ICCAT FIELD MANUAL:
Chapter 4. Data for Assessment and Research

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4.1 Introduction and statistical basics

This chapter is designed to provide an overview of the data requirements for assessment and research within ICCAT.

To this end, it provides the reader with a basic understanding of how to design data collection programmes, through sampling of vessel catches, and how to ensure these are representative of the entire population (section 4.2). This theme is repeated throughout this chapter, but readers should refer to this section initially. One of the main forms of data collected routinely is length data. The collection of this data, and its use to estimate the age structure of catches, is detailed in section 4.3. Another source of stock status information used in assessments is catch per unit effort (CPUE), commonly derived from vessel logbooks. These data need standardisation over time between areas as well as between the different vessel categories or fishing gears, to ensure signals in the data are consistent. The issues involved in the use of CPUE data are detailed in section 4.4.

When managing stocks, a number of biological attributes are highly important. These include the geographic range and boundaries of a stock, its interaction with sub-stocks, and patterns of migration. A number of techniques are available to examine these factors, including genetic methods (section 4.5), and tagging (sections 4.6 and 4.7). Within defined stocks, knowledge on the reproductive patterns of large pelagics, as well as the characteristics of growth and mortality, will largely define the regenerative capacity of a population. Hence they are extremely important for management and conservation, and the construction of reliable models for effective stock assessment. Methods to investigate these biological attributes are detailed in sections 4.8 and 4.9. It should be noted that most of these approaches require invasive examination of the fish. As a result of the high value of most tuna species, length information is commonly the only data that can be collected without buying individuals or starting a fishery-independent research programme.

A key approach to collecting information on a wide range of fishery-related characteristics, including searching patterns, characterisation of fishing effort, bycatch and discard mortality, plus the collection of accurate biological information, is through scientific observer programmes. Section 4.10 discusses basic approaches to optimise observer coverage, the forms of information that can be collected, and the important issue of estimating bycatch from observer data.

4.1.1 Biostatistics

Much of this manual contains details of the statistical methods used within the areas of interest. To assist understanding, this section provides a simple and brief reminder of the basic statistical concepts. For further information, readers are urged to refer to other texts on biostatistics, including "Biometry" by Sokal and Rohlf (1995) that contains both the theory behind approaches and useful examples of their use on data, "Sampling techniques" by Cochran (1977) and "Sampling" by Thompson (1992). Sparre and Venema (1998) also provide an excellent manual for tropical fish stock assessment, from which much of this section is sourced.

Mean value and variance

Consider a sample of n fish of a single species, all caught in a single set, and let x(i) be the length of fish no. i, i=1, 2, …, n. The mean length of the sample is defined as:

$$\bar{x} = \frac{\left[x_{(1)} + x_{(2)} + \ldots + x_{(n)}\right]}{n} = \frac{1}{n} * \sum_{i=1}^{n} x_{(i)}$$

As an example, if 12 fish were sampled of lengths (cm) of 176, 175, 162, 174, 161, 156, 178, 158, 195, 171, 177 and 154, the mean length of this sample would be:

$$\bar{x} = \frac{\left[176 + 175 + \ldots + 154\right]}{12} = \frac{1}{12} * 2037 = 169.75$$

The sample variance, a measure of the variability around the mean value, is defined as:

$$s^2 = \frac{1}{n-1} * \left[\left(x_{(1)} - \bar{x}\right)^2 + \left(x_{(2)} - \bar{x}\right)^2 + \ldots + \left(x_{(n)} - \bar{x}\right)^2 \right] = \frac{1}{n-1} * \sum_{i=1}^{n} \left[x_{(i)} - \bar{x} \right]^2$$

Usually this is calculated as $\sum x^2 - \left(\sum x\right)^2 / n / (n-1)$ to avoid rounding errors.

The variance is therefore the sum of the squares of the deviations from the mean divided by the number (n) minus one. If all fish in the same had the same length, therefore, the variance would be zero. For the sample of lengths detailed above, the variance would therefore be:

$$s^2 = \frac{1}{12-1} * \left[(176 - 169.75)^2 + (175 - 169.75)^2 + \ldots + (154 - 169.75)^2 \right] = \frac{1}{12-1} * 1556.25 = 141.48$$

The square root of the variance, s, is the standard deviation. In the example, s=11.89. Variance can also be expressed relative to the size of the mean, as the coefficient of variation. For this, the standard deviation is relevant since it has the same unit as the mean. The coefficient of variation is:

$$\frac{s}{\bar{x}}$$

From the example, the coefficient of variation (CV) is:

$$\frac{11.89}{169.75} = 0.07$$

Much of statistics relies on the 'normality' of data. This essentially means that the data (and the population from which they are taken) conform to a normal distribution:

$$Fc(x) = \frac{n * dL}{s * \sqrt{2\pi}} * \exp\left[- \frac{\left(x - \bar{x}\right)^2}{2s^2} \right]$$

where Fc(x) is the 'calculated frequency', n is the number of observations, dL is the interval size (of the measurement in question), s=standard deviation, $\bar{x}$ the mean length and π=3.14159…

A normal distribution is often observed for older, larger fish (young, small ones would need some negative values to be normally distributed) when recording length frequencies of fish from a single cohort (i.e. fish of the same age), and the probability of a fish more or less than a given size in the sample can therefore be estimated. Other probability distributions exist (e.g. lognormal), where the distribution of measurements is skewed, rather than being centred around the mean as in the normal distribution.

The concepts of bias and precision arise from the consideration of means and distributions **(Figure 4.1.1).** An estimate from a sample is said to be unbiased if the average of many replicate estimates is the same as the true value (that would be achieved if all specimens in the total population were sampled). An estimate is biased if it deviates from the true value in a systematic manner. For example, if estimates of mean length from samples were always greater than the true length in the population. This could occur due to the selectivity of the gear. With an unbiased sample, the true value can be more closely approached by increasing the sample size. This is 'consistency'. With a biased estimate, there will always be a difference between true and estimated values.

To obtain an unbiased estimate, a random sample should be taken. In this case, any fish sampled from the stock (as an example) should have exactly the same probability of being sampled. True random samples are often difficult to achieve in practice, however.

Precision is a measure of whether samples or estimates are 'precise'. In this case, the variance around the mean value of the sample or estimate is low (**Figure 4.1.1**). This does not necessarily mean the sample or estimate is unbiased – they can be precise (clustered closely around a given value), but biased (that given value is not equal to the true mean, for example).

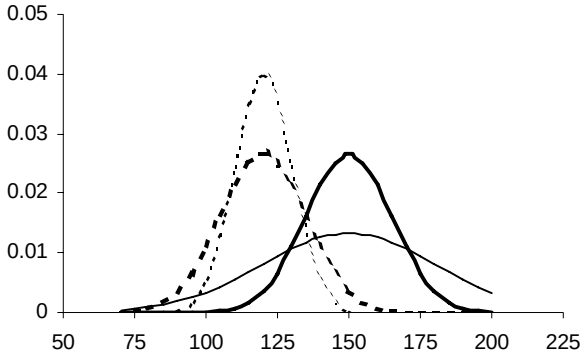

Figure 4.1.1 Demonstration of bias and precision. The normal distribution indicated by the thick black solid line represents the population distribution. The thin solid line represents an unbiased but less precise distribution (the mean is the same as the population, but the spread is wider). The distribution represented by the thick broken line represents a biased sample - the distribution has identical variance to the true population but the mean value is lower than the true value. The distribution represented by the thin broken line is biased, but more precise.

4.1.2 Further reading

COCHRAN, W.G. (1977). Sampling techniques. New York, J. Wiley & Sons, Inc.

SOKAL, R.R. and F.J. Rohlf (1995). Biometry: the principles and practice of statistics in biological research. W.H. Freeman and Company, New York.

SPARRE, P. and S.C. Venema (1998). Introduction to fish stock assessment. Part 1. Manual. FAO Fish. Tech. Pap. 306(1), FAO, Rome.

THOMPSON, S. K. (1992). Sampling. John Wiley & Sons, Inc. 343p.

4.2 Sampling catches, effort, CPUE and size

In principle, there are two data collection methods: complete enumeration, and sampling. A frame survey or fishery census is generally conducted by complete enumeration. For estimating the total annual catch, complete enumeration would be ideal. This is generally beyond the budget of most fisheries research centres, however. As a result, an appropriate sampling system is required to provide representative data that can be raised to the total fishery. A diagrammatical representation of the processes that can occur when assessing catch levels for Task 1 information is presented in **Figure 4.2.1**.

This section briefly considers statistical and related practical aspects of sampling tuna fisheries and fish in various ways in order to estimate summarising statistics for total landings, fishing effort, and size and other biological characteristics of the fish. Section 4.2.1 is a guide to basic sampling theory in the context of tuna fisheries. Section 4.2.2 describes and comments on common statistical sampling designs, and section 4.2.3 discusses sampling precision. Section 4.2.4 turns to more practical matters. It summarises the main different sources of information about tuna stocks and fisheries, drawing attention to their strengths and weaknesses, and suggests practical ways to sample and estimate in the light of the preceding statistical discussion. Section 4.2.5 presents potential problems in total annual catch statistics, and possible solutions. Finally, section 4.2.6 considers the raising of sample estimates to estimates for an entire fishing fleet or for a fish stock within a standard ICCAT time-area stratum, e.g. 5º×5º×month, 1º×1º×month.

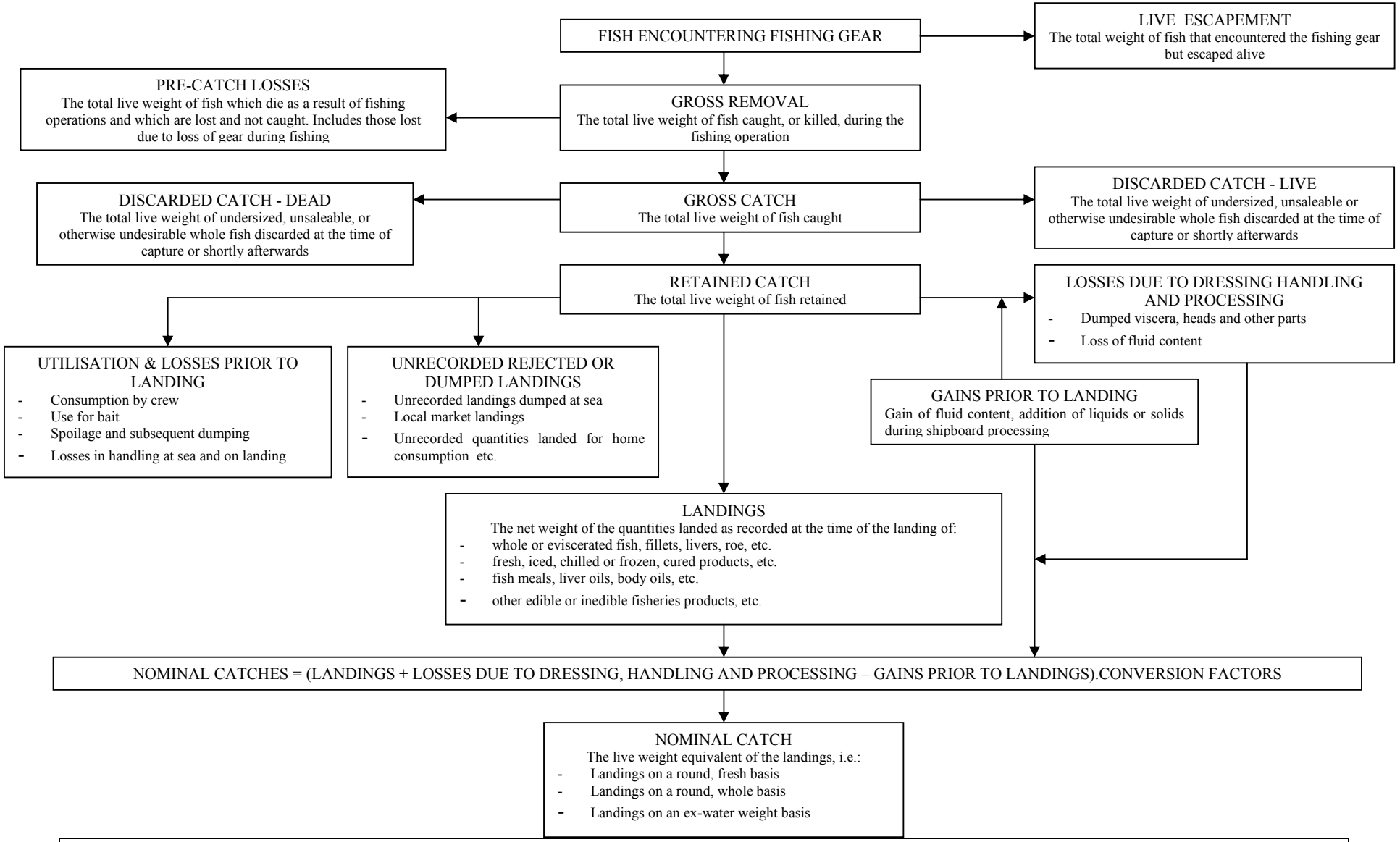

Figure 4.2.1. Diagrammatic representation of the concepts involved in the estimation of nominal catch

4.2.1 Sampling basics

Scientific sampling

Sampling is essential when we wish to describe or make inferences about a population that is too big to permit observation of every individual member. Scientific sampling requires that there be a relationship between the population and the sample. Two philosophies for this are (Thompson, 1992):

- Design-based sampling in which the relationship consists of a probabilistic rule for selecting individuals for observation; e.g. simple random sampling.
- Model-based sampling in which the population is a hypothetical construct based on a mathematical model whose parameters are estimated from the observed individuals; the model includes random errors, *e*; e.g. $Age = f(Length) + e$.

Design-based sampling allows descriptive statistics such as the mean, variance, and frequency distributions to be estimated with no assumptions about the population. These statistics are *design-unbiased*, i.e. they are expected to fall around the true value with repeated sampling by virtue of the probabilistic sampling design. Model-based sampling, on the other hand, allows the model to be fitted with no assumptions about the sampling. The estimated parameters are *model-unbiased*, i.e. they are unbiased if the model is true and complete.

In practice, both philosophies require compromises because probability sampling can seldom be ideal, and no model is ever completely trusted (Burnham and Anderson, 2002). However, a random sample is usually suitable for fitting a model, whereas a sample taken to optimise the fit of a model is likely to be biased and inefficient for estimating descriptive statistics. Furthermore, sampling design is more or less within the control of the sampler depending on practical constraints, whereas incomplete knowledge of the important explanatory variables needed to model a fishery without bias probably cannot be rectified easily by a modeller. Modelling is an important research tool in fisheries science but a design-based approach based on the best practical approximation to a probability sampling scheme is advocated here for the collection of basic statistics about tuna fisheries.

The population

The population to be sampled and the nature of its individual members, called the *sampling units* (s.u.), should be carefully considered before designing a fishery sampling scheme because it is likely that the *observable population*[1] will be a subset of the *population of interest*. For studies of a fishing fleet, the population of interest may comprise all vessels in the fleet but the observable population may only consist of those vessels that are accessible in nearby ports. For biological studies, the population of interest may be all fish in the stock but the observable population may be restricted to the accessible part of the total landings from the stock. Since the population of interest cannot be sampled, a link between it and the observable population must be assumed. For fishing fleets, for example, assuming that the unobserved part of the fleet behaves in the same way as the observed part would provide the link and would require only a raising factor to convert survey estimates to estimates for the population of interest. For biological sampling, the observable landings, L, may be related to the stock, W, by a catchability function, q, of length, l, and fishing effort, E:

$$L_l = q(l).E.W_l$$

Such a model assumes that fishing is random with respect to the fish (Hilborn and Walters, 1992, p. 177). In both examples the assumptions are strong and may be controversial. The population of interest, the observable subset, and the assumed link between them should be stated explicitly in any sampling report. In the following text, the word 'observable' will be intended if not stated with 'population'.

Randomisation

Statisticians call for random selection of sampling units so that estimation of parameters for the population can be justified by probability theory. In practice, this is often very difficult to achieve. The merits of striving for randomisation can be explained intuitively as follows. Consider the relatively simple task of estimating the average length of fish in the landings of a fishing vessel using simple random sampling. The constitution of the landings will have been affected by many influences such as the localities of the hauls, the season, the weather, the shift of crew that sorted the catches, etc. If the sample is collected from a restricted location in the bulk of the landings it may only reflect part of one or a few hauls taken in restricted circumstances, and the mean length of

[1] 'Observable population' is intended as a more self-explanatory term than 'sampling frame' of sampling theory.

that sample may, as a result, be very different from the (unknown) mean length for the bulk. In addition, the variability within a restricted sample is likely to be less than that in the bulk, meaning that the variance and confidence limits around the estimated mean are under-estimated, giving a spurious impression of good precision. By sampling fish as nearly as possible from randomly chosen locations in the bulk, the factors influencing the length of fish present can be expected to have the same proportionate effects on the sample. In statistical terms, randomisation provides (design-) unbiased estimates of the mean and variance. Achieving the best approximation to randomisation in different practical situations is discussed in section 4.2.4.

Information

Fishery sampling is usually costly so as much information should be taken and preserved from each sampling unit as possible. The information provided about the population by a single sampling unit depends on:

- The number of variables measured on the sampling unit, e.g. length, age, and maturity may all be measured on each fish drawn from a catch, although often only length is readily available.
- The relationships between those variables. e.g. maturity of fish is related to age. The observed values of different variables should be stored together and analysed as a vector for each sampling unit so that these relationships are preserved, e.g. for modelling. If not, information is lost.
- The precision of measurement. This is more of an issue for some variables than others. e.g. fishing effort is hard to measure on a certain type of vessel; maturity stage may be difficult to determine accurately for a fish. Ideally, the precision of measurements will be estimated for difficult cases by different people making independent measurements of the same variables on the same set of sampling units. A large measurement variance could negate the benefits of an elaborate sampling design carried out with much cost and effort.
- Whether the sampling unit was selected at random or by conscious choice. In the latter case, some of the information provided by the sampling unit relates to the method of choosing, i.e. to the bias, not to the population. An estimate is 'unbiased' if the average over many repetitions of sampling equals the true population value. Bias is not necessarily bad if it is constant and this is often a necessary assumption in fisheries work.
- The variance, σ^2, of sampling units in the population; the information provided by a sampling unit is proportional to $1/\sigma^2$. σ^2 is estimated by the sample variance, s^2.

The information provided about the population by a sample of $n > 1$ sampling units depends on:

- Whether the sampling units were drawn independently or in a pattern. The variance of the sample mean is estimated by s^2/n where n is the number of sampling units in the sample, but this is only true if the sampling units were drawn independently. Sampling units that are close together in space or time tend to be more similar than sampling units that are distant. Thus sampling units that are collected in a pattern will carry information that relates to the pattern and not to the population. For the same reason, sampling units drawn from compartments of a population are more likely to be similar within the compartments than among different compartments. Compartmentalised populations are common, e.g. fish arranged in a market by vessel, possibly also by size category; vessels using a particular port; fishing trips within a quarter. Statistical sampling schemes such as stratified, and multistage sampling are designed to isolate the variance among compartments; the sampling units are located independently and randomly within them. [Modellers would use mixed models to estimate the variances among compartments (Pinheiro and Bates, 2000).]

The number, n, of sampling units to include in a sample is usually a matter of taking as large an n as possible with the available sampling staff and resources. A more scientific approach requires decisions about the minimum acceptable precision, and the confidence level needed for a statement about whether the precision was achieved. These values may then be applied to sample size formulae, e.g. Thompson (1992, chapter 4; see box below) assuming that all sampling units are independently drawn.

Estimating sample size (based on Thompson (1992))

A population parameter θ (e.g. population mean) is to be estimated using an estimator $\bar{\theta}$. The aim is for the estimate to be close to the true value with high probability.

If the estimator $\bar{\theta}$ is an unbiased normally distributed estimator of θ, then $\frac{\bar{\theta}-\theta}{\sqrt{\text{var}(\bar{\theta})}}$ has a normal distribution. Using z to denote the upper $\alpha/2$ point of the standard normal distribution,

$$P\left(\frac{|\bar{\theta}-\theta|}{\sqrt{\text{var}(\bar{\theta})}} > z\right) = P\left(|\bar{\theta}-\theta| > z\sqrt{\text{var}(\bar{\theta})}\right) = \alpha$$

Variance of the estimator $\bar{\theta}$ decreases with increasing sample size n, so if the sample size is increased far enough, $z\sqrt{\text{var}(\bar{\theta})} \le d$, where d is the maximum allowable difference between the estimate and the true value.

When estimating a population mean with simple random sampling, the sample mean $\bar{y}$ is an unbiased estimator of the population mean μ with variance $\text{var}(\bar{y}) = \frac{(N-n)\sigma^2}{Nn}$, where N is the population size, n is the sample size and σ^2 the population variance. Setting

$$z\sqrt{\left(\frac{N-n}{N}\right)\frac{\sigma^2}{n}} = d$$

and solving for n gives the necessary sample size:

$$n = \frac{1}{\left(\frac{d^2}{z^2\sigma^2} + \frac{1}{N}\right)} = \frac{1}{\frac{1}{n_0} + \frac{1}{N}}$$

where

$$n_0 = \frac{z^2\sigma^2}{d^2}$$

If the population size N is large relative to the sample size n, so that the finite population correction factor can be ignored, the formula for sample size simplifies to n_0.

For sampling designs more complex than simple random sampling, sample size can generally be selected in the same way, with sample size determined so that the half-width of the confidence interval equals the specified distance.

As an example, we try to identify the sample size needed to estimate the mean length of a large tuna population within 1cm of the true mean with 95% confidence (α=0.05). The variance from previous samples thought to be representative of the population distribution is 52.2cm. Given the large population size, the formula for n_0 can be used. This gives:

$$n_0 = \frac{(1.960^2) * 52.2}{1^2} = 200.53 \sim 201$$

where the constant 1.960 is the upper α=0.025 point of the standard normal distribution.

If relative error (r), the difference between the estimate and the true value, divided by the true value, is of interest, then the following criterion must be met:

$$p\left(\left| \frac{\bar{\theta} - \theta}{\theta} \right| > r \right) < \alpha$$

To estimate the population mean μ to within $r\mu$ of the true value with probability 1-α, the sample size formula is:

$$n = \frac{1}{\left(\frac{r^2 \mu^2}{z^2 \sigma^2} + \frac{1}{N} \right)}$$

If γ represents the coefficient of variation for the population, i.e. $\gamma = \frac{\sigma}{\mu}$, the sample size formula can be written:

$$n = \frac{1}{\left(\frac{r^2}{z^2 \gamma^2} + \frac{1}{N} \right)}$$

Therefore, the coefficient of variation is the population quantity on which sample size depends when relative precision is to be controlled.

Unfortunately, customers for fisheries data tend to be unwilling to specify precision and confidence less than "as good as possible", so the pragmatic approach – which is incidentally much less work – is likely to be most popular, especially as few important fisheries are over-sampled. There is however a more important question which is how sampling resources should be directed among different sources of information, e.g. logbooks, landings, and catch sampling at sea. This depends on relative costs and available precision, the uses to which the combined data are put, and the independence maintained in the different data sets. No easy formulae are available to solve the problem generically and each case will probably need a research project. An example of such a project was by Beare *et al*. (2002) who used bootstrapping with different levels of random error to assess the influence of abundance indices on a stock assessment.

4.2.2 Sampling designs

Thompson (1992) describes a wide variety of statistical sampling designs and the estimation formulae to go with them. Other good sampling texts are by Cochran (1977), Raj (1968), and Sukhatme and Sukhatme (1970). The focus here is to introduce sampling designs likely to be most readily suitable for fisheries work. The final sub-section comments on the optimisation of survey efficiency.

Simple random sampling without replacement

Simple random sampling (srs) means that each sample of n different sampling units (s.u.) drawn from a population of N has an equal probability of selection. A table of random numbers, or, in many circumstances, the best practicable simulation of one, is used to pick sampling units 'without replacement', i.e. so that no unit can occur more than once in a sample. Simple random sampling may be used on whole populations, on pre-defined subsets of them, e.g. within sampling strata, or within the hierarchical stages of a multi-stage sampling scheme (see below). Simple random sampling is a sensible sampling scheme when there is no prior information about the likely values of the variable of interest on different sampling units. If such information does exist and is known to be reliable, it can be used to design other sampling schemes that would deliver better precision per observation. Simple random sampling is satisfactory when you have no interest in variation of the variable over time or space. It has the valuable advantages of being simple to implement and to estimate from. Simple random samples are often adequate for fitting models, or for 'post-stratification' after sampling if there is a need to look at results by some variable such as e.g. age or sex.

Simple random sampling with replacement

Simple random sampling 'with replacement' means that an individual sampling unit is replaced in the population whenever it is drawn for the sample. Thus a sampling unit may occur more than once in any sample. Under simple random sampling with replacement, each possible sequence of *n* sampling units has equal probability. Ordinarily, this would be inefficient but it is useful when the possibility of repeated observations on one individual sampling unit is needed, e.g. to draw multiple trips on one vessel for observation.

Sampling with probability proportional to size

Sometimes prior information indicates that certain 'large' sampling units are likely to display a larger value of the variable of interest than 'small' sampling units. E.g. large fishing vessels may be expected to catch more fish than small. With sampling with probability proportional to size (pps) every sampling unit is assigned a probability of drawing that is proportional to the expected value of the variable of interest. A simple way to draw a probability proportional to size sample is to form a list of all sampling units in the population together with their assigned probabilities. Cumulative probabilities from zero to one are put in an additional column. Uniform random numbers from 0 to 1 are drawn and matched to the cumulative probabilities to find the next selected sampling unit. Probability proportional to size sampling is more efficient than simple random sampling, possibly much more, but only if the prior information used to assign selection probabilities is reliable. Otherwise it can be worse (Cotter *et al.*, 2002) and may not be worth risking. Special estimation formulae are needed to correct probability proportional to size for the sampling bias towards 'large' sampling units. Probability proportional to size is an alternative to stratification of sampling units by size and may be easier to implement.

Systematic sampling

In this scheme, there is a fixed distance or number of sampling units between each sampling unit selected for the sample, i.e. sampling locations are arranged in a one- or higher-dimensional grid. There have been many applications in marine science when a spread of observational effort over space and/or time is wanted, e.g. taking a measurement every *x* hours, surveying fish over a 2-dimensional grid of geographic points, etc. Estimation of means and variances from systematic samples often uses the formulae for simple random sampling without replacement but there are risks of bias in doing this due to the pattern of the sample:

- Trends or oscillations in the variable of interest may mean that the sampling grid finds more high values than low, or vice versa.
- Periodicity in the variable of a wavelength comparable to the grid interval may mean that most of the observations fall at the high or low part of the oscillations. This type of bias is called 'aliasing'.

The starting point and orientation of the grid should be chosen randomly within the region of interest if that is feasible. Systematic samples are generally good for modelling over the time or spatial dimensions of a grid but another risk then arises. It is well known that arrangements of purely random numbers along a linear axis will often suggest the presence of trends (Kendall, 1976, para. 3.17) so any modelling of apparent trends over a grid should be supported by sound prior reasons for including the explanatory variables.

Stratified sampling

Samplers often compartmentalise a population into geographic, temporal, biological (e.g. length) or fishing mode (e.g. FADs versus free school) sampling 'strata'. This can be for two reasons:

- To distribute observational effort evenly over space and time.
- To use prior information about variation of the variable of interest to improve the efficiency of the survey for estimating an overall mean and variance.

The first reason is common and valid for many practical purposes but is not necessarily statistically efficient for estimating a mean value. Samples are usually collected within each stratum by simple random sampling, or the best approximation to it. For best statistical efficiency, stratum boundaries should be located so that the within-stratum variances are as small as possible; i.e. locate the boundaries where discontinuities, or the steepest gradients occur in the variable of interest. Efficiency is also affected by the sample sizes allocated to each stratum. Proportional allocation assigns an equal number of observations per unit area or time. It is often a sensible choice when stratification is for the first reason. Optimal allocation assigns observations to each stratum in proportion to its size and its within-stratum standard deviation. This makes sense when stratification is for the second reason.

Stratified random sampling schemes require that at least two sampling units be located in every stratum in order that overall variance can be estimated. In practice though, 2 sampling units do not give a reliable estimate of a

within-stratum variance even if there are no missing values, and many more than 2 sampling units are preferable. There is a danger that a requirement to estimate a variance will lead to over-sampling of the least variable strata, causing expensive inefficiency. Strata can be thought of as a luxury: keep their number to a minimum when you do not have large resources for sampling, and settle for less geographic and/or temporal information. The estimates will then be more precise and dependable.

Multistage sampling

Fisheries scientists frequently encounter hierarchically structured populations; an example is fish within catches within fishing trips within vessels within a fleet. Such a population of fish could conceivably be sampled by simple random sampling ignoring the hierarchical structure but this is often impractical to arrange, e.g. if observers would have to transfer from one vessel to another at sea to sample different catches. A more convenient procedure is to draw a sample of 'primary' sampling unit (p.s.u.) at the highest level first, then a sample of 'secondary' sampling unit (s.s.u.) from each principle sampling unit drawn, then a sample of 'tertiary' sampling unit (t.s.u.) from each secondary sampling unit, and so on. For the example (and ignoring practical issues discussed below for observer surveys), one would first draw a sample of vessels (p.s.u.), then a sample of trips (s.s.u.) made by each drawn vessel, then a sample of catches (t.s.u.) from those fished on each drawn trip. Having sampled in this way, standard formulae are available for estimation of the mean and variance at each level. Theory also exists to examine the variance at each level and to adjust sample allocations among levels to improve efficiency. However, the improvements will not necessarily be practicable in a fisheries context.

Optimisation of sampling

Sampling is an expensive business, not just in fisheries, and much statistical attention has been given to maximising the quantity of information obtained per observation by variation of sampling designs, sample allocations, and formulae for estimation. Application of these ideas in a fisheries context can however be disappointing firstly because sample survey design is often tightly constrained by geographic and logistical factors, and secondly because fishery surveys tend to be concerned with more than one species. A survey that is optimal for one species could be hopelessly inefficient for another due to different geographic distributions etc. A multivariate approach may be possible using a principal component in place of the result for a single species to optimise the survey. However, when different species become relatively more important, there will be a high risk of finding a major lack of information. Ease and reliability of implementation tend to have more relevance to the design of fishery surveys than statistical efficiency.

Trials of intensive sample collections of either continuous large-size samples or repeated samples of smaller size are recommended to audit the quality of the sampling. Using this type of trial allows the assumption that the perception of the population is unaffected by the sampling regime.

4.2.3 Estimating precision

A precisely estimated statistic is here taken as one that falls closely around a fixed value on repeated sampling. An accurately estimated statistic is one that falls closely around the true value for the population on repeated sampling (see also section 4.1.1). Thus the sample variance of the statistic estimates precision; it estimates accuracy only if the sample and the estimation formula are unbiased. The mean square error is the sample variance plus the square of the bias. It estimates accuracy but since the bias is seldom estimable in fisheries work it is little used and the concept of precision measured as 1/(sample variance) is of more use.

The sample variance is estimable in many cases from analytic formulae given in sampling texts. An important assumption is that every observation is made independently (c.f. section 4.2.1) which will usually be the case if sampling is randomised and in accordance with an established statistical sampling scheme. If not, the analytic formulae are likely to over-estimate sampling precision because dependence between the observations reduces the effective degrees of freedom used as the divisor in estimators of variance.

Most sampling formulae assume that the numbers of individuals in the sample and in the population are both known exactly. Consequently their variance (var) does not have to be taken into account when raising a mean for a sample to an estimate of the total for a population. If the raising factor is known exactly and x is a random variable, a basic result from mathematical statistics is that

$$\mathrm{var}(kx) = k^2 . \mathrm{var}(x) \ .$$

In fisheries work, presumption of exact knowledge about the raising factor would sometimes be too optimistic. The corresponding estimation formula when k is also a random variable independent of x is (Goodman, 1960)

$$\mathrm{var}(kx) = k^2.\mathrm{var}(x) + x^2.\mathrm{var}(k) - \mathrm{var}(k).\mathrm{var}(x).$$

An example of uncertain raising factors occurs in observer surveys when a single catch is sampled and the relative volumes of sample and catch must be estimated. The variance of the estimate for the whole catch would require the second estimator. More complicated formula must be used when k and x are not independent (Goodman, 1962; Bohrnstedt and Goldberger, 1969).

Analytic formulae may not be available, or may be difficult to use for statistics derived from a complicated estimation process; e.g. numbers-at-age based on an ALK which involves sampling for length, then sub-sampling for age (see section 4.3.6). A rough and ready approach to this problem is to compare the number and independence of observations contributing to each estimate. So, for example, the number of hard parts read for age might be used to gauge the relative precision of estimated numbers of fish at different ages particularly if the hard parts were collected on several fishing trips from different regions. However, for formal scientific work the bootstrap should be used.

The bootstrap is a computerised method that works by repeatedly sampling with replacement from an existing sample on the assumption that that sample is a good representation of the population. This is called re-sampling (Efron and Tibshirani, 1993; Davison and Hinkley, 1997). Bootstrapping an ALK created by double sampling is a two stage process: firstly the length sample is bootstrapped, then, for each re-sample created, an age sample is drawn from the available otoliths within each length class. The re-sampling should preferably follow the actual sampling process in all aspects. By repeating the re-sampling many times, a distribution is formed for the statistics of interest from which variances and confidence intervals can be estimated. Programming such a bootstrap can be complicated, and running it may take appreciable time, particularly for large samples. There is little point in undertaking the work if the original sample is thought to be seriously biased towards one locality, time period, or circumstance.

4.2.4 Information sources

Our ability to assess and forecast fish stocks and to understand migrations and processes regulating their success depends on our knowledge of the fisheries and the biology of the target species in different parts of the ocean. The total landings and total effort of a fishing fleet each year must often be estimated by a sampling procedure because collection of data from all fishing trips (a census) is too expensive or impractical. Biological information must also be obtained by sampling the fisheries because fishery-independent research vessel surveys at the scale of the Atlantic Ocean are likely to be uneconomic. This section describes three fishery-dependent methods for collecting information about the fisheries for, and biology of tuna-like species, namely logbooks, sampling of landings, and observer surveys. Other sources of information worth considering are canneries and sport fishing organisations.

The limitations of fishery-dependent information should be kept in mind (Paloheimo and Dickie, 1964; Hilborn and Walters, 1992; Swain and Sinclair, 1994; Rose and Kulka, 1999) because fishers tend to target known high concentrations of fish rather than acting as random samplers of the stock. They may therefore achieve high CPUE even though stocks are low. Furthermore, the catching power of individual vessels tends to increase over time as they are fitted with more powerful engines, and better fish finding equipment. The catching power of the fleet as a whole may also increase as a result of these changes, particularly if old vessels are replaced by new; alternatively, it may decrease due to a net loss of vessels for economic reasons.

Whether or not the following sampling procedures are adhered to, the sampling methods, formulae, and models actually used should be recorded in brief documents, here called ‘Standard Operating Procedures’ (SOPs). One individual can then take over a data gathering task from another without varying procedures, or, if procedures should be updated for some reason, a record can be kept of what changes are made and of when they occurred, as can be crucial for evaluating time-series. The SOPs should be available to ICCAT scientific groups so that the scientific value of the sampling results may be better assessed.

Logbooks:

Most fishing captains of purse seiners, longliners and baitboats will use logbooks to record the course of each voyage and the fish caught (see **Annex 1**). They may therefore be happy to use an adjusted design for the purpose of better monitoring the fishery, particularly if the design is drawn up in consultation with them and any others having an interest. A successful logbook scheme should provide low-cost information on quantities of fish retained for landing, fishing effort, landings per unit effort (LPUE), fishing strategies, and details of fishing

vessels. There may also be opportunities to collect additional useful data, e.g. on quantities of fish discarded and thus catch[2] per unit effort (CPUE). This is discussed further in section 4.4.

The success of a logbook scheme will partly depend on attitudes to it. The captain needs to understand fully the logbook and its purpose. A personal briefing and possibly some training, e.g. on species identification, may be needed. But it is also necessary for the fishery authority to take a constructive interest in all of the logbooks being completed since people soon lose interest in ignored communications. Regular examination and discussion with the captains should help prevent recurring errors or ambiguities, and regular feedback of summarised, useful information is likely to encourage continuing interest as well as serving as a check for errors. The feedback might be on a trip-by-trip basis or as a published annual report of aggregated data about the activities and landings of the whole fleet. Putting the logbook system on a laptop computer for use by the captain may be of mutual benefit if it reduces error-prone transcription work, and if the captain can then conveniently summarise or chart details of previous fishing activities.

A logbook system, however well designed, will be of low value if there are legal constraints on what the captain records, e.g. due to landings quota or restricted fishing areas. Promises that the data will be confidential may not be sustainable in a court of law and legal advice should be obtained before giving them. There may also be commercial restraints that inhibit a captain from declaring fishing positions and catches. Inadequate attention to accuracy and species identification are other potential problems for a logbook scheme, as is the omission of fish that are discarded or consumed at sea. In the absence of sampling data for unlanded fish, enquiries about policies on discarding, minimum acceptable sizes, and consumption of fish could greatly improve the scientific value of logbook data.

Installing a fishing logbook on every vessel in a fishery may not be practicable e.g. due to an unwillingness to co-operate, due to the geographic distance of a port, or due to the artisanal nature of the fishery. The possibility for bias then arises if, for some reason, vessels without logbooks fish differently from those that do. There may also be practical limits on the numbers of logbooks that can be collected and used. This, in contrast, is a sampling problem even if a large fraction of the fishing trips made are logged. Some randomisation of the vessels selected, with frequent changes, would help to diminish possibilities of biased inferences about the fleet as a whole that could result from repeatedly logging the same subset of vessels. Whatever the reason for incomplete logbook coverage of a fishery, raising the results from the observed vessels to the total fleet is needed to estimate total landings and effort (but not to estimate average LPUE). Estimation and raising are discussed in section 4.2.6.

Having decided that a logbook scheme is worthwhile, every logbook should record once **for each trip**:

- Identification of vessel, captain, owner.
- Details of vessel including type, flag nationality, gross registered tonnage, power of engines (preferably as transmitted to the propeller shaft, i.e. excluding power used for generators, refrigeration, winches, etc.); length (specifying whether length overall or registered length); capacity for fish; number of fishing crew and the times of any shifts worked (in case catch processing differs between them).
- Date, time, and port of departure and arrival including for stops during the trip.
- Time lost due to breakdowns, poor weather, or other interruptions.
- Details of any trans-shipments or landings of fish made during the trip.
- Specifications of fish finding equipment available on board;
- Generalised details of fishing gear, i.e. excluding modifications made from set to set. For nets, this would include mesh sizes (specifying whether knot to knot, or stretched mesh measurement), twine type and construction, and preferably a net plan. For long-lining the general details would include the total number of hooks, number of hooks between floats, hook type, and a general diagram of the dimensions of the longline.
- Generalised details of fishing techniques including shooting and hauling operations, typical fishing depths, immersion times, weather limitations on fishing.
- The target species for the trip, plus policies used by the crew to decide whether to discard or keep fish of different species, e.g. minimum landing sizes.
- The names of fish species that will be identified in the catch log if caught, and of those that are likely to be mixed up because they are difficult to separate or because the market does not require separation.

[2] 'Catch' is here understood to refer to retained + discarded fish. 'Landings' may be a subset of retained fish if some are consumed on board, trans-shipped, or subsequently discarded to make space for fish of higher value.

[Vernacular names are sometimes confused (e.g. bonito for skipjack) so species' identities should be checked and translated to Latin names for the logbook records archived by the fishery authority. See section 4.2.5.]

- Methods used to estimate quantities of fish retained (and discarded if possible).

Many of these details need only be copied from trip to trip.

Logbooks should record **for each day** during the trip (regardless of whether or not a catch was made) the date, noon position, position of fishing, activities, the times spent steaming, scouting for fish, and fishing, amount of fishing effort employed, and catch by species.

Logbooks should record **for each set**, whether or not it produced fish:

- Gear deployed (if it changes from set to set). Details given should be sufficient to calculate a useful measure of effective fishing effort for each set.
- Positions and times of shooting and hauling, plus way-points if the vessel did not travel directly between the two.
- Damage sustained by gear during fishing.
- Weather and sea state. Oceanographic variables by arrangement with the fishery authority, depending on the sensors available for use.
- The retained quantities of each species, and mix of species, as numbers or weights.
- And, if available, estimates of the discarded quantities of each species and mix.

Logbooks should record **at the end of each trip**:

- Total time in stated units (e.g. hours, working days, 24-hr periods, etc) spent looking for and catching fish.
- The total quantity landed as registered by a commercial scale, preferably separately for each species and mix of species.

At the end of a trip, a check should be made to see whether the total landed quantity recorded for commercial sale matches the total quantities retained from each set. A systematic estimation error could easily arise, particularly if weighing equipment is not used on board. If so, the logbook records of daily quantities retained should be adjusted proportionally so that their sum matches the total landed weight (less any quantities known to have been lost during the trip). The adjustment factor should be recorded with the data. Another way of improving the scientific value of logbook data after landing is to add more detail about the species compositions of each catch. This is possible if mixtures of species are separated and their weights recorded separately as part of the marketing process.

The days in which a vessel was searching for fish but unable to catch any must be considered as fishing days. It is often misunderstood that fishing days mean only the days that yield catches. Scouting for fish is one type of fishing activity. Therefore, the logbook must be designed and instructions added to report activities, i.e. what the fishing vessels were doing on days when no catches were made. Whether the vessel was floating due to bad weather or gear breakdown, was moving from one fishing ground to another, or was looking for a school makes a difference in counting fishing days. Another measurement of effort, widely used for small fishing vessels, is the "search time" - the amount of time per day that the boat is actively looking for fish. The "search time" is calculated by subtracting the cruising time from the "fishing day". These data can be collected from the logbook, directly by observers, or can be estimated from observer's data. Where FADs are used, new measurements of fishing effort have been introduced. These include the number of sets, number of sets obtaining a catch, and average catch size of the set. All of these should be noted by the type of fishing gear.

Effort data must be reported in number of hooks for longline and in fishing days for surface fisheries. The number of hooks between floats is also used as a unit of effort in the case of multi-species fisheries. If this is not practical, the unit of effort should be chosen to reflect the effort directly made to harvest the corresponding catch. Recommended units of effort are listed below in descending order of preference for each type of fishing gear.

Longline:

1. Total number of effective hooks used (excluding hooks which were not effective in fishing)
2. Total number of hooks used
3. Total number of sets of longlines
4. Total number of boat-days fishing
5. Total number of boat-days at sea (out of port)
6. Number of hooks between floats
7. Total number of trips (cruises) made
8. Total number of boats actually engaged in fishing

Pole and line (baitboat)

1. Total number of boat-days fishing (including searching days, whether or not fish were actually caught). The number of boat-days spent baiting should be excluded, but can be recorded separately for use in assessing bait stocks.
2. Total number of boat-days at sea
3. Total number of fishing poles used; that is, the number of crew engaged in fishing with a pole
4. Total number of trips (cruises) made
5. Total number of boats actually engaged in fishing

Purse seine, ring net, lift net (bag net), seine net, gill net, trawl

1. Total number of boat-days fishing (including all days, whether or not fish were actually caught)
2. Total number of boat-days at sea
3. Total number of searching days (excluding the time spent in setting and hauling the net)
4. Total number of trips (cruises) made
5. Total number of boats actually engaged in fishing

Trolling, handline

1. Total number of hook- (or line-) days fishing
2. Total number of boat-days fishing
3. Total number of boat-days at sea
4. Total number of trips (cruises) made
5. Total number of boats actually engaged in fishing

Traps

1. Total number of trap-days (trap units multiplied by days at sea)
2. Number of trap units in operation

FADs fishery

1. Total number of sets
2. Total number of positive sets

Landings

Sampling of landed fish may be necessary to estimate total landings by a fishing fleet. It can also provide useful information about length and age compositions, weight-at-length, maturity-at-length, and other biological characteristics of a stock although they may be restricted by a requirement to purchase fish that are dissected or otherwise damaged during observation. The present section discusses sampling of a population of landing events. Estimation and/or raising to the level of total fleet landings, or landings for a time-area stratum, is discussed in section 4.2.6.

There are a number of potential biases in examining landings (as opposed to catch), which need to be remembered. These include:

- Fish caught are generally kept until the end of the trip, and may be unloaded at a port far from where the catch was made (particularly in the case of industrialised fisheries). In this case, the area and time of landing may be quite different from those of the catch. For example, some catches in the Atlantic Ocean can be unloaded in Pacific or Indian Ocean ports the year following the year of the catch was taken.
- Fish may be processes to some extent on board the vessels (e.g. dressed, filleted, gilled-and-gutted, frozen, or even canned).
- Fish may be eaten at sea by the crew, or discarded.

The first consideration is whether sampling is directed at a fleet, a stock, or a time-area stratum. This defines the 'population of interest' (cf. section 4.2.1). In practice, only landed fish, or a subset of them, are accessible for sampling so they form the 'observable population'. The models to be assumed to link the observable fish to the total landings and thence to the fish in the population of interest should be discussed and documented in a Standard Operating Procedure (SOP) before undertaking any expensive sampling. Possible linking models might be:

- 'observable landings per unit effort are the same as the total landings per unit effort'. Effort can then be used as a raising factor.
- 'All fish > X cm were retained' implying that landings = catch above X cm.
- An elaborate model used to assess the stock from landings data.

Any biases in these assumed models will be added to biases in the sampling of the landings so it will be good to review them regularly and, if possible, to strive to minimise their importance, e.g. by seeking access to previously inaccessible landings, or by implementing an observer programme to estimate discarding (see also **Table 4.2.1**).

Landed fish are observable either in a fishing vessel before it has unloaded, on the quayside before transportation to buyers, or in a port market prior to sale. Given a choice, the best site to sample will be the one offering the sampler best access to the fish and most time to work before they are moved on. Observation at other sites, e.g. on a freighter used to trans-ship fish to port, possibly from more than one fishing vessel, may not be worthwhile if the origins of the fish are uncertain. Landings are a subset of total catch if any discarding takes place at sea, or if some fish were transhipped or consumed at sea. In the absence of sampling data, information on what happened to unlanded fish during a fishing trip should be sought if available.

The method of choosing which landing events to include in a sample should be decided in advance of a sampling programme so that it may be used consistently. A complication is that we do not know in advance when, or how many landings will occur. The timing of landings might be influenced by season, weather, day of the week, fishing location, identity of the captain, and a host of other potential factors. Systematically arriving at a port to sample on alternate Wednesdays, say, could result in bias from one or more of these factors. Randomising the sampling days within a sampling period, e.g. a quarter or year, offers less scope for bias except that vessels making short trips (and landing frequently) will be encountered more often than of those making long trips. As a result, inshore stocks would probably be better represented than distant water stocks in the samples. The identity of the population of interest (cf. 4.2.1) is important here. If it is 'the total landings of the fleet', then randomly choosing sampling days is a reasonable policy because short and long distance fishing trips are expected to be represented in the sample in the same proportions as they occur in the population. If, on the other hand, it is 'the total stock of fish', and much of the stock is thought to be present in distant waters, frequent occurrence of short trips in a sample would represent a bias. Stock-orientated sampling also suffers from the additional complications of confounding of gear and vessel effects with geographic location. For these reasons, it is probably an approach to avoid if possible.

Another option for randomly sampling landings by a fleet would be to pick vessels randomly with replacement from a list of the whole fleet, as suggested for observer surveys below, provided that practical arrangements can be made to meet specific vessels when they land. This option is more trouble to implement but would be better if landings of some vessels reside in port for appreciably longer than others, a factor that could bias sampling based on randomly timed visits. Stratification and probability proportional to size (cf. 4.1.2) based on vessel sizes or activities are further options for sampling landings. The population of interest and the sampling scheme should both be documented in a SOP.

Landings can be available for sampling in several different ways. The fish may be in bulk, e.g. as a pile, or as a mass of fish in the well of a vessel, or they may be arranged in boxes or other containers. There may be one species present or several mixed together. There also may be different size or freshness categories. The following notes are an attempt to cover most circumstances:

- Sampling bulk fish:

  There is no guarantee that a large load or sampled well of fish will be homogeneously mixed; rather, the opposite is more likely. Ideally, sampling would give each fish in the load an equal chance of inclusion in the sample but this is seldom achievable in practice given restricted physical access, time, and other typical difficulties. So, to maximise the accuracy of the mean of the sample, the sample should be a composite from sub-samples of fish taken from several locations in the load, e.g. from the centre and all extremities, surface

and bottom. If this is impractical, the sampler should try to devise other practical ways to minimise his/her influence over the choice of individual fish, so that all possible classes are present in the sample in roughly the same proportions as they are in the bulk. Classes of fish that might easily be over-represented for human reasons are big, small, "representative", eye-catching, and obscured-but-searched-for-anyway. To improve accuracy further, the number of fish collected in a sample should be large but only if the fish are selected independently. Time spent making many measurements on a large sample collected from just one location in the bulk would probably be better spent in trying to get fish from other locations and then accepting a smaller sample. Further comments on the numbers of fish to take in a sample are given below.

- Mixed species:

Fisheries data are seldom of much use unless they are linked to known species. When faced with a mix of species for sampling, the first basic task is to estimate the proportions of each. Often the mix will be present as a bulk load. In this case, the comments above on accurate sampling apply except that it will probably be necessary to take larger sub-samples of fish from each location in the bulk as a practical step to minimise the sub-conscious influences of the sampler on which species of fish are included. Each sub-sample should be of approximately similar size. The estimate of the proportion of species *s* in the load will then be the numbers, n_s, of individuals of that species in the composite sample divided by the number, *N*, of individuals of all species. The sample may be adequate for subsequently estimating biological characteristics of the common species but not for the rare species. Additional, monospecific samples are to be collected if required, again by looking for each species at different locations in the load. The issues of sampling multi-species catches are now discussed in more detail.

In some cases, the complexity of the catch requires a complicated sampling scheme. The purse seine fishery for tropical tuna falls into this category. These fisheries often represent a combination of species and fishing types, where the declaration of catch per species may also be strongly dependent on fish size. A description of the simultaneous sampling procedure for this particular fishery is given below as an example of combined sampling. This procedure allows the specific composition and the size distribution of the catch to be obtained.

In the Atlantic and Indian Oceans, sampling strategies for tropical tuna from purse seiners in port have been derived (Sarralde *et al*., 2005). Multispecies catches are particularly common when fishing on FADs. Strata are based upon the geographic location of catches, time and association (e.g. FADs, free schools), all identified from the vessel logbook and well plan. Preferably, a well that contains fish from sets belonging to a single stratum (location, time and type of school) should be sampled. In exceptional cases, depending on the amount of sampling and forecasts made, wells in which sets not belonging to the same geographic zone or time stratum but close in position (less than 5° difference) or in time (fewer than 15 days difference) could be considered valid. However, sampling should **never** be undertaken on wells containing fish from different associations. Sampling should not be concentrated either in time (all months in a quarter should be sampled) or in space (all zones should be sampled). 15-25 samplings are recommended for each stratum.

Once priority wells for sampling have been selected, sampling can begin. It is recommended that at least two persons are present for sampling, one for selecting and measuring, and the other for noting the data on appropriate forms. A safe sampling site should be selected, ensuring that unloading is not hindered and that access to the fish is easy and safe. Sampling can occur where the fish are unloaded via the deck (with the agreement of the Captain), on the conveyor belt, or where larger fish and smaller fish are separated they may be measured separately, ensuring no pre-selection occurs.

Sampling different areas of the well (e.g. top versus bottom) may result in a different species composition. To avoid this, sampling should always be carried out on each well in two stages, or through sub-sampling. The first stage should be done shortly after the well is opened, and the second several hours later, but before well unloading is finished.

If unloading involves any selection of species (by species or weight category), the sampler must take the sample directly from the well. If there has been no selection, sampling may be performed during unloading, but always at random.

If the well only contains large fish (>70cm), 100 specimens should be measured at each stage (200 in total). All specimens (mixed species) should be taken at random until the optimum number is reached.

If the well only contains small fish (<70cm), during the first sampling stage 300 specimens should be taken (all species included). If this involves skipjack, frigate tuna or little tunny, the first 25 species per species can be measured, and the rest counted. If it involves bigeye, yellowfin or albacore, all specimens should be measured. During the second stage, 200 specimens should be measured and/or counted in a similar fashion.

If wells contain a mixture of large and small specimens, a total of 300 specimens should be measured and/or counted (all species included) at the first stage. If this involves skipjack, frigate tuna or little tunny, the first 25 specimens per species should be measured, and the rest counted. If this involves bigeye, yellowfin or albacore, all species should be measured until the recommended number is reached. At the second stage, 200 specimens should be measured and/or counted in a similar fashion. The weight of both weight categories in the well (fish above and below 10 kg) must be known.

Sampling of baitboats can be carried out following the same approach as listed for purse seiners above. The sampling unit in this case is the entire boat, rather than a single well. Generally, only one sampling will be performed, unless the vessel is large in which case two samples can be taken. When the catch is selected by size, species or commercial category before unloading, or if it is accessible to the samplers, a fraction of the fish will be sampled. As a result, all categories present will be randomly sampled. The number of categories into which the catch is divided defines the number of samples. The weight for each category should be noted.

As an example, fresh fish (from the most recent sets) may be unloaded from one side of the vessel, and frozen from another. Two samplings should therefore be made, one of the fresh fish, and one of the frozen. Similarly, weight should be known for both landings.
Catches from several vessels may be mixed together, for example where bait boats unload onto purse seiners or merchant ships. In these cases, no information is available on the fishing area or mode of fishing. As a result, a single sampling of the entire vessel must be performed.

- Containerised fish:

When landings have been containerised, e.g. in boxes, the containers themselves must be sampled. A random sampling scheme based on rows, or storage areas, is relatively easy to arrange using random numbers to pick the next container for measurements. Very large containers may themselves have to be sampled as a bulk load (see above), thereby creating an extra stage in a multi-stage sampling scheme (see 4.2.2). Containerised fish may be frozen, gutted, de-headed, etc. Their state should be reported and appropriate conversion factors applied to estimate the condition of the fish in life. Conversion factors that may be useful in tuna statistics are given in **Appendix 4**.

- Categorised fish:

Fish categorised into size or freshness grades will probably be containerised in some way. The containers should be sampled as described above. A sample that omits one or more categories evidently has a major potential for bias so the availability of all categories should be established before beginning observations. In addition, the total weights or volumes of each category in the landings must be known so that the results for each can be weighted appropriately in an estimate for the whole landing.

- Artisanal fisheries:

Sampling of catches from artisanal fisheries will largely take place at the landing site or market. Sampling at market will generally limit the accuracy of information on the fishing location, but artisanal fisheries are unlikely to operate too far from shore. Fishers can be interviewed to obtain desired information on fishing techniques and locations. Physical sampling of artisanal catches will merely require modification of the forms of sampling already described above. The unit of sampling will be at the scale of the vessel.

- Catch and release (sports) fisheries:

Catch and release fisheries provide an additional source of catch rate information that can prove important in particular countries. Methods to collect this information are described in Guthrie *et al*. (1991). Biological sampling of catch and release (sports) fisheries by definition can only occur while on board the vessel. Therefore, sampling will generally conform to that described for observers (see below). However, note that since samples are returned to the sea and mortality is negligible, there is a small but present danger of sampling individuals twice if an individual is subsequently caught in a commercial fishery. It is recommended that sports fisheries be utilised for tagging and other biological studies (see sections 4.6 and 4.7).

Having obtained a sample as randomly as possible, the next task is often to estimate biological characteristics of interest. A length frequency distribution (LFD) is usually the first priority for each species (see also section 4.3.1). The number of fish that should be measured depends on how many modes (peaks) are present in the LFD. At small sizes, these will probably represent successive year-classes, although the size selectivity of the fishing method will affect their relative frequencies. Sufficient fish should be measured to define all of the modes present. In practice, this means measuring until modes are identified, then measuring, say, an extra one third of the existing sample to see whether any additional modes appear. Clear definition of all the modes is extremely helpful for distinguishing different age-classes. When there are clearly only one or two modes, a small sample may be sufficient, say 50 fish. When there are many modes, measurement of 300 or more fish is likely to be necessary. Adjusting the sample size in this way according to the results found requires that the initial random sample must have an excess of fish and be homogeneously mixed. Alternatively, additional samples of fish could be collected from the landings in exactly the same way as the first sample.

Some biological characteristics vary according to the size of fish. There are three options for estimating the relationship:

1. Estimate the characteristic on all fish in the original sample.
2. Remove a sub-sample of fish from each of a set of length classes and estimate the characteristic for these fish only[3].
3. Remove a sub-sample without regard to length and fit a model.

Option (1) provides the biggest sample but there must be time and facilities to process every fish. Also, the most frequent sizes might be relatively over-sampled. For a statistical analysis of options (1) and (2) in connection with estimation of age composition, see Smith (1989).

Options (2) and (3) are suitable when sub-sampling is restricted. Option (2) is often used to develop age-length keys (see section 4.3.6, and Westrheim and Ricker, 1978; Lai, 1993) using annually marked hard parts (see section 4.9). It could also be used to estimate maturity- or weight-at-length (see section 4.8). The sub-samples should be randomly selected from each length class but, in practice, provided that the characteristic being estimated is not visible to, and does not influence the sampler (as e.g. age and maturity would not), the first fishes that come to hand from each length class are suitable for the sample. Taking a fixed number of fish in the sub-sample from each length class is relatively easy to implement but may not be the most efficient practice (Kimura, 1977; Lai, 1993). A separate proportion-at-length or mean-at-length is estimated for each length class with option (2). There is no model or major assumptions but the large number of values to be estimated can result in low sampling precision, particularly if sub-sample sizes are small. The double sampling involved in this procedure complicates a statistical analysis to estimate standard errors.

Option (3) requires that care must be taken to ensure that the choice of fish for the sub-sample is not influenced by their size. Fitting a model is likely to require estimation of fewer parameters than estimation of mean values for many size classes (option 2) and the estimation can therefore be done with better precision. Disadvantages are that a model has to be assumed, and rare size groups are likely to be poorly represented in the sub-sample.

Observers

Observers travelling on fishing vessels can provide high quality data on quantities of most or all species retained and discarded, fishing effort, fishing methods, strategies and in some cases biological characteristics such as length frequency distributions (see section 4.10). As a spin-off, they can promote good communications between scientists and the industry. Observers may or may not have a role in enforcing fishery regulations. For purely scientific purposes it is better if they do not so that the captain fishes normally, without fear of prosecution. Observers may or may not have a right to travel on a fishing vessel. If not, the observable population of vessels may be restricted to those with co-operative captains and owners, leading to a possibility for bias. Observer programmes tend to be expensive because observers must be scientifically trained and must spend long periods at sea. Observers should be supervised at least on their first trip to make sure that they identify species and carry out all biological sampling competently. They should also be trained in marine, and specifically fishing safety (Luo *et al.*, 1999).

An observer is mandatory on all vessels in a few fisheries. More commonly, observers must pick which vessels and trips they sail on to get most information about fishing and fish stocks. The 'population of interest' (cf. 4.2.1) is best defined in terms of the fleet of fishing vessels. Defining it as the stock of fish would require that

[3] Thompson (1992, p143) refers to this as 'double sampling for stratification'.

trips be selected to evenly sample the different geographic areas occupied by the stock, a difficult task if the fleet focuses on certain parts of the stock, if vessels change fishing destinations during a trip, or if different gears are used in different areas causing a confounding of gear with geographic influences. Another complication is that the observable trips to be made by a vessel are often not known in advance due to interferences from poor weather, mechanical problems, poor fishing prospects, etc. Observer surveys are inherently hierarchical because sets (catches) are nested within trips within vessels but logistical constraints may prevent implementation of a multistage sampling scheme.

A first necessity for an observer sampling programme is a list of all vessels in the fishing fleet of interest. If necessary, obtaining a complete list would probably justify special research. The list should be updated before each sampling period to allow for changes in the fleet.

Secondly, information should be sought about the type, power and size of the different vessels, and about their history of activities, and landings or catches. This should be examined to decide whether there is sufficient reliable information for using a stratified or probability proportional to size sampling scheme based on an indicator of the fishing power of each vessel. Such a survey would be more efficient than simple random sampling but only if the information proves to be a good predictor of performance specifically for the forthcoming sampling period.

Thirdly, a decision is needed about whether to observe a sample of vessels (principle sampling unit) with several trips (secondary sampling unit) on each during the sampling period, or whether to try to observe fishing trips randomly from all those made by the fleet. The former would be a two-stage scheme that allows estimation of a between-trip-within-vessel variance; the latter is simple random sampling for trips. For large, diverse fleets and a relatively small number of observers, simple random sampling is probably the better choice because variation between trips on different vessels is likely to be larger than between trips on the same vessel; hence observation of as many vessels as possible is desirable. If there are sufficient observers to observe vessels repeatedly during a sampling period, or if only a few vessels within the fleet are observable, sampling of vessels and trips may be more informative if carried out as a two-stage scheme with all principle sampling units observed on more than one trip.

Simple random sampling for trips may be arranged by numbering all vessels in the fleet from 1 to V. Using random numbers from 1 to V, draw vessels from the list 'with replacement', i.e. so that the same vessel may occur more than once in the draw. Observers attempt to arrange trips on vessels in the order of drawing. Trip-level estimates can then be treated as independent observations of fishing activities by the fleet since each trip was independently selected and observed. Means and variances are computed from the trip-level estimates using the formulae for simple random sampling without replacement because, although vessels are selected with replacement, no trip is sampled more than once. This sampling scheme may be criticised if some vessels are known to spend many more days at sea than others per sampling period. In that case a more elaborate scheme could be used, e.g. probability proportional to size or stratification based on activity. Two-stage sampling could be arranged as for simple random sampling but fewer vessels would be drawn and more trips would be observed on each. Randomising the dates of trips on each vessel within the practical constraints is desirable.

An intuitive way to sample trips is to arrive at fishing ports on randomly chosen days during the sampling period and to choose the next vessel to go to sea. This scheme could be biased towards vessels spending most time in port and, possibly, to those offering the best conditions at sea for the observer. It is not recommended.

Once on board, the observer will collect information on the boat and fishing activity, and will pay special attention to data that cannot be estimated in any other way, such as discard estimation and identification and size measurement of accessory species. Regarding the target species, the observer should sample as many catches as practicable (without jeopardising safety through personal tiredness). Discarded and retained fish should be recorded separately. If only subset of catches can be sampled, the times of day should be varied and sampling should try to include catches from each different fishing locality visited. Each catch may itself be sampled in which case a raising factor to raise the sample to an estimate of the total catch must also be estimated. This might be achieved from relative volumes, or by relative times on a conveyor belt, etc. Sampling the catch should be guided by the procedures described above for sampling landings. The observer should record fishing effort for each set including those that are not sampled; less satisfactorily, at least a count of the sets not sampled should be taken from the vessel log. Results for catches sampled may then be raised to estimate results for all catches taken during the trip.

4.2.5 Potential problems in total annual catch statistics

Table 4.2.1 presents typical problems relating to the collection of Task I statistics within ICCAT, and potential solutions.

Table 4.2.1 Problems relating to collection of Task I statistics.

Problems	Examples	Solutions
Species breakdown		
1. Species reported together. The same prices per unit of weight paid.	- Portuguese Islands fisheries - Eastern Atlantic tropical surface fisheries (French/Ivorian/Senegalese fleet, Japan, Korea, E.S., etc. - Ex-Soviet purse seine fishery (all tunas combined)	- Encourage, educate, instruct and/or oblige fishermen to report catch by species - Carry out sampling and examine sample species composition in order to estimate catch species composition
2. Misidentification or un-identifiable speceis. Lack of easy, clear identification key.	- Young yellowfin vs. bigeye tuna	- Find easy key and inform fishermen - Carry out sampling to estimate total species composition
3. Confusion in local vernacular names.	- Spanish names for albacore (bonito), yellowfin (atún) - Japanese, Korean and Chinese names for marlins (black marlin locally called white marlin, blue marlin called black marlin) - Portuguese names for tunas (albacore, bigeye classified by size, but not by species)	- Biologists become involved in central statistical office so that persons responsible for statistics realise problems and correctly identify species reported by local names. - Train local statistical staff and fishermen to report using correct names
4. Groups of species reported together. No column provided on reporting forms to report a certain species.	- Many countries where tuna fisheries are of minor importance, or where one species of tuna is minor to the other	- Add a column on reporting form to report species in question
Inadequate coverage		
1. Landings at some ports are missing. Survey system does not cover them.	- Many countries	- Expand survey system - Make occasional visits to those ports for landing estimates
2. Certain fleets (most likely very localised) are missing.	- Many countries	- Raise catches to 100% coverage, using ratio of no. of boats covered to those not covered
3. Landings at foreign ports are not covered.	- Panamanian fleets	- Oblige captains of boats to report catches by law
4. Catch was used for family consumption or not sold through markets.	- Almost all countries	- Make sample survey to estimate amount
5. Catch is sold on the local market.		- Make survey by team of non-governmental personnel to make estimates
6. Catch is classified and reported mixed with non-tuna species.	- Many countries in the Mediterranean, Africa, South America and Caribbean Sea	- Establish system (and format) to report tuna - Sample mixed species
7. Catch is transhipped at sea from a fishing vessel to another fishing or cargo vessel of the same or different flag.	- U.S., Spain, Japan etc.	- Oblige captains to report catches regardless of landing or transhipping - Check landing ports (e.g. Puerto Rico) for cargo and foreign transhipments
8. Catch is landed at a customs zone and from there exported to a foreign	- Many African ports - Foreign flag vessels unloading at Canary Islands	- Check landings at custom zones (do not use through-custom statistics)

country (often after canning).		
9. Catch is processed on the motherboat and is landed as canned product.	- Japan, former U.S.S.R	- Oblige captains to report catches instead of using landing statistics
Flags		
1. Double reporting by flag country, country that licenses the boats, importer of catch and/or country where fish are transhipped.	- Fleets of Korea, Panama, Japan, Ghana etc. landing at African ports	- People involved should realise the problem - Each country involved should report catches by flag - Secretariat monitors the flow of fish and fleets
2. No reporting for boats where different nationalities of owners, operators, crew, investors, licensers, registration etc. are involved.	- Panamanian flagged vessels	- Government of operators of boats could encourage or request reporting of catch of such foreign flag boats (catch should be reported separately by flag to avoid confusion)

4.2.6 Estimation and raising

Estimating for the observable population

Estimation of means, totals, and variances from sample surveys of logbooks, landings, or fishing trips by observers can be achieved with the standard estimation formulae appropriate to the sampling scheme used to draw the samples. Examples of statistical sampling schemes corresponding to those in the text books were listed in section 4.2.2. The estimated statistics then apply to the observable population (cf. section 4.2.1) without additional raising. Using inappropriate formulae, e.g. using simple random sampling formulae for a probability proportional to size sample, would risk biasing the results. Four examples are given to clarify these statements in a fishery context:

1. Suppose that n landings are sampled approximately randomly (simple random sampling without replacement) from N made by the fleet during a quarter of a year, and total numbers of fish, y , and length frequency distributions are estimated for each observed landing. The mean number per landing is $\bar{y} = \sum y / n$ and the estimated total landed number for the fleet is $Y = \bar{y}N$ (Thompson, 1992, eq. 8, chapter 2). The raising factor is thus N/n. It could be used to raise the LFD as well if required.
2. Suppose that n fishing trips were accompanied by observers during a year, and that the trips were selected without replacement from N made by the fleet so that each trip had an approximately equal chance of being observed. The raising factor is N/n.
3. As a contrast to 2), suppose an observer survey in which v vessels were selected randomly without replacement from V in the fleet, and no more than one randomly selected trip was observed on each. Firstly, the total quantity caught in the year by each observed vessel is estimated by raising the quantity observed on the trip by the annual number of trips by that vessel. Next, the total caught by the fleet is estimated by raising the vessel annual totals by V/v.
4. A logbook survey in which not all vessels could be logged could be treated as example 3). The annual results for v logged vessels should be available directly from the logs. They would be raised by V/v to allow for the missing vessels.

Estimators applicable to standard sampling designs without assumptions are arguably not the most precise way of estimating for the observable population when good auxiliary information is available. Auxiliary information is brought into estimation by modelling using either a ratio estimator or a regression estimator (Thompson, 1992, chapters 7 and 8). Both are slightly design-biased, but model-unbiased.

For example 1), suppose that the total tonnage, *W*, landed by the fleet is known. It can be argued that the relative tonnages, *w*, of landings for the sample of *n* and for the whole fleet give a more precise raising factor than the numbers of landings because they give more information about the activities of the fleet. A ratio, rather than a regression estimator is appropriate if zero landed numbers always weigh zero tonnes, and positive landed numbers are proportional to tonnage. The ratio estimate of total numbers landed is $Y_{\text{ratio}} = W.\sum y / \sum w$. The raising factor is $W / \sum w$.

For example 2), a raising factor based on the quantities of fish landed by the fleet, and retained on the *n* observed trips may be thought more precise than one based on relative trip numbers. Raising by landings does however bring its own problems:

- If the species was not landed there is no raising factor unless composites of different species are used.
- If retained quantities were small on the observed trips the raising factor will be very imprecise due to the small divisor.
- If landed quantities are as weights and retained fish are as numbers, a conversion must be applied which could add further error.
- If landings are themselves suspected to be in error, the observer data become contaminated with the same errors.

Raising by relative fishing effort will often be preferable for observer trips if suitable data are available. The raised data are then independent of the landings data that can be important for modelling the fish stock using both types of data.

For example 3), relative effort might be used to replace total numbers of trips when estimating the annual total per vessel, whilst relative engine power might be used instead of V / v.

For the logbook example 4), a raising factor based on numbers of vessels logged and in the total fleet uses no information about the fishing powers of the different vessels and could often be improved. Other estimators could be based on engine power, GRT, days spent at sea or another effort measure, or on quantities of one or more species landed by the logged and by the total fleet. The choice will often depend on the information available and on whether the same information is being used in a linked way in an analysis of the fishery or stock.

Whatever estimation and raising formulae are used in preparing estimates, they should be documented in the SOP for the sampling programme.

Estimating for the population of interest

As pointed out in section 4.2.1, the observable population will probably be a subset of the population of interest in many practical situations associated with ocean fisheries and a relationship between the two has to be assumed (and documented in an SOP). The relationship may be a simple raising factor or something more elaborate but, in either case, estimation is purely a modelling exercise that does not involve design-based sampling theory. The models should be reviewed whenever new information becomes available.

A common but un-straightforward raising problem arises when the observable population for sampling is all or part of a fishing fleet but the population of interest is the stock of fish in a geographic region over a given time period, e.g. a ‘time-area stratum’. Two questions arise:

1. Did the fleet fish the time-area stratum so as to provide a satisfactory sample of the fish stock there?
2. Was a part of the fishing effort expended outside the stratum?

Question 1) requires an analysis of fishing patterns and fishing gears in use. If the fleet distributed effort fairly uniformly over the stratum, and used similar fishing gear, a good sample was obtained. More likely though, parts of the fleet focussed on different, relatively small localities and used different gears having different selectivity properties. There may also have been seasonal changes in fishing patterns. Options for dealing with these problems include:

- A model to estimate the effects of non-uniform sampling (Campbell, 2004). A Bayesian approach is worth considering because prior distributions for important parameters used in the model can be adjusted to reflect uncertainty about their values.
- Down-weighting results from heavily fished, small localities so that they do not dominate the estimates for the time-area stratum.
- Filling in missing data for sub-areas or sub-periods with data from previous periods or from neighbouring strata.
- Ignore all the irregularities and treat as a random sample.

All of the options carry a high risk of bias. Also, the bias could itself follow a trend over time resulting in distortion of time-series. A further danger is that data from certain useful locations will be used more than once causing dependence among results, and possibly exaggerating the effects of errors. The chosen solution and the reasons for choosing it should be documented in an SOP or in any report of the estimation procedure.

Question 2) is usually easier to deal with. The best solution is to disaggregate data for fishing trips into data for individual sets that can be assigned to the correct stratum. A quicker solution is to estimate for each trip the proportion of effort applied within each stratum.

Calculating the fraction of the total catch weight of a set represented by sampling

As noted in the section on sampling multi-species catches, the effective sampling unit assigned should be representative of the set. If a set is emptied into two or more wells of a purse seiner, the ratio that the weight in each well represents of the total weight caught in that set should be calculated. This is a weighted catch (Sarralde et al., 2005).

The sampled weighting of the catch cannot be calculated until the boat has finished unloading, as the catch in that set is spread over different wells and hence the individual set may have been sampled more than once.

The weighted catch of each set, defined by the date of the fishery and number of sets, can be calculated as:

$$Weighting = \frac{W1}{W2} * TW$$

where W1 is the weight of the set or sets in the well, W2 is the weight of the set or sets for all the wells sampled, and TW is the total weight of the set or sets.

For example, a vessel has caught 90 t in a set, which has been kept in three wells. 40 t were placed in well 1, 30 t in well 2, and 20 t in well 3. Wells 2 and 3 have been sampled.

For well 2, the weighting is: (30/50)*90 = 54 t.
For well 3, the weighting is: (20/50)*90 = 36 t.

54+36=90.

If the set had been sampled once only (either because the entire contents have been emptied into one well or shared over other wells that were not sampled), the weighted catch would be the same as the total catch of the set (weighting = TW). Samples can then be raised to the total catch of a set using this weighting.

4.2.7 Further reading

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4.3 Estimating catch at age

The majority of analytical stock assessments use age-based models. The age data from the reading of hard parts (Section 4.9) to supply such models is generally limited, due to the cost and complexities in obtaining and reading these structures. In contrast, catch-at-length data are more plentiful, as the collection of length information is relatively cheap. Length also provides some information on the age structure of the population, since age and length are correlated. However, there remains a need to convert catch-at-length into catch-at-age. A number of approaches to do this are available.

This section details the approaches to collect appropriate length frequency data for the purposes of ICCAT (sections 4.3.1 to 4.3.4). Approaches to convert catch-at-length to catch-at-age are detailed (sections 4.3.5 to 4.3.9).

4.3.1 Sampling for length frequency data

As already noted in section 4.2.4, biological information such as length can be collected from a number of locations:

At sea

The ideal location for measuring fish is at sea, aboard a fishing boat. If sampling can be achieved at the time of catch, all associated information (location, date, whether or not sampling was from a single school) can be recorded with accuracy. This approach may be the only method to obtain accurate biological and catch information from tuna caught for farming. These individuals are farmed in large cages before export, and are unlikely to be accompanied by information on their catch location without observation at sea. **See section 4.10 for further details.**

At the time of unloading at ports

If this approach is adopted, it is essential that the samplers have access to the fishing and/or engine log of the boat, so that the proper origin of fish from which a sample is taken can be identified. Even with this information, the identification of the exact location of the catch may be impossible to identify, although the larger catches taken by surface fishing vessels such as purse seiners may mean a well/hold is from a single school or a few schools caught within a short period in the same area. For longline catches this is particularly difficult, as the hold may contain fish from an extended period of fishing over a wide area. In the case of a coastal artisanal fishery, this may not be needed since most of the catches are made on the same day in an area very close to the landing site. The actual site of sampling can be as follows: in the fish hold of a fishing boat; on the deck of a fishing boat; on the pier (or beach) when the fish are brought up; on the vehicles (or carts) which transport the fish; and at the market when fish are laid out for auction or sale. Sampling at the time of unloading is generally the most economical, as one person stationed at a port can cover all the boats entering the port. Also, it provides a site for measuring fish safely and easy access to accurate auxiliary information on the location, date, gear etc. of the catch.

When transhipping from a fishing boat to a freighter

In order to cut down handling costs, a growing number of fishing boats unload fish directly to a freighter instead of to cold storage. If this transhipment is done at sea, only at sea (see above) or at port when freighters unload (see below) methods are valid. However, if transhipping to another vessel is done at port, a sampling method such as that at the time of unloading at ports (see above) can be applied. Transhipments should be carefully monitored as they are not necessarily done at the pier, but in the off-shore port area. A sampler might need to use a small launch to get to the freighter.

At cold storage or canning plant

This approach can be used when other methods cannot be pursued. However, it is only appropriate if the origin of the fish can still be traced.

At port when freighters (transshippers) unload

This is the least desirable approach since the origin of sampled fish can be traced only as far back as the fishing vessels that caught the fish. There is also a risk that the fish were sorted by size at a transhipping port and only part of the catch (of a certain size-class) was sent by freighter to the port where the sampling was performed.

Where all other approaches cannot be pursued, even sampling from freighters can provide some information on the overall catch composition of that particular fishery.

Whichever approach is used, it should be noted with the length frequency data when presented to ICCAT.

Fish should be sampled at random (see section 4.2.2), disregarding size. If sampling is performed during fishing operations (e.g. by observers), all the fish (for example in the case of longline operations) of a certain species, or one fish out of every 5 or 10 (or whichever frequency is most suitable) can be selected for measurement. Alternatively, where catches are larger, the first 10, 20, 30 or 50 fish of a species brought on board can be sampled, unless it is known that there is some difference in the size between the beginning and the end of fishing.

At a port, if fish are delivered by moving line (e.g. by a conveyor) one from every certain number of fish can be selected for measurement. If the condition of the selected fish is not suitable for measurement, the next fish can be measured, or that turn can be skipped. When more than one species of interest is mixed in a catch, first sample one species and then the other.

If circumstances do not permit the above procedure and the sampler has to select from a pile of fish, it is probably best to separate some fish from the top and bottom of the pile, and measure them. Caution must be shown, since larger fish may be selectively placed at the bottom of the pile (or vice versa). In this way, if only the fish at the top of the pile are measured, the sample is biased.

If the fish are already pre-sorted by size and/or species, special attention should be paid at the time of sampling. If this is the case, each pre-sorted section of the catch should be sampled independently and then raised to the catch of that size category (see section 4.2.6).

Assuming random samples from the population, the formulae presented in section 4.2.1 can be used to identify appropriate sample sizes per unit. Note, however, that the information needed on the size frequency at the required level of accuracy can usually be obtained (for tuna above 15kg) by measuring about 500 fish of each sampling area, period and each country and gear category. Where variances between sample boats and within a single boat are small, 200 fish may provide adequate data. However, for smaller-sized tuna, the number should be increased.

The following provides some examples for two different fisheries. The numbers provided are for indication, and should be confirmed for individual fisheries using appropriate statistical formulae.

Since longliners catch non-schooling fish at a great depth, and since a set extends as far as 120km to catch a few relatively large fish, the variance of fish size between samples from different boats is often no larger than the variance of fish size within a sample taken from one boat. For the target species (bluefin, yellowfin, albacore, and bigeye tunas, depending on the fishery), from 10 boats, around 50 fish each can be sampled to get 500 fish for each time-area stratum. For small coastal longliners, it may be better to take from 25 boats (5days x 5boats) 20 fish each. For species that are incidental to catches (billfishes, swordfish, sometimes even some major tuna species, depending on the fishery), it is unlikely that 500 fish could be measured for each stratum. In such cases, it is recommended that as many fish as are available be measured.

Purse seine, pole and line and trolling gears catch relatively small schooling fish near the surface. Their catches per day are much larger than those of longliners, even more so when viewed in terms of the number of fish, since the average size and weight of fish is smaller. In order to get the same coverage as for the longline fishery, the sample size must be increased. One fish per one metric ton of catch may provide sufficient sampling coverage and can be used as a guideline for establishing the sampling level. Sampling should be monitored and adjusted as appropriate to gain the required random samples.

Similarly sized fish tend to form schools near the surface. Therefore, a sample taken from a school has little within-sample variance of fish size. However, between-sample variance of fish size taken from different schools

is large, meaning that if the same total numbers of fish are to be measured, increasing the number of samples while reducing the sample size should give better estimates.

The following guidelines for surface gears can therefore be put forward:

- A sample should be taken from a catch of a single school as often as possible;
- In stratified sampling (single species), each sample should consist of 50 fish (if fish are large) to 100 fish (if fish are small);
- In multi-purpose sampling (with mixed species) and when fish sizes are relatively large (over 15kg), 100 fish should be sampled. If fish sizes are small, 200 fish are recommended;
- Large industrialised purse seiners should be sampled twice to three times from different wells known to contain catches from different schools;
- About ten boats (in the case of industrialised large boats) should be sampled for each time-area stratum;
- For small coastal fisheries, from 25 boats (5 days x 5 boats) 40-50 fish each can be sampled to get 500 fish for each time-area stratum.

4.3.2 Equipment for measuring

A range of appropriate tools for measuring large pelagic species is available.

Callipers

Callipers may be the most convenient tool for measuring (**Figure 4.3.1**), particularly for tunas (**Figure 4.3.2**). They are easily made of wood, brass, aluminium and/or plastic.

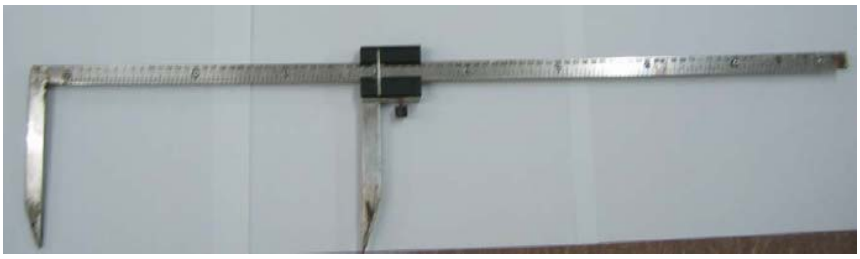

Figure 4.3.1. An example of callipers. Picture from Sarralde *et al*. (2005), reproduced with permission.

Measuring board

A measuring board may also be used **(Figure 4.3.2)**. A board is particularly suitable for measuring small fish.

Figure 4.3.2. An example of a measuring board. Picture from Sarralde *et al*. (2005), reproduced with permission.

Tape

A steel or fibreglass measuring tape can also be used, if there are no alternative methods. In this case, an attempt must be made to keep the tape straight. The best method would be to place a tape on the floor and place the fish on top of the tape, or to place the tape on the floor to the side of the fish being measured.

An exception is made for measuring the lower-jaw fork length of billfish, in which case the tape measurement should be over the body contour of the fish (i.e. curved body length). See section 4.3.3 for details.

Photographic techniques

In some countries, fishermen refuse to allow a sampler to touch the fish. In such a case, photographic techniques might be applied to estimate size composition. The basic principle is to take photographs of fish lying alongside a scale. Later, the fish length can be calibrated relative to the scale in the picture. Particular care should be taken so that the camera's line of sight is perpendicular to the plane of the fish.

This method is potentially costly (although digital cameras will eliminate film development costs), and provides less accurate data.

4.3.3 Measurements to be taken

The fish should be placed on a flat surface in the horizontal position while being measured. Fish with a broken snout (if snout-fork length is being taken) or tail, or frozen fish not in a straight position should be rejected.

Tunas

All species except billfishes must be reported to the ICCAT in **fork length**. This is a projected straight distance from the tip of the upper jaw to the posterior tip of the shortest caudal ray (fork). See figure 4.3.3.

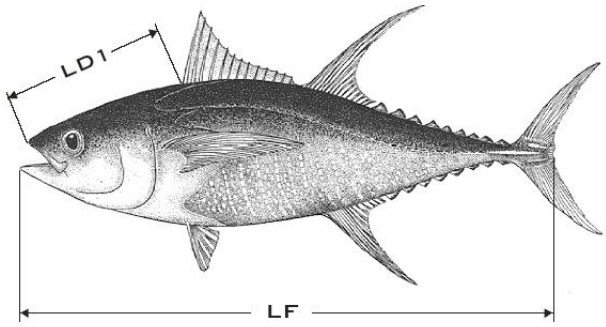

Figure 4.3.3. Measurements of tunas – Upper jaw-fork length (FL) and Upper jaw-1st dorsal (LD1). Picture from Sarralde *et al.* (2005), reproduced with permission.

It is best to measure fish in fork length. In particular, if smaller sized fish are abundantly found in the catch (e.g. skipjack, surface albacore), fork length measurements are recommended, although this is sometimes difficult to achieve. For example, it is not possible to measure the fish accurately when malformed due to freezing, the fish may be too large for equipment (callipers) being used; there is not enough room to handle long callipers (e.g. aboard small commercial fishing vessels); the fish tails have been chopped; or most of the fish are not lying straight. In these cases, the next best measurement is the pre-dorsal length (LD1), the straight distance from the tip of the upper jaw to the insertion of the first dorsal spine. **Do not** mix two measurements in one sample.

If the pre-dorsal length is measured, those data have to be converted to fork length prior to reporting to the ICCAT. The relationship between the pre-dorsal length and fork length **must** be established for each species and area, based on adequate samples, as they are quite variable. These conversion factors should be reported. Unless the data have been converted to the fork length or are received with an adequate conversion equation, the pre-dorsal length cannot be accepted for the ICCAT database.

Billfishes

An important difference in sampling billfish is that the fish should be sampled for length **and** for sex (see section 4.8) as far as possible. It is well known that male and female billfishes have significantly different growth rates. However it is sometimes impossible to identify the sex. In such cases, only length measurements should be taken.

The preferred and most reliable measure of body length for billfish is the lower jaw-fork length (LJFL) (see figure 4.3.4). For small fish, callipers are practical and provide an accurate straight line measurement. However, field use of callipers for large billfishes, which have a maximum length of over four metres, is impractical.

For purposes of standardisation, it is preferred that all length measurements of large fish be taken with a tape (fibreglass or steel if possible) over the body contour of the fish (curved body length). However, straight measurements by placing the fish over a board that has length scales are also acceptable.

As there is a difference in the value between straight and curved measurements, the measurements taken and equipment used **must** be clearly recorded on the sampling sheets and reported to the ICCAT with the data.

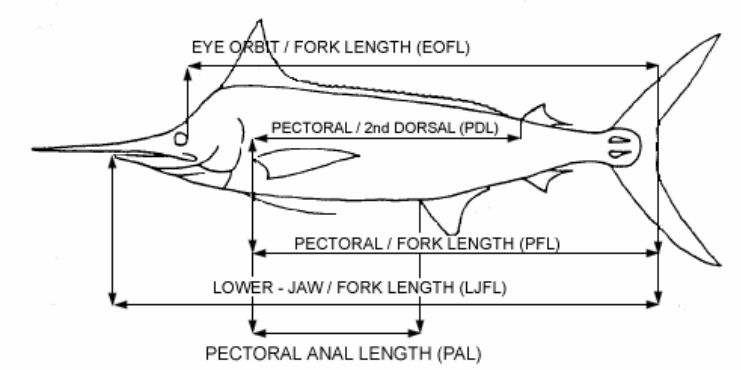

Figure 4.3.4. Alternative measurements of billfishes

Sampling from commercial billfish catches sometimes poses severe problems, since the fish are generally dressed on board, prior to freezing. This may cause some difficulties in species identification of carcasses, and/or affect the measurements.

Alternative measurements for billfish are (**Figure 4.3.4**):

- Eye-fork length. The projected straight or curved-body distance between posterior edge of the eye orbit to the fork of the tail.
- Pectoral-fork length. Projected straight or curved-body distance between the most anterior insertion of the pectoral fin to the fork of the tail.
- Pectoral-dorsal length. Projected straight or curved-body distance between the most anterior insertion of the pectoral fin to the most anterior insertion of the second dorsal fin.
- Pectoral-anal length. Projected straight or curved-body distance between the most anterior insertion of the pectoral fin to the most posterior rim of the anal sphincter.
- Dressed weight. Weight of the individual carcass. In this case, an accurate description of how the fish is dressed is essential (see below).

Measurements should be made in the vicinity of the lateral line. For example, when taking the Pectoral Second Dorsal Length (PDL), the distance to the anterior part of the second dorsal fin should be read along the lateral line, **not** up on the dorsal ridge of the back (regardless of whether a tape or callipers are used).

The measurements of length than can be taken on any individual carcass will depend on how it is dressed. The following measurements of length should be taken for the categories of dressed fish as follows:

- Whole (round) carcasses – lower jaw-fork length
- Bills, gills and fins off, gutted – lower jaw-fork or eye-fork length
- Dressed carcasses with heads and fins off and caudal peduncles present – pectoral fork length
- Dressed carcasses with heads, fins, and caudal peduncles off – pectoral second dorsal length and pectoral anal length.

As in the case of LD1 for tuna, if any measurement other than lower jaw-fork length (LJFL) is taken, the relationship between this alternative measurement and the standard (LJFL) must be studied so that the measurements can be converted to the standard. In order to develop a conversion equation for past measurements, as well as for new measurements from dressed fish where LJFL is not available, an adequate sample should be measured for all five alternative measurement categories given above, together with LJFL. Since the fish carcasses are landed dressed at many sampling sites, it would be impossible to take all the measurements. Until the conversion equations are well established, it is recommended that the samplers try to measure individuals by as many alternatives as possible, particularly where whole fish are available for sampling. All available conversion factors that may be useful in tuna statistics are given in **Appendix 4**.

Size class intervals

Most of the measurements discussed above should be made by 1cm size-class intervals. However, if necessary, fish over 60cm in fork length could be measured in 2cm intervals. If the fish is being measured by pre-dorsal length (LD1), the measurements require more accuracy, as 1cm of the pre-dorsal length is equivalent to 2 to 4cm in fork length, particularly in larger fish. For fish less than 35cm in fork length (although it is much more feasible to measure fork length rather than pre-dorsal length for such a small fish), Ld1 can be measured to the centimetre. However, for any fish over 60cm, LD1 should be taken in at least 5mm intervals.

Record the length to the nearest lower centimetre (less than a centimetre should be truncated, or 5mm, as in the following example:

13.0 – 13.9 cm = 13 cm
14.0 – 14.9 cm = 14 cm
94.0 – 95.9 cm = 94 cm

24.0 – 24.49 cm = 24.0 cm
24.5 – 24.99 cm = 24.5 cm

If for any reason your measurements are made to the nearest centimetre, rather than truncated, this should be specifically mentioned when they are reported to the ICCAT. Otherwise, the data will be assumed to have been measured in the standard way.

Recording data

Systems for recording data should be developed individually. Waterproof recording paper, if available, is invaluable. If one sampler were to perform the work, a tape recorder would prove useful. However, it should be ensured that the recorder is in working order and functioning properly when measuring the fish.

There are two distinct methods of recording. One is to record all the individual measurements directly as they appear; the second is to mark the appropriate size class, so that frequencies are recorded.

The recording sheet should have columns for dates, locations of catches, sampling, and other related data such as vessel name, catch unloaded at the time of sampling, well numbers which are sampled, weight of fish from that well, equipment used, type of length measurement made, sampling frequency applied, etc.

If sampling is multi-purpose and on mixed species, more information on catch and effort, as well as on species etc., would be required. In such cases, ICCAT Form 3-1 recording individual measurements would be more convenient as one sheet could be used for mixed species. On the other hand, if the sample is by species but species composition sampling is carried out at the same time, Form 3-2 may be used. If species composition sampling is not required, the column provided for it on the same form is not to be used.

4.3.4 Data processing

The procedure detailed provides a random sample of a specific unit within the stratum of sampling. This needs to be combined and raised to the level of the fleet/population. Raising has already been discussed in section 4.2.6.

Figure 4.3.5 presents a flow chart illustrating the steps to be followed when processing the raw data. The aim is to estimate catches with proper species breakdown and size. For this we have to estimate them by the appropriate strata, and add them. Catch by strata and size data (see section 4.3), as well as species composition (which will not be repeated hereafter, but should be understood) are essential to achieve this.

1. The raw data obtained from sampling have to be combined into the strata adopted (Level 1 data). During this process, raw size data could simply be combined. If a sub-sample of pre-sorted catches are taken, or if the samples are taken from different wells of the same boat and the catches are known by well, they could be partially extrapolated to the catch from which the sample is taken, prior to being combined (see below).
2. Then the Level 1 size data have to be matched to the catch reported for the corresponding stratum (Level 2). If any size data are missing for the catch, the size composition of that missing stratum should be assumed to be similar to some other size frequency (data substitution). Then, using the size data, catch by size in each stratum has to be estimated (raising the size to the catch).
3. This section explains procedural techniques. If the sampling is multi-purpose (size and species composition), the substitution and raising should be made in the same way for size and species all together, or first catches should be estimated by species in each time-area stratum and then by size. In either case the technique of substitution and raising is identical as explained here for size data (see below).

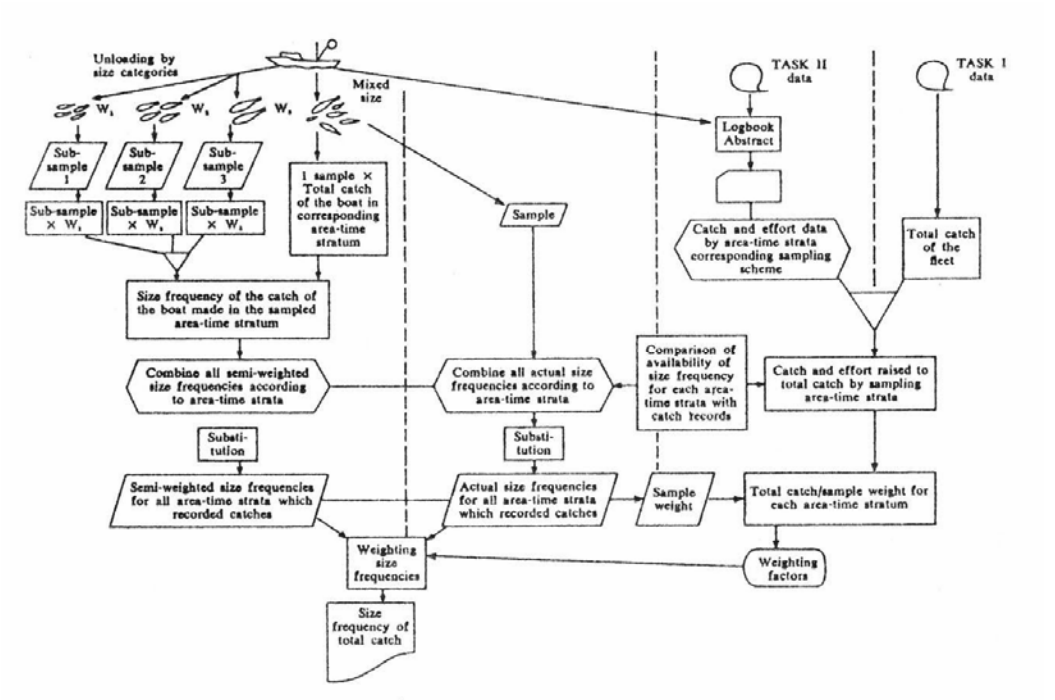

Figure 4.3.5 Flow-chart for weighting size data

Obtaining Level 1 data

The size data obtained from sampling have to be processed into the form required as Level 1 data and then eventually into the form of Level 2.

If the size data are, for some reason, recorded in a unit other than standard (fork length or lower jaw-fork length) such as LD1 etc., they should be converted into the standard (see section 4.3.3). If all the measurements are in the same unit, such conversions could be made after all the data are combined and raised. However, if various measurements are mixed, the conversion has to be made prior to combining all the samples.

If the catches were pre-sorted by size etc., prior to sampling, and consequently sub-samples were taken or the sampling can be identified by wells of boats and associated information (such as catch by wells) is available, the (sub-) samples should first be raised to the catch of the pre-sorted categories, or sampled wells, using the techniques described in section 4.2.6 and below.

Then, these (sub-) samples raised to the catches from which the samples were taken, should be accumulated to the desired minimum stratum (e.g. 1° x 1° and by 10-day periods, or 5° x 5° and by month).

If immediate raising is not possible (e.g. longline size data), a size frequency has to be generated by combining the size data recorded on daily sampling sheets for each unit of stratum. This can be done manually but more easily with any computer. ICCAT can provide programming assistance, if needed. The results of these Level 1 statistics should be reported to ICCAT using the forms in **Appendix 1**.

Obtaining Level 2 data

Data submission

The size data (Level 1) combined for each stratum have to be checked for their availability against the catch data compiled by the same time-area stratum. If a catch is recorded for any strata, but not size data are available, a substitution of data has to be made. There are several ways to do this:

1. Use size frequencies observed by the same type of fishery of another country in the same time-area stratum;
2. Use size frequencies observed by the same fishery in the neighbouring areas during the same time period;
3. Use size frequencies from the same time-area strata but from previous years;
4. Use size frequencies observed in the same area but during the time periods preceding or following the period from which data are missing;
5. Use size frequencies for the last several years combined for the same time-area stratum, by the same fishery.

The best substitution varies according to fishery, season, area etc. In the surface fisheries, 1) might be the best solution. In the longline fishery, 2) or 3) would be better than 1). If the results (Level 2) are to be used in virtual population analyses where catch-at-age for each year plays an important role, 3) should be avoided as much as possible. When using 4), one can even adjust the size by applying a growth curve. When data are very scarce, 5) is often used.

The reader must be aware that data substitution may lead to considerable bias in the Level 2 data. The resulting catch by size may be completely different depending on how the substitution was made, and may even lead to a different conclusion in the population analyses. It is important that **all** the substitution procedures adopted be well documented together with the data.

Raising to the total catch

When the substitution is completed, the size frequencies can be raised to the total catch (see also section 4.2.6). Raising should be done for each time-area stratum.

1) Size frequency expressed in terms of number of fish should be converted to weight using length-weight relationships. (This is not necessary if the catch is known in number of fish rather than weight. The total number of fish in the catch divided by the total number of sampled fish equals the raising factor). Now the fish in each length class is expressed in weight. The sum of those weights will give the estimated sample weight.

Example: Yellowfin tuna

Size classes	*Frequency (No. of fish)*	*Avg. weight of fish*	*Weight of fish in size classes*
52 cm – 53.9 cm	10	2.87 kg	28.70 kg
54 cm – 55.9 cm	12	3.11 kg	37.32 kg
56 cm – 57.9 cm	15	3.47 kg	52.05 kg
…	…	…	…
…	…	…	…
…	…	…	…
Total	250		1050.24 kg*

* sample weight

If all fish measured have also been weighed, the above procedure would be unnecessary as the sum of weights can be used as sample weight.

2) Total catches (in weight) recorded for each time-area stratum can then be divided by the sample weight. This will give raising factors.

For example: if the catch of yellowfin tuna in corresponding time-area strata is 1,520 MT, while the sample weight is 1,050.24 kg, the raising factor is 1, 520 MT divided by 1.05024 MT or 1,447.2882.

3) Actual size frequency should be multiplied by the raising factors in order to obtain catch by size.

Example: Yellowfin tuna. Raising factor = 1,447.2882

Size classes	*Actual Frequencies*	*Raised frequencies (No. of fish caught)*
52 cm – 53.9 cm	10	14473 (=10 x 1447.2882)
54 cm – 55.9 cm	12	17367 (=12 x 1447.2882)
56 cm – 57.9 cm	15	21709 (=15 x 1447.2882)
…	…	
…	…	
…	…	
Total	250	361822 (=250 x 1447.2882)

4.3.5 Age or cohort slicing

Age slicing divides a catch length range into different ages, partitioning it into catch at age.

Size distributions are separated into age classes by assuming there are distinct lengths which separate adjoining age classes. The lengths dividing age classes can be defined in a number of ways. Often these sizes are defined as being the length half way between mean lengths-at-age predicted from a growth curve. This approach assumes equal variability in lengths at neighbouring ages. Whichever approach is used to select the dividing lengths, it should be clearly stated, along with the growth curve used.

These dividing lengths are used in the following way. Fish smaller than the first dividing length are referred to as the 0-group, those of lengths between the first and second dividing length as the 1-group and so on. Some

lengths will have to be distributed proportionally upon two age groups. If, for instance, the length class interval is 1cm, and the first dividing length is 12.6 cm long, then six-tenths of the fish in the 12-13 cm class are referred to age group 0, and four tenths to age group 1. If the length interval is 6 cm with a length class of 12-18 cm, then only a fraction of 0.6/6=0.1 of the fish goes to age group 0, while nine-tenths (0.9) end up in age group 1.

Age slicing can be performed on an annual, quarterly or monthly basis, dependent upon the growth patterns of the fish (e.g. seasonal growth as in yellowfin tuna) and the data available. If annual age frequencies are required, and age slicing is performed at time steps more frequent than an annual step, the number of individuals at age accumulates throughout the year.

The benefits of age slicing are that the approach is easy to use, and can take two-stanza growth patterns into account. However, it requires a number of strong assumptions, including that there is no overlap in length between cohorts. This assumption is not likely to be true, and hence there is the potential to over-estimate the strength of a weak year class, and underestimate a strong year class. This results in a smoothing effect in the catch at age data, decreasing the variability between cohorts. There also tends to be considerable overlap in length-at-age at older ages, biasing the number of older fish estimated.

4.3.6 Age-Length Keys (ALKs)

Put simple, age-length keys (ALKs) are generated through the ageing of a sub-sample of the population, and used to convert larger length samples from a population into ages. ALKs describe distributions of size for each age, and the relative number of individuals at each age, i.e. they represent a matrix detailing the probability that a fish of a given length is of a particular age. Once such a key is available, samples of fish that were only measured for length can be distributed over age groups according to the key. The use of ALKs assumes that the sample of aged fish and the sample of fish measured for length are simple random samples from the same population. Then, the probability that a fish is of a particular age, given its length is the same for both samples.

The ALK should generally be applied to length data from the same time period, since variability in recruitment and survivorship at age will change the age-length composition over time, and hence the number of survivors at age used to weight the size at age compositions will vary. The ALK may need to be seasonal if growth is temporally distinctive or seasonal migration occurs. A single ALK should only be applied to size data from a number of years if growth is reasonably stationary, and the approach of Kimura and Chikuni (1987) is used. Suitable justification should be presented for multi-seasonal or multi-annual application of ALKs. It must also be noted that the application of an ALK derived from a single time of year can cause serious bias if used to compute catch at age for the entire year.

Age-at-length data from hard parts should be combined into suitable length groups for required gears, time periods and locations. The size of these length groups will depend on the spread of lengths found within the catch length frequencies, the growth rate of the species, and the variability in length-at-age. Length-stratified sampling is required to ensure that the required number of fish (determined by the variability of length-at-age) is available over all length groups. Developing ALKs represent is laborious, and hence the optimum collection of information is desirable. Formulae exist to estimate the number of age determinations and length measurements necessary to guarantee a given level of accuracy. Oeberst (2000) developed a universal cost function for ALKs, for example.

The proportion at age is calculated as:

Number at age for a length group / Number of fish aged in that length group

The ALK for the time period is raised to the length distribution for that time period:

Raised numbers at age by length group = Numbers at length * Proportion at age for that length

If the ALK does not contain data for all the length groups in the length distribution then data in the length distribution may be assigned to adjacent length groups where data are present in the ALK. An appropriate age-length distribution by gear group and time period is then produced. Care must be taken since considerable biases can result, particularly at large lengths where individuals may be distributed over a wide range of ages.

The numbers at age by length group are summed over the length range to give numbers at age. The variances are also summed over the length groups and the two components labelled variance due to ageing and variance due to length sampling. This gives the age composition for the required time period.

Numbers at age for all gears can be calculated as:

$$\sum N_a * \left(\frac{W_{ct}}{W_{cs}} \right)$$

where $\sum N_a$ is the sum of sampled numbers at age, W_{ct} is the total commercial catch weight, and W_{cs} is the sampled commercial catch weight.

Variance due to ageing of numbers at age for all gears can be calculated as:

$$\sum Var_a$$

where $\sum Var_a$ is the sum of variances due to ageing.

Variance due to length sampling of numbers at age can be calculated as:

$$\sum Var_l$$

where $\sum Var_l$ is the sum of variances due to length sampling.

The variances should be raised by:

$$\frac{W_{ct}}{W_{cs}}$$

where W_{ct} is the total commercial catch weight, and W_{cs} is the sampled commercial catch weight.

A number of developments to ALKs have been put forward. Hoenig *et al*. (1994) describe a generalized 'inverse' key that can use information from previous years to aid in the estimation of the age composition in the current year. Kimura and Chikuni (1987) outlined an extension of the ALK approach, iteratively determining the age structure from a length sample using the key from a different sample. It assumes that the distributions of size for each age are known, which provides an ALK for the analysis. The proportions-at-age are then adjusted to find the best fit between the observed size frequency data and that predicted by the proportion-at-age and the ALK. The method can work well where the distributions of size for each age are close to those in the length frequency, but convergence can be slow. The reader is referred to the paper for more information.

4.3.7 Schnute and Fournier

The approach of Schnute and Fournier (1980) has been further developed into the MULTIFAN package (Section 4.3.8), which has been used for albacore (*Thunnus alalunga*). The approach of Schnute and Fournier is therefore only covered here briefly.

The approach assumes that mean lengths-at-age in a population represented by the catch length frequency data follow a von Bertalanffy growth curve, and the length at a given age is normally distributed. Proportions at age, growth parameters and a parameter defining the standard deviations of lengths-at-age can be estimated. The approach assumes that the number of age classes is known. Selected parameters represent the 'best fit' between observed and predicted length frequencies.

The Schnute and Fournier approach may present issues when trying to obtain unique solutions for all model parameters, and the mean lengths at younger ages (which may be identified from modes in the length frequency data) may need to be fixed. If this is required, it must be stated, and the assumed mean lengths-at-age presented.

4.3.8 MULTIFAN

The MULTIFAN approach is described in full in Fournier *et al*. (1990). It represents a likelihood-based analytical method for estimating growth and age composition parameters from multiple length frequency data sets. It uses a mixture of distributions approach, and allows the inclusion of biological constraints within the model.

MULTIFAN is an extension of the Schnute and Fournier approach (Section 4.3.7) to simultaneously analyze several length frequency data sets, sampled at different times. The assumed error structure differs between methods, and different estimation methods are used to estimate model parameters.

MULTIFAN makes a number of key assumptions, as described by Fournier *et al*. (1990). These are that 1) there is a normal distribution of lengths within each age class, around a mean length at age; 2) standard deviation of mean length at age varies as a simple function of that mean; and 3) growth follows the von Bertalanffy growth function.

The program varies the von Bertalanffy parameters and number of age classes, and compares the resulting fits of the probability of observing a fish at a given interval defined by the set of growth parameters with the observed proportion of fish in a given length interval, using the log-likelihood function. By examining the results from multiple models, a likelihood ratio chi-squared can be used to objectively evaluate alternative model hypotheses. This examines whether the addition of additional parameters (e.g. age classes) in the model results in a significant increase in the maximum value of the log-likelihood function.

The parameters estimated are 1) proportions within a sample at age; 2) mean length of the first age group; 3) mean length of the last age group; 4) von Bertalanffy parameter K; 5) two parameters predicting the pattern of the standard deviation of length at age; 6) a parameter related to the overall variance of the sampling errors in the length frequency data sets; and 7) a parameter describing the age-dependent selectivity of the fishing process. If the age of the first age class is unavailable, MULTIFAN assumes t_0 is zero.

MULTIFAN is sensitive to the time interval chosen between samples, and the characteristics of catchability and selectivity in the data. There may also be a tendency to group the final age classes together if mean lengths-at-age are not greatly different, or if there are small percentages of fish in those size ranges.

Care must be taken not to constrain the bounds on mean lengths to greatly. Given high variability in fish growth, highly constrained bounds may distort the results obtained. However, bounds must be sufficiently tight to insure that the correct age-class is associated with a mode. Care must also be taken to specify a sufficient parameter space for the programme to search through. This will help prevent identification of local minima during the search.

4.3.9 The performance of approaches

The performance of different approaches will be dependent on the data to which they are applied, and the background knowledge of the fishery and biology of the stock. The best way to identify which approach may work best is to test through simulation. For examples, see Mohn (1994), Goodyear (1997) and Restrepo (1995).

4.3.10 Further reading

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FOURNIER, D.A, J.R. Sibert, J. Majkowski, J. Hampton. 1990. MULTIFAN a likelihood-based method for estimating growth parameters and age composition from multiple length frequency data sets illustrated using data for southern bluefish tuna (*Thunnus maccoyii*). Canadian Journal of Fisheries and Aquatic Sciences. Vol. 47, no. 2, pp. 301-317.

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4.4 CPUE and LPUE as relative abundance indices

Section 4.2.4 described sources of information about tuna fisheries and pointed out that these are mostly linked with commercial fisheries. This section comments on the use of fishery dependent data for landings or catch per unit effort (LPUE or CPUE respectively) as indices of relative abundance of fish. A concluding paragraph comments very briefly on fishery independent CPUE data.

CPUE is usually taken to be proportional to numbers of fish, N, in the stock present in an area:

$$CPUE = q.N$$

The constant of proportionality, q, is called the 'catchability'. The equation could be re-written with subscripts, l, to refer to specific length classes if required. Strong assumptions are inherent in the general relationship (Paloheimo and Dickie, 1964; Maunder and Punt, 2004), e.g.

- Mean CPUE is estimated for the same time period, depths, and geographic region as those supporting the N fish of the stock.
- q is constant under all fishing conditions.
- q does not vary with N.

The difference between LPUE and CPUE unfortunately creates further uncertainty if no information about discarding or other losses of fish at sea is available. When estimating abundance as an index based on mean LPUE or CPUE by time-area strata, it is necessary to consider many factors, e.g.

- whether fishing covered the same area as the stock;
- whether fishing covered the same depths as the stock;
- what the effects of migrations, both horizontally and vertically, would be on local abundance (or q);
- whether fish aggregate and become less catchable at low stock numbers; and
- whether the technologies and strategies being used by the fishing fleet are sufficiently stable to assume that q is constant. A gradual improvement in the fishing power of a vessel is often observed as the captain develops fishing skills, and as the vessel is fitted with better fish finding equipment, occasionally accompanied by more capacity to explore the fishing zones, etc. This is referred to as 'technical creep'.

Other potential specific issues for tuna include:

- seasonal migration effects on the CPUE data from a single nation;
- the effect of Fish Aggregation Devices (FADs) on CPUE;
- co-operation between different gear types when fishing on FADs[4];
- calculating CPUE as an index of population abundance for a schooling species;
- calculating CPUE where tuna are caught for farming. Length and weight measured at market (e.g. Japan) will not be comparable to that of 'wild fish'.

Clear answers to these questions are seldom available so it will be necessary either to accept the proportionality assumption with great caution, or to undertake modelling to try to improve LPUE or CPUE as an index of abundance (Xiao *et al.*, 2004, part I). Regression trees offer another, less prescriptive, model based approach (Watters and Deriso, 2000).

Modelling of CPUEs is a research exercise. The predictor variables usually have to be selected from a long list of possibilities that should include the interactions among the variables (e.g. Rodríguez-Marín *et al*., 2003). Omission of one important variable could cause the model to perform erratically when used to predict outside the time or space frame of the observations used to fit the model. Prior biological knowledge is the best guide for an

[4] Purse seine vessels may hold a large school of tuna in place while baitboats take part of the fish. In this case, when the baitboats are sampled in port, the composition of their catch will be different from that achieved by baitboats under normal circumstances. The effort to catch these fish will also be different to that under normal circumstances. This might require the addition of a gear category for purse-seine co-operating baitboats, and the issue returns to the clear definition of the fishery to be sampled. Another example is the co-operation of purse seine vessels to search for and catch bluefin in the Mediterranean. CPUE of individual vessels are then inconsistent.

initial selection of predictor variables which can subsequently be refined by statistical methods (Burnham and Anderson, 2002). An approach to avoid is that of stepwise selection through all available variables. This is because the statistical significance of a predictor with one set of data and one set of additional predictors will often change substantially when slightly different conditions prevail. The distribution of 'error' (=observed – fitted) values around the model has to be chosen from several statistical possibilities which include allowance for zero CPUE values (Ortiz and Arocha, 2004). The modelling method has to be chosen to suit the error distribution. The simplest situation is when log(CPUE) can be treated as approximately normally distributed around a linear model with zeros ignored; least squares linear regression methods, described in many textbooks, are then suitable. Other distributions, e.g. Poisson, would require a Generalised Linear model (McCullagh and Nelder, 1989). Non-linear relationships can be estimated with Generalised Additive models (Hastie and Tibshirani, 1990). They require a decision on the degree of flexibility to be allowed in the fitted curves, in addition to specification of the model function. Differential weighting of observations having different degrees of reliability is another consideration for modelling (Cotter and Buckland, 2004). A useful general summary of modelling theory in a fisheries context is by Venables and Dichmont (2004).

Given all this flexibility associated with modelling approaches to standardisation of LPUE and CPUE, it is **essential** that those reporting the results of modelling work to ICCAT should summarise all the choices and assumptions made and, so far as possible, explain the reasons for them. The resulting diagnostic plots (e.g. residual, QQ plots) should also be presented to demonstrate appropriate selection of model and error structure. General understanding of the foundations of a modelling study and of its strengths and weaknesses is of considerable assistance when weighing up the information it produces for the purposes of assessment and management of a stock.

LPUEs of fishing vessels can vary by orders of magnitude from set to set. As a result, it is important to use the right estimator for average LPUE in a time-area stratum. For simplicity, consider just two sets labelled $i = 1,2$ in which L_i fish were retained for landing following application of E_i units of fishing effort. Two different estimators for average LPUE are:

$$mean_1(LPUE) = \frac{(L_1/E_1) + (L_2/E_2)}{2} \qquad (1)$$

and

$$mean_2(LPUE) = \frac{L_1 + L_2}{E_1 + E_2} \qquad (2)$$

Suppose, for illustrative purposes, that contrasting catches of fish occurred such that $L_1 = 1$, $L_2 = 100$, $E_1 = 1$, and $E_2 = 2$. Then

$$mean_1(LPUE) = 25.5$$

and

$$mean_2(LPUE) = 33.66.$$

The first estimator is the unweighted average of the two point values of LPUE, one for each set. This estimator uses the information of which sets provided each pair of *L* and *E* values (cf. second bullet point under *Information*, above) and is the recommended estimator for average LPUE because each set, whatever the catch, is an equally valid observation of fishing success. In contrast, the second estimator gives more weight to the larger landing figure, L_2. This estimator has to be used when total landings and total effort for multiple sets are the only available data. The bias for the example data is +32%.

CPUE data from fishery independent sources such as surveys by research vessels or spotter planes may be available. The advantage of these is that they are not influenced by commercial decisions about fishing locations and times, or, if well standardised and documented in SOPs, by changes of fishing gear and technique over time. The disadvantages of such surveys are that they are unlikely to cover the whole area occupied by a stock, and that the degree of overlap may itself vary with season, migrations, and possibly from year to year. The design of the survey is also important. A systematic grid, for example, will be poor for finding fish when the stock is low and aggregated in small, localised concentrations that fall between the nodes of the grid. Generally, survey abundance indices are likely to have higher variance than mean LPUE values from a widespread commercial fishery. They are also likely to be biased due to the mismatch of locations of fish and survey observation points. Use of a time-series of survey results requires the strong assumption that the survey bias is constant over time.

4.4.1 Specific ICCAT issues

A growing issue concerns the overlap between the time-space 'sampled' by the gear and the time-space inhabited by the fish; does the degree of overlap change through time?

For bycatch species such as Atlantic white marlin, the only available time series of relative abundance are fishery-derived CPUE indices. Commercial indices come from wide-ranging fisheries, but these may have changed in spatial distribution, gear (moving from shallow to deeper longline sets) or target species over time (deeper set hooks indicate a change in targeting to bigeye tuna). Other CPUE data come from more localized sport fisheries that have always targeted marlins. Alternative GLM formulations have been put forward in an attempt to remove biases caused by changes in fishing depth over time in the fishery (Babcock and McAllister, 2004).

A further extension for billfish species is the application of 'habitat-based' standardisation models (Hinton and Nakano, 1996). 'Habitat-based' models incorporate understanding of behavioural (depth and temperature preferences) and oceanographic parameters to standardise historical CPUE time series data, as well as accounting for significant gear changes over time. The basic idea is that if a hook is fished in an environment that is preferred by the species, it has a higher probability of capturing that species (Hinton and Maunder, 2004). Bigelow *et al*. (2002) have used the habitat based standardization method to create CPUE based indices of relative abundance for bigeye and yellowfin tuna in the Pacific Ocean. These indices have been used for assessments in both the western-central Pacific Ocean by SPC (Hampton, 2002) and the eastern Pacific Ocean by the IATTC (Maunder, 2002). The debate over the use of 'habitat-based' standardisation models is on-going.

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4.5 Genetics sampling

4.5.1 Objectives of genetics sampling

The tools of population genetics provide methods for identifying a variety of attributes about a population. Of particular interest in fisheries are identification of aspects of the species (groups of species, species types (i.e. individual species), sub-species, stocks) as well as the structure, geographical range and boundaries of each of these species attributes.

Species identification can be useful for enforcement when mis-identification is common. For example, small yellowfin and bigeye tuna individuals can be confused.

For effective management of highly migratory tunas, it is important to identify appropriate stock boundaries (e.g. for Atlantic bluefin tuna). The approach is based upon the theory that population sub-division can result in the genetic differentiation of populations isolated by genetic drift and selection. To identify populations, the general approach is therefore to look at genetic diversity/dissimilarity at the population scale.

It is important to note that the absence of genetic evidence for population sub-structure does not mean that such sub-structure does not exist. Genetic differentiation between stocks sharing the same ocean basin may be fairly small, often of the same order of magnitude as the sampling error. Genetic studies of stock structure must therefore pay careful attention to experimental design and sampling protocols to maximise the signal-to-noise ratio in the data. However, genetic differentiation can be prevented where population sizes are large, and by migration. Theoretical models of nuclear gene product differentiation and mtDNA differentiation indicate that migration of the order of individuals per generation may be sufficient to prevent genetic differentiation. This rate of exchange is minimal in terms of the amount of exchange that would be needed to rebuild depleted populations on a time scale of interest to humans exploiting those populations. Given the limitations inherent in each individual method, the best approach to evaluating stock structure is a holistic one that draws on all the information available from genetic, demographic, ecological and life history studies (Waples, 1998).

4.5.2 Targeting samples

The specific targeting of samples to be taken will be defined by the aims of the sampling programme. Local sampling will define localised variations and mixing in populations through statistical analysis of genotypic data. Broader sampling will identify larger scale genetic differences and similarities. If the aim is to sample population natal characteristics, small individuals should be targeted, for example. These individuals should be within the natal area. In contrast, population scale examinations will require samples from across the known or suspected geographical range. Comparison of genetic profiles in different samples separated by space and/or time may provide evidence for multiple gene pools, or stocks.

4.5.3 Sample size

Available financial resources often limit sample size. Results of genetic analyses can be strongly influenced by sample size, however. The number of sites and years sampled will also increase the number of individuals to be sampled. In general, full programmes analyse over 100 samples per sampling unit (e.g. species, location, year, etc.). The actual required sample size will depend on the genetic differentiation between individuals of the species in different geographic areas (for example). Furthermore, studies have found that maximising sample sizes and temporal coverage is important. The results of studies based upon small sample sizes can produce false-positives (e.g. Ely *et al*., 2002). For all these reasons appropriate statistical advice should be sought at the programme planning phase to ensure that the defined sampling programme will enable the programme goals to be attained.

4.5.4 Sampling procedures

Cleanliness of samples

Contamination must be avoided. The knife must be cleaned (for example in ethanol) before cutting each fish. Contamination might occur if a cutting tool is used on different fish without cleaning. If contamination may have occurred, this must be noted on the form for that sample.

Sampling

Liver, heart and skeletal muscle tissues can be sampled, as well as blood, fin clips or a portion of the whole animal (generally larvae or juveniles). It is recommended that samples from the heart, liver and muscle be taken from an individual. Access to these tissues may be limited in particular fisheries, where the market value of the fish is condition dependent. White muscle may be the most appropriate tissue in this case. When sampling white muscle, remove a flap of skin approximately 9cm in diameter in the central body area between the dorsal fin base and lateral line, to expose the muscle.

Take around $4cm^3$ each (~5g) of muscle, heart and liver. Muscle and liver are recommended for DNA analyses. Clean, trim and wash in cold buffer if required (e.g. 50mM EDTA). Rinsing has been found in some studies to increase yields of closed circular mitochondrial DNA (mtDNA). Smaller pieces are recommended for DNA analysis, since this ensures the ethanol can penetrate the tissues for storage.

There are two different methods for storage of fish material: freezing and ethanol. The use of these alternatives is study dependent. Freezing is the best method for the storage of specimens for electrophoresis and other biological analysis (e.g. biochemistry and physiology), because of the liability of enzymes *in vitro*. Proper cryogenic storage will preserve enzyme activity and minimise breakdown (e.g. through the use of liquid nitrogen). Samples preserved in ethanol can ONLY be used for genetic studies, such as DNA amplification and sequencing. Samples can be stored in 96% ethanol.

Package the sample into plastic bags (when freezing samples) or into the vial of ethanol and then plastic bag (for ethanol) for storage. In each case, the bags should be labelled with (if available), date, vessel, suspected species, length, weight, sex, location of capture (latitude and longitude), tuna school type and school association, tissue type and a unique sample number. All samples from the same fish should be labelled with the same code. If this fish has been used in other studies (maturity etc.), the same code should be used throughout.

When freezing, samples should be frozen as soon as possible after collection. If this is not possible, the sample should be kept on ice until arrival at the laboratory. Samples should then be placed immediately in the freezer.

Shipping of frozen samples

Samples should be shipped to the required recipient on dry ice (within a stay-foam cooler is sufficient). If dry ice is not available, the cooler should be covered with ice and brought into the freezer for some days prior to shipping. Shipment should be carried out by Air Cargo System in regular flight as personal cargo. This approach is faster and cheaper than other delivery approaches. The "Air Waybill" document should be faxed to the recipient. This is the preferred approach. Alternatively, the invoice number for the shipment should be sent.

Shipping of samples in ethanol

Shipment of bags containing vials can be carried out by any regular mail system or other delivery system, to the recipient.

4.5.5 Analysis of samples

Analysis of tissue samples for DNA requires trained personnel and appropriate equipment. The general techniques will be described here, to ensure readers have an understanding of the roles of genetic analysis. For further details, see articles listed in the further reading section.

The tissue sample can be sub-sampled and small (e.g. 100mg, although this will depend on the sensitivity of the technique selected) samples can be incubated in 1ml of digestion buffer. The period of incubation and temperature will depend on the tissue and approach (see further reading). Alternative approaches for DNA extraction include standard phenol/chloroform procedures, followed by ethanol precipitation.

Species identification

Allozyme electrophoretic patterns and mitochondrial DNA (mtDNA) have proved useful for distinguishing different tuna species. DNA is the preferable target for examination, since DNA is the same in all cell types of an organism, while proteins can vary from tissue to tissue. DNA is also stable and provides more information for

analysis than protein. Furthermore, electrophoretic techniques have been shown to be less capable of species differentiation in Atlantic tunas (Bartlett and Davidson, 1991).

mtDNA haplotype analysis has also been used for species identification. For example, ATCO mtDNA haplotypes have been used to differentiate between bigeye and yellowfin catches. Ward (1995) noted that RFLP (restriction fragment length polymorphism) analysis of several mitochondrial genes permitted the unambiguous discrimination of all seven *Thunnus* species on the basis of exclusive haplotypes. This was supported by allozyme and mtDNA tests (Ward 1995).

Population discrimination

While allozymes have been analysed to quantify levels of genetic variation within and among populations, more powerful approaches are available. These include nuclear DNA microsatellite techniques, and analysis of the mtDNA control region (D-loop).

Although the value of mtDNA in identifying population subdivision has been well documented, analyses based solely on mtDNA haplotype frequencies might actually reflect sex-specific dispersal or migration patterns. This is because mtDNA is only passed down from the female of the parents. Furthermore, the non-recombining nature of the mtDNA genome causes it to behave as a single genetic locus, potentially reducing the power to detect significant genetic differentiation (Greig *et al*., 1999). Therefore, the most informative analyses of population structure combine multiple loci to test for similarity of phylogenetic patterns.

4.5.6 Analysis of results

Levels of genetic variation can be assessed in terms of the numbers of alleles per locus, and observed (H_{obs}) and Hardy-Weinberg expected heterozygosity (H_{exp}) (for nuclear DNA only). By comparing H_{obs} with H_{exp}, and testing for deviations from the Hardy-Weinberg equilibrium within samples, the significance of genetic variation can be assessed.

Homogeneity of microsatellite allele frequency can be assessed between temporal and spatial populations. Temporal samples from same spatial area can be pooled if they do not differ significantly in allele frequency. Spatial data can then be compared. Use of the sequential Bonferroni technique (Rich, 1989) is recommended to adjust significance levels for multiple simultaneous comparisons. Population differentiation can also be measured using analysis of molecular variance (AMOVA) (Excoffier *et al*., 1992).

A further technique is the use of hierarchical analysis of nucleotide diversity as a measure of population differentiation (Holsinger and Mason-Gamer, 1996). This approach allows the examination of geographically structured populations using restricted site and DNA sequence data where the variation is not independently inherited. Populations are grouped based on the average time to coalescence for pairs of haplotypes. Results are depicted in a tree diagram that shows the relationship between populations after resampling the data 10,000 times. Significant P-values imply that the mean time to coalescence for two haplotypes drawn from the same node of a tree is less than that for two drawn from different nodes.

4.5.7 Further reading

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4.6 Tagging

Tunas and billfishes are currently being tagged by many different organisations in all parts of the world where they occur, and fishermen and fish handlers of many nations have the opportunity of encountering tagged fish. ICCAT has developed an international cooperative tagging program in the Atlantic Ocean and its adjacent seas. A number of member countries are now participating in the program and releasing many tunas, billfishes and tuna-like fishes tagged with either "conventional" tags, or electronic tags of various types (acoustic transmitters, archival tags, pop-up archival tags (section 4.7)). Tunas and billfishes are tagged to obtain information about their movements, migrations, stock structure, growth, population size, mortality, schooling behaviour, and physiology and to investigate the effects of various patterns of fishing on the fish and the fisheries.

Tagging these large, active fish is not easy, and workers who have had relatively little experience with this type of work can profit from the experiences of those who have.

To make this program successful, it is essential to secure the cooperation of both fishermen and industry in recovering these tags. There may be substantial rewards associated with the recovery of a tagged fish, especially if the tag is an electronic one. These rewards are paid by the research agency involved in the tagging campaign. In addition, to promote recovery of tags, ICCAT holds annual lotteries (see 4.6.4 below). Many of the tags that have been returned have been accompanied by incomplete data, or no data at all, so obviously there is a need for better systems for collection of the required information for the tagged fish that are recaptured.

This section of the Field Manual is a summary of the methods used to tag tunas and billfishes and to secure the return of the tags from those that are recaptured, along with the required information.

4.6.1 Tagging experiments in tuna stock assessment and management in the ICCAT area

Tuna are highly prized by both commercial and recreational fishers. But, their size power and swimming speed have made it a challenge to study their behaviour and biology, especially in the wild. Their thermoregulatory physiology and size enable them to migrate between polar seas and warm temperate or tropical waters over periods of week or months. However, comparatively little is known about the lifetime patterns of movement of tuna, where they breed, or how their populations are structured. This lack of knowledge has accompanied the recent demise of some tuna stocks (e.g. Atlantic bluefin). The US National Research Council (NRC, 1994) committee report on the status of Atlantic bluefin tuna noted that current research on the biology of this species was insufficient to address major biological questions relevant to the management of the fishery. A specific recommendation of the report was to use new tools, such as electronic tags, as a means for resolving stock structure.

ICCAT presently manages northwest Atlantic and northeast Atlantic-Mediterranean Sea bluefin tuna resources as two separate management units. One stock is recognised in the eastern Atlantic with a breeding area within the Mediterranean Sea and a second stock is presumed to exist in the western Atlantic with a breeding ground in the Gulf of Mexico (Metcalfe *et al*., 2002). The NRC review recommended that the two-stock hypothesis be re-examined (NRC, 1994). The greatest uncertainty identified in the report was the extent of bluefin movement within and between the eastern and western Atlantic, spawning site fidelity and the results such lifetime trans-oceanic movements have on the choice of management strategy.

To understand the life history of bluefin and other tuna species and to develop effective management strategies, the temporal and spatial patterns of movement in the oceans needs to be identified and quantified. Resolution of the stock structure questions for Atlantic bluefin tuna is critical to the management of the species. Data on dispersal patterns of pelagic fishes with large geographical ranges are difficult to obtain because of the limited resolution the analytical tools available for studying such animals in the wild.

Results from conventional tagging studies demonstrate that all size classes of bluefin have the propensity to make trans-Atlantic crossings (NRC, 1994). Currently, technologies are needed that can augment conventional tagging data sets to improve the definition of the geographical boundaries of the stocks. A fundamental tuna management problem in relation to spawning site fidelity is to determine, for those individuals that move across the Atlantic, whether tuna breed only in one area (e.g. the Gulf of Mexico or the Mediterranean) or in both places. Recent research using electronic tags to study the movements and population structure of Atlantic bluefin tuna supports the two-stock hypothesis and provides evidence for distinct spawning areas that overlap on North Atlantic foraging grounds. Results also reveal hot spots for spawning bluefin tuna in the northern slope waters of the Gulf of Mexico (Block *et al*., 2005).

4.6.2 Tagging Programs

Many research organisations carry out tagging programs aimed at collecting data on different tuna and tuna-like species in different regions of the Atlantic. A list of recent or on-going tagging programs can be found at: www.iccat.int/tagging.htm

ICCAT maintains inventories of the tags that are released. Scientists who carry out tagging campaigns should report the relevant information (tag type, number, area, gear, date, species, size, etc.) to ICCAT so that the inventory can be maintained up to date.

4.6.3 Opportunistic or directed tagging experiments?

Which particular approach is taken to catch and tag tuna is dependent on the aim of the tagging programme.

If the aim is to engage fishers in tagging activities as a means of increasing awareness and responsibility for fish conservation (e.g. by encouraging sport fishers to release the fish alive rather than kill them), then opportunistic tagging has a role, but chances of getting useful scientific data are often diminished. This applies not only to where and how many fish are tagged in a population (since no targets are set against scientific objectives) but it may also result in poor tag recovery rates, either because fish are not handled as carefully as is required to ensure long-term post-tagging survival or, more likely, because there has been insufficient attention paid to a good tag recovery programme, lacking sufficient or suitable publicity about releases and/or with no structured system for returning recapture details to taggers and paying rewards. Key to the success of any tagging programme is good recovery of tagged fish and accurate recapture data.

This consideration indicates that tagging programmes should be carefully planned with clearly defined objectives (e.g. population abundance estimation; estimation of mortality rates; identification of stocks/migration routes; evaluation of who is exploiting a particular stock; etc.).

In planning a tagging programme it is important to have an idea about the size the "stock", the extent of its geographical distribution, and what tag recovery rates are likely to be. These factors are important in estimating how many fish need to be tagged, where and when, in order to achieve a statistically robust result. It is also important to understand who is likely to catch the fish; can they be used for tagging, or is experimental fishing necessary to get sufficient fish tagged in the appropriate location(s)?

4.6.4 Tag recovery, publicity and rewards

Tagging experiments are usually costly exercises requiring vessel time, experienced staff and, if using electronic tags, involving the deployment of expensive devices. It is therefore paramount that an appropriate amount of resource is deployed to encourage fishers to return tags together with accurate tag recapture details and, when appropriate, the fish carcass. These considerations are likely to be particularly important in the case of tuna where the commercial value of the fish is high. It is often the case, particularly in opportunistic tagging, that tagging programmes fail to achieve the potential because insufficient resources are allocated to publicity and rewards to ensure maximum tag recovery.

Publicity and rewards

The number of tags recovered will improve considerably with good publicity and reward systems in association with a good catch/stock scanning programme (see below). Tag recovery programmes should therefore include:

- an investigation of the likely geographic area where tags will be recovered
- advertising the tagging programme in the appropriate geographical area and in the local language(s)
- adequate tag scanning programmes and sufficient sample sizes
- clear instructions to fishermen
- an incentive to declare tags and information.

Investigation of the likely geographic area of recovery

Tagging programmes should take into account the probability of recapture of the tagged fish. In marine fisheries, the area of encounter is potentially vast but can be reduced significantly with backup information from catch data or earlier tagging studies. For electronic tagging programmes, pre-tagging surveys with conventional tags should be carried out to provide a rough estimate of where the electronic tags will be recovered and what the target

fisheries are likely to be. Subsequently, standard fishing techniques can be applied to recover tags or catches can be scanned in a similar manner to conventional tags.

Advertising the tagging programme

Initially, the objectives, tag type, secondary tag type (if used) and the rewards (if any) should be clearly advertised. Prospective individuals who are likely to recover tags or be aware of recovered tags (fishermen, fish processors, sport anglers etc.) should be informed that tags of different types may be present in the fish they handle. It is important to emphasise the scientific value of the tagging programme, and the value of the data recovered from electronic tags (if used) as well as the overall benefits of the data for protecting and possibly enhancing stock assessment and management.

Publicity can include:

Advertisements in international, national and local newspapers – if the tagging programme is locally based, it is probably best to advertise only in local papers to emphasise the probable recovery location of the tagged fish.

Posters – these should show the features that will identify a tagged fish (presence of an external tag, fin-clip, mark etc) and a clearly identified contact for return of the fish or the tag. Posters have been used extensively in conventional and electronic studies and placed prominently in fish processing facilities and at fishing ports. The language in which the poster is printed should be customized for anticipated regions of tag recovery.

Public presentations – Experience has shown that direct interactions between scientists and commercial fishermen or the public improve the rate of recovery of tags and provide a more lasting impression of the objectives of the programme. Public presentations should be directed at fishermen and fishing organisations, processors, local representative groups and all users of the resource being studied. Direct contact with fishermen or other local contacts through local interviews allows any queries to be dealt with expediently and creates a valuable dialogue between scientists and the public.

Subsequent reinforcement - reinforcing both the original message and the initial contacts has been shown to be effective in obtaining tags which might otherwise not be recovered, especially if tags may be recovered in more than one fishing season.

Tag scanning programmes and sample size

Even if the general area of encounter has been identified, there is still the problem of tag retrieval. For marine fisheries, where shoal sizes may be large relative to the number of tagged fish, large numbers of fish may need to be captured to ensure recovery of a single tag. In general then, marine tagging programmes are usually associated with commercial fisheries where large numbers of fish are available for examination. Ideally, the entire catch should be examined for tags. If this is not feasible then a sufficient proportion of the catch should be examined. Numbers will depend on the estimated size of shoals, their temporal and geographic distribution and the number of tagged fish released initially. Significant improvements could be made if entire catches were routinely scanned for tags on board fishing vessels or in processing plants. This might be performed by scientific personnel at port, by scientific observers on board vessels, or by key appropriately trained fishermen.

Clear instructions to fishermen and processors

Instructions on removing the tags and the procedures to be followed for recording relevant information, or retaining the fish, should be issued well in advance of the tagging period, and then reinforced while the fishery is taking place. For some research programmes, it may be important to recover the carcass of the fish to investigate growth and condition, or determine whether spawning has taken place. During intensive commercial fishing operations and in busy fish processing plants, retrieval of tags should not interfere substantially with routine processing, or interfere with commercial operations. If tag removal is simple, then more co-operation can be enlisted from fishermen or fish processors who are most likely to come into contact with tagged fish. This can be done on a contract basis or by organising a fee for tags recovered. In some instances, the time available to fishermen or processors to retrieve tags may be short, and it may be better to rely on trained technical personnel to scan landings and remove tagged fish.

Incentive to declare tags

Tagging data is valuable, particularly if it involves the used of electronic tags since the data recorded by even a single archival tag can be significant. There should therefore be a good incentive to return tags, particularly if tag recovery is dependent on commercial fishermen or processors. The following incentives have been used extensively in conventional tag recovery programme with varying degrees of success.

(a) Monetary rewards
This is a time honoured standard, although it is often difficult to decide on an adequate monetary reward. If the intention is to retrieve transmitting tags for re-use, the reward should be less than the cost of a replacement tag. For data storage tags the value must be decided in relation to the cost of the tagging programme, the value of the data and the effort needed to obtain tag recoveries, although this may be difficult to estimate in terms of direct cost benefit. ICCAT offers a reward of $1000 (U.S.) for the return of each implantable archival tag and $500 (U.S.) for each external popup satellite archival tag from its Atlantic bluefin and billfish tagging programmes (Prince & Cort, 1997).

(b) Gifts
Gifts are often preferred as they are easier to administer and are often more
acceptable, particularly if they have a high 'popularity' value. In many parts of the world institutes are moving towards offering T-shirts, sweatshirts, badges and peaked caps, all of which have a collectable appeal.

(c) Information
Often, the incentive to return tags can be increased if there is a corresponding return of information back to the individual recovering the tag, particularly if he/she is working within the fishing industry. Generally, the information would be in the form of an information leaflet outlining the objectives of the tagging study, information on the tagged fish that was recovered and information on the overall results of the programme.

(d) Recognition
Publication of a list of individuals who have recovered tags in an institute or fishing newsletter is often useful to advertise the tag programme and encourage tag recovery.

(e) Competitions and lotteries
As a general incentive, a lottery scheme can be a useful method to improve return rates for tagged fish. ICCAT holds annual lotteries. Three draws are held, one each for billfish, temperate tunas and tropical tunas, with a US$500 prize for each winner. The ICCAT tagging lottery takes place annually during the SCRS meeting.

4.6.5 Methods of fish capture

There are many methods for catching live tuna that can be appropriate for tag and release programmes with either conventional or electronic tags, these include line fishing, netting and trapping. Fish may be tagged within a few seconds or minutes of capture and in the same sequence that they are caught (baitboat, trolling, or sport-fishing gear), or there may be a longer period of time between capture and tagging with the fish not being tagged in the same sequence in which they were caught (purse seines, traps, gill nets, or longlines). Much more success is realised from experiments in which the fish are tagged a few seconds to a few minutes after they were caught. The return rates for tagged purse seine-caught tunas are lower than those for tagged baitboat-caught tunas, and the return rates decrease as the times of confinement in the net prior to tagging and release increase (Bayliff, 1973). In some cases at least, large portions of the fish tagged and released from traps are recaptured by the same traps within a few days.

Special methods have been developed for capturing and tagging large pelagic species such as sharks, tunas, marlins and sailfish, which are difficult to handle and sedate on board a boat because of their size and strength. Pole and line fishing from vessels using lures with special barbless hooks is the main method of capture. The fish are handled rapidly without anaesthesia and care is taken not to cause skin damage by using soft plastic covered tagging or measuring cradles (Williams, 1992).

4.6.6 Fish handling

Once caught, fish must be handled gently. They should be tagged and returned to the water or released as quickly as possible, provided they appear capable of maintaining forward movement through the water. Alternatively, if fish appear to be exhausted or show signs of stress (i.e. coloration or obvious injuries) that would inhibit them from swimming away after release, every effort should be made to resuscitate (see Prince *et al*. 2002 for resuscitation methods for tuna and billfish). Fish should not be dropped on the deck or allowed to strike the side of the boat or the bulkhead. When picked up they should be held horizontally and the gills should not be touched with the fingers. Only fish in good condition should be tagged and released. This is not only important from a fish welfare point of view, but also because electronic tags (if used) are expensive so long-term survival of the fish is critically important.

In field experiments, the ideal conditions for handling fish cannot always be met. Setting up facilities for anaesthesia and recovery may be difficult because of spatial restrictions or poor weather at sea. The experimenter must then evaluate the relative difficulties of applying anaesthesia against possible trauma and damage caused by handling unanesthetized fish, although legal considerations may be paramount. When tags can be attached rapidly and non-intrusively, anaesthesia has often been replaced by simpler methods of keeping the fish quiet during tagging such as blindfolding. Anaesthesia has in general not been applied when tagging tuna or billfish. The capture process is likely to be much more stressful and time consuming than attaching the tag, even when electronic tags are being used, which generally only requires a minor surgery. Instead, covering the eyes usually quietens the fish. Special devices to ease the process and minimise handling time have been developed. (See below and Block *et al*. (1991a, 1991b, 1998a), Carey & Robison (1981), Holland *et al*. (1990a; 1990b) and Williams 1992; Prince *et al*., 2002).

Block *et al*. (1998a) developed a successful method of capturing and handling Atlantic bluefin tuna (*Thunnus thynnus*) for use in archival tagging and acoustic tracking studies. The fish are caught by heavy tackle using circle hooks and bait presented in a chum stick ("chunk fishing"), a technique that allows chasing down the fish in order to minimize fight times. The fish are taken on-board the tagging vessel by lip hooking the tuna through the tip of the lower jaw with a small gaff through and pulling the fish through a "tuna door" in the stern onto the deck on a wet mat. The eyes of the fish are immediately covered with a soft wet cloth and the gills are then aerated with a saltwater wash-down hose while the tag is implanted inside the body cavity. The method is suitable also for handling large individuals (up to 250 kg) with low risk of damaging the fish. A similar approach has been used with southern bluefin tuna (Gunn *et al*. 1994)

Various methods for handling tuna and tuna-like fishes have been described in the FAO Fisheries Technical Paper "Materials and methods for tagging tuna and billfishes, recovering the tags and handling the recapture data" (Bayliff and Holland, 1986) and these are described below. In addition, more recent guidance on tagging methods for stock assessment and research in fisheries has been published as a report of a Concerted Action FAIR project (CATAG) (Thorsteinsson, 2002).

In-the-water method

This method is employed by commercial and recreational fishers, as well as scientists, using conventional or popup satellite archival tags for fish that are generally too large or dangerous to be brought aboard the vessel (Prince *et al*., 2002; Ortiz *et al*. 2003; Prince and Goodyear, 2006). The fish are brought along side the boat and tagging is accomplished while the vessel moves slowly ahead. but only after the fish is "played down" to a point where it is subdued and easier to handle. This approach has, in the past, sometimes been considered less advantageous than other methods since there is often a general lack of control of the fish in the water and some fish are in poor condition due to having struggled for some time during capture. Also, it is not always possible to measure fish accurately when handled in this manner. However, new fish handling devices and techniques have been developed to control the fish at boat-side and position the fish in the water to insure accurate and safe tag placement (Prince and Goodyear, 2006; **Figure 4.6.1**). In addition, innovative methods have also been developed for resuscitation of both tuna and billfish using this method and these procedures greatly increase the survival of tag released fish (Prince *et al*. 2002). Moreover, efforts to resuscitate tagged fish are increasingly being considered as critical to the post release survival (Prince and Goodyear 2006). In other words, in-water tagging methods have evolved over time from a relatively primitive approach, to one with increasingly more sophistication. Historically, this approach has proved valuable, especially for tagging rare event species, such as istiophorid billfish, where commercial methods of capture are often impractical. In other cases, the in-water method is useful when no alternative method has been found to handle very large fish safely and returns from fish tagged in this manner have added considerably to our understanding of the biology of large tunas and billfishes (Ortiz *et al*. 2003). A large portion of the ICCAT tagging data base for large pelagic species consists of data using this method, particularly from constituent-based tagging programs.

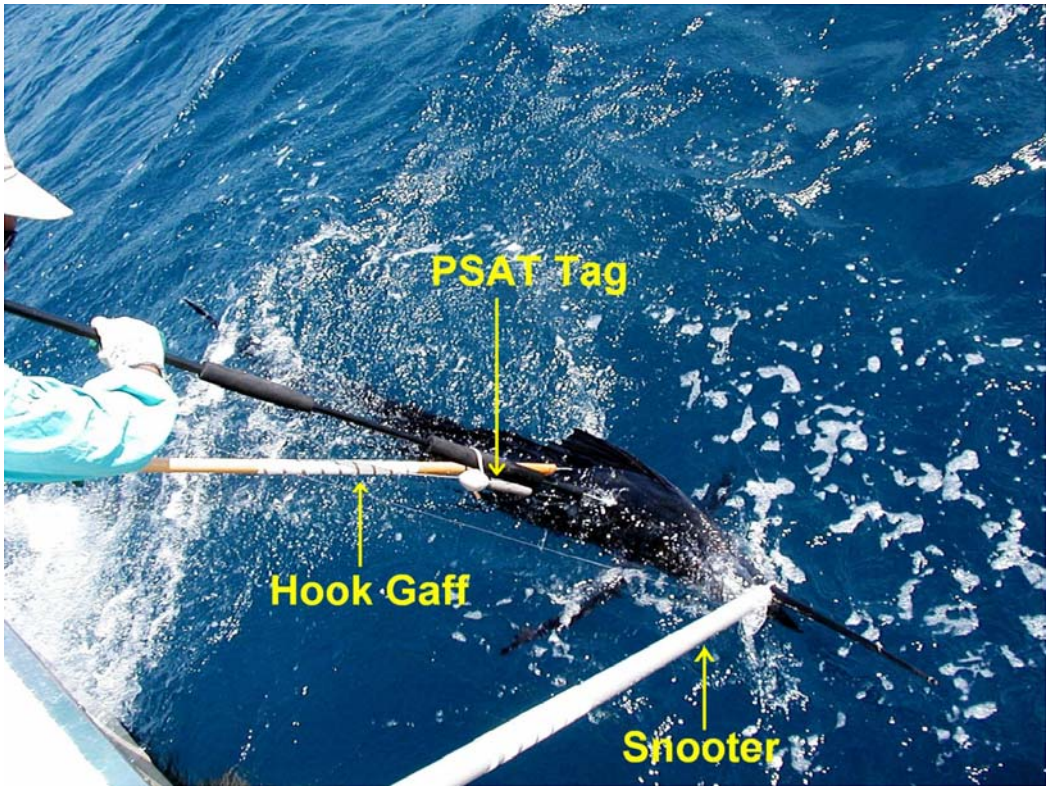

Figure 4.6.1. A snooter (pvc pipe and wire snare) and small hook gaff (wooden pole) are being used in tandem to control this Atlantic sailfish to insure safe and precise placement of a PSAT tag. Reprinted from Fisheries Oceanography with permission.

Winging

This method has been used from time to time with skipjack (*Katsuwonus pelamis*, Yamashita & Waldron, 1958) and albacore (*Thunnus alalunga* (Laurs, *et al*., 1976). In the fishing operation, the fish are hooked, swung up, caught under the left arm and unhooked. The tagger stands about 50 cm behind the fisher (usually there is one tagger for two fishers). While the hook is being removed the tagging needle is inserted, usually from the right side.

In general, this method is inferior to the cradle method (see below) because a significant amount of skill is required and it is difficult to measure and weigh the fish accurately. In addition, it probably results in more damage to the fish than does the cradle method. However, under appropriate conditions and when only a few fish have to be tagged, this method may be suitable.

Deck method

This method has been used mostly with large tunas. Its use was first reported by Fink & Bayliff (1970), for large yellowfin, *Thunnus albacares*, on a baitboat. Improvements for this method are described by IATTC/CIAT, 1981:26.

In this method, the entire stern deck of the vessel and the sides of the bait tanks adjacent to the deck are heavily padded with energy-absorbing (closed cell) plastic foam covered with Herculite, a smooth plastic material. This makes it possible to slide the fish into position with relative ease and without removing excessive amounts of mucus from them. Fishing takes place only at the port stern corner of the boat, and fish are tagged at the starboard stern corner and on the port side about 4 meters forward of the stern. The horizontal padding is raised slightly with extra padding at the port stern corner so approximately equal portions of the fish slide toward the two tagging stations. The fish are slid onto flat cradles with nose blocks so that they can be measured accurately. After being tagged and measured, the ones at the starboard stern corner are slid overboard through a small door cut in the starboard bulwark of the boat, and those on the port side are slid up a slight incline over the rail.

The deck method has also been employed for purse-seine caught fish and for baitboat-caught fish that are too large to be lifted into and out of cradles such as those described below. While it is the best method for tagging purse-seine caught tunas, confinement in the net is harmful to the fish, and the return rates are usually low.

Cradle method

More tunas have been tagged by the cradle method than by any other method. There are two basic types of cradles, those that hold only one fish and those that hold more than one fish. These will henceforth be called small and large cradles, respectively.

The small cradle (Wilson, 1953; Fink, 1965) is essentially a V-shaped trough, usually made of aluminium, closed at one or both ends (**Figure 4.6.2**). It is covered with padding, which is usually covered with smooth plastic fabric. The fish is placed in the cradle, the hook is removed, and the fish is tagged and released. The tags are usually stored further from the cradle to prevent them from being hit by the struggling fish. The sides of the cradle hold the fish in position, and also seem to reduce its struggles somewhat. It is important that the padding be covered with smooth fabric, as Bayliff (1973) showed that the return rates were higher for fish tagged in covered cradles than for those tagged in uncovered cradles. In some cases small cradles are fastened securely to some part of the boat, usually one of the rails, and in other cases they are not fastened down, and moved out of the way when they are not in use.

Large cradles (Kearney *et al*., 1972; Kearney and Gillett, 1982) are better than the small ones because it is easier to transfer the fish from the hook to the cradle without dropping them on the deck. Fish can also be stored momentarily at the large end of the cradle when, for brief periods, fish are being caught more quickly than the tagger can tag them. However, large cradles require more deck space and they cannot be moved out of the way as easily as small cradles when fish are not being caught. In general, small cradles are useful when there is limited working space and the numbers of fish to be tagged are relatively small, but for large-scale experiments large cradles are preferable.

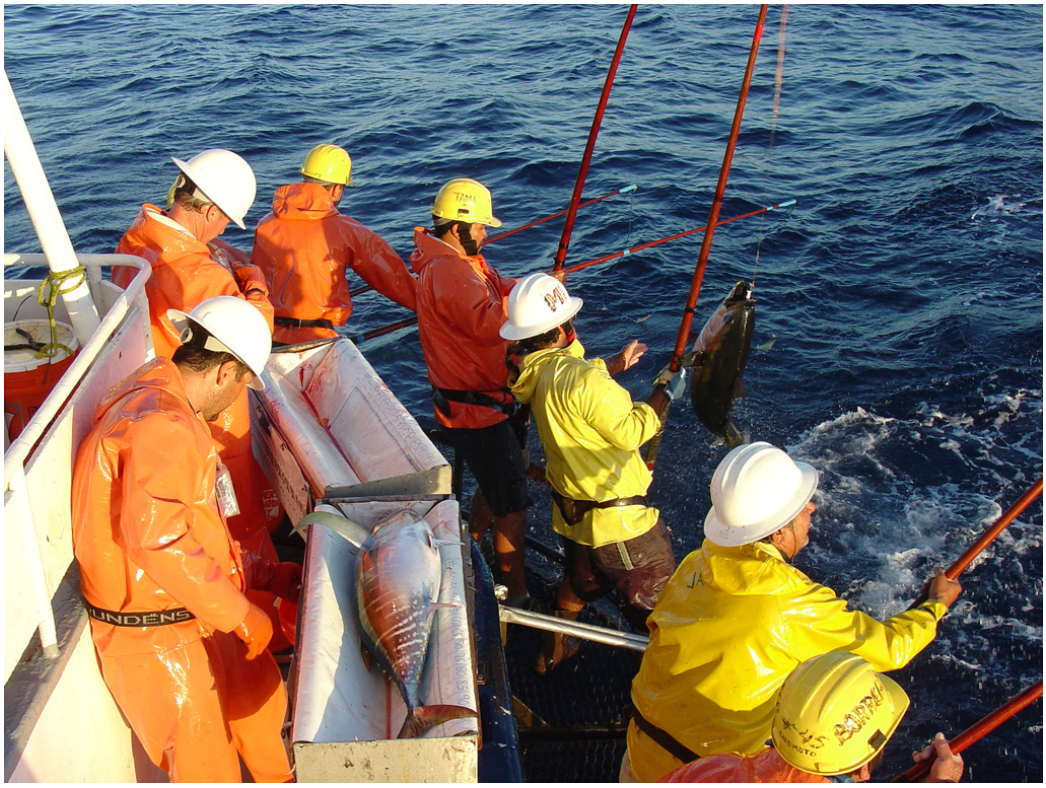

Figure 4.6.2 The small cradle method in use on the stern of a live-bait pole-and-line vessel during IATTC bigeye tuna tagging charters (courtesy of Kurt Schaefer)

Chute method

Scientists of the U. S. National Marine Fisheries Service, La Jolla, California, U. S. A., have modified small cradles for tagging albacore as follows.

A chute about 90 cm long is attached to the nose end of the cradle at its base with a hinge, and the nose block of the cradle is attached to the rest of the cradle with a single pivot so it can be lifted up to permit the fish to slide from the cradle to the chute. After a fish is tagged, instead of lifting it up and dropping it overboard, the nose block is lifted and the fish slides overboard through the chute, which is angled downward. This increases the speed of the tagging operation, decreases the amount of handling to which the fish are subjected, and eliminates the dropping of tagged fish on the deck, which sometimes occurred when the cradles without chutes were used. Most importantly, the fish enter the water head first and pointed toward the bow of the boat. Before the modified cradle came into use, when the fish were dropped overboard they entered the water at the stern of the boat in the middle of the school, and tended to scare the fish away, especially if they failed to enter head first (Bayliff, 1979).

A more elaborate chute system was constructed by the IATTC. With this system the fishers catching the fish deposit them into troughs constructed from a strong smooth fabric (e.g. Shelterite) on pipe frames. The troughs slope towards the cradles so that the fish slid in that direction. Assistants at the cradles unhook the fish if necessary and push them head first and one at a time into the cradles. The fish are tagged by the taggers and then put overboard (**Figure 4.6.3**). The principal advantages of this method are:

1. The fishers have a large target in which to deposit the fish;
2. the tagging process can be better controlled;
3. tagging location is well removed from the fishing position which means fish can be released away from where the fish are being caught;

The pads, cradles and chutes are marked at 1 cm intervals so that the fish can easily be measured while they are being tagged. Because these marks fade or ware quickly, they need to be renewed frequently at sea.

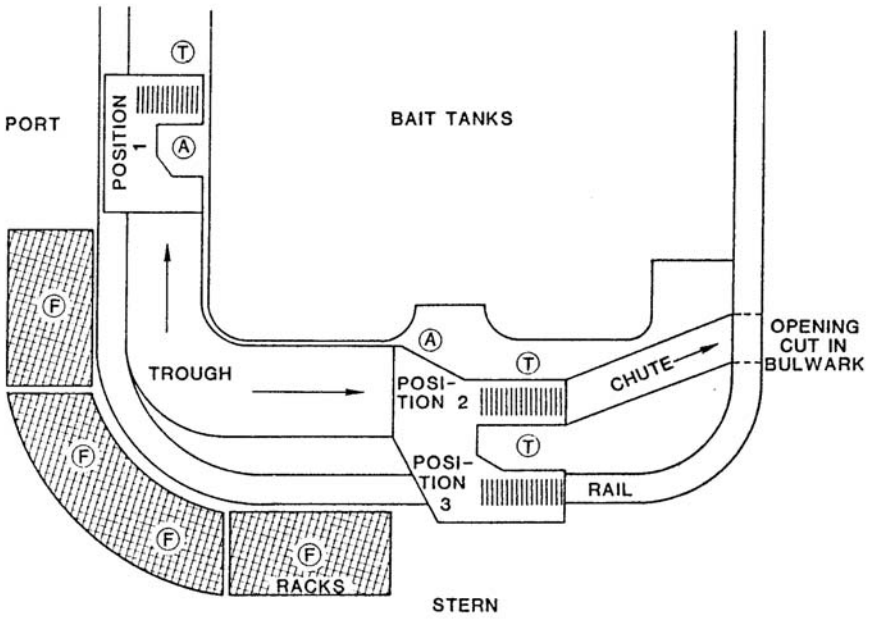

Figure 4.6.3 The chute system used by IATTC. The circles marked F, A and T indicate the position of fishers, assistants and taggers respectively (From Bayliff and Holland, 1986).

4.6.7 Conventional tags

Conventional tags are simple, uniquely numbered, tags. They usually consist of a plastic tube attached to a plastic surgical grade nylon, or metal dart anchor. (**Figure 4.6.4 and Figure 4.6.5**) The tags usually carry the address to which the tag (and fish) should be returned. They may also indicate a reward and what additional fish recapture information is required. Most nylon tag heads are manufactured or supplied either by **Floy Tag Manufacturing Inc.** (www.floytag.com, or: 4616 Union Bay Place NE, Seattle, WA 98105, USA. Phone: 206-524-2700 Fax: 206-524-8260 Email: floytag@halcyon.com) or Hallprint (www.hallprint.com or by **Hallprint Pty Ltd**., 15 Crozier Rd. Victor Harbor, South Australia 5211. Phone (International) +61 8 8552 3149, Facsimile (International) + 61 8552 2874; Email: davidhall@hallprint.com.au.

Tags, applicators and holders

During the 1950s and early 1960s tuna and billfishes were tagged with loop tags, but these have now been replaced by dart tags. The most common type has a nylon or head with a single barb. Tags are usually about 15 cm long and 2.5 mm in diameter but shorter tags (7-8 cm) have been used on small skipjack tuna. Larger dart tags with nylon or stainless steel heads are used to tag billfishes and larger tuna on sport-fishing vessels. Most of the tags are made from low-temperature vinyl tubing that is attached to the nylon head. This tubing tends to become brittle at temperatures close to freezing (below about 4°C). Since some fishing vessels freeze their catch, these tags are likely to break off and be lost. To overcome this problem, tags made of polyethylene tubing bonded to nylon heads have been introduced (Anon., 1986). Polyethylene is resistant to breakage at low temperatures and less springy than vinyl. The latter characteristic may be an advantage, as the tag may retain the configuration that causes the least resistance to the water when the fish is swimming in a straight line at its normal speed.

Most tags are yellow, but other colours have been used from time to time. Data presented by Broadhead (1959) and Blunt and Messersmith (1960) indicate that yellow tags are easier to see than red, blue, white, or clear ones. Fish that were injected with tetracycline (see below) have been tagged with yellow tags with the tips painted red or with red or international orange tags to let the persons who recover them know that the fish were of special interest. Tags should have the name of the organization to which they should be returned and the codes on them. The codes should be printed on both ends of the tags so that the information is less likely to be lost if the tag is broken or mutilated when it is returned. Tags are most often coded with five digits (100,000 possible combinations), a letter and four digits (260,000 possible combinations for the English alphabet), or two letters and four digits (6,760,000 possible combinations for the English alphabet). They usually arrive from the manufacturer sorted into groups of 100, and they are almost always allocated to the various taggers at sea in those same groups. It is less confusing and more convenient for computerized analyses if these groups contain, for example, A0000-A0099, A0100-A0199. etc., rather than A0001-A0100, A0101-A0200. etc. (Kearney and Gillett, 1982).

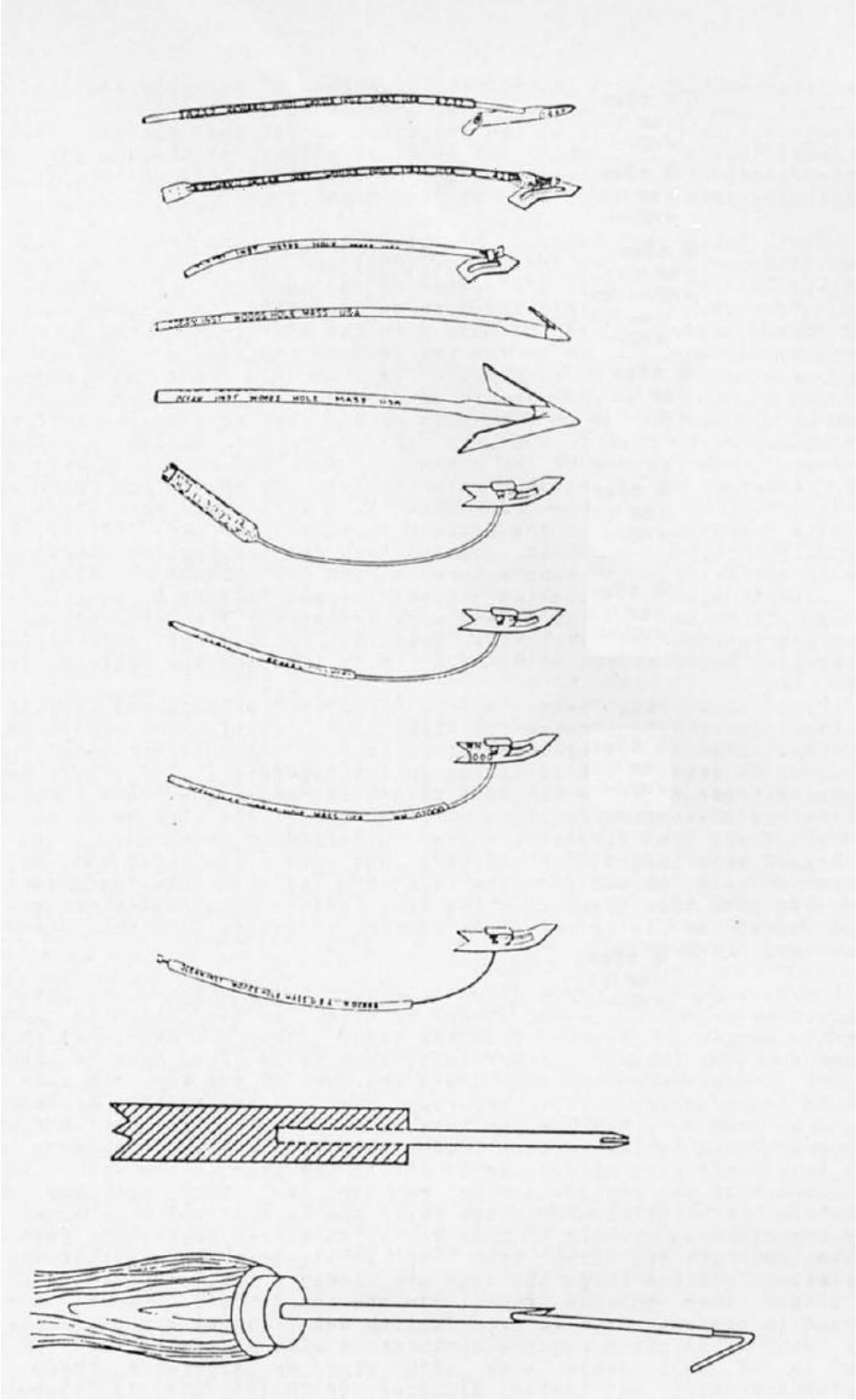

Figure 4.6.4. Various types of conventional tags and tag applicator used to tag tuna and tuna like fishes (from Bayliff and Holland, 1986. Reproduced with permission from FAO).

Figure 4.6.5. Stainless steel dart tag, Tag A (top) and hydroscopic nylon double-barb dart tag, Tag B (bottom) used in the double-tagging study to evaluate retention of the two tag types on billfishes (1990–1999). Reprinted from Prince *et al.* (2002) with permission of the authors.

According to Mather *et al*. (1974), metal heads are superior to nylon heads when the in-the-water tagging method is employed. However, Prince *et. al*. (2002) recommend using nylon double-barb dart tags on large fish because these result in higher tag retention rates. Ortiz *et al*. (2003) who reviewed tagging results of the world's 5 primary constituent-based billfish tagging programs found that tag retention of the medical grade nylon anchor had superior retention qualities when compared to the stainless steel dart tag. (Gaertner *et al*, 2004). Nevertheless, this type of tag is, in spite of everything, less adapted for the massive tagging operations carried out on tropical tunas and causes additional mortality just after the tagging.

Dart tags of the type shown in **Figure 4.6.4 and Figure 4.6.5** are attached to the fish with applicators that consist of pieces of steel (tubing or solid) slightly longer and/or slightly larger in diameter than the tags. As shown in the figure, these are sharpened at one end, as shown in the figure. Commercially-made heads often have an indentation in the sharpened end to accommodate the barb of the tag, but this does not seem to be necessary. It is important that the applicators be longer than the tags, otherwise the tags will not go all the way into them when they are stored in the holders before use, and the head will be cut off when attempting to attach the tags to the fish. It is also important that the applicators be neither too large nor too small in diameter. If they are much too small the tags cannot be slipped entirely into the applicators, and if they are slightly too small the tags may be pulled out of the fish when the applicators are withdrawn. If the applicators are too large the tags are likely to fall out when attempting to attach them to the fish. However, in the latter case they can be crimped to prevent the tags from falling out (Kearney and Gillett, 1982). It is suggested that an organisation which is planning to tag tunas or billfishes for the first time order its tags and applicators from the same manufacturer so as to be sure that the tags will fit the applicators.

Prince *et al*. (2002), recommend using a dual applicator tagging stick (**Figure 4.6.6**) for in-water tagging because these applicators increase the flexibility of the angle of tag entry when the fish may turn sideways.

Figure 4.6.6. Dual applicator tagging pole (Courtesy of Eric Prince, NOAA).

4.6.8 Tagging procedure

To minimise tag loss, each tag should be inserted into the dorsal musculature sufficiently deep so that the barbed heads passes between the pterygiophores below the base of the second dorsal fin on tunas; and in the hump behind the head or near the base of the first dorsal on billfishes (**Figure 4.6.7**). Ideally, the tag should be positioned at an angle of 45º, or less, to the axis of the fish to minimise water resistance. The tag should not go so deep as to cause unnecessary damage to underlying tissue. Once the tag has been inserted, only the tube or capsule should be visible. With experience, the tagger should be able to feel when the barb has passed between the pterygiophores. The rates of shedding of tags differ among taggers (Bayliff, 1973; Prince *et al*., 2002), indicating the importance of careful placement of the tags and suitable training of taggers (also see below on double-tagging).

Prior to use, tags should be inserted into the applicators. In situations where many fish will need to be tagged over a short period of time, applicators with tags can be stored in groups of 100 in holders made of fabric (Wilson. 1953) or wood (Fink, 1965; Bayliff, 1973; Kearney and Gillett, 1982). The compartments or holes in the holders are numbered from 00 to 99, and the tags are matched with these numbers. Fabric holders are suitable for small-scale tagging, as on a troller or sport-fishing vessel, but wooden holders are better for large-scale tagging. Up to about 30 holders are loaded with tags prior to fishing. Since the sharpened points of the applicators are exposed, all of the holders but the first ones to be used are stored in wooden boxes (open on one side, but not at the top) from which they can be easily removed.

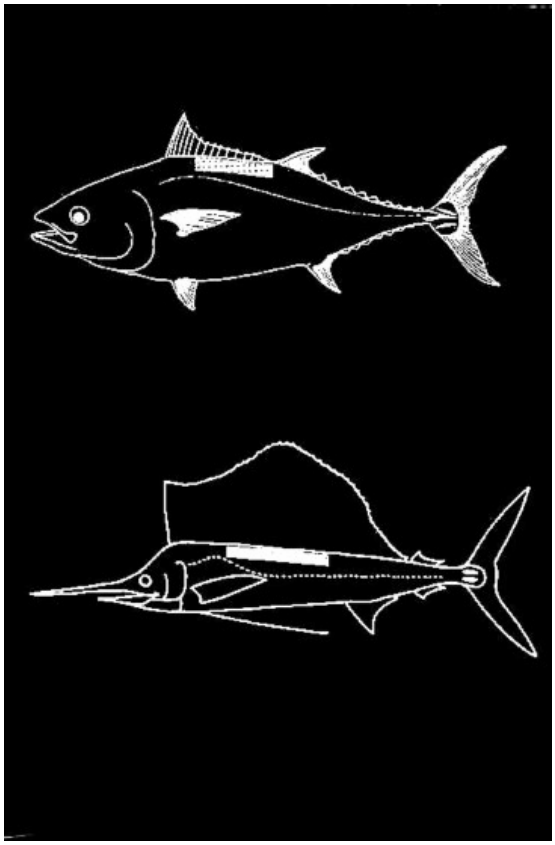

Figure 4.6.7. Target area (rectangles) for tagging tuna (top) and billfish (bottom) recommended by the Southeast Fisheries Science Center's Cooperative Tagging Center. Tags should be placed above the lateral line, away from the head and other vital organs along the dorsal musculature. Reprinted with permission of the authors (Prince *et al.* 2002).

Recording equipment and materials

The data corresponding to each tag which is used (location, date, species, length, remarks concerning the condition of the fish, etc.) must be recorded. A list of the data that are commonly recorded is given below. In some situations large numbers of fish are tagged in short periods of time aboard baitboats (and also purse seiners), so it is imperative that everything be well organised at all times. Tagging is usually much slower aboard other types of vessels, so less organisation is required. An adequate number of tags and applicators should have been loaded into the holders before tagging starts. A piece of masking tape with the tag series written on it can be stuck to the end of each holder so the tagger can quickly choose the series with the lowest codes and record which series he/she is using without pulling one of the tags out of its applicator. The holders should be placed in boxes near each tagging cradle or position. Each tagger, if he/she is using a tape recorder, should ensure that it is working properly and has enough tape for recording. Each tagger should record the location, date, time, cradle or position, etc. Cotton or wool gloves should usually be worn by taggers and assistants during tagging to protect them from cuts and enable them to get a better grip on the fish. When large numbers of fish are tagged the hands of the persons who handle them sometimes develop a rash and blisters; this can be prevented by wearing thin rubber gloves beneath the cotton or wool gloves. Water should be sprayed or poured over the cradles or chutes and the gloves should be thoroughly wetted just before tagging commences.

Data that could be included in a release-recapture record for a tagged fish.

Release data

- Cruise number
- Tag code Tag type Species Location
- Country in which released and gear used
- Date
- Time of day
- Length
- Sea-surface temperature
- Tagger
- Position or cradle
- Injected or not injected with tetracycline
- Condition of fish

Recovery data

When a tag is recovered, the following information needs to be reported:

- The species
- The number(s) in the tag
- The date and place where you caught it and the fishing gear used
- The size (length) and/or weight of the fish, including the type of measurement
- If possible, the sex and information on the type of fishing (ex free school, FAD, shark-whale, etc.

Tag returns can be sent to the ICCAT Secretariat or to ICCAT tagging correspondents (see www.iccat.int/tagging.htm).

NOTE: To remove an archival tag, a 15 cm incision should be made in the belly cavity, in front of the area where the sensor enters into the fish. The silver or white archival tag (with light sensor attached) should then be removed by hand. DO NOT REMOVE THE ARCHIVAL TAG BY PULLING ON THE LIGHT SENSOR. Wash the tag with water and store it at room temperature.

Additional data that might usefully be recorded at recapture include:

- Sex
- Condition when measured (fresh, frozen, thawed after having been frozen, etc.)
- Vessel
- Process in which recovered (fishing, unloading fishing vessel, unloading freezer ship, butchering. etc.)
- Port returned
- Regulation status
- Person handling the return data

It is more common to record fish lengths in whole centimetres; the IATTC records them to the nearest centimetre and the organisations that participate in the tagging program of the ICCAT record them to the next lowest centimetre (i.e. lengths from 60.0 to 60.9 cm are recorded as 60 cm).

Double tagging

Fish are double tagged for at least three reasons. First, information about the effects of tagging on the mortality and growth can be obtained by comparing the return rates and growth rates of single- and double-tagged fish, e.g. if the return rates or growth rates for the double-tagged fish are lower than those for the single-tagged fish the tags are probably detrimental (I-ATTC/CIAT, 1984:31-32). Second, comparison of the return rates of single-tagged fish and of double-tagged fish with one or two tags retained makes it possible to estimate the rates of shedding of the tags (Bayliff and Mobrand, 1972; Laurs *et al*., 1976; Baglin *et al*., 1980; Kirkwood, 1981; Wetherall, 1982; Xiao, 1996; Adam and Kirkwood, 2001; Prince *et al*. 2002). It should be noted that the independent estimation of tag shedding rates from double tagging experiments is an integral part of a well-designed tagging experiment. Third, greater return rates, especially for fish at liberty long periods of time, are often realized when the fish are double tagged (Hynd, 1969; Bayliff, 1973). The Southeast Fisheries Center's Cooperative Tagging Center, in conjunction with the Billfish Foundation Tagging Program, double-tagged Istiophorid billfish and swordfish to test retention of two tag types (Prince *et al*. 2002). This program recommended inserting a tag on both sides of the fish to promote increased visibility. However, this was not always possible, as illustrated in **Figure 4.6.8.**

Figure 4.6.8. A hydroscopic nylon double-barb dart tag (left) and a stainless steel dart tag (right) used to double tag billfish, such as this blue marlin, to assess the relative retention of the two tag types. Reprinted with permission of the authors (Prince *et al*. 2002).

The IATTC has double-tagged large numbers of yellowfin and lesser numbers of skipjack and northern bluefin. The tags are placed on opposite sides of the fish, one about 1 cm anterior to the other. The taggers do not try to insert the two tags simultaneously, as this can result in one or both of them being too shallow or too deep. They are instructed to pair the tags so that the lower of the two numbers is an even number. i.e. A3900-A3901, A3902-A3903, etc., rather than A3901-A3902, A3903-A3904, etc. The holders and the plastic and paper forms for recording the data have the numbers paired in the manner just described. This helps prevent the tagger from getting the numbers mixed up when he/she is tagging. The South Pacific Commission (SPC, 1981) has double-tagged skipjack, inserting both tags on the same side of the fish. These are inserted either individually or both at the same time.

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4.7 Tagging with electronic tags

Conventional tagging experiments can be very useful for describing gross patterns of population movement (i.e. the location at release and capture), but the method is not able to provide information at fine temporal scales (i.e. where the fish went between release and recapture) or any detailed information about the behaviour of individuals. Also, population movements derived from conventional tagging studies rely on commercial and recreational fishers reporting details of the time and location of recapture of the tagged fish. Therefore, the results of such studies are inevitably an integration of both fish behaviour and fishing activity, and this confounds any analysis of population movements. Tagging data can be adjusted for spatial variations in fishing effort, where this is known, but movements of fish into un-fished or un-fishable areas, or changes in fish behaviour which alter availability or catchability, cannot easily be accounted for. Electronic tags yield more detailed and extensive information that provides the fuller understanding of tuna biology required for effective assessment and management.

4.7.1 Acoustic tags

Since the late 1960s electronic tags that transmit acoustic signals (radio signals do not be transmit effectively through sea water) have increasingly been used to track the movements of individual free-ranging fish for limited periods. Such work has yielded substantial advances in our understanding of how tunas and other large pelagic fish behave (Yuen, 1970; Carey and Lawson, 1973; Laurs *et al*., 1977; Carey and Robinson, 1981; Brill *et al*. 1993). But this technique is limited because, in most applications, only one fish can be followed at a time, each fish can only be followed for a short period (often only a few days), and sea-going work aboard research vessels is expensive. More recently, substantial advances in microelectronic technology have permitted the successful development of electronic "data storage" or "archival" tags that are small enough to be attached to fish.

4.7.2 Archival tags

Archival tags record and store environmental and behavioural data and, because there is no need for human observers to follow the fish, make it possible to monitor the behaviour and movements of many fish simultaneously over longer periods that can include entire migrations. A variety of such devices are now being used to study the movements of tuna (Gunn 1994, Gunn *et al*. 1994, Block *et al*. 1998a, Gunn and Block 2001) , billfish (Graves *et al*.,2002; Kerstetter *et al*., 2003;Prince *et al*. 2005; Prince and Goodyear 2006) and other large pelagic fishes.

Although most data storage tags currently measure only simple environmental variables such as pressure (depth) temperature (internal and external) and ambient daylight, the data can nonetheless be used to derive quite detailed information about the location and movements of fish. In the open sea, records of ambient daylight can be used to derive estimates of longitude (from the time of local noon) (Hill 1994, Gunn *et al*. 1994, Metcalfe, 2001) and latitude (from day length and/or sea surface temperature (Hill 1994, Gunn *et al*. 1994, Metcalfe, 2001, Block *et al*., 2005, Teo *et al*., 2004). The development of further onboard sensors that can monitor more complex variables such as compass heading, swimming speed, dissolved oxygen or feeding activity will do much to increase our understanding of the movements, migrations and ecology of tunas and other pelagic fish species.

4.7.3 Implantable archival tags

Although the data storage capacity of archival tags is high, their major limitation is the need to recapture the animal to access the data. This requires deployment of large numbers of tags in species with high exploitation rates. In addition, the multinational nature of most oceanic fisheries complicates the coordination of archival tag recoveries. Archival tags have been deployed recently on Atlantic bluefin tuna (Block *et al*., 1998a), but significant numbers of returns take years to retrieve. Satellite tags (conventionally towed or attached) have been employed to study the large-scale movements and physiology of marine mammals, birds, and sea turtles (see Block *et al*., 1998b). These tags have been deployed successfully on basking sharks, (Priede, 1984) but are only applicable for the largest pelagic fishes that frequent the surface.

4.7.4 Externally applied Pop-up Satellite archival tags

To avoid such problems and increase the probability of data recovery, a major area of development has been the "pop-up" tag. These tags are attached externally and have a release mechanism that causes the tag to detach from the fish at a predetermined time and "pop-up" to the sea surface where the data can be recovered via the ARGOS

system aboard polar-orbiting NOAA satellites. The first-generation pop-up tags provided only very limited data: the pop-up position as determined by ARGOS, and a small amount of environmental (usually sea temperature) data. These tags therefore provide fisheries-independent measure of the straight-line distance travelled from the point of tagging. More recently pop-up tags have become available that record temperature, depth and ambient daylight that can be reduced (e.g. as time-at-depth and time-at-temperature histograms and profile-depth-temperature data) on board the tag before data transmission. Such devices are now being deployed on tuna (Block *et al*. 1998b, Lutcavage *et al*., 1999). Although data transmission capabilities are currently very limited, further developments in this field give the prospect of much improved data recovery rates in the future, while further miniaturisation will allow the technology to be applied to small species. In situations where the pop-up tag is physically recovered, either because the fish is re-caught before the tag releases, or because the tag is washed ashore and found, the full minute-by-minute depth and temperature record can be recovered.

4.7.5 Attachment methods for electronic tags

External attachment of electronic (acoustic or archival) tags

Three types of transmitter attachment have been used to attach tags externally to pelagic fish: the "harpoon" technique, stomach insertion and intramuscular sutures. The harpoon technique has been successfully employed for large species (bluefin, marlins, sharks, etc.), although most investigators would prefer a more reliable technique if one could be devised. However, as stated for conventional tagging, this approach has become more reliable with the advent of special devices for maintaining control of the fish at boat-side to insure accurate, precise and safe tag placement, as well as provide opportunities for resuscitation for increased survival of tag fish **(Figure 4.6.1)**. The harpoon method involves the use of monofilament nylon or stainless steel leader material to secure the body of the tag to a flattened stainless steel harpoon tip or medical grade nylon anchor. For stainless steel or titanium anchors, the tip fits loosely into a notch at the end of the applicator pole (harpoon) and the tag body is loosely fastened to the harpoon pole with light rubber bands. The tag is attached to the fish by impaling the tip into the dorsal musculature with a thrust of the harpoon. The harpoon tip lodges in the muscle or beneath the skin, allowing the harpoon pole to be withdrawn and the tag to trail alongside the body. If the fish has been hooked to bring it to the boat the leader is cut and the fish allowed to swim away (Yuen *et al*., 1974). This method has also been successfully used with free-swimming swordfish that have been harpooned from above as they swim at the surface (Carey and Robison, 1981). Although no adverse reactions to the harpoon type of attachment have been reported, the major problem is the uncertainty of the tag attachment and how long the tag will remain in place before being shed. Nevertheless, tracks of several days duration have been acquired using this technique.

The general trend in tuna tracking in recent years has been toward attachment of the tag to the external surface of the fish using intramuscular sutures. Two variations have been used. Tags have been attached to yellowfin using a single nylon "tie-wrap" suture passed through the muscle and pterygiophores of the anal fin, allowing the tag to hang below the fish (Carey and Olson, 1982). The other method is to use two tie-wrap sutures to attach the tag to the dorsal surface of the fish. This technique has been successfully employed on albacore (Laurs *et al*., 1977), and has been employed in the study of yellowfin movements around Oahu, Hawaii (Holland *et al*., 1985). This technique involves bringing the fish aboard the boat and immobilizing it in a foam-lined cradle. A wet cloth is placed over the fish's eyes to further subdue it while the tag is attached. Sharpened hollow needles are used to pass the tie-wrap sutures through the dorsal musculature and pterygiophores associated with the second dorsal fin. One tie-wrap is placed through a loop on the end of the tag, and the other is placed around the middle of the body of the tag to prevent it from wobbling from side to side. Both tie-wraps are cinched down and trimmed, and the fish is released. Yellowfin with tags carried in this way have been observed to swim normally in captivity and have yielded consistent data from field tests. Also, a fish with a dorsally-attached transmitter was caught 4 weeks after release by a fisherman using a trolling lure (Holland *et al*. 1985). These results indicate that intramuscular attachment is a viable method with minimal effects on the fish's behaviour. The biggest problem with this technique is the need to bring the fish aboard the boat and this may preclude its use with larger specimens.

Stomach insertion

Stomach insertion involves gently forcing the tag down the oesophagus into the stomach of the fish. This is usually performed with a detachable rod that is removed once the tag is in place (Yuen, 1970; Carey and Lawson. 1973; Laurs *et al*., 1977; Dizon *et al*., 1978). This technique seems to work best with large fish such as northern bluefin (Carey and Lawson, 1973). For smaller species, such as skipjack and albacore, problems have occurred due to regurgitation of the tag or attenuation of the signal (Laurs *et al*., 1977; Dizon *et al*., 1978). Of course, when stomach temperature is of particular interest (Carey and Lawson, 1973), there is no alternative to placing the transmitter in the stomach.

Internal implantation of electronic (acoustic or archival) tags

As with external attachment methods (except harpooning) this method requires that the fish is brought aboard the boat and/or immobilised in a cradle. Once the fish is motionless, an incision of about 2 cm length is made in the abdominal wall, about 5–10 cm anterior to the anus and about 2 cm to the left of the centerline of the fish. Special care should be taken to cut only through the dermis and partially through the muscle, but not into the peritoneal cavity. A gloved finger is then inserted into the incision and forced through the muscle into the peritoneal cavity (Block *et al*. 2001 a & b). The tag, previously sterilized by soaking in Betadine solution or similar, is then inserted through the incision into the peritoneal cavity. Two sutures are usually sufficient to close the incision, using a sterile needle and suture material [e.g. Ethicon (PDS II) size 0, cutting cp-1, 70 cm]. The fish is measured using marked graduations on the liner of the cradle and then released back into the sea (Schaefer and Fuller, 2005).

External attachment of electronic Pop-up archival tags

Pop-off satellite tags are usually attached to tuna or billfish by using a dart machined of stainless steel, titanium, or moulded in medical grade nylon (Block *et al*., 1998b;Graves *et al*. 2002;Prince *et al*., 2005; Prince and Goodyear 2006). The dart is inserted about 10 cm deep (depending on the size of the fish), at the base of the second dorsal fin (see **Figure 4.6.1**), where it can anchor between the pterygiophores and connective tissue radiating ventrally from the fin. The tag is connected to this anchor by a 20- to 25-cm-long, 136-kg monofilament leader attached through the eye loop at the front end of the tag. The eye loop is fixed in place by a thin, stainless steel wire that is exposed to sea water externally and connected internally to a battery. At the programmed time, a low voltage is passed across the wire promoting corrosion and release. During tagging, the fish are usually on deck for about 2 minutes. Alternatively, the fish are tagged using the in-water method **(Figure 4.6.1)** while the tagging vessel moves slowly forward. Experiments on captive tunas indicate that, because the tuna body narrows after the second dorsal fin, tags placed here had minimal contact with the body and did not disturb normal swimming patterns.

4.7.5 Post tagging and release of fish

If no anaesthesia has been used, the general consensus is that fish should be released back to the sea as soon as possible, provided that the fish appears to be in sufficiently good condition to maintain forward movement. As all pelagic tunas and billfish are ram ventilators, the ability to maintain forward movement is essential for respiratory function and post-release survival. If the fish is showing signs of stress (based on physical appearance and color), every effort should be made to resuscitate the fish until vigor and color return. Methods for resuscitation of tuna and billfish are given in Prince *et al*. (2002). Details on the condition of the fish (attitude in the water, vigour of swimming etc.) at release should be recorded.

Antibiotics for prevention of infection

Bayliff (1973) sprayed the tips of about half the applicators and tags used on one cruise with oxytetracycline hydrochloride equivalent to 3.5 mg per g, 1.2 mg per g of hydrocortisone, and 1,200 units of polymyxin B as the sulfate. The return rates for the fish (yellowfin) with the sprayed and unsprayed tags were not significantly different. Majkowski (1982) states that southern bluefin *Thunnus maccoyi* tagged during the early 1960's were "injected with an antibiotic to help combat tag shock, handling and infection."

Tetracycline injection

Tunas and billfishes are sometimes injected with tetracycline at the same time that they are tagged to gain information on the meaning of the natural marks formed in the various hard parts (otoliths, vertebrae, spines, etc.) of the fish that could be used for age determination (Antoine and Mendoza, 1986). Veterinary-grade oxytetracycline hydrochloride solution (100 mg oxytetracycline base as oxytetracycline HCL per ml) is used for this purpose. Tetracycline that has exceeded its expiration date as an antibiotic is also ineffective as a marking agent. The tetracycline is incorporated into the peripheries of the otoliths (and probably the other hard parts) within 24 hours. When a fish is recovered and the otoliths are examined under ultraviolet light the tetracycline mark can be seen and the number of natural marks between the tetracycline mark and the edge of the otolith can be counted and correlated with the time elapsed between tagging and recapture.

The following amounts of tetracycline have been used by various workers:

Species	*Size*	*Amount*	*Reference*
Yellowfin	42-95 cm (1.5-17.4 kg)	1.25ml	Wild and Foreman, 1980
Skipjack	41-61 cm (1.3-5.0 kg)	1.25 ml	Wild and Foreman, 1980
Bigeye	88-134 cm	5-10 ml	Schaefer and Fuller, 2005
Albacore	51-85 cm (3.3-14.7 kg)	1.5 ml	Laurs, *et al.* 1985

The fish were all injected intramuscularly, the small to medium fish being given a single injection lateral to the first dorsal fin and the large ones two or three 1.25-ml injections in various locations.

The injection with tetracycline apparently does not affect the survival of yellowfin or skipjack, as the return rates of injected and control fish are not significantly different (Wild and Foreman. 1980). Injection is time-consuming, however, so in most circumstances it will result in less fish tagged.

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4.8 Sampling for maturity

Knowledge on the reproductive patterns of large pelagics, as well as the characteristics of growth and mortality, will largely define the regenerative capacity of a population. Hence they are extremely important for management and conservation, and the construction of reliable models for effective stock assessment.

Large pelagics are generally repetitive broadcast spawners, and hence require very high lifetime fecundities to ensure reproductive success. This is achieved through various degrees of protracted spawning, along with a combination of frequent spawning and relatively high batch fecundities (Cayré et Farrugio, 1986; Schaefer, 2003). This biological feature increases the complexity of maturity studies.

The main approach for assessing maturity patterns of tunas and billfishes is based on collecting gonads for detailed histological examination under a microscope. While this has proven to be an accurate method, providing valuable information, it is labour-intensive, expensive and lethal for the fish. In addition, gonad samples are often unavailable since tuna may be sold intact at the auction block and swordfish are gutted at sea. More recently, chemical approaches to determine maturity have been developed. These techniques are discussed.

4.8.1 Sampling for sex and maturity

The location and timing of sampling will be defined by the purpose of the programme. By obtaining samples throughout the year, temporal patterns in maturity can be ascertained. More detailed temporal coverage may ascertain daily cycles in spawning. For example, studies have indicated that spawning may be synchronised to occur at dusk in some species. Wide spatial coverage may determine spawning locations. These factors should be considered when sampling for maturity data, and prior knowledge used to appropriately focus sampling campaigns. Sex determination and collection of ovary material generally relies on access to carcasses that have not been eviscerated. Access may be restricted when dealing with high value species.

The gonads can be found in the ventral part of the body cavity. In sexually mature fish, both male and female gonads can frequently fill the area available in the body cavity. Ovaries are usually tubular, pink/red, and granular while testes are flat, white/grey and their ventral edges frequently have a wave-like outline. In billfish, male gonads have a relatively uneven appearance and irregular shape, with many nodules present on the external surface. Cross sections of male gonads have a characteristic rectangular shape, and when sexually ripe, milt is easily seen. This can be contrasted with females, which generally have a smooth external appearance and in cross section the goad is oval in shape and occasionally has a lumen (hole) in the middle. The weight of the fish is another factor in determining the sex of individual billfish, since the males of most species are considerably smaller (on average) compared to females. For example, Atlantic blue marlin males rarely grow over 100kg (220 pounds), while can grow over 400kg (880 pounds) and are common over 125 kg (275 pounds). In theory, therefore, it is unlikely to find male Atlantic blue marlin over 125 kg dressed weight!

For estimation of length-at-maturity and fecundity, a length-stratified sampling approach is appropriate. Length ranges comparable to the expected length-at-age distributions, or smaller length ranges, can be used. The sampling approach may need to be modified within the limitations of funding, given the requirement to sample different seasons, areas and years. Additional stratification may be required to compensate for fish behaviour, including spawning aggregation or spawning migrations.

On collection of samples (see below), the following details should be noted:

Date, vessel, species, length, weight, sex, weight of gonads, gonad sub-sample weight, location of capture (latitude and longitude), tuna school type and school association, and a unique sample number referring to the fish, sample from that fish, and including the region of the gonad sampled.

To estimate proportions of sexually mature individuals, precise criteria for the classification of maturity must be defined. This is discussed over the following sections.

4.8.2 Maturity stages

The visual assessment of ovaries to determine maturity stage is felt to be an imprecise indicator of reproductive condition (West, 1990). The use of histological and/or chemical methods is recommended. Scales are included here for completeness (**Table 4.8.1**).

Table 4.8.1 Maturity stages for visual examination of large pelagic gonads.

Stage	Criteria	
	Males	**Females**
I	Gonads small ribbon-like, not possible to determine sex by gross examination	Gonads small ribbon-like, not possible to determine sex by gross examination
1	**Immature**; testes extremely thin, flattened and ribbon-like, but sex determinable by gross examination	**Immature**; gonads elongated, slender, but sex determinable by gross examination
2	Enlarged testes, triangular in cross section, no milt in central canal	**Early maturing**; gonads enlarged but individual ova not visible to the naked eye
3	**Maturing**; milt flows freely if testes pinched or pressed	**Late maturing**; gonads enlarged, individual ova visible to the naked eye
4	**Ripe**; testes large, milt flows freely from testes	**Ripe**; ovary greatly enlarged, ova translucent, easily dislodged from follicles or loose in lumen of ovary
5	**Spent**; testes flabby, bloodshot, surface dull red, little or no milt in central canal	**Spawned**; includes recently spawned and post-spawning fish, mature ova remnants in various stages of resorption, and mature ova remnants about 1.0mm in diameter

4.8.3 Histological sampling and analysis

Histological sampling is the most common approach used to ascertain maturity stage for large pelagic species.

Either the whole gonad, or if too large gonad cross-sections (1 cm thick) taken across the central region of the ovary, should be taken immediately after the fish had been caught. These should be fixed in Bouin's solution, neutral 10% formalin, or 4% formalin in seawater, for return to the laboratory.

The samples should be dehydrated in increasing ethanol concentrations, clarified in Histolemon and embedded in paraffin wax. Sections (5-10 µm thick) can then be taken using a microtome. Sections can be stained with haematoxylineosin (Harris' hematoxylin followed by Eosin counter stain) alone, or supplemented with Mallory's trichrome and Periodic acidShiff (Pas) reaction, before viewing under the microscope. Magnification (eyepiece and objective) should be stated.

For females, the oocyte classification scheme developed by Hunter *et al*. (1986) is recommended (**Table 4.8.2**). This classification scheme covers both the spawning frequency and the likelihood that a female with continue to spawn (through the atretic state of the ovary). If alternative schemes are used (e.g. Corriero *et al*. (2003) for bluefin tuna) they should be fully referenced and the interpretations of immature and mature status detailed.

Table 4.8.2. Maturity stages from ovary histology examination

Stage	Maturity	Oocyte condition	Atresia	Comments
1	Immature	Majority of oocytes in late diplotene or early perinuleus stage	No atresia	Densely packed oocytes darkly stained with hematoxylin
2	Immature	Mix of early and late perinucleus stage oocytes. No yolk granules present	No atresia or minor atresia of unyolked oocytes	Early developing stage
3	Immature	Partially yolked	No atresia or minor atresia of unyolked oocytes	Red staining yolk granules or globules evident from cell periphery inward to within ¾ of distance to perinuclear zone
4	Mature	May be unyolked or partially yolked	Atresia of fully yolked oocytes evident	Considered to have reached a fully yolked and potentially reproductive state but regressed to a reproductively inactive state
5	Mature	Fully yolked oocytes present by no post ovulatory follicles observed	Zero or less than 50% atresia of fully yolked oocytes	A mature, potentially reproductive fish
6	Mature	Fully yolked oocytes present. Oocytes may be in migratory nucleus or hydrated condition and/or post ovulatory follicles present	Less than 50% atresia of fully yolked oocytes, generally zero or minor atresia	An actively swimming spawning fish with zero or minor atresia
7	Mature	Fully yolked oocytes present. Oocytes may be in migratory nucleus or hydrated condition and/or post ovulatory follicles present	Atresia of 50% or more of fully yolked oocytes	An actively spawning fish with significant atresia
8	Mature	Some fully yolked oocytes present but none in migratory nucleus or hydrated condition. No POFs present.	Atresia of 50% or more of fully yolked oocytes	A potentially reproductive fish with significant atresia
9	Mature	No fully yolked oocytes but atresia of fully yolked oocytes evident	100% atresia of fully yolked oocytes	A mature fish in non-spawning phase
10	Mature	No fully yolked oocytes present. Oocytes resemble Stage 1 or 2.	Advanced atresia of oocytes	A mature fish in advanced atretic, post-spawning phase

This classification scheme can be simplified into a maturity classification system (**Table 4.8.3**).

Table 4.8.3. Maturity classification system based upon Hunter *et al*. (1986)

Category	Stage	Fully yolked oocytes present	POF present	Comments
Immature	1, 2, 3	No	No	Oocytes have never reached fully yolked condition
Mature	4 to 10	Yes for St. 5-8	Yes for St. 6, 7	Having developed fully yolked oocytes
Reproductively active	5, 6, 7	Yes	Yes for St. 6, 7	Fully yolked oocytes present
Spawning	6, 7, 5*	Yes	Yes for St. 6, 7. No for St. 5	Histological evidence of recent or imminent spawning
Reproductively inactive/atretic/post spawning	4, 8, 9, 10	Yes for St. 8	No	Had developed fully yolked oocytes but now regressed to partially or completely inactive condition

* considered spawning only if oocytes observed in migratory nucleus or hydrated condition

The diameter of a set number of oocytes (e.g. 350-400 per section) should be measured in microns to obtain frequency distributions of selected stages of oocytes development.

Spawning time and location can be based on specimens with hydrated oocytes in the ovaries, which indicate imminent spawning.

For males, Abascal *et al*. (2004) and Schaefer (1996) have both developed keys for testes development in separate tuna species. That of Schaefer provides a guide for male spawning status, while the descriptions of Abascal *et al*. describe the microstructural and histological stages which may be found in tuna testis.

Schaefer's classification (**Table 4.8.4**), developed for *T. albacares* in the eastern Pacific, is based on the size of the sperm duct (vas deferens), thickness of the myoid tissue surrounding the duct, the amount of spermatozoa within the duct, degree to which the duct was convoluted, whether the tissue adjacent to the duct appeared to be heavily nucleated, and the staining characteristic of the tissue adjacent to the duct (under Haematoxylin-eosin stain).

Table 4.8.4. Development stages from testes microscopic examination

Stage	Vas deferens contents and structure	Van deferens epithelial stain
Pre-spawning	Devoid of sperm, extremely convoluted	Darkly stained
Spawning or recently spawned	Sperm filled, open duct smooth along its border	No conspicuous dark staining

Evidence of recent spawning in male *T. albacares* from the eastern Pacific was only found about 12 hours after the spawning event. Sampling must therefore be temporally focussed.

Abascal *et al*. (2004) noted two distinct zones in the cross-section of *T. tynnus* testes. In the outer region, seminiferous lobules have a think wall formed by the germinal epithelium, where germ cells develop in association with Sertoli cells. The lumina of the lobules are filled with spermatozoa that have been released after completion of the spermiogenetic process. The release of mature sperm from spermatocycts into the lobule lumina results in the germinal epithelium becoming discontinuous. In the central region of the testis, testicular lobules lose the germinal epithelium and become ducts where lobule function has shifted from sperm production to sperm storage. Only mature spermatozoa are found in this region, which fill the swollen lumina of the lobules. Gamete stages are listed in **Table 4.8.5**.

Table 4.8.5. Development stages of spermatozoa from histological and SEM examination

Stage	Description	Location
Primary spermatogonia	Large, ovoid cells, nucleus with diffuse chromatin and single central nucleolus. Large numbers of chromatid bodies in cytoplasm	Distributed along the germinal epithelium
Spermatogonia	Result from successive mitoses of primary spermatogonia. Found in small groups. Nucleus contains patchy chromatin	
Primary spermatocytes	Clusters, with cells interconnected by cytoplasmic bridges. Heterochromatic nucleus. Cytoplasm contains free ribosomes	
Secondary spermatocytes	Seldom found in histological samples. Cytoplasm reduced, nucleus shows diffuse chromatin forming moderately electron-dense patches	
Spermatids and spermatozoa	Found in groups with heads facing the lobule walls and bundles of flagella directed toward the seminiferous lobule lumen. Early spermatids have spherical nucleus with dense chromatin. Chromatin becomes more homogenous in mid spermatids. Chromatin condenses into a coarse granular pattern in late spermatids. The nucleus also assumes an ovoid shape, and forms a basal indentation over the proximal segment of the axoneme. Flagellum elongates, cytoplasmic mass reduces, and mitochondria coalesce around the proximal portion of the axoneme. Flagellum remains parallel to the base of the nucleus in spermatozoon.	Held within spermatocysts

4.8.4 Chemical approaches

In many fisheries, fish are either landed already gutted, or the value of the flesh prevents ventral opening and the determination of sex and sexual maturation. Absence of sexual dimorphisms also makes external identification difficult. In these cases, molecular endochrinological approaches allow the sex and maturation stage to be identified from blood and tissue samples. Through the collection of muscle samples from a broad size range of individuals from each management unit, maturity at size can be estimated.

Blood and muscle can be sampled for chemical analysis for reproductive hormones. Samples from mature individuals are obviously of greatest interest. A muscle biopsy punch has been developed to allow samples to be taken (Bridges *et al*., 2000), which samples approx 100-150mg of muscle without obvious damage to the fish. Blood and muscle samples should be frozen following extraction.

Blood should be centrifuged to collect plasma (e.g. 5000 *g* for 15 minutes). Resulting plasma samples can be analysed directly. Muscle samples need to be homogenised and steroids extracted with Diclormethane before measurement.

Assessment can be performed using standard Enzyme-Linked ImmunoSorbent Assay (ELISA) methods for sex hormones (e.g. 17β-estradiol (E_2), 17α-20β-dihydroxy-4-pregnen-3-one (17,20β P), 11-ketotestosterone (11-KT)) and the lipoprotein vitellogenin (Vtg), which is synthesised under the influence of E_2.

Changes in steroid hormones and vitellogenin can normally be correlated with gonadosomatic index (GSI) and oocytes diameter. 17,20β-P can be used to determine the pattern of both egg and sperm release. The relationship between testosterone and 11-KT may be used to identify sex, while various sex steroid rations can be used to define both the maturity and sex of a given fish (e.g. presence/absence of Estradiol, vitellogenin).

It should be noted that while steroids are stable at room temperature for several weeks, vitellogenin samples require storage at low temperatures.

4.8.5 Estimation of maturity-related features

The statistical procedure for deriving a maturity schedule involves fitting an appropriate weighted non-linear predictive regression model directly to the maturity data. The model can then be used to predict proportions sexually mature at specific lengths and/or ages. Also, statistical evaluations of spatial and temporal variation in

maturity functions can be conducted on the data. Maturity at length can be estimated through a logistic curve of the form:

$$\%mature = \frac{100}{1 + e^{-a(length+b)}}$$

or in the linear form:

$$\ln\left[\frac{p}{1-p}\right] = \alpha + \beta * length$$

where p is the probability that a tuna as mature, α and β are linear regression parameters of the model, and length is the fish length. 95% confidence intervals should be calculated. If length-stratified sampling has not been used, the model fit should be weighted by the number of samples at each length class, to ensure that limited sample sizes at the extremes of the sampled length range do not overly influence the fit of the model.

For billfish species, gonadal index (GI) can be calculated. This is the relationship between ovary weight (O_w) and length. Lower jaw fork length (LJFL) is generally used. GI is then:

$$GI_{LJFL} = \frac{Ow}{LJFL^3} * 10^4$$

(Albaret, 1977 ; Cayré and Laloé, 1986). Beyond a critical value of the GI, particular to each species, it is accepted that the individual studied is in a state of sexual maturity GI in swordfish greater than or equal to 2.09 is an *a priori* indication of females in an active reproductive stage (García Cortés and Mejuto, 2003). 95% confidence intervals should be calculated for GI where possible.

Gonadosomatic index (GSI) is the ratio between the gonadal weight and body weight, and can be indicative of the maturation state:

$$GSI = \frac{W_G}{W} * 100$$

where W_G is gonad weight, and W is the gonad-free weight of the individual. If a gonadosomatic index is calibrated, for example through the use of histology, it may be used to determine spatio-temporal spawning distributions. It is not sufficiently accurate for the classification of maturity or reproductive activity, however. This relies on the analysis of detailed histology data.

Estimation of the annual fecundity in tunas requires spawning frequency estimates by length classes, and corresponding estimates of batch fecundities over the length range of mature females. Knowledge of the appearance and longevity of postovulatory follicles in ovaries after spawning is necessary for estimation of spawning frequency. The frequency at which ovaries of mature females contain postovulatory follicles can then be used to estimate spawning frequency. Larger females appear capable of maintaining a higher spawning frequency.

Only at the final stages of oocyte maturation, beginning with the migratory-nucleus phase and followed by hydration, is there a distinct hiatus in the distribution of oocytes from which the batch fecundity estimates can be derived. Batch fecundity should only be estimated from ovaries in a hydrated but pre-ovulatory condition. Any loss of oocytes would bias fecundity estimates. Since many tuna are serial spawners (e.g. Corriero *et al*., 2003), fecundity estimates based on non-hydrated ovaries can significantly over-estimate batch fecundity as successive spawning batches cannot be clearly differentiated until the onset of hydration. Batch fecundity should be determined using the gravimetric method that counts the number of hydrated oocytes present in a weighted subsample of ovarian tissue (O_w). Sections of ovigerous lamellae should be taken from the anterior, middle and posterior region of the ovary. Each of these samples should be spread evenly over a microscope slide (longitudinal etching of the slide can aid counting), saturated with a glycerine solution and covered with a slide cover. The number of hydrated oocytes present in each sample should be counted three times, and the numeric mean of hydrated oocytes applied to calculate batch fecundity:

$$B_f = H_e * O_w$$

where B_f is batch fecundity, H_e is the number of hydrated oocytes per unit of weight in the tissue sample, and O_w is the ovary weight. Estimates from the anterior, middle and posterior sections of the ovary can then be averaged to yield an estimate representative of the entire sample. Multiple samples and individuals should be taken to obtain some measure of variability in batch fecundity estimates.

Batch fecundity at length is usually described by a power function of the form:

$$B_f = cL^b$$

where L is the length of the fish and c and b are estimated parameters. Batch fecundity at weight is usually described by a linear relationship of the form:

$$B_f = aW + b$$

where W is the weight of the fish.

Annual fecundity can then be estimated from batch fecundity estimates (number of oocytes released per spawning) and spawning frequency.

4.8.6 Further reading

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4.9 Hard parts

Many parameters are considered critical for the assessment and management of species (as already detailed in this chapter). Amongst these are the age and growth rate of fish.

Where hard parts show marks laid down at a regular time-interval, they can be used to age fish. Marks may be on a seasonal or annual scale (macroincrements), and comprise an opaque and translucent band that can be seen under a light microscope. Marks may also be laid down on a daily basis (microincrements). These require high-power microscopy or scanning electron microscopy to view. Microincrements can be particularly useful when ageing larvae and juveniles. The formation and biomineralization of these growth bands depends on many metabolic and environmental factors, including climate, migrations, nutrition etc.

It is recommended that the nomenclature detailed in Kalish *et al*. (1995) be used when reporting all studies.

Readers are also referred to the excellent manual prepared by CCSBT for southern bluefin, available at: http://www.ccsbt.org/docs/pdf/about_the_commission/age_determination_manual.pdf.

4.9.1 Validation

Before increments in hard parts can be used for routine ageing, they must be validated. This means proving a technique is accurate (Beamish and McFarlane, 1983).

The interaction of factors influencing band formation may result in the formation of bands once or twice a year (e.g. Ortiz de Zárate *et al*., 1996 for albacore). Therefore, the periodicity of formation of bands must be validated to ensure they can be used for accurate age reading. Failure to validate ages can lead to considerable errors in stock assessments.

There is a wide range of methods which can be used to attempt to validate bands in hard parts. These include back-calculation and marginal increment analysis. The most conclusive approach is the use of mark-recapture techniques, including the use of markers such as oxytetracycline (e.g. Ortiz de Zárate *et al*., 1996). Oxytetracycline can be introduced inter-muscularly to captured and tagged fish at dosage rates of approximately 70mg/kg body mass, administered by syringe in body area of the dorsal fin. The resulting mark can be seen as a yellow/gold fluorescence under UV light, and related to the elapsed time since release and the natural marks formed in the hard part. Strontium chloride ($SrCl_2$) can also be used where potential health concerns rule out the use of oxytetracycline. $SrCl_2$ marks in sectioned otoliths can be seen under scanning electron microscopes with a Robinson backscatter detector (Clear *et al*., 2000). Care must be taken to ensure there is no change in the pattern of growth following the marking procedure.

It **must** be stated whether validation was achieved in any study presented. There is also a need to specify the ages for which validation has been achieved.

4.9.2 Sampling for hard parts

A wide range of hard parts have been used to age tuna and billfish species. These include otoliths (sagittae, e.g. Atlantic bluefin tuna), the 1st dorsal fin spine/ray (where spines are generally hard and rays soft) or anal fin spines/rays (e.g. swordfish (spines), yellowfin tuna, bigeye tuna (rays)), vertebrae (generally from the caudal peduncle, vertebra no. 35, e.g. Atlantic bluefin tuna, bigeye tuna).

Some structures are more suitable for a particular species or age than others. There are further practical considerations. Spines can be removed without damage to the fish. This is of particular advantage where purchase of the fish in high value fisheries would otherwise be necessary to examine hard parts such as vertebrae. The caudal peduncle can also be accessed without affecting some commercial processing approaches.

Two strategies are usually used for sampling; random sampling or sampling by length (where a certain number of samples are collected from each length group) (see section 4.2.2). The sampling approach is defined by the purpose of the programme. Monthly samples may be required to validate the use of hard parts for ageing through marginal increment analysis (section 4.9.2), while less frequent sampling (up to the annual level) may be required to develop age-length keys (section 4.3), or even less frequently to estimate general growth parameters. Sampling from different sexes will be required to identify sex-specific growth rates.

A length-stratified sampling programme is preferable, as it will ensure adequate sampling of the whole length range, and improve the estimates of growth parameters (see Section 4.9.5) and the utility of ALKs. However, there are often problems in obtaining fish at the lower or upper end of the length range. In these cases, it may be necessary to form a lower or upper group and combine all the hard parts into this group.

Ruiz *et al*. (2005) have developed recommendations for the length-stratified sampling of hard parts, from which much of the following is taken (with permission). Every month a number of hard parts (e.g. spines) must be collected for each 5cm fork length range. Sampling should take place on different days throughout the month until sufficient hard parts have been collected to complete, as far as possible, the length range of landings. Samples should come from the different catch areas of the stock under study such that most catch areas are covered as well as possible. Therefore, sampling must also be spread amongst different vessels and landing ports.

Hard parts should be obtained from the same landings as the length samples when generating ALKs. If separate landings are used, efforts should be made to ensure samples are obtained from areas/gears that have previously been sampled for length measurements.

Information must be collected corresponding to the individual from which the hard parts were taken, and its capture. These include:

Data	**Notes**
Species	
Unique fish identification number	
Specimen size	The most commonly used measurement is Fork length (FL). (See section 4.3.3). Fork length is the straight line from the end of the upper jaw (end of the snout) to the posterior of the shortest caudal ray (fork of the caudal fin) (**Figure 4.9.1**). This can best be measured using a calliper. Alternatively, a tape measure can be used, although it **must** be kept straight while measuring. The fish should be placed on a flat surface in a horizontal position. In the case of very large specimens in which this measurement is very difficult to take, one of the following two lengths may be used to substitute it: - First dorsal length (LD1): this is the straight line from the end of the upper jaw (end of the snout) to the base of the first dorsal spine (the start of the first dorsal fin) (**Figure 4.9.1**). - Curved fork length (CFL): this is the length from the upper jaw (end of the snout) to the fork by an imaginary longitudinal line, with the corresponding fish curvature (**Figure 4.9.1**). The type of measurement being used must be clearly specified, with the measurement unit (cm). FL and CFL are measured to the lower centimetre (a specimen of 70.8 cm or 70.2 cm would correspond to the 70 cm range), LD1 is measured to the lower half centimetre (a specimen of 30.4 cm measures as 30 cm and one of 30.7 cm corresponds to 30.5 cm).
Date of capture of specimen	Day, month and year
Fishing area	This is the location of the catch from which the sample was extracted, and does not refer to the place where sampling took place. A precise geographical delimitation must be established. The most exact is the latitude and longitude where it was caught. As this information is not always available, in the case of sampled specimens captured in different fishing operations, the latitude and longitude of the area (between 44º - 45ºN and 5º - 7º W, for example), or at least a more or less defined geographical area such as the Bay of Biscay or the Alboran Sea, for example, should be noted.
Country	The country to which samples, organization and personnel responsible for sampling correspond.
Date of sampling	Day, month and year
Live and/or gutted specimen weight	kg
Sex	Male, female, unknown
Vessel type and fishing gear used	Purse seine, longline, baitboat etc.
School type	Free school, FAD associated
Vessel name	Name of vessel that caught the specimen and the port at which it was landed
Hard part	Otolith (left, right, both), vertebrae (and details of vertebrae number), or spine (and spine number)

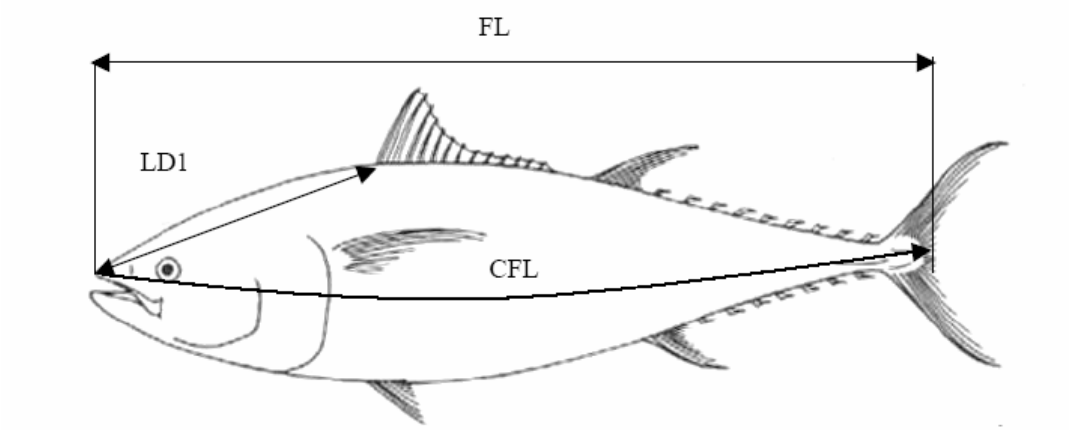

Figure 4.9.1. Types of measurements of bluefin tuna: Fork length (FL), First dorsal length (LD1), Curved fork length (CFL) (from Ruiz *et al*., 2005, used with permission).

The details should be noted on the relevant statistical sheet to ensure the sampling regime is completed.

Spine sampling

The first spine of the first dorsal fin should be collected from each specimen of the appropriate species. The spine must be pulled out whole from the base.

Using a knife, cut the membrane joining the 1st and 2nd dorsal fin rays (**Figure 4.9.2**). Push the spine forward progressively **(Figure 4.9.3B)** until the ligament breaks (**Figure 4.9.3C**). Twist the spine left and right alternatively until it comes loose and pull to finally extract it (**Figure 4.9.3D**).

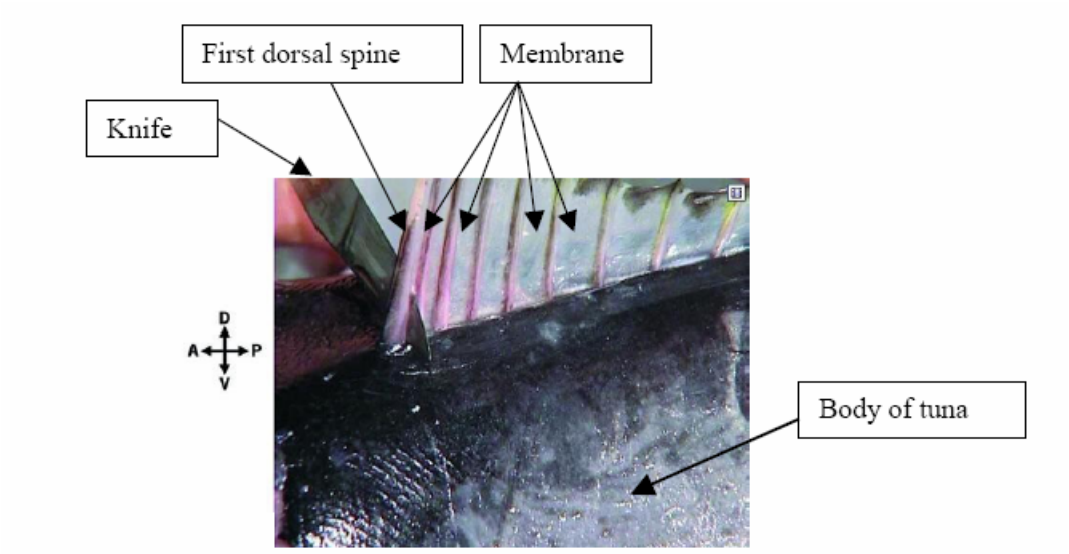

Figure 4.9.2. Insertion of the knife into the membrane separating the first two spines of the 1st dorsal fin. (Figure taken from Panfili *et al*., 2002).

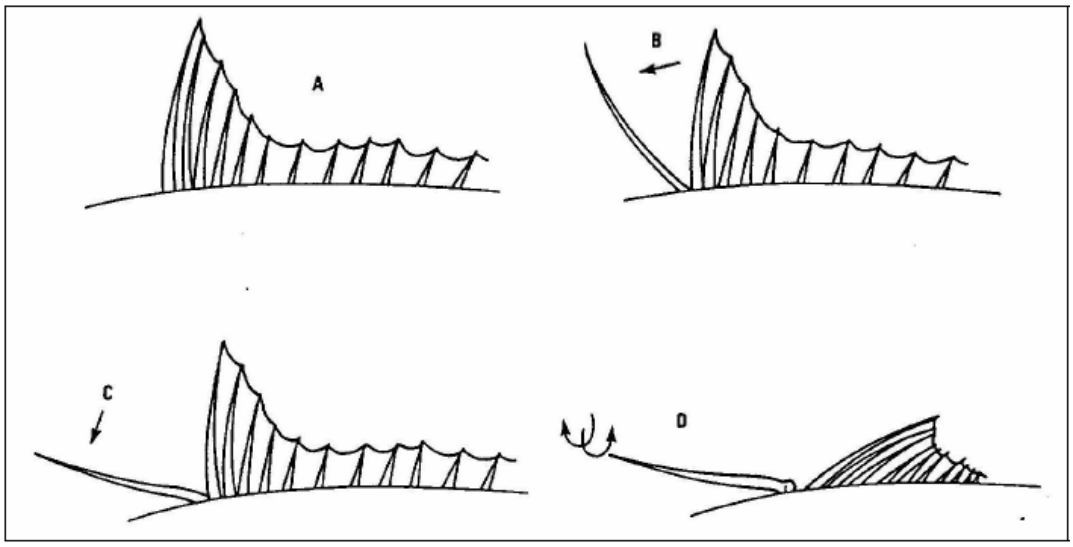

Figure 4.9.3. Technique of extraction of the first spine of the bluefin tuna dorsal fin. (Figures taken from Compeán-Jiménez, 1980).

Spines are ideally preserved dry in a paper envelope, which should be kept in a cool place (refrigerated). If the spine collected is too large to fit in the envelope, it can be cut in half or even in three pieces and kept in the envelope, remembering that the piece forming the base of the spine is the most important since it is the part used for age interpretation. The data of the specimen sampled or its corresponding code must appear on the envelope.

Otolith sampling

Sagittal otoliths are small, calcified structures found in the semicircular cavities of the inner ear, situated at the base of the brain. They are formed by the accumulation of calcium carbonate and protein. The sagittal otolith is the largest of the three otoliths found in each inner ear of the bluefin tuna.

There are two main techniques of removal: transverse head section and frontal head section. In the second, a frontal section of the superior part of the cranium is made, passing above the eye and parallel to the major axis of the fish. The first technique is detailed here.

The transverse head section approach consists of making a cut in the upper part or back of the head at the level of an imaginary line: trace an imaginary line perpendicular to the horizontal fish, which passes through the mid-point between the corner of the mouth and the preoperculum (**Figure 4.9.4A**). For this purpose, the use of a ruler is recommended for dividing this distance in two, and afterwards making a cut in the upper part of the fish which follows this imaginary line. Once the point has been marked to make the cut, use a metal saw and cut down through the head perpendicular to the horizontal axis of the fish.

The sectioned part of the head contains the otoliths. If the above described cut has been made properly, the cavities below the brain in the upper part of the head (**Figure 4.9.4B**) should be searched to find the otoliths. If they are not found here, it may be that they are in the other part of the sectioned fish. Using fine forceps and with great delicacy to avoid breaking these fragile pieces, extract each otolith. They must be taken out of a very fine transparent capsule, which covers them. The otoliths are between 7 and 20 mm in size approximately, and both otoliths must be collected from each specimen. If the otolith has broken, try to recover the pieces and keep them all together. Once extracted, rinse them in water or diluted alcohol and leave them out to dry.

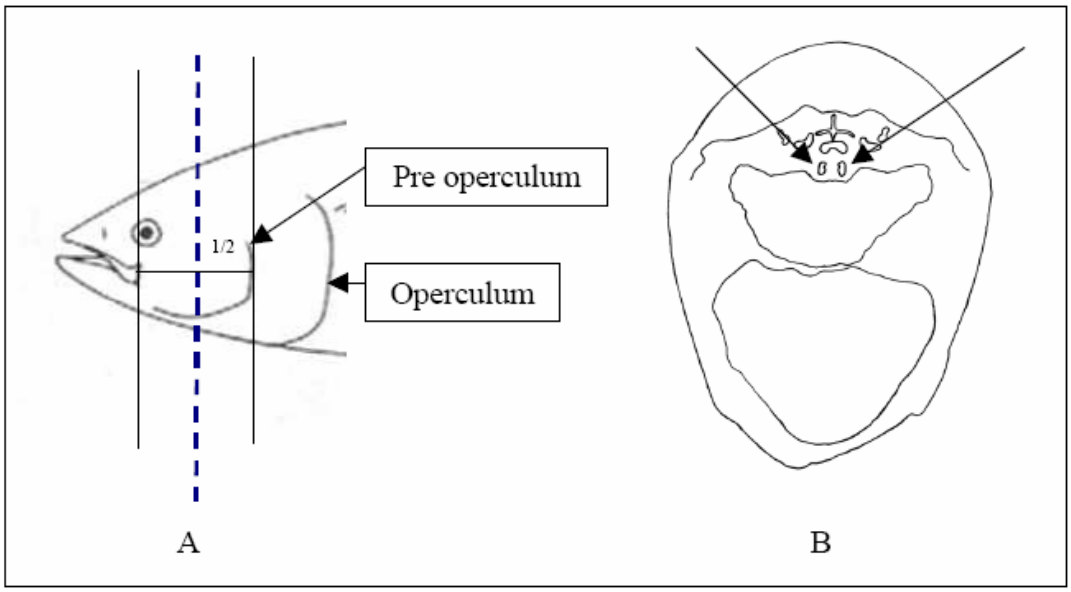

Figure 4.9.4. A. Tracing the imaginary line (dotted) along which to make the cut. B. View of the cavities where the pair of otoliths are found in the back of the head. (from Ruiz *et al*., 2005, used with permission)

Otoliths are best stored dry in a tube or in an envelope. If using an envelope avoid applying pressure that might break them. The data of the specimen sampled or its corresponding code should appear on the envelope or the tube.

Caudal vertebrae

Vertebra 35 is used for the study of growth (Farber and Lee 1981). However, it is better to collect vertebra 35 and 36 without separating them. Collecting both gives the opportunity of comparing the "whole vertebra" and the "vertebra section" methods. Also, storing vertebrae 35 and 36 attached preserves the quality of the inner surface preventing dehydration caused by refrigeration. As the surface comes in contact with air, it dries and becomes more difficult to read.

To find vertebra 35, a transversal cut is made in the caudal area between the 4th and the 5th finlet (counting from the end of the tail forwards, i.e. there must be 4 more finlets behind the one indicated). On making the cut vertebra 35 should be exposed. The cut should coincide with the intervertebral space and the tail can be cut easily. If not, the intervertebral space must be found further forward in the fish. Vertebra 35 is the first vertebra found in the part sectioned, and can be separated together with vertebra 36 from the rest of the caudal vertebrae, cleaned and peeled, with any flesh attached to it removed.

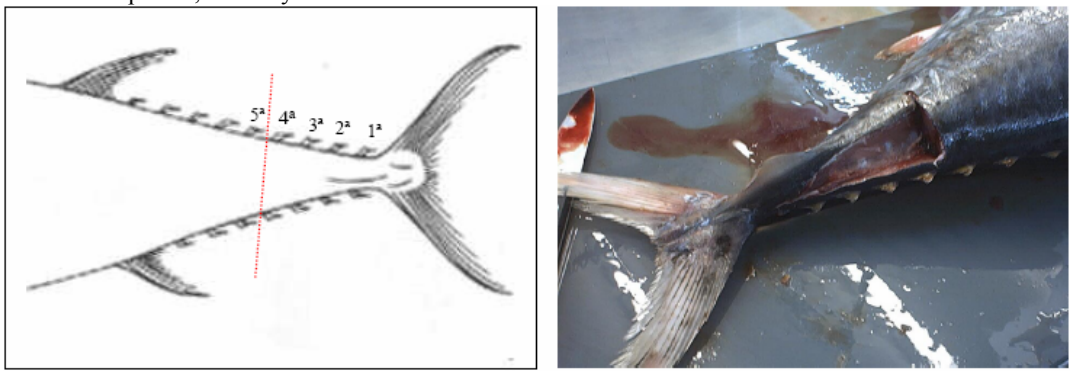

Figure 4.9.5. Cutting line to find vertebra 35. The photograph shows the transversal cut and the tail has been peeled to uncover the vertebrae (white marks). (from Ruiz *et al*., 2005, used with permission)

The two vertebrae should be stored attached, and not separated until they are analyzed. They should be stored dry in an envelope and refrigerated (some flesh always remains attached). The vertebrae can be stored together with the spine in the same envelope.

4.9.3 How to prepare hard parts for reading

Spines are prepared by taking a cross-section through the basal portion of the spine (where the spine is approximately half the maximum width of the condyle base). These sections are mounted in resin and cut with a low-speed saw to obtain a thin section (e.g. 0.5 mm thickness). These thin sections can then be mounted on a slide in resin, and can be cleared with 95% ethanol for 5mins, if required. The sections can then be examined under the microscope.

Otoliths have been read whole, but it can be difficult to age otoliths of older individuals and ages may be under-estimated. Sectioning is recommended. Otoliths should be embedded in polyester resin and a transverse section taken through the primordium using a low-speed saw. The slice can be attached to a microscope slide using resin and polished with appropriate polishing grit if necessary. The otolith can then be read under a binocular microscope.

Vertebrae can be thin-sectioned in the sagittal (dorso-ventral) plane, using a low-speed saw. Following mounting on a microscope slide, they can be stained for additional clarity using silver nitrate or polished. Stained sections can then be read under a binocular microscope.

4.9.4 Reading

Reading of prepared hard parts develops an integer age for an individual fish, and by reference to the length of that individual, a length-at-age.

Ages are developed relative to an assigned 'birthday' for a species. The birthday is usually related to the spawning period for a species. When ageing relative to a birthday, a complete annual ring will not be counted until this date is passed. For example, if the birthday were 1st June, a fish with a third annual ring that was just completed would be counted as a two-year-old until caught on or after the 1st June.

Generally, readers should not be provided with additional information on the fish (e.g. length, date of capture) to avoid bias. Date of capture may be important when assigning ages around the birthday of the species.

Care must be taken when reading spines, as the central portion of the spine can become vascularised in older fish. This obliterates the age bands formed when young. These bands have been accounted for in ageing by back-calculating the likely number of annuli suspected (e.g. Lee and Yeh, 1993) or through the use of values provided in previous studies (e.g. in Cort (1991) for bluefin tuna).

A simple measure of the precision hard part age estimates from multiple readers is the individual average percentage error (IAPE, Beamish and Fournier, 1981). This can be calculated as:

$$IAPE = \frac{100}{N}\sum_{j=1}^{N}\left[\frac{1}{R}\sum_{i=1}^{R}\frac{|X_{ij}-X_j|}{X_j}\right]$$

where N is the number of fish aged, R is the number of readings, X_{ij} is the ith age determination of the jth fish, and X_j is the mean age calculated for the jth fish.

4.9.5 Growth parameter estimation

Length-at-age data can be fitted to growth equations to estimate parameters important for stock assessment and management. Generally, a von Bertalanffy growth equation is fitted to the data. This equation satisfies two important criteria, fitting most of the observed data of fish growth, and being readily incorporated into stock assessment models. The formula is:

$$L_t = L_\infty\left[1-e^{-K(t-t_o)}\right]$$

where L_t is the length at age *t*, L_∞ is the asymptotic length, K is the coefficient of growth, and t_0 the theoretical age for length at zero.

Gascuel *et al*. (1992) proposed a five-parameter growth function to model the two stanza growth curves in Atlantic yellowfin tuna. This model combined a linear function and generalized von Bertalanffy model:

$$L_t = L_0 + bt + \left[L_\infty - (L_0 + bt)\right]\left[1 - e^{-Kt}\right]^m$$

where L_t is the length at age t, L_0 is the length at age 0, L_∞ is the asymptotic length, K is the coefficient of growth, *b* is the initial growth rate, and *m* is an estimated parameter.

Growth equations can be fitted to hard-part derived length-at-age data through least squares methods, or likelihood approaches (Kimura, 1980). In either case, the standard errors of the parameters should be presented.

Care should be taken when interpreting growth parameter estimates, as they are strongly affected by the quality and quantity of data available. Issues arise due to a lack of smaller younger individuals due to gear selectivity, and larger individuals due to historical fishing pressure. Failure to include larger, older individuals reduces the information on the L_∞ parameter of the von Bertalanffy growth equation, while a lack of younger individuals reduces the information on the K parameter. Considerable uncertainty can result, which is transferred to stock assessments when these growth parameters are used.

4.9.6 Age-length keys (ALKs)

Age and growth data are required for the development of age-length keys. The construction of these keys has been described in Section 4.3.6.

4.9.7 Microconstituent analyses

Microconstituent analysis refers to the examination of trace elements occurring in otoliths (Secor and Chesney, 1998). The approach relies on two properties of otoliths: that they grow throughout the life of the fish, and unlike bone, otoliths are metabolically inert; the calcium carbonate and trace elements that make up over 90% of the otolith structure are derived mainly from sea water, as modified by ambient temperature (Humphreys *et al*., 2005). Particular elements are incorporated into otoliths in direct proportion to their availability in ambient water or food. Therefore, individuals from different locations may incorporate different mixtures of elements in their otoliths, forming an elemental fingerprint unique to the area/stock. Analysis of otolith microconstituents therefore has the potential to measure a number of life history characteristics. They may be used for validation, and to study homing fidelity, nursery origins (where juvenile otoliths are examined; Rooker *et al*., 2003), stock structure, migration rates etc.

Magnesium (Mg), calcium (Ca), strontium (Sr) and Barium (Ba) are incorporated and retained in the inorganic lattice structure of otoliths, and can therefore be used to examine environmental histories. Other elements such as sodium (Na), sulphur (S), potassium (K) and chlorine (Cl) are associated with organic material or interstitial spaces, and are likely to be less stable.

Appropriate decontamination and handling procedures are required to prevent leaching of elements post-extraction. Contamination can occur during dissection, handling, storage or cleaning procedures. Typically, highly purified water (e.g. doubly de-ionized water) is used to soak the otoliths to hydrate and aid removal of remaining biological tissue. 3% hydrogen perozide can then be used to soak the otolith for 5 minutes to dissolve remaining tissue. Otoliths can then be immersed for 5 minutes in 1% nitric acid to remove surface contamination, and then the otolith can be flooded with doubly de-ionized water for 5 minutes to remove the acid. The otolith should then be dried under a laminar flow hood. This decontamination procedure has been shown to be effective in removing Mg, Mn and Ba contaminations, without affecting the original composition of the otolith.

The main technique used to study otolith microconstituents is ICP-MS – Inductively Coupled Plasma Mass Spectrometry. The technique is capable of simultaneously assaying multiple elements at very high sensitivity (at sub parts per million detection limits). Solution-based ICPSM requires the material to be introduced in solution after dissolving in acid.

The stable oxygen isotope ratios ($\delta^{18}O$:$\delta^{16}O$) in otoliths can be used as a proxy of the ambient water temperature. At higher temperatures, otoliths contain more of the lighter $\delta^{16}O$ isotope. Carbon isotope ratios ($\delta^{13}C$) can be related to metabolism. However, factors controlling the stable carbon isotope composition ($\delta^{13}C$) in otoliths are more complex than those controlling oxygen isotopes, since 13C is also influenced by fish metabolism and feeding pattern. Micro-scale sampling techniques in otoliths using micromill or laser ablation techniques allow the evaluation of environmental information in high temporal resolution, with the limitation now the constraints of the mass spectrometer. Accurate sampling of material from otoliths using micromill or laser ablation techniques therefore allows temperature patterns to be related to the age and hence life history of the fish.

4.9.8 Further reading

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4.10 Observer information and other biological samples

The role of observer programmes can vary widely. A primary focus can be enforcement, ensuring that international and national requirements are met during the operations of fishing vessels. Of more interest to this manual are scientific observers, whose role is the collection of scientific data, monitoring of fishing effort and bycatch numbers and rates. Observers also offer one of the few methods appropriate to obtain accurate location, catch and effort information for tuna caught for farming. This is of particular importance given the increased farming efforts within the Mediterranean. Access to individuals to collect biological data may be limited, however, due to fishermen's reluctance to allow handling and further stressing of tuna destined for pens.

Sampling at sea can be conducted either by a biologist, by a trained technician aboard, or occasionally by well instructed fishermen. This may be particularly relevant for longliners operating far from base ports, since trips for these vessels may last several months. Daily catches may be few, and consequently when the vessel returns to port for unloading, most of the fish in the hold will have lost their identity in terms of time, date and place where the fish were caught. Since the daily catch is rather small, it is easier to request fishermen to measure some of these fish.

4.10.1 Observer coverage

Observer coverage refers to the fraction of fishing effort (e.g. vessel trips) that is sampled at sea by trained scientific data collectors. As noted in section 4.2.4, sampling requirements from this coverage will depend on the aims of the survey – e.g. collection of length data, information on a non-target species, or a protected sea bird or mammal, for example. Sampling requirements for particular species will depend on the species frequency of occurrence, patchiness, seasonality, variability in recruitment, and other factors.

A key area has been the examination of observer coverage levels to assess threatened or endangered species, where low levels of mortality may jeopardize their recovery. In this case, an exact count of the total incidental mortality may be required, and 100% observer coverage becomes necessary. This is the case in the eastern tropical Pacific tuna purse seine fisheries, in which the Inter-American Tropical Tuna Commission requires 100% coverage so that individual vessel quotas on dolphin bycatch may be used.

As noted in section 4.2.4, often the level of observer coverage is limited by budget. 100% coverage may therefore not be possible. In these cases, coverage must be sufficient to ensure estimates are sufficiently accurate and precise for assessment and management purposes. Precision depends on the size of the sample, the size of the fishery, and the variability of the factor. Accuracy depends on these factors, as well as whether the sampled part of the fishery is representative of the entire fishery.

It is difficult to define coverage of observers based upon a desired precision in the value of outputs. Catch levels can vary widely between trips, due to environmental, economic, social and management influences. Within these constraints, the realistic approach may be to maximise coverage given available funds and observers, and operational considerations. Pooling of data may then be necessary to reduce uncertainty in outputs. Readers should be aware, however, that parameter estimates from observer data could easily be biased (i.e., not accurate) if the coverage is less than 100%.

As noted, the level of precision obtained from a given level of coverage depends upon a number of factors, including the number of time, area and gear categories to be covered, and the level of set-to-set and vessel-to-vessel variability in the factor to be studied. The former requires observer coverage to be spread among all nations/vessel types/gears/fishing strategies/areas to cover the range of potential situations. For example, samples taken in only one part of the year or from only one area covered by the fishery will usually not be representative of the annual landings. The latter requires a reasonable level of coverage within nation/vessel/gear/etc. category. These conflicting factors require substantial amounts of observer data to calculate.

Once homogenous spatial/temporal/gear strata have been identified, vessels can be selected randomly. If the sample is really random, coverage levels can be defined using the sampling formulae detailed in section 4.2.1. As noted in section 4.2.4 and above, however, practicalities, safety and feasibility must all be taken into account.

Adaptive sampling approaches can also be used, where coverage is modified based upon observations made during the observer programme. For example, identified areas of high abundance may be sampled more

intensively using more observers on other vessels. The reader is referred to statistical texts (e.g. Thompson, 1992) for more information.

The reader should be aware of a number of potential biases in observer data, and attempt to mitigate against them. They include:

- Bias caused by observer effects (e.g. vessel behaviour is changed due to the presence of an observer)
- Bias due to non-random allocation of sampling effort
- Bias caused by logistical constraints (e.g. components of the fishery which are logistically difficult to sample)
- Bias caused by inaccurate recording of data by observers
- Bias caused by small sample size
- Bias caused by inappropriate stratification

4.10.2 Examination of fishing practices

Observers are ideally placed to examine the characteristics of the vessel on which they are stationed, and its practices of setting and hauling (longlines), searching and setting (purse seines) etc. ICCAT forms are available for this purpose (see **Annex 1**). Details to examine include:

Details	**Specifics**
Vessel characteristics	Vessel name/code, flag, type, storage capacity, tonnage, horsepower
Gear characteristics	Purse seine: length, depth, mesh Longline: line length, number of hooks, hooks between buoys Bait boat: baiting gear, length, depth, bait capacity, basket/scoop
Trip characteristics	Port of departure, departure date, return port, return date
Sighting (more for purse seiners)	Searching and setting based on birds, mammals, flotsam, FADs, fish jumping, aircraft
Searching (purse seine) or setting (longline) characteristics	Course (in degrees), vessel speed, binocular power and number, radar specifications, weather and Beaufort state

NOTE that this list is not exhaustive. Observers should refer to already developed data forms Gaertner and Pallares (2002a).

Although effort for CPUE calculations (see section 4.4) are likely to be pre-defined by vessel logbook information such as 'days fishing', 'number of sets', 'number of hooks' etc., observers can identify finer scale factors including those relevant to searching success (Gaertner *et al*, 1999; e.g. number and power of binoculars, radar power, vessel power and speed of both vessel and skip). These may lead to refinements in effort estimation in the future (Gaertner and Pallares (2002b).

Catch may be more difficult to monitor, particularly if biological sampling is being carried out as the fish are brought on board. However, observer information can provide a general check on the levels entered into the vessel logbook.

As noted in section 4.2.4, catch and landings of key species are often not equal, due to discarding at sea. Furthermore, other 'bycatch' species of little economic value may be caught by the gear and discarded at sea. These may not be noted in vessel logbooks. Scientific observers are well placed to monitor these bycatches and discards, which are key to identifying the impact of fishing operations on the wider ecosystem (Gaertner *et al*, 2002). Specific species may be discarded due to certain market or regulatory conditions, including minimum size limits or catch limits. In addition, non-targeted bycatch, which may be hooked or entangled in the gear, may similarly be discarded. A proportion of these will be discarded dead. Data on the number and status of discard species collected by observers is invaluable. The calculation of discard rates is discussed further in section 4.10.4.

4.10.3 Biological information

The collection of biological information has been detailed in the previous sections of this manual. The advantage of observers collecting such information at sea is that they can directly link it with the location from which the samples were taken (as in the geographic location of the catch). This is in contrast to sampling from wells that may contain individuals from a large number of catches in a general area, or longline catches where the catches from sets made over an extended period and geographical range may be present. The association of the caught individuals with particular features (e.g. FADs) can also be noted.

4.10.4 Discards and discard rate estimation

As noted, the estimation of discard rates is a topic of considerable importance in tuna fisheries. The issue has been much debated in U.S. tuna fisheries in particular, with the interaction of gears with dolphins being discussed in great detail within IAATC. As noted, where the bycatch species is endangered, the level of precision required in bycatch estimates may result in the requirement for 100% vessel coverage. Where bycatch estimates are required for stock assessment, the level of precision required may depend on the stock assessment methodology and the management system itself. Where bycatch mortality is high compared to other sources of mortality on a stock, higher levels of coverage may be needed.

The methodology of estimating discard rates will not be detailed here. As references, Brown (2001) presents an estimation approach to assess dead bluefin tuna discards in the U.S. Atlantic pelagic longline fleet. O'Brien *et al*. (2003) devised an alternative approach to estimating discard rates and overall discard levels in the U.S. longline tuna fishery, employing the ideas of conditionality, flexible mixture distributions (in this case the negative binomial) and generalized linear models. It is often appropriate to test data with a range of models, and further study indicated that the estimates devised by Brown (2001) were not inappropriate, despite potential issues with the statistical assumptions made. However, the benefits of conditioning should be investigated when estimating discards.

4.10.5 Further reading

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Annex 1 to Chapter 4

PART I: Example Logbook Forms

1- Daily Catch Records and Landings Records forms used in Ghana for Surface Fisheries (Source: ICCAT).

2- Cuaderno de pesca para flota de cerqueros congeladores (Source: IEO, Spain)

3 - Libro de pesca para pesquerías de túnidos y afines (Source: IEO, Spain)

4- Logbook for Japanese longliners (Source: NRIFSF, Japan)

5- Trip-by-trip and set-by-set logbook forms for USA (Source: NMFS, USA)

Part II: Example Scientific Observer Forms

1- Bitácora diaria de observadores pesquería de palangre en Venezuela (Source: F. Arocha, Venezuela)

2- Formularios del Plan Nacional de Datos Básicos de España (Sorce: IEO, Spain)

DAILY CATCH RECORDS　日別漁獲記録　일일어획량 기록

Mon 月 월	Day 日 일	LOCATION 位置 위 치	CATCH (IN NO. FISH AND/OR KG) 漁獲量（尾数または重量または両者） 어획량 (미수／중량)											
			Unit 単位 단 위	YELLOWFIN キハダ 황다랭이				SKIPJACK カツオ 가다랭이				BIGEYE メバチ 눈다랭이	OTHERS その他 기 타	TOTAL 計 계	WELL NO. 魚倉番号 어창번호
					13.6	3.4	1.8 KG		3.4	1.8	1.4KG				
				GG	R1	R2	R3	Jumbo	R1	R2	R3				
		0 _ ' N S 0 _ ' E W	No. Kg.										★		
		0 _ ' N S 0 _ ' E W	No. Kg.										★		
		0 _ ' N S 0 _ ' E W	No. Kg.										★		
		0 _ ' N S 0 _ ' E W	No. Kg.										★		
		0 _ ' N S 0 _ ' E W	No. Kg.										★		
		0 _ ' N S 0 _ ' E W	No. Kg.										★		
		0 _ ' N S 0 _ ' E W	No. Kg.										★		
		0 _ ' N S 0 _ ' E W	No. Kg.										★		
		0 _ ' N S 0 _ ' E W	No. Kg.										★		
		0 _ ' N S 0 _ ' E W	No. Kg.										★		
		0 _ ' N S 0 _ ' E W	No. Kg.										★		
		0 _ ' N S 0 _ ' E W	No. Kg.										★		
		0 _ ' N S 0 _ ' E W	No. Kg.										★		
		0 _ ' N S 0 _ ' E W	No. Kg.										★		
		0 _ ' N S 0 _ ' E W	No. Kg.										★		

★Fill in major species.　その他の魚種のうち主要魚種名を記入する。　혼획량에는 중요어종을 표시

LANDING RECORDS 水揚記録 양육량 기록

BOAT NAME 漁船名 선 명		OWNER 所属会社 소유자		FLAG 船籍国 국기명		NO. OF CREW 乗組員数 승무원수	

PORT OF DEPARTURE 出発港 출항지	DATE OF DEPARTURE 出港月日 출항일자	DATE ARRIVAL-ABIDJAN アビジャン入港月日 아비쟌 입항일자	DATE ARRIVAL-TEMA テマ入港月日 테마 입항일자	NO. DAYS AT SEA 航海日数 항해일수	NO. DAYS AT BAITING 餌場滞在日数 어료어장 체류일수	NO. DAYS TUNA FISHING マグロ漁業日数 다랑이 어획일수

TOTAL LANDING (IN METRIC TONS) 総水揚重量(MT) 총양륙량(톤)

LANDING PORTS 水揚港 양륙항	YELLOWFIN キハダ 황다랭이		BIGEYE メバチ 눈다랭이		SKIPJACK カツオ 가다랭이		OTHERS その他 기 타 Major Species 主要魚種 중요어종	Weight 重量 중량
ABIDJAN アビジャン 아비쟌	GG >13.6		GG		Jumbo >3.4			
	R1 13.6kg 3.4		R1		R1 3.4kg 1.8			
	R2 3.4kg 1.8		R2		R2 1.8kg 1.4			
	R3 <1.8		R3		R3 <1.4			
	Total		Total		Total		Total	
TEMA テマ 테 마	GG		GG		Jumbo			
	R1		R1		R1			
	R2		R2		R2			
	R3		R3		R3			
	Total		Total		Total		Total	
OTHERS その他 기 타	GG		GG		Jumbo			
	R1		R1		R1			
	R2		R2		R2			
	R3		R3		R3			
	Total		Total		Total		Total	

MINISTERIO DE AGRICULTURA, PESCA Y ALIMENTACIÓN
SECRETARIA GENERAL DE PESCA MARÍTIMA

INSTITUTO ESPAÑOL DE OCEANOGRAFÍA

CUADERNO DE PESCA

Flota atunera - Cerqueros congeladores

BARCO _____

AL FINAL DE CADA MAREA ENTREGUE LAS HOJAS DEL CUADERNO DE PESCA, JUNTO CON LA HOJA DE DISPOSICIÓN DE LAS CAPTURAS EN LAS CUBAS, AL ***BIÓLOGO O TÉCNICOS QUE MIDEN EL PESCADO DURANTE LA DESCARGA***.

TAMBIÉN PUEDE ENVIARLAS A LA SIGUIENTE DIRECCIÓN:

CENTRO OCEANOGRÁFICO DE CANARIAS
INSTITUTO ESPAÑOL DE OCEANOGRAFÍA
APDO. 1373 - 38080 SANTA CRUZ DE TENERIFE

BIEN DIRECTAMENTE O A TRAVÉS DE LA OFICINA DE LA COMPAÑÍA ARMADORA.

ATENCIÓN

Las hojas de este cuaderno son: original en blanco y dos copias, una en verde y otra en amarillo. *Para la copia no se necesita papel carbón*, únicamente interponga una cartulina entre la hoja amarilla y la siguiente hoja blanca.

INSTRUCCIONES PARA RELLENAR EL CUADERNO DIARIO DE PESCA

Los recursos pesqueros no son ilimitados e inagotables. Si se administran mal se agotan o se obtienen rendimientos bajos. Unas estadísticas completas y fiables son la base para conocer el grado de explotación de los recursos pesqueros y sus posibilidades.

Las instrucciones que siguen le ayudarán a rellenar este Cuaderno de Pesca correctamente. Informaciones complementarias, como por ejemplo qué hacer con las marcas recuperadas, las diferentes especies y la forma de distinguirlas, y la relación entre la talla, el peso y la edad, se ofrecen al final de las instrucciones.

Se ha diseñado este Cuaderno de Pesca de una forma sencilla, para que no ofrezca dificultades a la hora de cumplimentarlo. *Si al final de cada día anota los datos solicitados, encontrará que el trabajo que exige rellenarlo es muy pequeño*.

1. DATOS SOBRE LA PESCA

♦ Se rellenará el Cuaderno de Pesca por mareas o viajes completos, desde el día de salida hasta el de llegada al puerto de descarga.

♦ Anote todos y cada uno de los días aunque no haya habido pesca. En este caso con la situación del mediodía, o una próxima, es suficiente.

♦ Cubra una línea por cada lance. Si en un día hay mas de uno, numérelos correlativamente y anote todos ellos, aunque hayan sido en blanco.

Se han incorporado pequeños cambios a esta nueva edición del Cuaderno de Pesca, con la finalidad de facilitarle el trabajo que supone el cumplimentar los datos del mismo. Los cambios, con respecto al anterior Cuaderno, son los siguientes:

♦ HORA: Se incorpora una casilla para anotar la hora a la que se efectúa cada lance.

♦ LANCE (+) / (-) : Marcar con una cruz según el lance sea positivo o nulo.

♦ ASOCIACIONES (banco rabil, banco listado, objeto, baliza, pinto, ballena, tiburón): Marcar con una cruz, si el lance se realiza sobre alguno de estos supuestos.

EN EL CASO EN QUE EL LANCE SE PRODUZCA EN OTRAS CIRCUNSTANCIAS O CON OTRO TIPO DE ASOCIACIÓN ANOTAR EN OBSERVACIONES.

2. DATOS SOBRE TEMPERATURA

En la parte derecha de cada hoja del Cuaderno de Pesca hay una columna reservada para anotar la temperatura del agua en la superficie del mar en ºC (con una precisión de una décima de grado).

3. DATOS GENERALES DE LA MAREA.

♦ Al finalizar la marea, rellenar la parte superior de la hoja. Esto sólo es necesario con la primera de las hojas de cada marea.

♦ En los apartados *Corredera comienzo de marea* y *Corredera final de la marea* se anotarán las millas que marca la corredera (o el satélite). Se trata de saber con ello las millas que recorrió el barco durante cada viaje.

4. DISPOSICIÓN DE LAS CAPTURAS EN LAS CUBAS.

Al final de este Cuaderno se incluyen unas hojas para anotar la disposición de las capturas en las cubas de congelación. Se trata con ello de identificar, fácilmente, la fecha y la situación en que se capturaron los peces cuando se muestrea pescado a bordo durante la descarga.

♦ Se rellena una hoja para cada marea y se adjunta a las hojas correspondientes del Cuaderno de Pesca.

● ●

RELACIÓN ENTRE LA TALLA (longitud a la horquilla o furca en cm) Y LA EDAD

RABIL		***PATUDO***		***LISTADO***	
Edad	Talla cm	Edad	Talla cm	Edad	Talla cm
0.5	43.9	0.5	30.4	1	35.75
1.0	52.7	1.0	44.4	2	39.92
1.5	61.6	1.5	57.6	3	44.09
2.0	68.6	2.0	70.1	4	48.26
2.5	92.5	2.5	81.9	5	52.43
3.0	111.9	3.0	93.0	6	56.60
4.0	140.3	4.0	113.5	7	60.77
5.0	159.0	5.0	131.8		
6.0	171.3	6.0	148.2		
7.0	179.3	7.0	162.8		

RELACIÓN ENTRE LA TALLA (longitud a la horquilla o furca en cm) Y EL PESO (en kg)

RABIL		***PATUDO***		***LISTADO***	
Talla cm.	Peso kg.	Talla cm.	Peso kg.	Talla cm.	Peso kg.
30	0.54	30	0.60	30	0.48
35	0.85	35	0.95	32	0.59
40	1.26	40	1.41	34	0.72
45	1.79	45	2.00	36	0.86
50	2.45	50	2.74	38	1.03
55	3.25	55	3.64	40	1.22
60	4.22	60	4.72	42	1.42
65	5.35	65	5.99	44	1.66
70	6.67	70	7.47	46	1.92
75	8.19	75	9.17	48	2.20
80	9.92	80	11.11	50	2.51
85	11.88	85	13.31	52	2.85
90	14.09	90	15.78	54	3.23
95	16.55	95	18.53	56	3.63
100	19.28	100	21.59	58	4.07
105	22.29	105	24.97	60	4.54
110	25.60	110	28.68	62	5.06
115	29.22	115	32.73	64	5.61
120	33.17	120	37.16	66	6.20
125	37.45	125	41.96	68	6.83
130	42.09	130	47.16	70	7.50
135	47.09	135	52.76	72	8.22
140	52.47	140	58.80	74	8.99
145	58.25	145	65.27	76	9.80
150	64.43	150	72.21	78	10.67
155	71.03	155	79.61	80	11.58
160	78.07	160	87.51		
165	85.56	165	95.90		
170	93.51	170	104.82		

EL MARCADO DE PECES

Desde hace años se están realizando campañas de marcado de las principales especies de túnicos, pero *¿qué interés tiene esta actividad?*

- ♦ *CONOCER LAS MIGRACIONES.*
- ♦ *CONOCER SU CRECIMIENTO*.

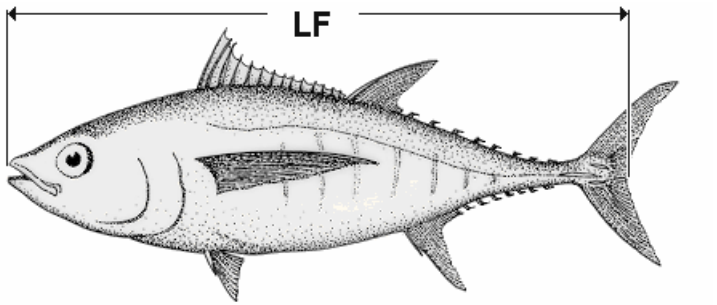
La marca convencional consiste en un *espagueti* de plástico, que se sujeta clavándolo en la carne del pez, cerca de la primera aleta dorsal.

Cada marca lleva un número de serie y una dirección donde enviarla. Hay dos tipos de marcas convencionales: unas ROJAS y otras AMARILLAS.

¿*QUÉ DEBE HACER SI ENCUENTRA UNA MARCA*?

MARCA AMARILLA:

Anote: *SITUACIÓN* donde se capturó, *FECHA* de la captura y *TALLA* del pez, medida según el dibujo adjunto.
Arranque la marca y envíela, junto con estos datos y su nombre y dirección al biólogo o técnicos que miden el pescado en el puerto *o a la dirección que indica la marca.*



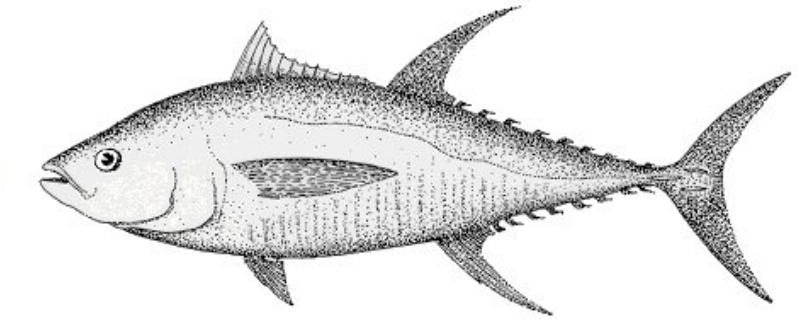
MARCA ROJA:

Anote los mismos datos que para una marca amarilla pero, si es posible, guarde el pez entero, congelado, sin arrancar la marca. Comunique la recuperación a la misma dirección, o a los científicos que trabajan en los puertos de desembarco.

Después de recuperar una marca, se comunica al pescador el lugar y fecha en que fue marcado el pez, y se le da una *RECOMPENSA.*

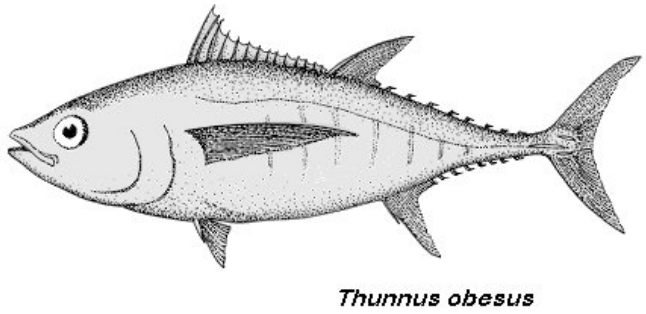
Recientemente se ha comenzado a utilizar una MARCA ARCHIVO que se implanta en la cavidad estomacal de los atunes. Unas marcas externas convencionales avisan de la existencia de *marca electrónica en estómago* y de una gran recompensa (*Big $$$ reward*). Si captura un ejemplar con *marca archivo NO QUITE LA MARCA TIRANDO DEL CABLE EXTERNO EN LA CAVIDAD ESTOMACAL*, avise al biólogo o técnicos del puerto de descarga. Tras verificar la marca se le recompensará con 1000 $ USA.

PRINCIPALES ESPECIES DE TÚNIDOS TROPICALES



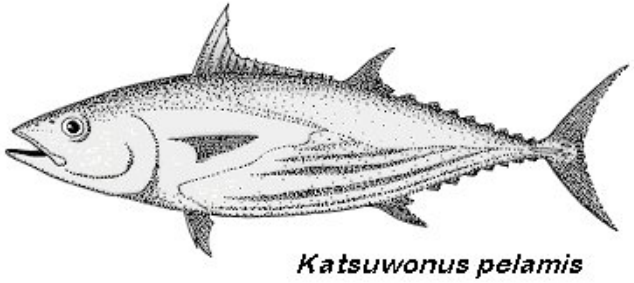
Thunnus albacares

RABIL (Esp.) YELLOWFIN TUNA (Ing.) ALBACORE (Fra.)
Otros: Atún, cimarrón.



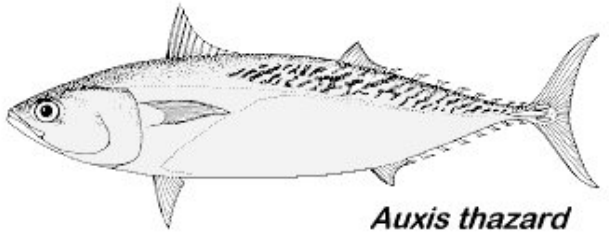
Thunnus obesus

PATUDO (Esp.) BIGEYE TUNA (Ing.) PATUDO (Fra.)
Otros: Atún, monja.



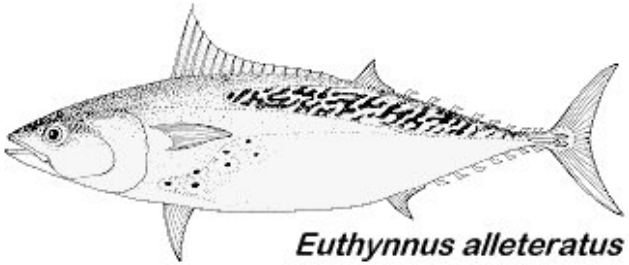
Katsuwonus pelamis

LISTADO (Esp.) SKIPJACK (Ing.) LISTAO (Fra.)
Otros: Alistado, serrutxue.



Auxis thazard

MELVA (Esp.) FRIGATE TUNA (Ing.) AUXIDE (Fra.)
Otros: Melva blanca



Euthynnus alleteratus

BACORETA (Esp.) ATLANTIC LITTLE TUNA (Ing.) THONINE (Fra.)
Otros: Melva negra.

Plan de Cuves - Mapa de Cuba - Wells map

Navire Barco Vessel	Date d'arrivée Fecha de llegada Arrival date	Date de départ Fecha de salida Departure date

Date et N° coup Fecha y N° lance Day and N° set	Albacore Rabil Yellowfin		Listao Listado Skipjack	Patudo Patudo Bigeye		Germon Atun blanco Albacore	Autres 0tros Others
	+ 10Kg	- 10Kg		+ 10Kg	- 10Kg		

Date et N° coup Fecha y N° lance Day and N° set	Albacore Rabil Yellowfin		Listao Listado Skipjack	Patudo Patudo Bigeye		Germon Atun blanco Albacore	Autres 0tros Others	N° de cuve de cuva Well	Date et N° coup Fecha y N° lance Day and N° set	Albacore Rabil Yellowfin		Listao Listado Skipjack	Patudo Patudo Bigeye		Germon Atun blanco Albacore	Autres 0tros Others
	+ 10Kg	- 10Kg		+ 10Kg	- 10Kg					+ 10Kg	- 10Kg		+ 10Kg	- 10Kg		

Espèce Especie Species	Albacore Rabil Yellowfin		Listao Listado Skipjack	Patudo Patudo Bigeye		Germon Atun blanco Albacore	Autres 0tros Others	Total	
Cat	+ 10Kg	- 10Kg		+ 10Kg	- 10Kg			+ 10Kg	- 10Kg
Total									

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e-mail: tunidos.corunha@co.ieo.es

LIBRO DE PESCA

NOMBRE DEL BARCO: ..... PATRON/ CAPITAN: .....

PUERTO BASE: ..... DIRECCION (*): .....

BANDERA: .....

.....

TELEFONO/ FAX: .....

MAREAS DE FECHA: ..... HASTA FECHA: .....

(*) Indique una dirección completa donde podamos contactar con usted.

NOTA: Este libro de Pesca es de carácter voluntario, para fines exclusivamente científicos.
Le rogamos que nos lo remita cubierto una vez conluida cada marea. El original le será devuelto

571.21

Estimado amigo:

Al igual que hacen otras flotas del mundo, la mejor forma de conocer los cambios en una pesquería es mediante el uso de libros de pesca que reflejen de forma fiable las faenas de pesca lance a lance.

El análisis año tras año de la información recibida puede ayudarnos a comprender aspectos fundamentales de la biología de las especies, además de aportar datos básicos para la evaluación de los stocks.

Como Vd. recordará, durante 1989 y 1990 hemos distribuido entre la flota unos borradores de libro de pesca que han sido probados por varios patrones. Hemos recibido opiniones a favor de tal libro y otras en contra, sobre todo en relación a la comodidad que ofrecía ese libro para ser cubierto. Agradecemos todos los comentarios y críticas que hemos recibido.

Pensando en todo ello, hemos confeccionado este nuevo libro para ser cubierto por la flota, pensando en las necesidades de información que tenemos los equipos de biología pesquera, pero también se ha pretendido que este libro pueda ser útil para que patrones y capitanes puedan llevar sus anotaciones de una forma completa y ordenada, en un libro diseñado especialmente para esta flota.

Le recomendamos que lea las instrucciones y vea los ejemplos antes de ponerse a cubrir el libro. Le aseguramos que es muy sencillo y hemos tratado de incluir la mayoría de las anotaciones que los patrones hacen en sus libretas personales.

Una vez cubierto el libro nos lo puede enviar por correo, puede entregárselo a nuestros informadores de puerto del Instituto Español de Oceanografía, o por cualquier otro medio que considere oportuno. ***Nosotros le devolveremos el original íntegro junto con un nuevo libro.*** *De esta forma Vd. podrá tener archivadas las mareas previas.*

NOTA IMPORTANTE: Le rogamos que cubra el libro de pesca de la forma mas completa posible y con Datos Reales.
Si nosotros recibimos información sesgada las conclusiones de los análisis no serán realistas. Asímismo le pedimos que, a ser posible, tome nota de los pesos de cada pieza capturada, ***incluso de los peces pequeños.***

Esperamos que le sea de utilidad y no dude en hacernos llegar sus comentarios o sugerencias. Le agradecemos su colaborarión.

Túnidos I.E.O.

SUGERENCIAS PARA CUBRIR EL LIBRO DE PESCA.

Hemos estructurado este libro en varios bloques:

EL PRIMER BLOQUE, *ofrece unos ejemplos cubiertos para que, de una forma práctica, se vean algunas de las posibilidades que existen para cubrir este libro. Las hojas de ejemplo corresponden al modelo de libro de pesca anterior, por lo que encontrará ligeras diferencias con relación a las hojas actuales que deben ser cubiertas.*

ÈL SEGUNDO BLOQUE, *a cubrir por los patrones y capitanes, consiste en hojas donde se pregunta el tipo de peso que se anota en este libro (peso total, eviscerado, en canal, etc.).*

Las demás hojas de este apartado están pensadas para que Vd. anote el resultado de cada marea. Es por tanto un resumen de ***descargas*** *de cada una de las mareas efectuadas y le permitirán conocer rápidamente el resultado global de las mareas efectuadas con anterioridad.*

EL TERCER BLOQUE, quizás el más importante, *está pensado para que* ***Vd. anote lance a lance*** *una serie de datos que normalmente son anotados por los patrones en sus notas personales. Algunos de esos datos son imprescindibles para nosotros (casillas sombreadas). Hemos incluido unas líneas para que Vd. pueda anotar el peso individual de las piezas capturadas por si Vd. tiene costumbre de pesarlas o medirlas para estimar luego su peso. Le rogamos que anote en estas casillas los pesos de* ***todas las piezas capturadas, incluso de las pequeñas, aunque nos las contabilice en sus sumatorios.***

HOJA DE EJEMPLO

TIPO DE PESO.

Como Vd. conoce, el pez espada y las otras especies capturadas pueden ser estibadas a bordo de diferentes formas.

PESO VIVO ..... *: El pez es estibado según sale del mar. En el caso del pez espada, generalmente se le corta la espada.*

PESO EVISCERADO ..... *: El pez es estibado a bordo abierto por la barriga y sin las vísceras (estómago, intestino, hígado, gónadas, etc.) pero se le conserva la cabeza, aletas y cola.*

PESO EN CANAL ..... *: También llamado "peso limpio" o "tronco". Al pez se le sacan las vísceras, se le corta la cabeza (a la altura de las agallas y la cola)*

Le rogamos nos indique en el siguiente apartado que ***TIPO DE PESO*** *usa Vd. para cada especie.*

(INDIQUE PARA CADA ESPECIE SI USA PESO: VIVO, EVISCERADO, EN CANAL)

ESPECIE	TIPO DE PESO	ESPECIE	TIPO DE PESO	ESPECIE	TIPO DE PESO		
ESPADA	Canal	PEZ VELA	Canal	CAELLA (tintorera)	Canal		
ATUN RABIL	Eviscerado	AGUJA AZUL	Canal	MARRAJOS	Canal		
ATUN PATUDO	Eviscerado	AGU. BLANCA		JAQUETON	Canal		
ATUN ROJO	—	AGU. PICUDA		CORNUDAS	Canal		
ATUN BLANCO	—	AGU. NEGRA		ZORROS	Canal		

HOJA DE EJEMPLO

DATOS DE BASCULA EN LA DESCARGA

RESUMEN AL TERMINAR LA MAREA

Año 8 9

Fresco ☐

Congelado X

Puerto de salida VIGO Fecha 20-05-89

Puerto de llegada VIGO Fecha 20-08-89

Lugar de descarga FRIGALSA Fecha 21-08-89

Nº DE MAREA	Nº DE LANCES	ZONAS DE PESCA
1	55	BISSAU-CONAKRY LIBERIA

ESPECIE	Nº DESCARGA	Kgs. DESCARGA	Nº TIRADO	Kgs. TIRADOS			
ESPADA	1670	75520	0	0			
MARRASO AZUL	150	9150	0	0			
JAQUETON	70	6300	0	0			
ATUN RABIL	120	4800	0	0			
ATUN PATUDO	50	1500	0	0			
P. VELA	42	2940	5	520			
CAELLA	102	2040	± 670	± 10000			
OTROS	—	10000	—	2500			
ALETAS	—	500	—	—			
OTROS	40	3205	0	0			

DATOS DE BASCULA EN LA DESCARGA

RESUMEN AL TERMINAR LA MAREA

Año 8 9

Fresco ☐

Congelado X

Puerto de salida VIGO Fecha 30-08-89

Puerto de llegada VIGO Fecha 20-11-89

Lugar de descarga VIEIRASA Fecha 21-11-89

Nº DE MAREA	Nº DE LANCES	ZONAS DE PESCA
2	50	de 10° al 15° N de 10° a 20° W

ESPECIE	Nº DESCARGA	Kgs. DESCARGA	Nº TIRADO	Kgs. TIRADOS			
ESPADA	2300	110000	0	0			
MARRASO AZUL	200	18000	0	0			
JAQUETON	50	3000	0	0			
ATUN RABIL	12	785	0	0			
ATUN PATUDO	127	8570	0	0			
P. VELA	58	3407	0	0			
CAELLA	0	0	±2500	±20000			
CORNUDAS	53	6205	0	0			
ZORROS	35	2801	0	0			
AGUJA AZUL	10	975	5	500			

EJEMPLO

Nº MAREA: 4 | MES: Septiembre | AÑO: 90 | CONGELADO: X | FRESCO:

OBSERVACIONES: Pescando junto al barco "Espadero"

	Fecha lance	Nº lance	Posición inicial / final	Rumbo	Fondo	Viento	Corriente	Nº anzuelos	Boyas	Tª	Color	Luna	Falsa Orca Cetáceos
DATOS DEL LANCE	10-09	5	02°45'N, 06°24W / 03°24'N, 06°24'W		300 / 500	S	0'5 E	2800	28	27 / 27'5	- - -	Llena	Si → Nos comieron 7 espadas

ESPECIE	ESPADA GRANDE		ESPADA PEQUEÑO		MARRAJO		ATUN PATUDO		JAQUETONES		CORNUDAS		QUELLAS			
CAPTURAS DEL LANCE	Nº	Kgs.	Nº	Kgs.	Nº	Kgs.	Nº	Kgs.	Nº	Kgs.	Nº	Kgs.	Nº	Kgs.	Nº	Kgs.
	11	645	3	55	1	35	7	410	2	50	7	320	10	150		

PESOS O TALLAS DE CADA PIEZA CAPTURADA (ANOTE TAMBIEN LAS PIEZAS PEQUEÑAS)

30					22				35															
60					13																			
68					20																			
86																								
42																								
55					CHUPAS																			
82					5	7																		
35					6	9																		
54					SIN SUMAR																			
55																								
78																								

SUMA LANCE PREVIOS	84	4555	34	423	20	1000	2	70	20	410	2	50	115	1200		
TOTAL ACUMULADO	95	5200	37	478	21	1035	9	480	22	460	9	370	125	1350		

OTRO EJEMPLO

Nº MAREA: 5 | MES: Noviembre | AÑO: 91 | CONGELADO: X | FRESCO:

OBSERVACIONES: Primero las vismos y nos comieron el cebo, pero no comieron espadas.

DATOS DEL LANCE	Fecha lance	Nº lance	Posición inicial / final	Rumbo	Fondo	Viento	Corriente	Nº anzuelos	Boyas	Tº	Color	Luna	Cetáceos
	1-05	1	01°50'N, 15°20W / 01°40'N, 15°00'W	S	+1000	N		2400	28	27°1 / 27°			Si

ESPECIE	ESPADA -40		ESPADA +40		MARRAJO		ATUN PATUDO		JAQUETON		CORNUDAS		QUELLAS		ALETAS	
CAPTURAS DEL LANCE	Nº	Kgs.	Nº	Kgs.	Nº	Kgs.	Nº	Kgs.	Nº	Kgs.	Nº	Kgs.	Nº	Kgs.	Nº	Kgs.
	6	128	9	580	1	35	5	237	2	50	7	320	10	150		50+20=70

PESOS O TALLAS DE CADA PIEZA CAPTURADA (ANOTE TAMBIEN LAS PIEZAS PEQUEÑAS)

[0-20] 20-30 30-40 40-50 50-60 60-70 +70

ESPADA -40				ESPADA +40				MARRAJO				ATUN PATUDO				JAQUETON				CORNUDAS				QUELLAS				ALETAS			
8	13	20	30	42	55	68	78	35				42	60			25	25			40	50	52	57	10	15	12	14				
		22	35		54		86					44								51	34	36		17	20	10	18	QUELLA = 50			
					55		82					43												17	17			CORNUDAS = 20			
					60							48																			
CHUPAS																TIRADAS:								TIRADAS:							
4	5	7	6													1 pieza								5 piezas							
Sin contabilizar en los sumatorios																12 kg.								60 kg.							

	ESPADA -40		ESPADA +40		MARRAJO		ATUN PATUDO		JAQUETON		CORNUDAS		QUELLAS		ALETAS	
SUMA LANCE PREVIOS	37	478	95	5200	21	1035	9	480	22	460	9	370	125	1350	—	—
TOTAL ACUMULADO	43	606	104	5780	22	1070	14	717	24	490	16	690	135	1500	—	70

TIPO DE PESO.

Como Vd. conoce, el pez espada y las otras especies capturadas pueden ser estibadas a bordo de diferentes formas.

PESO VIVO *: El pez es estibado según sale del mar. En el caso del pez espada, generalmente se le corta la espada.*

PESO EVISCERADO *: El pez es estibado a bordo abierto por la barriga y sin las vísceras (estómago, intestino, hígado, gónadas, etc.) pero se le conserva la cabeza, aletas y cola.*

PESO EN CANAL *: También llamado "peso limpio" o "tronco". Al pez se le sacan las vísceras, se le corta la cabeza (a la altura de las agallas y la cola)*

Le rogamos nos indique en el siguiente apartado que ***TIPO DE PESO*** *usa Vd. para cada especie.*

(INDIQUE PARA CADA ESPECIE SI USA PESO: VIVO, EVISCERADO, EN CANAL)

ESPECIE	TIPO DE PESO	ESPECIE	TIPO DE PESO	ESPECIE	TIPO DE PESO		
ESPADA		PEZ VELA		CAELLA (tintorera)			
ATUN RABIL		AGUJA AZUL		MARRAJOS			
ATUN PATUDO		AGU. BLANCA		JAQUETON			
ATUN ROJO		AGU. PICUDA		CORNUDAS			
ATUN BLANCO		AGU. NEGRA		ZORROS			

DATOS DE BASCULA EN LA DESCARGA

RESUMEN AL TERMINAR LA MAREA

Año

Fresco

Congelado

Puerto de salida ..... Fecha .....

Puerto de llegada ..... Fecha .....

Lugar de descarga ..... Fecha .....

Nº DE MAREA	Nº DE LANCES	ZONAS DE PESCA

ESPECIE	Nº DESCARGA	Kgs. DESCARGA	Nº TIRADO	Kgs. TIRADOS			

DATOS DE BASCULA EN LA DESCARGA

RESUMEN AL TERMINAR LA MAREA

Año

Fresco

Congelado

Puerto de salida ..... Fecha .....

Puerto de llegada ..... Fecha .....

Lugar de descarga ..... Fecha .....

Nº DE MAREA	Nº DE LANCES	ZONAS DE PESCA

ESPECIE	Nº DESCARGA	Kgs. DESCARGA	Nº TIRADO	Kgs. TIRADOS			

OCEANO | Nº MAREA | MES | AÑO | CONGELADO | FRESCO | TIPO-PALANGRE * Americano / Español / etc.

Fecha lance	Nº lance	Posición inicial / final	Rumbo	Fondo	Viento	Corriente	Nº anzuelos	Boyas	Tª	Color	Luna	Cetáceos
DATOS DEL LANCE												

OBSERVACIONES

Cebo: Nº Luces

* NOTA: Si el tipo de palangre es el mismo en toda la marea, anotelo sólo en el primer lance.

ESPECIE															
CAPTURAS DEL LANCE	Nº	Kgs.	Nº	Kgs.	Nº	Kgs.	Nº	Kgs.	Nº	Kgs.	Nº	Kgs.	Nº	Kgs.	Nº	Kgs.

PESOS O TALLAS DE CADA PIEZA CAPTURADA (ANOTE TAMBIEN LAS PIEZAS PEQUEÑAS)

SUMA LANCE																
TOTAL ACUMULADO																

The Japanese Catch Report (Log Sheet) for Tuna Longliner

The catch report is prepared in Japanese and the form shown here is not exactly the same one, but it was attempted to reproduce the original one in English. Instruction for the users is also given in Japanese.

Instructions in filling out catch report of longline fishery.

1. Catch report should be submitted for each fishing trip within 30 days of its completion. Fishing trip is defined as the duration between port calls with fishing activity. For offshore and coastal fisheries fishing trip is defined as between departure and arrival at domestic port when catches were not unloaded at foreign port.
2. Date reported : Fill date when catch report was reported.
3. Name of reporting person : List a name and telephone number of reporting person.
4. Departure and Arrival dates : Fill departure and arrival dates and names of port.
5. Days at sea : Number of days at sea spent in the fishing trip. Include departure and arrival days.
6. Number of sets : Total number of sets made in the fishing trip.
7. Name of boat, gross tonnage, license number, call sign : Fill respective characteristics.
8. Number of crews : Fill number of crews including foreign crews.
9. Kind of license : Select a kind of license.
10. Gear (Target) : Identify target. Tuna is included in others. When several targets were set, pick up one of the most important species.
11. Gear (Kind of main line) : Separate nylon gear from others.
12. Gear (Kind of branch line) : Separate nylon gear from others. Nylon gear could be defined such that most parts are made of nylon.
13. Gear configuration (Branch line length) : Length in meter between snap and hook. See Fig. 1.
14. Gear configuration (Float line length) : Length in meter from the float to the snap.
15. Gear configuration (Length between branch) : Length of main line in meter between successive branch lines.
16. Duration of trip : Give dates for the first and the last sets.
17. Date : Fill date when set was made.
18. Noon position : Fill latitude and longitude (in degree) at noon.
19. SST : Record sea surface temperature at noon with one decimal point, if available.
20. Hooks between floats : Specify number of hooks between bloats (hooks per basket). If different hooks between floats were used in a single set, select most representative one.
21. Number of hooks : Fill number of hooks used in a set.
22. Catch by species for tunas, billfishes, sharkes and other fishes : Fill number of catch by species in upper row and processed weight in kg in lower row. Refer to Talble 1 for the classification of shark species.
23. Total landings : Fill total landings in processed weight in tons.
24. Amount of sales : Give an amount of sales in 10,000 yen on the first sheet, if possible.
25. Total number landed : Fill total number of catch by species on the first sheet.
26. Total landed product : Fill total catch by species in processed weight in tons on the first sheet.
27. Put the total number of log sheets and respective sheet number in the upper right corner.

Table 1 Classification of shark species.

Standard name	Local name
Blue shark	Mizubuka, Ao, Aota, Aobuka, Guda, Mizuzame
Salmon shark	Mouka, Rakudazame, Goushika, Nezumi, Rakuda
Shortfin mako shark	Ao, Aoyagi, Katsuozame, Katsuzame, Maira, Moro
Oceanic whitechip shark	Hiragashira, Mobuka, Nagarebuka
Thresher sharks	Onaga, Nezumi, Ginnezumi, Dobunezumi, Hataori, Chuuta

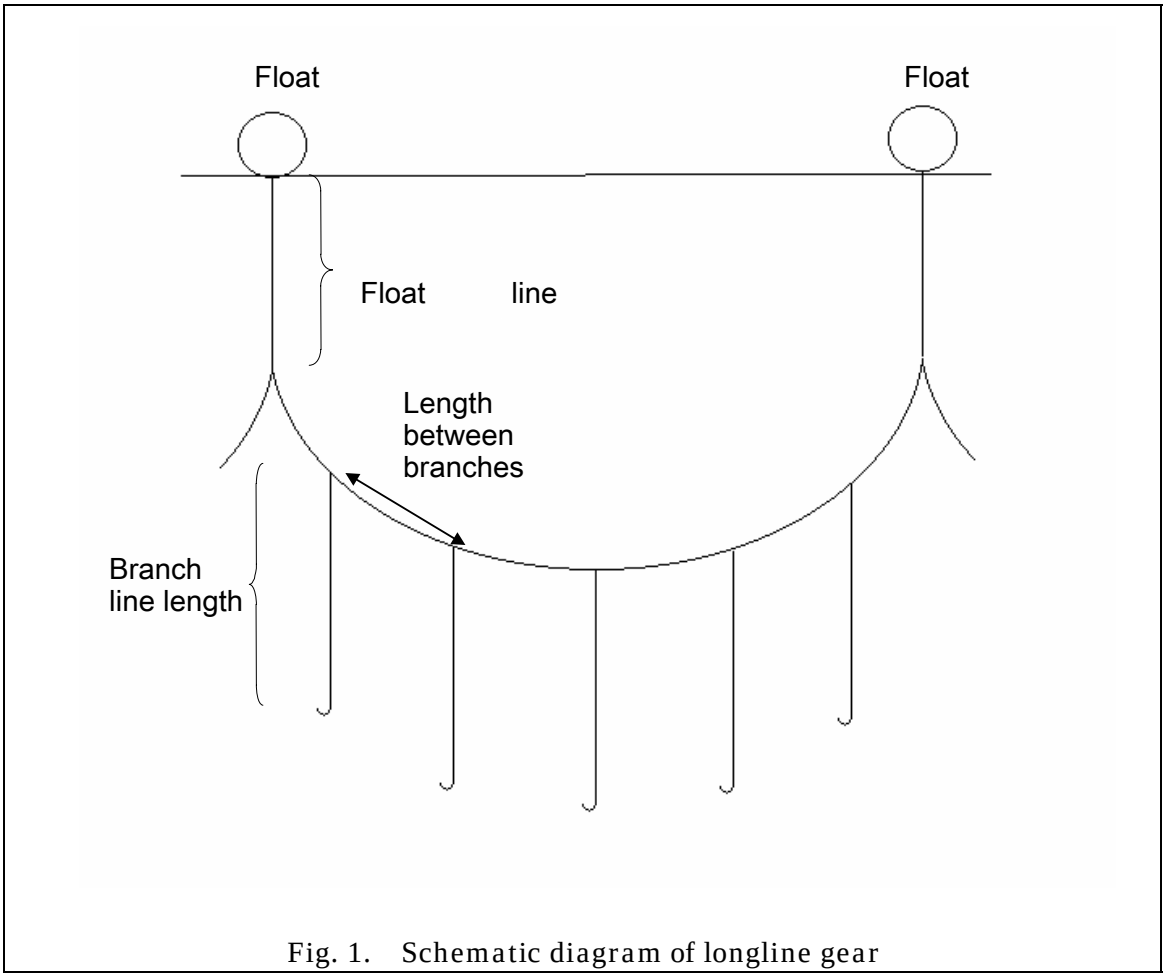


Fig. 1. Schematic diagram of longline gear

Catch Report of Tuna Longliners

To The Minister of Agriculture, Forestry and Fisheries:

(Address) (Name or Company)

Date Reported	YYMMDD [: :]	**Name of Captain**	
Name of reporting person	TEL: ( )		
Departure Date	YYMMDD [: :]	**Departure Port**	
Arrival Date	YYMMDD [: :]	**Arrival Port**	
Days at Sea	Days	**Number of Sets**	Sets

Name of Boat	maru
GRT	. MT
License Number	
Call Sign	
Number of Crews	

License	1. Distant water fishery (Full time) 2. Distant water fishery (Part time) 3. Offshore fishery 4. Coastal fishery (Approved) 5. Coastal fishery (Notified) 6. Research and Training boats	
Gear	Target	1. Swordfish 2. Shark 3. Others
	Kind of main line	1. Nylon 2. Others
	Kind of branch line	1. Nylon 2. Others

Gear Configuration	
Branch line length.	m
Float line length.	m
Length between branch	m

Duration of Trip YYMMDD[: :]～[: :]

<u>In each set, catch should be given both in number and weight (in kg) in upper and lower row, respectively.</u>

Date	Noon Position				SST ℃	Number of Hooks between Floats	Number of Hooks	Tunas					Billfishes							Sharks							
	Latitude		Longitude																								
(YYMMDD)	Degree	NS	Degree	EW				Bluefin tuna	Southern bluefin tuna	Albacore	Bigeye tuna	Yellow-fin tuna	Sword-fish	Striped marlin	Blue marlin	Black marlin	Sailfish	Shortbill spearfish	Skipjack	Blue shark	Salmon shark	Shortfin mako shark	Oceanic white tip	Thresher sharks	Other sharks	Gastero-chisma	Other fishes
. .	.	N S	.	E W	.																						
. .	.	N S	.	E W	.																						
. .	.	N S	.	E W	.																						
. .	.	N S	.	E W	.																						
. .	.	N S	.	E W	.																						
. .	.	N S	.	E W	.																						
. .	.	N S	.	E W	.																						
. .	.	N S	.	E W	.																						
. .	.	N S	.	E W	.																						
. .	.	N S	.	E W	.																						
. .	.	N S	.	E W	.																						
. .	.	N S	.	E W	.																						
. .	.	N S	.	E W	.																						
Total Landing		. Tons			Total number landed																						
Amount of sales		in ¥10,000.			Total landed product (MT)			.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

UNITED STATES DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMIN.
NATIONAL MARINE FISHERIES SERVICE

2006

TRIP SUMMARY FORMS

FISHING VESSEL LOGBOOK RECORD
ATLANTIC HIGHLY MIGRATORY SPECIES FISHERIES

YOU ARE ADVISED THAT DISCLOSURE OF THE INFORMATION REQUESTED IN THIS REPORT IS MANDATORY FOR THE PURPOSE OF MANAGING THE FISHERIES IN ACCORDANCE WITH THE ATLANTIC TUNAS CONVENTION ACT (16 U.S. 971 ET. SEQ.) AND THE FISHERY CONSERVATION AND MANAGEMENT ACT OF 1976 (16 U.S.C. 1801 ET. SEQ.). FAILURE TO REPORT MAY RESULT IN CIVIL OR CRIMINAL SANCTIONS.

NAME OF VESSEL : _____

PERMIT NUMBER : _____

NOAA FORM 88-191 **OMB NO. 0648-0371** **Expires: 07/31/2008**

Use BLACK or BLUE Ink Only OMB 0648-0371 Exp. 07/31/2008

2006 ATLANTIC HIGHLY MIGRATORY SPECIES TRIP SUMMARY FORM

NMFS USE Only Received Date Schedule #

Vessel Name: _____

Vessel Number: _____

Contact Phone Number: (_____) _____-_____

Contact Name (Please Print): _____

I certify the information contained on this form is accurate and complete to the best of my knowledge:

Captain Signature: _____

Captain Name (Please Print): _____

Port & State of Departure:_____ | | |

Port & State of Landing: _____ | | |

	Month	Day	Year
Date of Departure		/	/ 2006
Date of First Set		/	/ 2006
Date of Last Set		/	/ 2006
Date of Landing		/	/ 2006
First Day Offload		/	/ 2006
Number of Sets			
Number of Crew Members (excluding captain)			

State Trip Ticket #: _____

Dealer Names:

_____ _____

_____ _____

_____ _____

MAIL TO NATIONAL MARINE FISHERIES SERVICE, P.O. BOX 491740, MIAMI, FL, 33149

Use BLACK or BLUE Ink Only OMB 0648-0371 Exp. 07/31/2008

2006 ATLANTIC HIGHLY MIGRATORY SPECIES TRIP SUMMARY FORM

NMFS USE Only Received Date Schedule #

Vessel Name: _____

Vessel Number: _____

Contact Phone Number: (_____) _____-_____

Contact Name (Please Print): _____

I certify the information contained on this form is accurate and complete to the best of my knowledge:

Captain Signature: _____

Captain Name (Please Print): _____

Port & State of Departure:_____ ☐☐

Port & State of Landing: _____ ☐☐

	Month	Day	Year
Date of Departure	☐☐ /	☐☐ /	2006
Date of First Set	☐☐ /	☐☐ /	2006
Date of Last Set	☐☐ /	☐☐ /	2006
Date of Landing	☐☐ /	☐☐ /	2006
First Day Offload	☐☐ /	☐☐ /	2006

Number of Sets ☐☐

Number of Crew Members (excluding captain) ☐☐

State Trip Ticket #: _____

Dealer Names:

_____ _____

_____ _____

_____ _____

TRIP EXPENSE & PAYMENT SUMMARY (Mandatory if selected; otherwise voluntary)

		Unit Cost	Quantities Used (Whole numbers only)
Fuel	Price Per Gallon	$ ☐ . ☐☐	Gallons used ☐☐☐☐☐
Bait	Price per pound	$ ☐ . ☐☐	Pounds ☐☐☐☐☐
Light Sticks	Price per stick	$ ☐ . ☐☐	Light Sticks Used ☐☐☐☐☐
Ice	Price per unit	$ ☐☐ . ☐☐	Quantity of Ice ☐☐☐☐☐ Please circle one: Tons Blocks Lbs

Ice Maker Yes ☐ No ☐

Grocery Expenses $ ☐☐☐☐ . ☐☐

Other Trip Costs (Other costs incurred on this trip, excluding items listed elsewhere on this trip summary form. See instructions.) $ ☐☐☐☐☐ . ☐☐

		Percent Share			
Crew Shares	Owner:	☐☐☐	%	**Was crew share compensation used?**	Yes ☐ No ☐
	Captain:	☐☐☐	%	**Was the owner on board?**	Yes ☐ No ☐
	Crew Average:	☐☐☐	%		

Total Shared Costs (Includes only those costs subtracted from gross revenues to calculate crew payments. See instructions.) $ ☐☐☐☐☐ . ☐☐

Did you use a Broker? Yes ☐ No ☐

Broker/Selling Expense $ ☐☐☐☐ **OR** Broker Percentage ☐☐ % By Revenue? ☐ or By Weight? ☐

Captain License Number: _____ State ☐☐

USE THIS COPY FOR SENDING IN THE TRIP EXPENSE REPORT.
MAIL TO NATIONAL MARINE FISHERIES SERVICE, P.O. BOX 491740, MIAMI, FL, 33149

Use BLACK or BLUE Ink Only OMB 0648-0371 Exp. 07/31/2008

2006 ATLANTIC HIGHLY MIGRATORY SPECIES TRIP SUMMARY FORM

NMFS USE Only Received Date Schedule #

Vessel Name: _____

Vessel Number: _____

Contact Phone Number: (_____) _____-_____

Contact Name (Please Print): _____

I certify the information contained on this form is accurate and complete to the best of my knowledge:

Captain Signature: _____

Captain Name (Please Print): _____

Port & State of Departure:_____ ☐☐

Port & State of Landing: _____ ☐☐

	Month	Day	Year
Date of Departure	☐☐ /	☐☐ /	2006
Date of First Set	☐☐ /	☐☐ /	2006
Date of Last Set	☐☐ /	☐☐ /	2006
Date of Landing	☐☐ /	☐☐ /	2006
First Day Offload	☐☐ /	☐☐ /	2006

Number of Sets ☐☐

Number of Crew Members (excluding captain) ☐☐

State Trip Ticket #: _____

Dealer Names:

_____ _____

_____ _____

_____ _____

TRIP EXPENSE & PAYMENT SUMMARY (Mandatory if selected; otherwise voluntary)

		Unit Cost	Quantities Used (Whole numbers only)
Fuel	Price Per Gallon	$ ☐ . ☐☐	Gallons used ☐☐☐☐☐
Bait	Price per pound	$ ☐ . ☐☐	Pounds ☐☐☐☐☐
Light Sticks	Price per stick	$ ☐ . ☐☐	Light Sticks Used ☐☐☐☐☐
Ice	Price per unit	$ ☐☐ . ☐☐	Quantity of Ice ☐☐☐☐☐ Please circle one: Tons Blocks Lbs

Ice Maker Yes ☐ No ☐

Grocery Expenses $ ☐☐☐☐ . ☐☐

Other Trip Costs (Other costs incurred on this trip, excluding items listed elsewhere on this trip summary form. See instructions.) $ ☐☐☐☐☐ . ☐☐

		Percent Share		
Crew Shares	Owner:	☐☐☐	%	**Was crew share compensation used?** Yes ☐ No ☐
	Captain:	☐☐☐	%	**Was the owner on board?** Yes ☐ No ☐
	Crew Average:	☐☐☐	%	

Total Shared Costs (Includes only those costs subtracted from gross revenues to calculate crew payments. See instructions.) $ ☐☐☐☐☐ . ☐☐

Did you use a Broker? Yes ☐ No ☐

Broker/Selling Expense $ ☐☐☐☐ **OR** Broker Percentage ☐☐ % By Revenue? ☐ or By Weight? ☐

Captain License Number: _____ State ☐☐

KEEP THIS COPY FOR YOUR RECORDS

Instructions for the Trip Summary form

NOTE: All data provided are CONFIDENTIAL and will be used to determine the effects of existing and proposed management policies on fishery participants. Consistent and accurate reporting is critical for achieving the benefits of conservation and management of Atlantic Highly Migratory Species fisheries. The *blue page* is a continuation of the set form and is *mandatory* for all permitted vessels. The *green page* (Trip Expense and Payment Summary) is *mandatory* only *if* your vessel has been *selected* and you have been notified in writing by NOAA Fisheries that this information is required of you. Vessels not selected are encouraged to supply the information on the green page on a voluntary basis. If you have any questions, please contact the Logbook Program at (305) 361-4581, or Mr. Andy Bertolino at (305) 361-4240, or alternatively, visit our website (http://www.sefsc.noaa.gov/fls.jsp). For additional logbook supplies, include a written request with your logbook submission. If your vessel **did not fish** during a given calendar month, fill out a No Fishing Reporting Form located at the back of this logbook. Instructions have been included in the Set Form Logbook, pg. 1. These reports **must be mailed (faxes are no longer accepted)** within the time period delineated below to NATIONAL MARINE FISHERIES SERVICE, P.O. BOX 491740, MIAMI, FL, 33149.

*Please use a ballpoint pen and print clearly to record the following on the **Blue Page***:

- **Vessel Name** and **Vessel Number**: U.S. Coast Guard vessel identification number or state registration number as recorded on permit.
- **Contact Telephone Number and Name**: Printed name and telephone number of the person completing the form.
- **Captain Signature and Name**: Signature of the person completing the form (normally, this would be the captain for the trip, although the vessel owner may complete the second portion of the form).
- **Port & State of Departure**: Location of port from which the vessel departed.
- **Port & State of Landing**: Location of port that vessel returned.
- **Dealer Name(s)**: List of names of dealers purchasing the harvest.
- **Date of Departure**: Calendar date (month/day/2006) on which the trip was started.
- **Date of First Set**: Calendar date (month/day/2006) of first set made on trip.
- **Date of Last Set**: Calendar date (month/day/2006) of last set made on trip.
- **Date of Landing**: Calendar date (month/day/2006) the vessel arrived back at port. This can be different from the offloading date.
- **First Day Offload**: Calendar date (month/day/2006) that vessel began offloading fish.
- **Number of Sets**: Number of times the fishing gear was set out during the trip.
- **Number of Crew Members**: Number of persons paid as crew (excluding captain).
- **State Trip Ticket #**: For states that require trip tickets, include the ticket # from your sales receipt.

Remove the blue page, attach corresponding set forms and tally sheet, and mail within 7 days after last offloading date.

*The following information (found on the **Green Page**) is mandatory for selected vessels and voluntary for all other vessels.*
For selected vessels, the following information must be mailed within 30 days after last offloading date.

- **Fuel**: Price per gallon paid for fuel used during trip. *(If you did not refuel for the trip, record price paid when fuel was last purchased.)*; indicate gallons actually **used** during the trip. *(Exclude fuel purchased but not used.)*
- **Bait**: Record price per pound purchased and amount of bait **used** during trip in pounds. If no bait is purchased, then record a zero.
- **Light Sticks**: Record price per light stick and number of light sticks **used** during the trip *(If a light stick was re-used, only count it once.)*
- **Ice**: Indicate the price per unit. Also indicate the **Quantity of Ice** purchased and circle the correct unit size.
- **Ice Maker**: Indicate if an ice maker is used on the vessel by marking 'Yes' or 'No.'
- **Grocery expenses**: Indicate grocery costs (food, toiletries, etc.).
- **Other Trip Costs**: Other costs incurred for this trip **excluding** items listed elsewhere on this trip summary form (for example, docking/offloading fees (if separate from broker fee), crew travel/lodging, fishing supplies).
- **Crew Shares**: Crew share is compensation based upon percentage of net revenues. If you did not use crew share compensation on a trip, then calculate payments as percentage of (*estimated*) gross revenues.
  - **Owner** Share: Percentage of net revenue (*gross revenue less total shared costs*) paid to owner.
  - **Captain** Share: Percentage of net revenue paid to captain.
  - **Crew Average** Share: Average percent share of net revenue paid to crew, excluding captain.
  - **Was Crew Share Compensation Used**: Indicate 'yes' or 'no'.
  - **Was the Owner on Board**: Indicate 'yes' or 'no'.
- **Total Shared Costs**: Record the sum of all costs incurred for this trip that are subtracted from gross revenues prior to calculating crew share payments, **including** (*estimated*) shared gear, repair and maintenance costs. If vessel does not use crew shares, record zero.
- **Broker Used**: Indicate if a broker was used to sell your catch by marking 'Yes' or 'No.'
- **Broker/Selling Expense** or **Broker/ Percentage**: Report either the (*estimated*) broker/dealer fee or the percentage by gross revenue or weight of fish charged by the broker. (*If catch is sold to multiple brokers/dealers, please report for broker/dealer handling the majority of catch or report the average charged across brokers/dealers.)*
- **Captain License Number** and **State**: Record license number and issuing state.

UNITED STATES DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMIN.
NATIONAL MARINE FISHERIES SERVICE

2006

SET FORMS

FISHING VESSEL LOGBOOK RECORD
ATLANTIC HIGHLY MIGRATORY SPECIES FISHERIES

YOU ARE ADVISED THAT DISCLOSURE OF THE INFORMATION REQUESTED IN THIS REPORT IS MANDATORY FOR THE PURPOSE OF MANAGING THE FISHERIES IN ACCORDANCE WITH THE ATLANTIC TUNAS CONVENTION ACT (16 U.S. 971 ET. SEQ.) AND THE FISHERY CONSERVATION AND MANAGEMENT ACT OF 1976 (16 U.S.C. 1801 ET. SEQ.). FAILURE TO REPORT MAY RESULT IN CIVIL OR CRIMINAL SANCTIONS.

NAME OF VESSEL : _____

PERMIT NUMBER : _____

NOAA FORM 88-191 **OMB NO. 0648-0371** **Expires: 07/31/2008**

2006 FISHING VESSEL LOGBOOK RECORD
ATLANTIC HIGHLY MIGRATORY SPECIES FISHERIES
SET FORM INSTRUCTIONS

This form is to be used to report fishing activity for Atlantic highly migratory species permits. Under current regulations, all fishermen are responsible for submitting a logbook for every fishing trip. Set forms must be filled out within 48 hours of that day's activities or before offloading.

Please print all requested information clearly. A form with incomplete or unclear information may delay processing and not be credited towards your compliance. This lack of compliance may result in your permit renewal being denied.

Monthly reporting for individuals holding a Swordfish and Shark permit will be considered complete and in compliance with the regulations only if: 1) the (a) Trip Summaries for each trip completed during the month, (b) individual Set Records for each set made during the trip(s), and (c) Tally Records for all fish sold are provided; or 2) a no fishing report is provided.

If a permitted vessel did NOT fish during a calendar month, a No Fishing Reporting Form must be completed. No Fish Reports are located in the back of the Trip Summary Logbook, behind the trip report forms. Please note the following for No Fish Reports:

- A separate form must be completed for each month that no fishing occurred.
- Please do not submit one form for multiple months.
- Do not submit more than one form for each month.
- Put a check by each permit for the fishery(ies) that no fishing occurred.
- Multiple fisheries can be reported on one form.
- Do not check fisheries for which you do NOT have a permit.

In the pre-addressed envelopes provided, please mail original set forms, along with the Trip Summary Form and weighout slips (tally records), or a No Fishing Reporting Form, to:

National Marine Fisheries Service
Logbook Program
P.O. Box 491740
Key Biscayne, Florida 33149-9915

Mailing should be postmarked no later than the 7th day after offloading all Atlantic Highly Migratory Species, or (7) days after the end of a month which you are reporting no fishing activity. **Faxed reports are no longer accepted.**

When additional forms or envelopes are needed, please include a note with your logbook submission or call the Logbook Program at the number listed below. Include your name, address and your vessel identification number. If you have any questions, please contact the Logbook Program at (305) 361-4581, or Mr. Andy Bertolino at (305) 361-4240. Alternatively, you can visit our website at http://www.sefsc.noaa.gov/fls.jsp.

DESTROY OLD UNUSED FORMS. USE ONLY CURRENT YEAR FORMS.

Please use a separate log sheet for each set. If using a gear that is not fished in sets, use one sheet for each day of fishing.

- Record the **Official Vessel Number.**
- **Signature**, each set form must be signed by the captain or a person responsible for maintaining the records for the vessel.
- Designate primary **Target** species.
- Record **Gear Used**.
- Record **Set Date** and **Haulback Date** (calendar day when set or haulback began).
- Enter Times when using longlines or gillnets for:
  -- **Begin Set** and **End Set** (designate **AM** or **PM**)

-- **Begin Haulback** and **End Haulback** (designate **AM** or **PM**)
(Please note, do not use military time).

- At the start of each set, record the location to the nearest degree and minutes of **Latitude** and **Longitude**, and the **Surface Water Temperature**, in degrees Fahrenheit.
- Enter the following data for each set if using **Longline** gear:
  - -- **Number of hooks per set**
  - -- **Number of hooks between floats**
  - -- **Number of light sticks**
  - -- **Length of Mainline** (in miles)
  - -- **Average Length of Gangions** (in fathoms)
  - -- **Average Length of Floatline** (in fathoms)
  - -- **Indicate whether "J" Hooks or Circle Hooks were used**
  - -- **Indicate what size hooks were used: 16° or 18°**
  - -- **Indicate whether offset hooks were used: Yes or No**
  - -- **Bait Type: indicate Live, Dead or Artificial**
  - -- **Bait Used: indicate the type of bait used: Squid, Mackerel, or Other**
- Enter the following data for each set if using **Gillnet**:
  - -- **Mesh Size** (in inches)
  - -- **Total drift gillnet net length** (in fathoms)
  - -- **Fishing Depth Range** (Depth of top and of Bottom of net in fathoms)
- Record **NUMBERS OF SWORDFISH, TUNAS, SHARKS AND OTHER SPECIES KEPT AND THROWN BACK.** For the fish that were thrown back, please specify the number of those that were **Alive** and the number of those thrown back that were **Dead**. For **Est. Lbs Kept.**, write down the estimated dressed weight in pounds of fish kept for each species. For catches of species not listed on the form, print the species name in the blank spaces and record the appropriate catch information.
- Record **NUMBERS OF ENDANGERED SPECIES INVOLVED**
  - -- **Total Number Involved**. Write down the total number of each sea turtle species that were caught in, or interacted with, your fishing gear for the period of your report.
  - -- **Number Injured**. Write down the number of each sea turtle species that were injured while in, or by, your fishing gear.
  - -- **Number Dead**. Write down the number of each sea turtle species that were observed to be dead while in, or by, your fishing gear.

Remove page(s), and with the corresponding Trip Summary form and tally sheet(s), mail within 7 days after the last offloading date.

Retain the second copy of set forms for your records.

PAPERWORK REDUCTION ACT STATEMENT: Atlantic highly migratory species vessel logbooks provide information on fishing effort, target catch and bycatch in the fisheries for tunas, sharks and swordfish. This information is the basis for quota monitoring and stock assessment and is used to meet international obligations to report fishery statistics to the International Commission for the Conservation of Atlantic Tunas. Public reporting burden for this information collection, including time for reviewing instructions, searching existing data sources, gathering and maintaining data needed, and completed & reviewing the collection of information, is estimated to average: 12 minutes per response for the set form (daily report); 30 minutes per response for the trip expense and earnings summary; 2 minutes per response for the no-fishing report; and 30 minutes per response for the annual expenditures form. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to: Highly Migratory Species Management Division, National Marine Fisheries Service, F/SF1, 1315 East West Highway, Silver Spring, MD 20910. Providing the requested information in the vessel logbook is mandatory, if selected, and is necessary for managing the Atlantic highly migratory species fisheries in accordance with the Atlantic Tunas Convention Act (16 U.S.C. 971 et seq.) and the Magnuson-Stevens Fishery Conservation and Management Act (16 U.S.C. 1801 et seq.). In accordance with NOAA Administrative Order 216-100, it is agency policy not to release confidential fisheries statistics, other than in aggregate form. Notwithstanding any other provision of the law, no person is required to respond to, nor shall any person be subject to a penalty for failure to comply with a collection of information subject to the requirements of the Paperwork Reduction Act, unless that collection of information displays a currently valid OMB Control Number. This is an approved information collection under OMB #0648-0371 and expires July 31, 2008.

2006 ATLANTIC HIGHLY MIGRATORY SPECIES LOGBOOK - Set Form

OMB 0648-0371 Exp 07/31/2008
Version Date 09/05
NOAA Form 88-191

Please Use Black or Blue Ink only

Official Vessel Number:

Signature: _____

I certify that the information contained on this form is accurate and complete to the best of my knowledge.

NMFS Use Only:

TARGET: ○ Swordfish ○ Yellowfin ○ Bigeye ○ Mixed Tuna ○ Sharks ○ Dolphin ○ Other (list) _____

GEAR: ○ Pelagic Longline ○ Bottom Longline ○ Handline ○ Harpoon ○ Gillnet ○ Bandit
○ Rod & Reel ○ Otter Trawl ○ Squid Trawl ○ Other (list) _____

Set Date: ___/___/2006 Haulback Date: ___/___/2006

Begin Set:	End Set:	Begin Haulback:	End Haulback:
___:___ ○am ○pm	___:___ ○am ○pm	___:___ ○am ○pm	___:___ ○am ○pm

Latitude at beginning:	Longitude at beginning:	Surface Water Temp:	Date Received: (NMFS Use Only)
___ Deg ___ Min North	___ Deg ___ Min West	___.___ ºF	

LONGITUDE:

Please do not use decimals or ranges. Use whole numbers only.

No. of Hooks: ____

No. of Hooks between Floats: ____

No. of Light Sticks: ____

Mainline Length (nm): ____

Average Gangion Length (fm): ____

Average Floatline Length (fm): ____

Hook Type: ○ "J" ○ Circle

Hook Size: ○ 16° ○ 18°

Hook Offset: ○ Yes ○ No

Bait Type:
○ Dead ○ Live ○ Artificial

Bait Used:
○ Squid ○ Mackerel ○ Other

GILLNET:

Mesh size (in): ____

Total Net Length (fm) ____

Fishing Depth Range (fm): ____ to ____

SWORDFISH and TUNA

	No. Kept	No. Thrown Back Alive	No. Thrown Back Dead	Est. Lbs. Kept
Swordfish				
Bonito Tuna				
Bluefin Tuna				
Skipjack Tuna				
Yellowfin Tuna				
Blackfin Tuna				
Albacore Tuna				
Bigeye Tuna				

SHARKS

	No. Kept	No. Thrown Back Alive	No. Thrown Back Dead	Est.Lbs Kept
PELAGIC SHARK				
Blue				
Mako, Longfin				
Mako, Shortfin				
Oceanic Whitetip				
Porbeagle				
Thresher, Bigeye				
Thresher, Common				

OTHER SPECIES

White Marlin				
Blue Marlin				
Sailfish				
Spearfish				
Escolar				
Dolphin (Mahi)				
Wahoo				
King Mackerel				
Greater Amberjack				
Banded Rudderfish				

COASTAL SHARK

Bignose				
Blacktip				
Dusky				
Bonnethead				
Hammerhead				
Night				
Sandbar				
Sharpnose				
Silky				
Spinner				
Tiger				
White				

ENDANGERED SPECIES

	Involved	Injured	Dead		Involved	Injured	Dead
Leatherback				Kemp's Ridley			
Loggerhead				Hawksbill			
Green				Sm. tooth Sawfish			

KEEP THIS COPY FOR YOUR RECORDS

CICAA FORMA C BITACORA DIARIA DE OBSERVADORES

(Palangre Pelágico)

Fecha de Salida:_____ **Fecha de Llegada**:_____ **AÑO:**

Nombre del Barco:

Nombre del Capitan:

Nombre del Observador:

NUMERO DEL LANCE:

ESPECIE OBJETIVO:

	Mes	Dia	Hora	Latitud	Longitud	Temp (^{o}C)
Comienzo del lance						.
Fin del lance						.
Comienzo de recoger						.
Fin de recoger						.

Carnada1 _____ viva ☐

Carnada2_____ muerta ☐

Palito fosforesnte. Si ☐ No ☐

Baño fosforesnte. Si ☐ No ☐

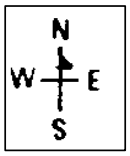
Rendal de acero Si ☐ No ☐

Tipo de Anz : Circular ☐ "J" ☐ Tamño. ☐

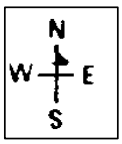
Marca anzuelo

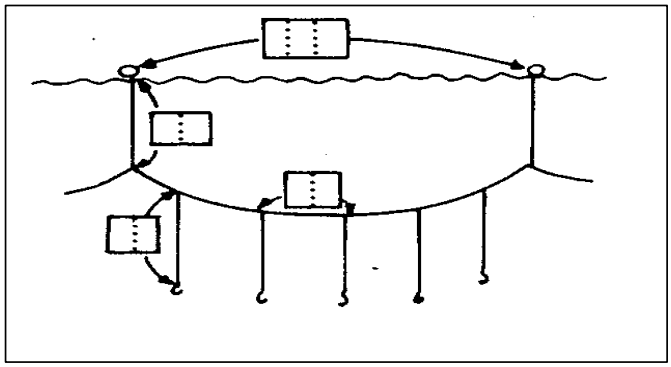
Longitud del palangre (m):

Dirección del lance



Dirección de recogida





Indique dimensiones de la unidad en metros

Número total de unidades:

Número de anzuelos por unidad:

Número total de anzuelos:

CAPTURA DEL DIA

ESPECIES	Numero			kg		
Atun aleta amarilla (YFT)						
Atun albacora (ALB)						
Atun ojo gordo (BET)						
Pez espada (SWO)						
Aguja blanca (WHM)						
Aguja azul (BUM)						
Pez vela (SAI)						
Pez lanza (SPF)						
TIB:						
TIB:						
TIB:						
TIB:						
Atun aleta negra (BLF)						
Dorado (DOL)						
Peto (WAH)						

CICAA FORMA D MUESTREO DE ESPECIES (observadores abordo)

(SIRVE PARA TODAS LAS ESPECIES)

NUMERO DEL LANCE:

NOMBRE DEL BARCO	FECHA DE MUESTRA	OBSERVADOR	EQUIPO USADO
			☐ Vernier ☐ Cinta

Conteo	ESPECIES	Muerto	Vivo	Hora embarq	Medidas de longitud L1 (cm)		Medidas de longitud L2 (cm)			Peso (kg)		Sexo M/H/J	Número de muestra u Observaciones
				hrs min	MILH	LH	CK	PELH	TRNC	Est.	Med.		
1										☐	☐		
2										☐	☐		
3										☐	☐		
4										☐	☐		
5										☐	☐		
6										☐	☐		
7										☐	☐		
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23										☐	☐		
24										☐	☐		
25										☐	☐		

CICAA FORMA C BITACORA DIARIA DE OBSERVADORES

(Palangre Pelágico)

Fecha de Salida:_____ **Fecha de Llegada**:_____ **AÑO:**

Nombre del Barco:

Nombre del Capitan:

Nombre del Observador:

NUMERO DEL LANCE:

ESPECIE OBJETIVO:

	Mes	Dia	Hora	Latitud	Longitud	Temp (^{o}C)
Comienzo del lance						.
Fin del lance						.
Comienzo de recoger						.
Fin de recoger						.

Carnada1 _____ viva ☐

Carnada2_____ muerta ☐

Palito fosforesnte. Si ☐ No ☐

Baño fosforesnte. Si ☐ No ☐

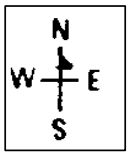
Rendal de acero Si ☐ No ☐

Tipo de Anz : Circular ☐ "J" ☐ Tamño. ☐

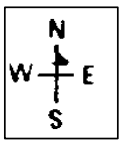
Marca anzuelo

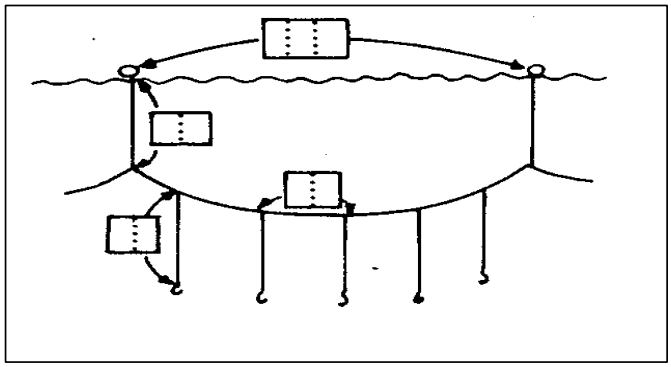
Longitud del palangre (m):

Dirección del lance



Dirección de recogida





Indique dimensiones de la unidad en metros

Número total de unidades:

Número de anzuelos por unidad:

Número total de anzuelos:

CAPTURA DEL DIA

ESPECIES	Numero			kg		
Atun aleta amarilla (YFT)						
Atun albacora (ALB)						
Atun ojo gordo (BET)						
Pez espada (SWO)						
Aguja blanca (WHM)						
Aguja azul (BUM)						
Pez vela (SAI)						
Pez lanza (SPF)						
TIB:						
TIB:						
TIB:						
TIB:						
Atun aleta negra (BLF)						
Dorado (DOL)						
Peto (WAH)						

CICAA FORMA D MUESTREO DE ESPECIES (observadores abordo)

(SIRVE PARA TODAS LAS ESPECIES)

NUMERO DEL LANCE:

NOMBRE DEL BARCO	FECHA DE MUESTRA	OBSERVADOR	EQUIPO USADO
			☐ Vernier ☐ Cinta

Conteo	ESPECIES	Muerto	Vivo	Hora embarq	Medidas de longitud L1 (cm)		Medidas de longitud L2 (cm)			Peso (kg)		Sexo M/H/J	Número de muestra u Observaciones
				hrs min	MILH	LH	CK	PELH	TRNC	Est.	Med.		
1										☐	☐		
2										☐	☐		
3										☐	☐		
4										☐	☐		
5										☐	☐		
6										☐	☐		
7										☐	☐		
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23										☐	☐		
24										☐	☐		
25										☐	☐		

RUTA Y PARAMETROS MEDIOAMBIENTALES

Formulario ruta n°:	**Corredera mañana:**	**Nombre del barco:**	**Barco n°:**
Fecha:	**Corredera tarde:**	**Nombre del observador:**	

Linea	**Hora** h h m m	**Cua-drante**	**Latitud** g g m m	**Longitud** g g m m	**Activid. barco**	**Activid. circund.**	**Veloci-**dad	**Temperatura de superficie**	**Veloc. viento**	**Modo deteccion**	**Sistemas observados**	**Distancia**	**Razón no lance**	**Formul. B**	**Formul. D**
0	0 9 2 5	3	0 6 5 6	1 4 0 4	0 3	4	1 2	2 6 , 7	2	2	0 7 0 7 0 7	0 8 , 6	0 7	11	22
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2								,				,			
3								,				,			
4								,				,			
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Notas:

Datos verificados:

Plan Nacional Datos Básicos

Formulario **B**

CARACTERISTICAS DE LA PESCA

Lance nº:	Fecha:	Nobre del barco:	Barco n°:

Formulario ruta nº:	Línea ruta nº:	Nombre observador :

Características de la pesca

Hora comienzo lance			
h	h	m	m

Hor.fin recogida jareta			
h	h	m	m

Hora final del lance			
h	h	m	m

Profundidad cierre jareta [(1)]

Razón lance nulo

Estimación tamaño del banco (t) y Peso medio (kg)	
	YFT: /
	SKJ: /
	BET: /
	Total: /

Utilización del Sonar			
	Antes maniobra	Espesor del banco	
		Profundidad media	
		Profundidad comienzo	
	Durante maniobra	SI	NO

Sistemas observados					

Capturas atunes

Especie	Cat.	Peso	Cuba	Especie	Cat.	Peso	Cuba	Especie	Cat.	Peso	Cuba	Especie	Cat.	Peso

Especie	Cat.	Peso	Cuba	Especie	Cat.	Peso	Cuba	Especie	Cat.	Peso	Cuba	Especie	Cat.	Peso

Especie	Cat.	Peso	Cuba	Especie	Cat.	Peso	Cuba	Especie	Cat.	Peso	Cuba	Especie	Cat.	Peso

Descartes de atunes

Izado a bordo	Si	No

Especie	Cat.	Peso	Especie	Cat.	Peso	Especie	Cat.	Peso	Especie	Cat.	Peso

Otras especies

Especie	Estimac. cuantitat.	p nº	talla peso	Deve-nir	Especie	Estimac. cuantitat.	p nº	talla peso	Deve-nir	Especie	Estimac. cuantitat.	p nº	talla peso	Deve-nir

Notas

Datos verificados:

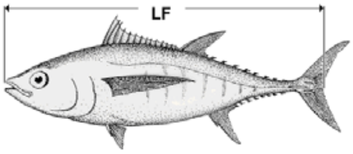
MUESTREO ATUNES

Formulario muestreo n°: | Lance n°: | Fecha: | Nombre observador:

Formulario ruta n°: | Línea ruta n°: | Nombre barco: | Barco n°:

Captura

Descartes



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2		2		2		2		2		2		2	
3		3		3		3		3		3		3	
4		4		4		4		4		4		4	
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6		6		6		6		6		6		6	
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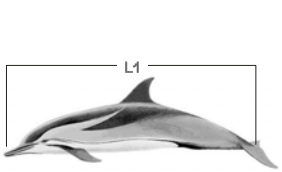
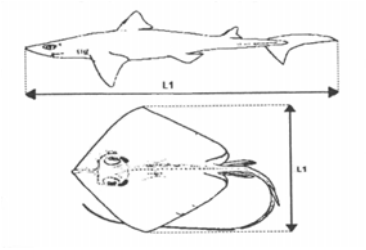
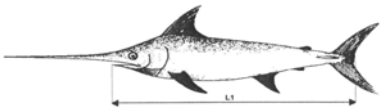
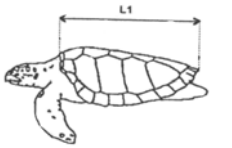
MUESTREO ESPECIES ASOCIADAS

Formulario muestreo n°:	Lance n°:	Fecha:	Nombre observador:
Formulario ruta n°: Línea ruta n°:		Nombre barco:	Barco n°:









	ESPECIE	L1	SEXO	FOTO nº	ROLLO nº
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	ESPECIE	L1	SEXO	FOTO nº	ROLLO nº
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NOTAS:

SEGUIMIENTO DE OBJETOS FLOTANTES

Formulario D nº:									
Formulario ruta nº:	Linea ruta nº:	OPERACIÓN CON OBJETO		TIPO DE OBJETO	DEVENIR del OBJETO	TIPO BALIZA		CODIGO BALIZA	
								Al recoger	Al plantar	Al visitar
		Plantado				Radiogoniometro				
		Visitado				Radiogoniometro + GPS				
		Pesca				GPS Tipo SHERPE (Bola)			Días en el mar	
		Recogido sin pescar				Satelite + Ecosonda				
						Satelite sin Ecosonda				

	EN CASO DE NO REALIZACIÓN DEL LANCE	
	ASOCIADA (en Tm.)	CATEGORIA COMERCIAL
Rabil		
Patudo		
Listado		
Melva		
Bacoreta		
Total Túnidos		

OBSERVACIONES:

ESTADILLO A
LINEA

OBJETO

Naturaleza (codigo tabla 8)	actividad	Codigo	Tipo
	Plantado	Al recoger	Radiogoniometro
	Visitado	Al plantar	Radiogoniometro + GPS
	Pesca		GPS Tipo SHERPE (Bola)
			Satelite + Ecosonda