GUIDE TO THE USE OF THE LENGTH-BASED DATA TO ESTIMATE FISHING MORTALITY IN DATA-LIMITED FISH STOCKS

[**Catch Curve**](#_Catch_Curve)

[**MPA Catch Curve**](#_MPA_Catch_Curve)

[**LBAR**](#_LBAR)

[**Spawning Potential Ratio**](#_Spawning_Potential_Ratio)

# Fishing Mortality (F) Estimators

In fisheries, determining stock status means estimating one or more biological characteristics of the stock, such as abundance (numbers of fish) or biomass (weight), and comparing estimated values to reference values that define desirable conditions. Although there are many possible reference values or benchmarks to indicate status, most fishery management plans use two biologically-based indicators. The first is stock biomass (i.e., the weight of all fish in a stock) – this estimate is difficult to obtain in fisheries where data is limited. The second measure is the rate of fishing (i.e., exploitation or fishing mortality). If fishing mortality is above the reference level, overfishing is occurring. If fishing mortality is below the reference level, overfishing is not occurring. Management actions are typically concerned with finding measures to stop overfishing when it occurs and rebuilding stocks considered overfished. Management also strives to avoid overfishing and prevent viable stocks from becoming overfished.

Pros: mortality rates are critical for determining abundance of fish populations

Cons: all of the models assume equilibrium conditions. Most of these methods only reflect fish that have recruited to a fishery and does not reflect the full age structure of a stock.

**Step 1: Getting Started**

1. Target Species:
   * Identify a target species where you have either fishery dependent length-frequency data or fishery independent data from inside and outside of a no-take marine reserve.
   * Gather life history information (FishBase or primary literature) or carry out surveys, online resources such as FishBase should be vetted with fisherman interviews and/or field sampling.
2. Excel Spreadsheet:
   * Use the Excel spreadsheet provided in the downloadable workbook to keep track of the life history information and results (tab 2 of “Length Based Assessment Methods” workbook) and navigate to the tab for the analysis of interest.

## Catch Curve

It has been observed that, as fish get older, more of them will die either by natural causes or by fishing. In a fishery, this means that there are usually more smaller (and therefore younger) fish in catches than there are large or old individuals. Assuming that fish could be aged, it is possible to plot the number of individuals caught at each age in a given year. Typically, it would be observed that few young fish will be caught, that catches peak for a certain age, and then the catch of older fish will drop. This observation is due to different processes: (1) younger fish are less vulnerable to fishing gear, but as they age, they become more vulnerable, until they are said to be fully selected by the fishery at a certain age and (2) catches of older (fully selected) ages decline simply because there are fewer of them due to fishing and natural mortality (Cano & Restrepo, 2001).

A catch curve is a breakdown of total catch into different age groups of fish, showing the decrease in numbers of fish caught as the fish become older and less numerous or available. Catch curve analysis assumes that the decrease in observed numbers of individuals across the age structure of the population is the result only of mortality. Thus, if the number of individuals in each age class are known, total mortality (Z) can be estimated (Simpfendorfer, Bonfil, & Latour, 2005). Fishing mortality can then be calculated as the difference between total mortality and natural mortality (F=Z-M).

**Step 2: Input data**

Life History Parameters: M (Natural Mortality), Linf (von Bert), k (von Bert), to (von Bert),

Data:length-frequency data

**Step 3: Using the excel tool**

1. Length frequency data is transformed into age frequency data using an age-length key.

2. The numbers of animals in each age class are log (base e) transformed.

3. The log-transformed numbers are plotted against age.

4. A linear regression is fitted to the descending right-hand side of the catch curve.

5. The value of total mortality is calculated as the negative slope of the regression.

6.  Fishing mortality is estimated by F=Z-M

**References**:

Cano, J. Gonzalez, and V. R. Restrepo. “Part III Stock Assessment Methods.” In Report on the FAO/DANIDA/CFRAMP/WECAFC Regional Workshops on the Assessment of the Caribbean Spiny Lobster (Panulirus Argus): Belize City, Belize, 21 April - 2 May 1997; Merida, Mexico, 1 - 12 June 1998, by Food and Agriculture Organization. Rome: Food and Agriculture Organization of the UN, 2001.

Simpfendorfer, Colin, Ramón Bonfil, and Robert J. Latour. “Mortality Estimation.” In Management Techniques for Elasmobranch Fisheries, edited by John A Musick and Ramón Bonfil. Rome: Food and Agriculture Organization of the United Nations, 2005.

Thorson, James T., and Michael H. Prager. “Better Catch Curves: Incorporating Age-Specific Natural Mortality and Logistic Selectivity.” Transactions of the American Fisheries Society 140, no. 2 (May 20, 2011): 356–66. doi:10.1080/00028487.2011.557016.

## MPA Catch Curve

Similar to the Catch Curve method, the MPA Catch Curve method utilizes length-frequency data to examine the descending slope of the right-hand side of the log transformed age-frequency to estimate total mortality (Z). Fishing mortality then be calculated based on the difference between total mortality and natural mortality from literature (F= Z – M), the difference is that this method uses no-take marine protected areas to estimate M.

Step 2: Input data

Life History Parameters: Linf (von Bert), k (von Bert), to (von Bert),

Data: length-frequency data

Step 3: Using the excel tool

1. Use length frequency from inside in a no-take marine reserve, the length frequency data is transformed into age frequency data using an age-length key.

2. The numbers of animals in each age class are log (base e) transformed.

3. The log-transformed numbers are plotted against age.

4. A linear regression is fitted to the descending right-hand side of the catch curve.

5. The value of total mortality is calculated as the negative slope of the regression, this is the estimate of natural mortality or M.

6. Run step 1-5 with data outside of the no-take marine reserve.

7. The value of total mortality is calculated as the negative slope of the regression.

8.  Fishing mortality is estimated by F=Z-M

## LBAR

The Mean Length (LBAR) method can use fishery-dependent or independent length-frequency data. LBAR uses the minimum and maximum fished sizes, and the mean length of the fish within the fished sizes from a fished population, along with growth parameters. LBAR provides an estimate of fishing mortality (F) that can be compared to an estimate of natural mortality (M). Intuitively, increasing fishing pressure will often cause decreasing mean length.

Fishing reduces the mean size of fish in a population. Therefore, mean length of the exploited part of the population (LBAR) reflects the rate of fishing mortality (F). When calculating LBAR, it is important to only take the mean length of the fish that are fully selected by the gear. Thus, one of the first steps involves isolating the data that falls between the first length at full selectivity (Lc), and the asymptotic length (Linf). Linf is one of the life history parameters from the Life History and Data Exploration workbook. Lc is determined by analyzing a histogram of length-frequency data.

**Step 2: Input data**

Life History Parameters: M (Natural Mortality), Linf (von Bert), k (von Bert)

Data:length-frequency data

**Step 3: Using the excel tool**

1. Length at full selectivity (Lc) is determined from length-frequency data as the length with highest catch (the mode).

2. Length-frequency data for the fished population that is fully selected by the gear (lengths between Lc and Linf) is identified.

3. LBAR (mean length of the exploited part of the population) is calculated as a weighted mean of the length-frequency data identified in step 2.

4. An estimate of total mortality (Z) is calculated from LBAR using the equation: Z=k(Linf-LBAR)/(LBAR-Lc)

5.  Fishing mortality is estimated by F=Z-M

**References**:

Ault, J, S Smith, and J Bohnsack. “Evaluation of Average Length as an Estimator of Exploitation Status for the Florida Coral-Reef Fish Community.” ICES Journal of Marine Science 62, no. 3 (May 2005): 417–23. doi:10.1016/j.icesjms.2004.12.001.

Cano, J. Gonzalez, and V. R. Restrepo. “Part III Stock Assessment Methods.” In Report on the FAO/DANIDA/CFRAMP/WECAFC Regional Workshops on the Assessment of the Caribbean Spiny Lobster (Panulirus Argus): Belize City, Belize, 21 April - 2 May 1997; Merida, Mexico, 1 - 12 June 1998, by Food and Agriculture Organization. Rome: Food and Agriculture Organization of the United Nations, 2001.

Gedamke, Todd, and John M. Hoenig. “Estimating Mortality from Mean Length Data in Nonequilibrium Situations, with Application to the Assessment of Goosefish.” Transactions of the American Fisheries Society 135, no. 2 (March 2006): 476–87. doi:10.1577/T05-153.1.

## Spawning Potential Ratio

The Spawning Potential Ratio (SPR) method is based on the notion that enough fish must live to an age where they can spawn to ensure the sustainability of the stock. SPR is used to assess a fishery for recruitment overfishing. Recruitment overfishing is defined as when the fishing mortality rate is so high that fish are captured before they reach maturity and have the ability to spawn. In general, it is assumed that spawning is proportional to the weight of a species. For this reason, information about the size and weight structure of a stock is particularly helpful in determining the amount of spawning potential retained. Spawning Potential Ratio (SPR) is defined as the percent of unfished spawning potential retained under a given harvest policy. As the fishing mortality increases, the number of fish surviving to a time when they can produce eggs decreases, and so the total egg production decreases. This fished egg production is always expressed as a percentage of the total expected eggs produced under unfished conditions.

The spawning potential ratio incorporates the principle that enough fish have to survive to spawn and replenish the stock at a sustainable level. It is a measure of current egg production relative to maximum possible production at un-fished levels.

As an example, imagine that 10 fish survive the first couple years of life and are now large enough to reproduce and be caught in the fishery. Four are caught before they spawn (no eggs produced), three are caught after they spawn once (some eggs produced), and three live to spawn three times (many eggs produced) before dying of old age. During their lifetime, the 10 fish produced 1 million eggs and the average fish produced 100,000 eggs (1 million eggs/10 fish).

In an unfished population, 10 fish survive as before. Three die of natural causes after spawning once (some eggs produced) and the other seven spawn three times (many eggs produced) before dying of old age. During their lifetime, these 10 fish produce 5 million eggs, and the average fish produces 500,000 eggs (5 million eggs/10 fish).

**Step 2: Input data**

Life History Parameters: F (fishing mortality), M (Natural Mortality), Linf (von Bert), k (von Bert), to (von Bert), fa (fecundity), fb (fecundity), Wa (weight), Wb (weight), m50 (maturity), m95 (maturity), V50 (vulnerability), V95 (vulnerability).

**Step 3: Using the excel tool**

1. Estimate F (fishing mortality) by using the LBAR, Bounded LBAR, or Catch Curve method and enter the estimate.

2. Enter this estimate of F for your species in cell label F.

3. Enter life history parameters in cells B3-B14.

4. Adjust the size of the table to include all ages for the species of interest. Highlight last row in table and click bottom right of highlighted cells and click when cusor turns into a cross. Hold the click and drag cusor down until you reach the max age of the species.

5. The spawning potential ratio (SPR) will be calculated.

6. The spawning biomass per recruit (SBPR) for an average organism in a fished and unfished population will be calculated for you in the output cells.

7 .The spawning potential ratio (SPR) will be calculated.

**References**:

Goodyear, C. Phillip. “Spawning Stock Biomass per Recruit in Fisheries Management: Foundation and Current Use.” Canadian Special Publication of Fisheries and Aquatic Sciences, 1993, 67–82.

Wallace, Richard K., and Kristen M. Fletcher. “Understanding Fisheries Management.” Mississippi-Alabama Sea Grant Consortium, 2001.

# Note on the above length-based methods and gear:

Because these length-based methods depend on the assumption that the reduction in the numbers of fish in the size classes above Lc (average length) is due only to mortality, it’s important to ensure that the gear or the way it is being used is not causing peaks in certain size classes, or otherwise affecting the length-frequency composition. Another way to think about this is to regard the catch as a sample of the population of fish and ask, is this sample likely to be representative of the true length composition of the population? If there are good reasons to believe that it is not (if, for example, fishers are discarding the smallest individuals before they can be counted in the catch), then length-based methods may not be appropriate for your data.