GENERAL METHODS OF ESTIMATING NUMERIC ABUNDANCE OF FISH

1. Estimation from catch statistics
2. Correlated population method
3. Direct enumeration
4. Change-in-ratio-methods (survey-removal methods)
5. Mark-recapture methods

1. ESTIMATE FROM CATCH STATISTICS

Imagine a fishery in which a sequence of identical fishing operations successively removes catches of fish from the population. These catches should decline in a regular manner (i.e. apart from random variation due to "Sampling")

If q^1 is the probability of individual fish being captured, then $(1 - q^1)$ is the probability of escaping capture. In this case a fishing event is considered a "trial" then, a proportion of the original stock will be captured in the first trial, and a proportion will survive. Then the "expected" catches will be:

* $E(C_1) = Nq^1$ Survivors $= N(1 - q^1)$
* $E(C_2) = Nq^1(1 - q^1)$ Survivors $= N(1 - q^1)(1 - q^1)$
* $E(C_3) = Nq^1(1 - q^1)^2$ Survivors $= N(1 - q^1)(1 - q^1)$

Therefore, $E(Cn) = Nq^1(1 - q^1)^{n-1}$ Survivors $= \pm N(1 - q^1)(1 - q^1)^n$

This is the sequence of expected catches assuming that the fisherman does not change tactics from one trial to the next and that the fish react independently to each trial

Setting up the expected catches in a ratio, we have:

$$\frac{[E(C_1)]^2}{E(C1) - E(C_2)} = \frac{N^2(1-q^1)}{Nq^1 - N\,q^1(1-q^1)}$$

The final equation represents a useful formulation of the population estimate, given any two catches in succession

II. ABUNDANCE ESTIMATED BY CHANGE IN CATCH PER UNIT OF EFFORT

The basic assumption is that the fishing mortality coefficient is proportional to the fishing effort.

$$F = qf.$$

The constant of proportionality, is called the catchability coefficient.

In general, a population is fished until enough fish are removed to significantly reduce the catch per unit of effort, C/F, or, CPUE.

Example: If removal of 10tons of fish reduces C/F by a quarter, the original stock must have been 10/0.25 or 40tons.

METHODS:

1. Leslie– plots of CPUE against cumulative catch, and
2. Delury – log of CPUE is plotted against cumulative effort.

Leslie Derivation:

$$\frac{C_t}{F_t} = qN^t \text{ by definition} \ldots\ldots\ldots\ldots\ldots\ldots \text{(i)}$$

At the time K_t fish have been caught, the population N_t is:

$$N_t = No - K_t \ldots\ldots\ldots\ldots\ldots\ldots \text{(ii)}$$

$$\frac{C_t}{F_t} = qNo - qKt$$

where q is the catchability coefficient.

This is the basic Leslie formulation use to estimate initial population size (x – intercept) and catchability coefficient.

From Y = a + bX (linear model)

The equation above when rewritten becomes…………………………..(iii)

$$\frac{C_t}{F_t} = qN_o\left(\frac{N_t}{N_o}\right) \ldots\ldots\ldots\ldots\ldots\ldots \text{(iv)}$$

From which the $\log_e$ form

$$\text{Log}_e \left(\frac{C_t}{F_t} \right) = \text{Log}_e (qN_o) + \text{Loge} \left(\frac{N_t}{N_o} \right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(v)$$

Delury Derivation:

When the fraction of the stock taken by a single unit of effort in small (say less than 2%0 it can be used as an exponential index to show the fraction of the stock remaining after E_t units (of effort) have been expended.

$$\frac{N_t}{No} = e^{-qEt}$$

Substituting into the logarithmic equation above……………………………..(v)

$$\text{Log}_e \left(\frac{Ct}{Ft} \right) = \text{loge} (qN_o) - qE_t$$

From this both q and N_o may be estimated.

III. CORRELATED POPULATION METHOD:

In this method, it may be possible to estimate population size from the production of eggs or the number of nexts. For some species of fish, the tecundity of the species together with the size of femelas and sex composition of the population, and an estimate of the number of eggs deposited would provide the basic information required to estimate population size. The simplest models is:

$$N = \frac{r_n \hat{E}}{\hat{e}} \quad \text{and} \quad r_n = \frac{N f + Nm + N_1}{Nf}$$

Where: Nf, Nm, N_1 are the numbers of mature fish of each sex and the number of immature fish beyond a certain age or size, E is the total number of eggs spawned in the season and **e** is the mean number of eggs spawned per mature female.

This estimation procedure requires that the ratio (r_n) be obtained from an experimental survey or from sampling the commercial catch. The total number of eggs spawned involves taking samples of known volumes of water (for pelagic eggs or of known areas of bottom (for benthic eggs)

IV. ESTIMATION BY DIRECT ENUMERATION:

Suppose we know the boundaries of a total population space, but we do not know how the population is distributed in this space. We arbitrarily divide the space into A equal spaces and select "a" of these to enumerate completely. The experiment yields error free numbers.

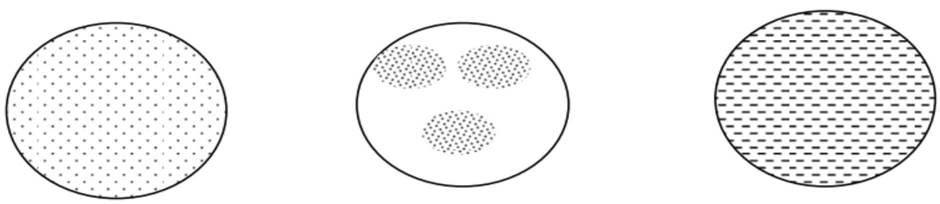
N_1, N_2, N_3 …………………… Na for the spaces 1, 2, 3…………………..a

Where $$N = \sum_{i=1}^{A} Ni$$

Our estimate of N becomes:

Where $$N = \sum_{i=1}^{A} \frac{Ni}{a}$$

This estimate is valid whether the population is randomly dispersed is space or contagiously distributed (i.e. – "over – dispersed") or uniformly distributed ("under – dispersed")



Two applications of this method are used in fisheries using acoustic methods:

(a) Mobile sector – scanning sonar – may be applied by running the vessel along randomly chosen transects and enumerating the sonar blips

(b) Sonar Scanner – placing sonar scanners in migration path and enumerate the blips as the fish pass the station.

V. CHANGE-IN-RATIO ESTIMATORS

Methods of this type have been variously known as change-of-composition, survey-removal or dichotomy methods. The basis for the methods is an observed change in the relative abundance of two classes of animals within a population. The classes may be naturally occurring groups such as age, species, or sex classes, or they may be artificially constructed classes change-in-ratio of the classes allows us to estimate population abundance and survived.

Example:

In a situation where males or females might be selectively removed is evident here in the equation.

$$\text{Proportion males in Population after removal} = \frac{\text{(\# males before removal)} - \text{(\#males removed)}}{\text{(Pop. Size before removal)} - \text{(Total \# animals removed0}}$$

Note that the signs in the word equation depend upon whether fish are entering or leaving the population.

$$N_1 = \frac{R_x - P_2R}{P_2 - P_1}$$ for estimate population abundance

Number of X-type fish in the population at t_1.

$$X = \frac{P_1 (Rx - P_2R)}{P_2 - P_1}$$

Where P_1 – proportion of X – types of fish at time t (1, 2) which is equal to

$$Pi = \frac{Yi}{Ni} \quad \text{where } Ni = Xi + Yi$$

N_i = total no of all fish, X_i = total number of X- fish

R_X = Net change in numbers of X – type of fish in the population between t_1 and t_2

R = Rx + Ry = Net removal (–) or addition (f) to the population between t_1 and t_2

VI. MARK – RECAPTURE METHODS:

In 1896, C.G.T. Petersen (Danish biologist) used this method to compute the rate of exploitation and, subsequently the total population of a group of fish. Ten years later Knut Dahl employed the method to estimate a trout population in Norway.

General Considerations:

Mark recapture models for estimating abundance depend upon capturing a portion of a stock, marking it and releasing the marked fish, some of which are subsequently caught in the next capture event.

Factors to consider include:

1. How many fish can be marked in a single event?
2. How many can be recaptured?
3. Are Unique identifiers required or will batch – marked do an well.
4. Will there be losses on capture?

There are two types of mark-recapture methods

i. Single mark – recapture.

ii. Multiple mark – recapture

Single Mark-recapture

$$N = \frac{MC}{r}$$

Where: N is the total population

m = number of marked fish in population

c = number of fish in the sample of population

r = number of marked fish in C

$$V(N) = \sqrt{\frac{N^2(N - m)(N - C)}{mc\,(N - 1)}}$$

at 95% Cl . P = N + 1.96V (N)

Multiple mark – Recapture method

$$N = \frac{\sum mici}{\sum Ri}$$

i	mi	ci	Ri	Newly marked& released	mici
1	O	44	0	44	0
2	44	53	4	49	2332
3	93	58	4	49	5394
4	145	47	11	36	6815
5	181	52	17	35	9412
6	216	46	18	28	9936
Total		56		33889	

$$N = \quad N = \frac{\sum mici}{\sum Ri} \quad = 33889 / 56 = 605.2$$

Class work:

300 fish were marked and released in June 1. on September 25, 75 were marked differently and released. On October. 1, 250 fish were caught of which 35 bore the June mark and 12 bone the September mark. Estimate the survival of this MR survey.

Solution

$$N_1 = \frac{300 \times 250}{35} = 2143$$

$$N_2 = \frac{75 \times 250}{12} = \frac{1563}{580}$$

$$\frac{580}{2143} \times \frac{100}{1} = 27\% \text{ mortality}$$

Therefore, survival is 73%.