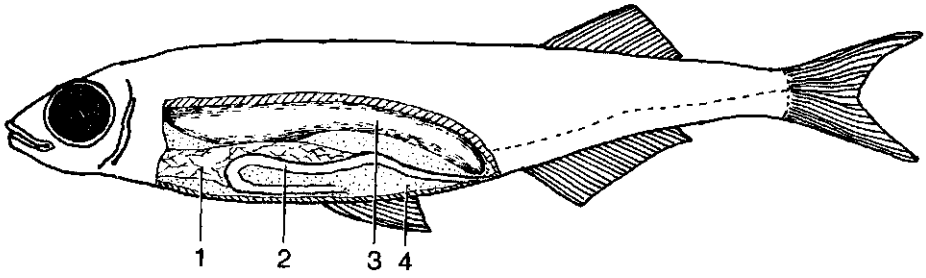

Figure 3.14 Lateral view of the body cavity in *Rastrineobola* after removal of the body cavity wall. The body cavity of this specimen is almost totally covered with visceral fat. 1 = liver, 2 = intestine (there is no real stomach), 3 = swim bladder, 4 = visceral fat.

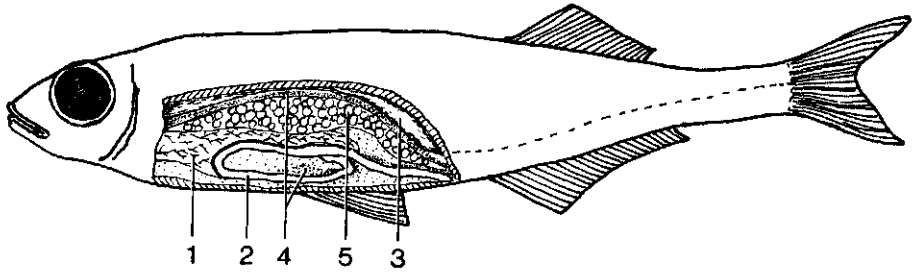

Figure 3.15 Lateral view of the body cavity in *Rastrineobola* after removal of the body cavity wall. This specimen is a ripe female. 1 = liver, 2 = intestine, 3 = swim bladder, 4 = visceral fat, 5 = gonads.

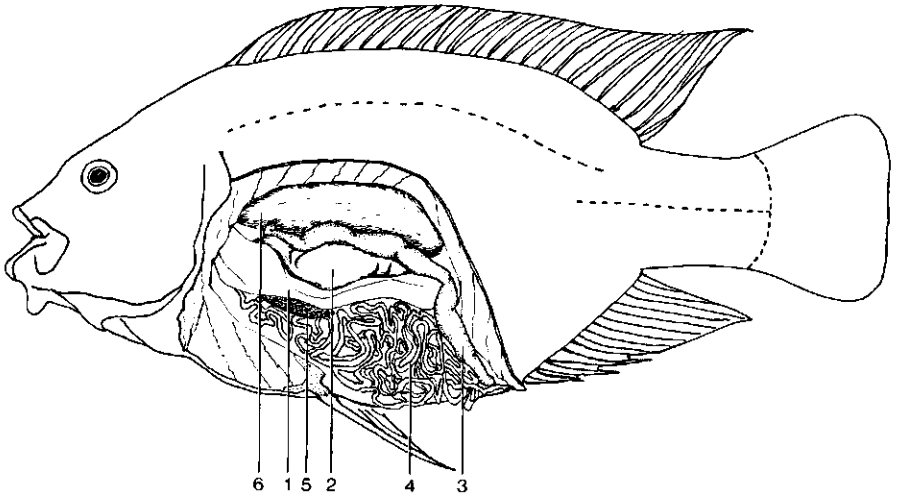

Figure 3.16 Position of the gonads and the other viscera in the body cavity of a male tilapiine cichlid (*Oreochromis niloticus*). 1 = liver, 2 = stomach, 3 = gonads, 4 = intestine, 5 = spleen, 6 = swim bladder.

Table 3.5 Coding of maturity stages in fresh individuals of *Oreochromis* and haplochromine species.

Males	Females
I. Immature: A pair of thin transparent strands running longitudinally along the median of the dorsal wall of the body cavity; sexes indistinguishable macroscopically.	I. Immature: Appearance like testes; sexes indistinguishable macroscopically.
II. *Early developing: Strands start to thicken; testes are* whitish-yellow.	II. *Early developing: Ovaries to be recognised by small* whitish dots (eggs); caudal part of the ovaries more thickened than the rostral part.
III. Developing: Testes are pinkish-reddish and sideways flattened.	III. Developing or recovering: Eggs developing inside the ovaries unequal in size.
IV. Early ripening: Testes thick and straight, increasing in volume. When cut and squeezed milt comes out.	IV. Early ripening: Eggs equal in size but not fully grown; all coloured yellow.
V. Ripe: Testes thick and straight, when cut waterish-white milt comes out.	V. Ripe: Eggs large and ovaries visible from the ventral side of the cavity.
VI. Late ripe: Testes thick and often curled or lobed, white in colour. When cut milt comes out.	VI. Spent: Eggs or juveniles in the buccal cavity; ovaries recovering, thin and reddish; eggs unequal in size, often including a few residual stage V eggs.

3.5 Food

Knowledge about food consumption and food compositon is of importance in studies of fish stocks. Fish growth, and thus the productivity of a fish stock, depends on the availability of food. Knowledge of the main food sources of the different species of a fish community will provide insight into the food web and consequently into the inter-relationships of the species.

Information on food composition can be obtained by analysis of stomachs and intestines. The type of analysis depends on the fish species, its food source(s) and the type of information which the researcher wants to collect. For investigation of the forage base of a fish species it is sufficient to concentrate on particular size groups instead of on individual fish. Stomach contents of fishes of the same size class can be mixed and afterwards analysed for:

1. Qualitative food composition, *i.e.* all identifiable species or taxa present are scored. These data can be used to calculate a frequency of occurrence of food items; stomachs containing a particular food item are expressed as percentage of all stomachs containing food.
2. Semi-quantitative food composition, *i.e.* for each taxon the number of individuals, or the relative volume present, in the sample is scored. Relative volumes can be determined in various ways, among others by estimating the volume percentage of each taxon in the sample, or by weighing the different taxa present, or by using them to displace water in a graduated cylinder.

Identification of prey species may be difficult when they are in an advanced state of digestion. This can often be overcome by searching for specific indigestible structures of prey species, *e.g.* skeletal elements, otoliths and eye lenses of fishes, chitine structures of insects and crustacea, and opercula or other shell parts of molluscs. Original size and weight of the prey species can be back-calculated from the characteristic relationship between the size of a particular structure and the size and/or weight of the prey species.

In order to determine the forage base of a species it is important to cover its total size range and its main distribution area during various seasons. Generally, food preferences change considerably throughout the ontogeny of a fish and in different areas and seasons. There may even be remarkable differences between prey species eaten during the night and the day. Thus haplochromine zooplanktivores feed almost exclusively on zooplankton during the day and mainly on *Chaoborus* larvae at night (Goldschmidt *et al.* 1990). The digestion of blue-green algae in *Oreochromis niloticus* in Lake George also showed a diurnal rhythm (Moriarty 1973). Such diurnal changes can be traced by analysis of fishes caught at intervals over a 24 hour period. Dividing the intestines into a number (*e.g.* four) of equal parts may also reveal the diurnal changes, *e.g.* in a zooplanktivorous haplochromine species caught during the day time, zooplankton will be found in the rostral parts of the intestine and *Chaoborus* in the caudal part, while the reverse holds true for specimens caught at night (Witte 1987).

Throughout its ontogeny in Lake Victoria, *Lates* feeds on a wide variety of prey organisms, starting with zooplankton, subsequently switching to insects, then to the prawn *Caridina* and finally to fish (Hughes 1986, 1992a; Ogari & Dadzie 1988; Ligtvoet & Mkumbo 1990; Ogutu-Ohwayo 1990b; Mkumbo & Ligtvoet 1992). The fish consumed comprise mainly juvenile *Lates* (cannibalism) and *Rastrineobola*. Stomach content analysis of the zooplanktivorous and insectivorous size classes can only be done microscopically, while the other categories can, to a certain extent, be examined macroscopically.

Table 3.6 The parameters a and b from the equation $SC = a \times TL^{b}$ to calculate an estimated weight of the stomach contents *(SC)* for a *Lates* with a certain stomach fullness and a certain total length *(TL)*. Stomach contents weight in g, length in cm.

Stomach fullness	Parameter a	Parameter b
0	0	-
1	0.0112	1.38
2	0.00667	1.80
3	0.00443	2.02
4	0.00391	2.21

During HEST/TAFIRI research *Lates* stomach fullness was indexed with the numbers 0 (empty), 1 (¼ filled), 2 (half full), 3 (¾ filled) and 4 (full). A relationship for each of these indexes was established between the weight of the stomach contents and the length of the fish:

$$SC = a \times TL^{b}$$

where SC is the weight of the stomach contents, TL is the total length of the fish and a and b are the stomach fullness parameters. The parameters for the relationships can be found in *Table 3.6.*

Seasonal as well as diurnal fluctuations in food composition and stomach fullness have been observed for *Lates*. More empty stomachs are found at night than during the day (Ligtvoet & Mkumbo 1990; Mkumbo & Ligtvoet 1992).

Rastrineobola is a zooplanktivore (Corbet 1961). As is common in cyprinids, the fish has no distinct stomach. Due to the small size of fish and prey, analysis of the gut contents can only be carried out microscopically. There are indications that feeding activities are more intensive during day time than at night (W. Hoogenboezem pers. comm.; J.H. Wanink pers. comm.).

The young fry of *Oreochromis niloticus* are omnivorous, feeding on zooplankton, insects, aufwuchs and detritus. After attaining 6 cm TL, phytoplankton forms almost their entire diet (Moriarty & Moriarty 1973; Trewavas 1983). Recent observations suggest that in Lake Victoria *Oreochromis niloticus* is presently also omnivorous when adult (Balirwa 1990). Analysis of stomach and gut contents should be performed microscopically. One should be aware that there may be a misleading resemblance between bottom deposits and the digested matter in the caudal part of the intestine (Trewavas 1983). Feeding in Lake George (Uganda) is a day time activity. Only when the stomach has expanded in the course of the day can blue-green algae like *Microcystis* be digested (Moriarty 1973; Moriarty & Moriarty 1973).

3.6 Sampling of food sources and other environmental parameters

Phytoplankton

Sampling of phytoplankton can be done with a Van Dorn sampler (2 litre). With this equipment, phytoplankton can be sampled at any depth in the water column. The measuring of phytoplankton concentrations can be effected in two ways.

1. Counting algae. Lugol solution is added to the samples after which they are stored for two weeks, so that any phytoplankton can settle down. The sample is reduced to 100 ml by sucking away fluid. Subsequently the sample is stored for a further week so that phytoplankton can settle down again and it is then reduced to less than 50 ml. Finally neutral formalin is added to adjust the volume of the sample to exactly 50 ml (final formol concentration approximately 4%). Counting is done under an inverted microscope (method of Utermöhl 1958 cited in Vollenweider 1969) with the aid of counting chambers. The species composition of the phytoplankton is determined by counting all algae which pass the lens until percentages remain constant (generally after 100-1000 items). Absolute counts (numbers/litre) are very time-consuming.
2. Measuring chlorophyl-a concentrations (Talling & Driver 1963, cited in Vollenweider 1969). As this concerns extinction measurements at 665 and 750 nm, a colorimeter (with proper filters) can be used instead of an expensive spectrophotometer. Another advantage of a colorimeter is that it does not need repeated calibration.

For the identification of phytoplankton in Lake Victoria refer to West (1907) and to Talling (1987). Seasonal variations in phytoplankton densities in Lake Victoria related to dry and wet seasons *(Figures 1.4, 1.7* and *IV.1)* have been described by Talling (1966), Akyama *et al.* (1977) and Ochumba & Kibaara (1989). Information on phytoplankton important to fish species in Lake Victoria is given in Appendix IV.

Zooplankton

Sampling zooplankton during the research of HEST was performed with a plankton net of 150 µm mesh size and a net opening with a diameter of 20 cm. The net was of a type that could be closed under water with a drop messenger. This makes it possible to sample at any particular depth of the water column. In case one works with a net that cannot be closed, zooplankton composition at a certain depth can be determined by subtracting samples of the top layer from those of the total column monitored at the same station. Another cheap sampler which was used is the Schindler plankton trap (*c.f.* Edmondson & Winberg 1971) This is a 20 litre perspex box with hinges on the top and bottom. The box is lowered to the desired depth with the top and the bottom open, and these are then closed by a drop messenger. As the instrument is lifted out of the water, the water contained in the box is filtered through a plankton net which is fixed at the lower side of the box. Samples are preserved in 4% formalin immediately after collecting. In the laboratory the samples are subdivided into ten sub-samples with the aid of the whirling apparatus of Kott (1953) *(Figure 3.17a)*. Sub- sampling can also be done using an automatic pipette with a wide (4 mm) mouth (Edmondson & Winberg 1971). The sample is stirred in an irregular way to avoid vortices, meanwhile a sub-sample of definite volume (5 ml) is drawn up with the pipette. If zooplankton is very abundant one sub-sample can be sub-sampled again. Counting can be done using a special counting grid (a 40x76 mm microscope slide with engraved lines at 3 mm intervals).

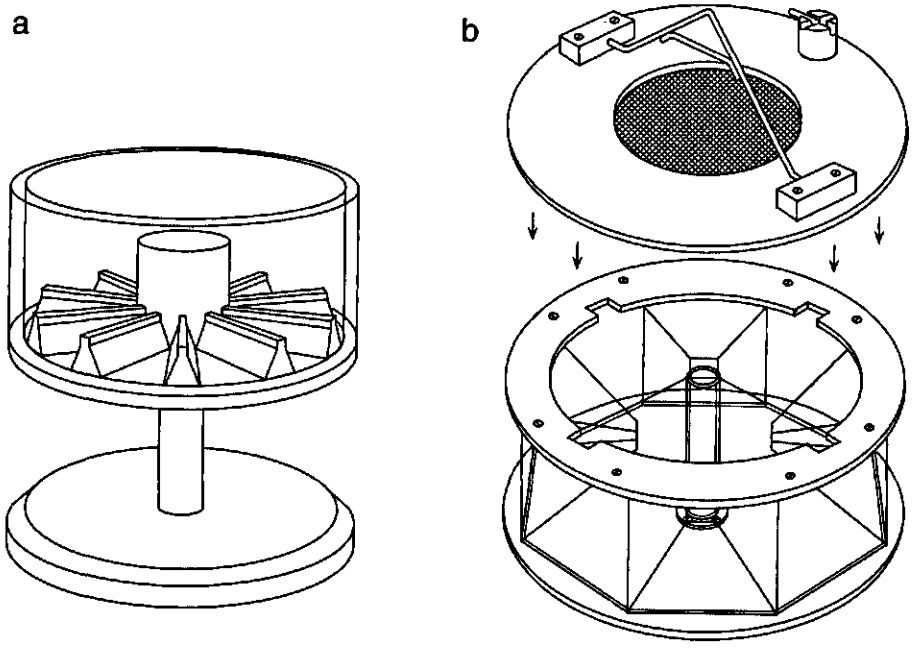

Figure 3.17 Whirling apparatus of Kott (a) and light trap (b).

Rzóska (1956, 1957, 1976) lists zooplankton species found in Lake Victoria, while seasonal variations of zooplankton in the Mwanza Gulf are described by Akyama *et al.* (1977) and Hoogenboezem (1985). Diurnal sampling for zooplankton revealed considerable differences in densities and distribution by day and night (Goldschmidt *et al.* 1990). The highest densities in the Mwanza Gulf were found at night in the top two metres of the column. Seasonal peaks in zooplankton densities were found during the dry season *(Figure IV.3)*. Information on zooplankton important to fish species in Lake Victoria is given in Appendix IV.

Insect larvae

The two main groups of insect larvae found in stomach contents of Lake Victoria fishes are chironomid and *Chaoborus* larvae. Chironomid larvae live in or on fine sediments (MacDonald 1956; Okedi 1990). Third and fourth instars of *Chaoborus* larvae live in mud bottoms during the day, but at night they move towards the water surface where they prey on zooplankton (MacDonald 1956; Goldschmidt *et al.* 1990). Therefore, *Chaoborus* can best be sampled at night with either a zooplankton net (see above) or a light trap *(Figure 3.17b)*. Although light traps yield good catches, a disadvantage of their use is that no absolute densities can be calculated since it is not known over what distance larvae are attracted. Special chemical light sticks (*e.g.* Cyalume lightsticks, green/yellow) are needed for these traps.

Sampling larvae which live in the bottom sediments is a problem due to the weak constitution of the mud bottoms in Lake Victoria. Ekman-Birge bottom grabs (*e.g.* Wildlife Supply Company, model 196) sink through the top layer of the mud, thus probably missing an important part of the bottom macrofauna. This might be overcome by using a tall modification (Edmondson & Winberg 1971) and/or by trimming the grab with floats.

There are at least two *Chaoborus* species and several chironomid species in Lake Victoria (MacDonald 1956). For further information on insects which are major food items of fish in Lake Victoria see Appendix IV.

Prawns

Proper sampling of the prawn *Caridina nilotica* is difficult in Lake Victoria as they live in beds of submerged vegetation or over muddy bottoms (Fryer 1960) where the fine meshed nets needed to capture these small organisms become clogged. Some results can, however, be obtained by using a small lift net (110x110 cm; 8 mm stretched mesh). This net can be hauled from any chosen depth in the water column. Before lifting the net it should be kept at the chosen depth for ten minutes to prevent sampling in a recently disturbed habitat. With this net an indication of the vertical distribution of *Caridina* over the water column has been obtained (Appendix IV; Goldschmidt *et al.* 1993). *Caridina* can also be sampled at night with light traps. However, as discussed above, this technique is not suitable for the estimation of absolute densities.

Oxygen and temperature

Oxygen concentrations and temperature are often factors determining the distribution patterns of fish. There are indications that, in Lake Victoria, *Lates* and *Rastrineobola* migrate upwards if low oxygen concentrations occur near the bottom due to stratification (Wanink *et al.* 1988; Ligtvoet & Mkumbo 1990; P.C. Goudswaard *et al.* in MS). Temporary thermal stratifications with low oxygen concentrations (less than 3 ppm) below the thermal discontinuity have been observed in offshore and sub-littoral areas of the lake (Fish 1957; Talling 1966; Van Oijen *et al.* 1981; Ochumba & Kibaara 1989). HEST used a combined oxygen-temperature meter made by Yellow Spring Instruments (model 57) for measurements. This instrument is suitable for estimating oxygen concentrations, but the thermometer is not accurate enough to indicate the subtle but constant temperature differences which can occur in tropical waters. For this purpose the use of a thermometer with a relative precision of 0.05°C is recommended (J.F. Talling pers. comm.).

When measuring an oxygen profile it is important to take care that the probe sinks straight to the bottom. The research vessel should therefore be at anchor and the probe should be lowered with a line with a sinker attached (do not attach sinker to the cable of the probe because this may damage the cable). As the probe itself 'uses' oxygen, the oxygen pressure in the water layer in contact with the membrane will decrease continuously. Thus a stirrer should be attached to the probe, or the probe should be moved manually by short jerks on the line to which it is attached. If the probe is moved from one point to another in the water column one should check carefully that it is adapted to the new environment before reading the new value. It is useful to measure each profile twice, from top to bottom and bottom to top. Information about calibration, correction for altitude and care of the probe can be found in the manual of the instrument.

Transparency

Transparency in a lake fluctuates temporally *(Figure 1.7)* and spatially due to differences in plankton density and turbidity caused by the up-stirring of sediments during periods of mixing, and by the silt-load of inflowing rivers. The transparency of the water can be measured with a Secchi disc. Secchi disc visibility depth (in m or cm) is the depth at which a white disc (or disc with black and white quadrants) with a diameter of 20-30 cm is just visible. During the period of HEST/TAFIRI research, light measurements were also carried out with an underwater photometer (LI-192 SA underwater quantum sensor and LI-185 B quantum/radio/photometer). Four broad-band filters were used to measure spectral distribution (de Beer 1989). It appeared that longer wavelengths (orange and red light) penetrate deeper into Lake Victoria than the shorter wavelengths (blue light) due to high amounts of organic debris (de Beer 1989).

3.7 Echosounder

Echosounders have two applications; firstly to measure the depth of the water under the vessel and secondly to detect fish and other organisms in the water column. A thermocline can also be detected by an echosounder. It falls beyond the scope of this handbook to give a complete outline of the different types of echosounder and their applications, but this information can be found in Nielsen & Johnson (1989) and Johanesson & Mitson (1983).

Although there are many different types of echosounder, the principle involved is always the same. From a transducer, which is fixed under the ship and connected to a recorder on deck, a pulse of sound is transmitted into the water. If this pulse encounters an object, some sound is reflected back from it as an echo. By measuring the time between the transmitted pulse and the receipt of an echo, the distance to the reflecting object is calculated. Sophisticated equipment can also measure the target strength (TS), which is the strength of the echo. Cheaper equipment is usually not capable of measuring TS. Target strength can be related to the size of the fish reflecting the sound pulse. It is possible to deduce size distribution of the fish population from those signals (Nielsen & Johnson 1989).

The main problem in fisheries acoustics is that of difficulty in interpreting the echoes. Information on local species composition (fish and other organisms) is indispensable for this. This means that 'wet' sampling (trawling, gill netting, zooplankton sampling) is still necessary.

During the HEST/TAFIRI research in Lake Victoria a Lowrance Mach I echosounder with an 1192-8' transducer was used. With this equipment, objects larger than 8 mm can be detected. This means that it should be possible to detect all major fish species (*Lates*, *Rastrineobola*, tilapiines), the shrimp *Caridina*, and the larvae of insects like *Chaoborus* if they occur in the water column. In practice the interpretation of the signals on the recordings was often a problem. However, during 24 hour sessions in the Mwanza Gulf it was possible to record and follow the diurnal migrations of *Chaoborus* larvae and *Rastrineobola (Figure 3.18)*. Some examples of echosounder readings from Lake Malawi can be found in Rufli (1982).

3.8 Statistics and sampling design

After having discussed how characteristics of fish and water can be collected and quantified, the next question concerns the number of measurements that are needed to draw useful

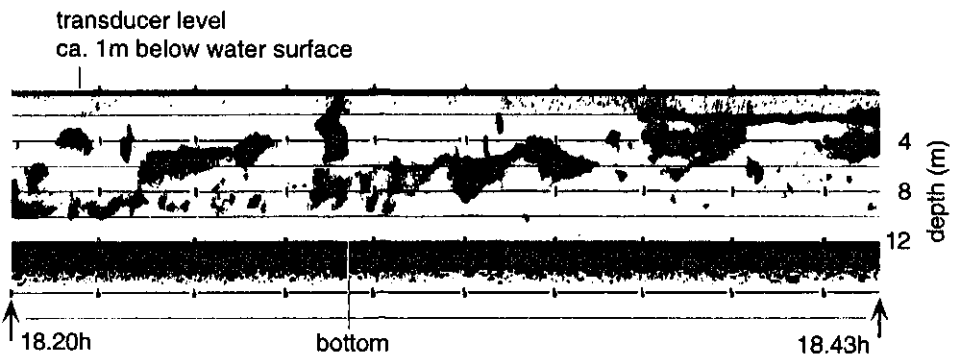

Figure 3.18 Echosounder recording made with a Lowrance Mach I echosounder on 11-2-1989 in the Mwanza Gulf. Recording was done between 18.20 and 18.43 h (dusk). The dark clouds are probably *Chaoborus* larvae and *Rastrineobola* migrating upwards in the water column. Recording was done with a stationary transducer (*i.e.* the boat was anchored). The depth of the water column was 12 m.

conclusions. If too few observations are made, no valid conclusions can be drawn, but on the other hand too many observations are a waste of time and money. By a statistical analysis the number of observations required to draw reliable conclusions can be estimated and the accuracy of results can be assessed.

Statistical methods are commonly used to interpret and summarize the observations. Some observations, like the length and weight of an individual fish, are related to each other. This relationship can be described in mathematical terms, or in terms of its strength or weakness. A researcher may also be interested in differences between observations, *e.g.* whether the average catch per net in the gill net fishery of the Mwanza Gulf is higher or lower than that in the Speke Gulf, or whether the condition of female *Lates* is significantly better or worse in the month of May than in the rest of the year.

An outline of the statistical methods used in fisheries research and management is not included in this handbook. Instead, references to several commonly used textbooks and manuals are given and their contents are briefly discussed. Full references to the books and reports mentioned here can be found in the reference list. An introduction to statistics can be found in Chapter 2 of *Introduction to tropical fish stock assessment* by Sparre & Venema (1992). This is an FAO Fisheries Technical Paper and as such it is widely available. The examples and exercises are fishery-related. In Chapter 2, entitled Biostatistics, of the manual by Sparre, the most elementary statistical methods are explained. The topics discussed are: mean value and variance, normal distribution, confidence limits, linear and functional regression analysis, linearization. In addition, basic sampling techniques (simple random sampling and stratified random sampling) are explained in the context of their application to the estimation of total catch weight in professional fishery. A method is described for calculating the sample size required to obtain a result with a pre-determined precision.

Bazigos, a fisheries statistician who worked for the FAO, produced several technical reports on fisheries statistics: *Applied fisheries statistics* (Bazigos 1974a), *Fisheries statistics, African inland waters* (Bazigos 1974b) and the more recent FAO Fisheries Technical Report *Statistical sampling surveys in manpower limited situations* (Caddy & Bazigos 1985). *Applied fisheries statistics* basically covers the same topics as summarized in Sparre & Venema (1992) but statistical tests and the analysis of variance (anova) are also discussed. The examples are fishery-related. The other two reports deal mainly with sampling strategies for catch and effort, and with the collection and processing of catch statistics.

The reports mentioned above all have as the advantage that they are fisheries-related. By getting acquainted with them, one can obtain an overview of most common statistical methods and their uses in fishery research and management. However, if a deeper understanding of statistics is required, reference to a general statistics textbook or to specialized publications is recommended. Textbooks offer a more elaborate explanation of statistical theories, through which statistical methods become more understandable. Further, some important issues are more completely discussed in them, such as under which circumstances certain tests or methods can be validly applied.

Statistical textbooks are written from different background points of view, *e.g.* sociology, medicine, agriculture and ecology. Those with an ecological backgound are most suitable for fisheries work, although it is certainly not the case that textbooks with examples from other disciplines cannot be used for fishery-related problems. A statistical textbook with a biological background is *Biometry* by Sokal & Rohlf (1981). The information presented in this book is readily accessible and most topics are touched upon. Some subjects, including non-normal distributions and non-parametric methods, are dealt with briefly. An overview of non-parametric methods is presented in *Practical non-parametric statistics* by Conover (1971). This book contains examples from several disciplines. An account of non-normal distributions can be found in *Some methods for the statistical analysis of samples of benthic invertebrates* by Elliott (1983). This book is not widely available. Since, in fishery science, non-normal distributions are rather the rule than the exception, the methods presented in the latter two books are useful additions to those in Bazigos (1974a) and Sokal & Rohlf (1981) for fishery-related problems.

If more information on sampling statistics is needed, see *Sampling techniques* by Cochran (1977). This book is particularly useful when dealing with the collection of catch and effort statistics from a commercial fishery, although there are no fishery-related examples in this book.