Fish Counting Procedures

The following information is taken from the American Fisheries Society publication, Investigation and Valuation of Fish Kills, Special Publication 24 (1992).
(http://www.esb.enr.state.nc.us/Fishkill/CountProc.html (12 of 13) [6/19/2007 11:02:26 AM])

The Nature of Fish Kills

Estimates of losses based on countable dead fish will be conservative. Very seldom will the counts represent more than a modest fraction of the fish killed. The counts are based only on fish actually seen once during a dynamic, ongoing process. Fundamental problems prevent accurate estimation of the total numbers of dead fish. Fish die at differing rates, and once dead, they float or sink on different schedules; for the same species and toxicant, these rates vary with water quality, temperature, and size of fish. A count of dead fish will miss many fish that are too deep in the water to be seen, are hidden by debris, have been taken by predators or scavengers, have decomposed, or are visible but overlooked (human error). All these factors contribute toward underestimating the numbers of fish killed.

The best way to determine the number of dead fish in an area is to count them all. Such complete enumeration, however, is rarely practical over an entire fish kill because the large numbers of fish, spread over a wide area, usually, vastly exceed possible coverage. Therefore, methods of survey sampling must be used. Complete counting over sample areas is basic to area sampling, discussed below, and complete coverage of small defined subareas (strata) may be appropriate. Each kill is unique and requires some adaptation of general methods. Biologists who may be forced to deviate from the methods described here should follow the principles of area sampling as closely as possible. Deviations from these methods and reasons for making them should be described in the field notes and in the fish kill investigation report.

Area sampling

Area sampling is appropriate for use with fish kills. In the choice of sampling areas, certain simple principles of area sampling must be followed.

(1) Sample units are areas. In a fish kill, dead fish are scattered over an extended area of stream, lake shore, or open water. The numbers of dead fish are estimated from sample units of area, selected at random. All dead fish on these units are counted, and the counts are expanded over the entire affected area to estimate the total number of fish in the kill. That is, a random sample is taken of areas, not of fish.

(2) Sample units must be chosen at random. To avoid the introduction of personal bias, either

intentional or unintentional, the sample units must be chosen by a completely objective method - one that, in principle, allows every possible unit a known chance of being selected for counting. If sample units cannot be selected at random, then every effort must be made to maintain objectivity in sampling. The presence of inaccessible areas does not prohibit use of random sampling in accessible areas.

(3) Precision depends on sample size and number of fish counted. The larger the sample size (number of sample areas surveyed) and the larger the number of dead fish counted, the more reliable will be the estimate of the total number of fish.

To use area sampling, the investigator must divide the area under study into unit areas that (1) do not overlap (2) together completely cover the entire area, and (3) are of practical field size -that is, small enough that all fish on several units can be counted.

Two types of sample units, transects and linear segments, meet the requirements for most counts of dead fish; uses of these are described below.

Transects

Transects, as used here, are parallel strips of known width that do not overlap and together completely cover some wide area, such as the open water of a lake or river or a piece of marsh. Typically transects vary in length (and therefore in area). The following directions are for selecting sample transects as a systematic sample with a random start.

To lay out parallel transects completely covering the area of the fish kill, first establish a convenient baseline, which must be perpendicular to the direction of the transects. The length of the baseline must be known. The baseline must be long enough that the two terminal transects (one perpendicular to each end of the baseline) will just enclose the area of the kill. The direction of the baseline should be parallel to the long axis of a lake and to the direction of flow in a large stream. This practice minimizes the variability among transect lengths.

Choose a transect width so that all dead fish floating within it can easily be counted or collected from a boat. Count dead fish only within this width, and use the same width consistently throughout an investigation. Next, decide how many sample transects will be selected for fish counts. The more sample transects used, the more precise the result will be. The exact number required will depend upon the variability of the observations; **run at least three.** Transects must extend completely across the area being studied. If there is to be a separate count of dead fish along the shoreline, transects must extend from the outer edge of one shoreline zone to the outer edge of the other to avoid double counting. If there is no shoreline stratum, transects extend from water edge to water edge. Record the numbers of dead fish separately for each sample transect.

The total number of dead fish in the kill area is estimated either by multiplying the average numbers of dead fish per sample transect by the total number of transects in the area, or by the arithmetically identical procedure of multiplying the total number of fish on all sample transects by an expansion factor. This expansion factor is calculated either as the ratio of the total number of transects to the total number of sample transects, or as the ratio of the length of the baseline to the combined total width of the sample transects.

If the biologist knows the area of the body of water, the width and total length of all sample transects, and the total number of fish on all sample transects, the total number of dead fish floating in the open-water stratum is estimated as the product of the area and the density of dead fish. Density (fish per unit area) is the total number of fish from all sample transects divided by the total area of all sample transects (transect width multiplied by the total length of all sample transects).

Segments

Segments, as used here, are areas arranged in a linear manner. Widths of these areas may be constant, as with successive segments in a shoreline zone along a lake, or variable, as with short stretches of a narrow stream of varying width. Under ordinary conditions, sample segments will be of uniform length, although segments of varied length may be more efficient under certain conditions. The segments must completely cover the area of study (e.g., total stream or shoreline being surveyed) without overlapping, and their total number must be known.

To establish segments that are uniform in length, first decide what the segment length will be. The objective is to have segments that are long enough to contain a useful number of fish yet not so long that it will be impractical to count all the fish on several sample segments. Aim for **50-200 fish per segment** in the more dense areas of the kill. Next, measure on a good map the total length of the shoreline or stream to be surveyed. Next, decide the number of sample segments on which fish will be counted and measured. **Include at least three sample segments**, but use more if possible. Keep separate records of the number and size of dead fish on each sample segment. If segments are of equal length, the total number of dead fish in the area of the kill is estimated either as the average number of fish per sample segment multiplied by the total number of segments in the area of the kill, or by multiplying the total number of fish on all sample segments by an expansion factor. The expansion factor can be calculated either as the total number of segments divided by the total number of sample segments, or as the total length of all segments in the area of the kill divided by the total length of all the sample segments. If segments are of unequal length, estimate the total number of fish killed either as the average number of fish per sample segment multiplied by the total number of segments, or as the total number of fish on all sample segments multiplied by an expansion factor.

Narrow Streams

A narrow stream, as the term is used here, is one along which an investigator can traverse each sample section by boat or by wading and walking the banks, and can count or collect every visible dead fish along both banks and out in the stream. A stream too wide for this should be sampled by methods outlined in this chapter for lakes and wide streams. Narrow streams may be either completely accessible or only partly accessible, and guidelines for sampling differ for the two classes.

Narrow Streams, Completely Accessible

When streams are completely accessible for the entire stretch affected by a kill, it is practical to count any designated segment. First, determine the extent of the kill and record the total length of affected stream. Next, determine the number and location of the sample segments where dead fish will be counted. When the sample segments have been located, identify and count all fish in each. Corrections will be needed if fish are drifting downstream. Keep separate field records for each sample segment because these data are needed to approximate the standard error. Expand the number of fish counted in each segment to the whole length of affected stream. Either multiply the average count per sample segment by the total number of segments or multiply the total number counted in the sample segments by an expansion factor.

Narrow Streams, Incompletely Accessible

When faced with a narrow stream that is partly inaccessible, the biologist must adapt the directions given previously for sampling narrow streams. For the inaccessible parts of the stream, the biologist may find it appropriate to speculate on numbers of dead fish, using professional judgment and experience in the accessible areas. Such speculation can be useful, and sometimes it is required because it is the best available information. The biologist must, however, make a clear distinction between the two kinds of information.

Example for Narrow Streams: When streams are completely accessible for the entire stretch affected by a kill, it is practical to count any designated segment. First, determine the extent of the I and record the total length of affected stream. Next, determine the number and location of the sample segments where dead fish will be counted.

> Say that a kill of bluegills extended over 2 miles of a completely accessible stream; 100yard segments were established every half mile as recommended; and the first sample segment to be counted was randomly selected in the first half mile and three other sample segments were selected at successive half-mile intervals. The following numbers of bluegills were counted:
>
> Segment
>
> <u>1 2 3 4 Sum</u>

420 280 165 45 910

Expansion factor

= (1760yards/mile) (2.0 miles) = 8.80

(4 segments X 100 yards per segment)

Estimate the total number of dead bluegills by either of the following methods.

a. *Mean number of fish counted per segment*:

mean number = (910 fish)/(4 segments) = 227.5 fish/segment.

In 2 miles, there are 35.2 segments each 100 yards long, so,

(227 Fish/segment) x (35.2 segments) = 8,008 fish. rounded, 8,000 fish.

b. *Expansion factor*:

910 total fish counted x 8.80 = 8,008 fish; rounded, 8,000 fish.

Lakes and Wide Streams

After a kill in a lake, most of the visible dead fish are found along the shoreline, and the rest float in open water. Here, it is more efficient and practical to use two zones each with a different sampling method and to sample the shoreline zone with segments and the open-water zone with transects. The total numbers of dead fish are estimated for each zone separately and then the totals are added.

This method is also appropriate for streams so wide that it is impractical to set up segments and collect fish on both banks and in the open water, as directed for narrow streams. If the shoreline is inaccessible or ill-defined (e.g., as with a marsh) or dead fish are not concentrated along the shore, transects may be used for the whole task, without a shoreline zone.

Sampling principles are the same for segments and transects: dead fish are recorded on sample units and counts of the various categories are expanded to estimate total numbers in each zone. Then the totals for each zone are added to estimate the total number of visible dead fish in the kill. When parts of the area of the kill are inaccessible, scientific sampling can be used only in the accessible parts, and the inaccessible area must be set aside as an immeasurable. Using professional judgment and experience in the accessible areas, the biologist may be able to speculate on the status of the inaccessible areas.

Shoreline Counts

In lakes, it is usual for most of the visible dead fish (often more than 75%) to accumulate along the shore, where they can be surveyed independently. Set up segments of uniform width in a shoreline zone and select a systematic sample of segments with a random start. For a 1-day investigation, extend the shoreline zone into open water far enough to include as many as practical of the dead fish that are visible and easily counted from shore. Once chosen, this width must be used consistently throughout the investigation because it determines where transects must begin and end. If the study lasts more than 1 day, the shoreline zone can be further divided into two subareas: one for fish stranded on the shore, and the other for fish floating along the shore. The shoreline zone is surveyed with segments in much the same way as surveys of narrow, completely accessible streams. Estimate the total number of dead fish by methods described for segments. Either multiply the average number of fish per sample segment by the total number of segments, or multiply the total number of fish counted on all sample segments by the expansion factor: total number of segments divided by the number of sample segments.

Open-Water Counts

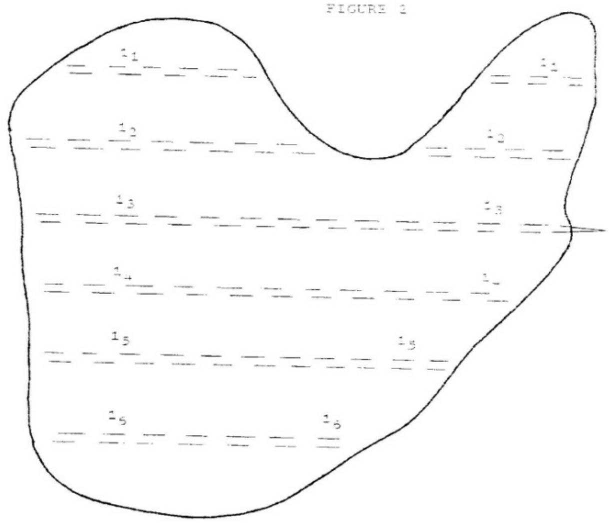
The total number of dead fish in the open-water zone (or stratum) is estimated by area sampling. The sample unit is a transect. Lay out a baseline and select a systematic sample of transects perpendicular to it. Count the dead fish on each transect and keep a separate record for each transect so that a standard error can be approximated if desired.

If a lake is irregularly shaped, transects can be interrupted by land. In this case, count and measure fish along both arms of a transect, as though the transect were continuous, and add the resulting counts.

Example for Lakes: In these lakes (see figure) where transacts would not average a fairly constant length (1), area should be the basis of computation. With this approach, the length (1) of the transects needs to be determined from a map as well as the acreage of the kill area. The following computations will yield the open water estimate on a total,
and per acre basis:

1. Acreage sampled
$$= \frac{W\,(1_1 + 1_2 + 1_3 + l\ (\text{no. of transects}))}{43{,}560}$$
2. Acreage considered = Feet of shoreline X width of shoreline sample strip in shoreline sampling / 43,560
3. Open water acreage = Total acreage - acreage considered in shoreline sampling (2)

FIGURE 2



4. Fish dead/acre open water = Total fish counted / acreage sampled (1)

5. Total fish dead = fish dead/acre open water(4) X open water acreage(3) in open water

Fish were counted in transects at about 300-foot intervals in a 13.1 acre lake. 300 fish were counted in total.

w = 20 feet
Number of transacts = 6
1_1 400 ft.
1_2 800,ft.
1_3 1000 ft.
1_4 900 ft.
1_5 850 ft.
1_6 600 ft.

1. Acreage sampled
   = 20 (400+800+1000+900+850+600) 43,560
   = 2.089 acres

2. Acreage considered in shoreline
   = 7000 ft. x 10 ft. = 1.6
   43,560

3. Open water acreage
   = 13.1 - 1.6 = 11.5 acres

4. Fish dead/acre open water
   = 300 = 144 fish
   2.089

5. Total fish dead in open water
   = 144 x 11.5 = 1,656 fish

Figures obtained from open water estimate are added to those from the shoreline estimate for a total number of fish killed in the lake.

Example for Wide Streams (see figure): Under these conditions, the transect length need not be determined. The total length of the kill (T) need not be determined until after the counting procedure. Simply count transacts at estimated constant intervals (e.g. w+ y = 300 ft.), keeping track of the number of transects you counted. The number of transects made should afterwards be divided into total kill length (T/no. of transacts made) for a check of your actual, average interval (w

+ y). Then, proceed to calculate total estimated fish in open water.

w + y(actual) X Total fish = Total fish in open water counted

Width of transect (w) = 20 feet

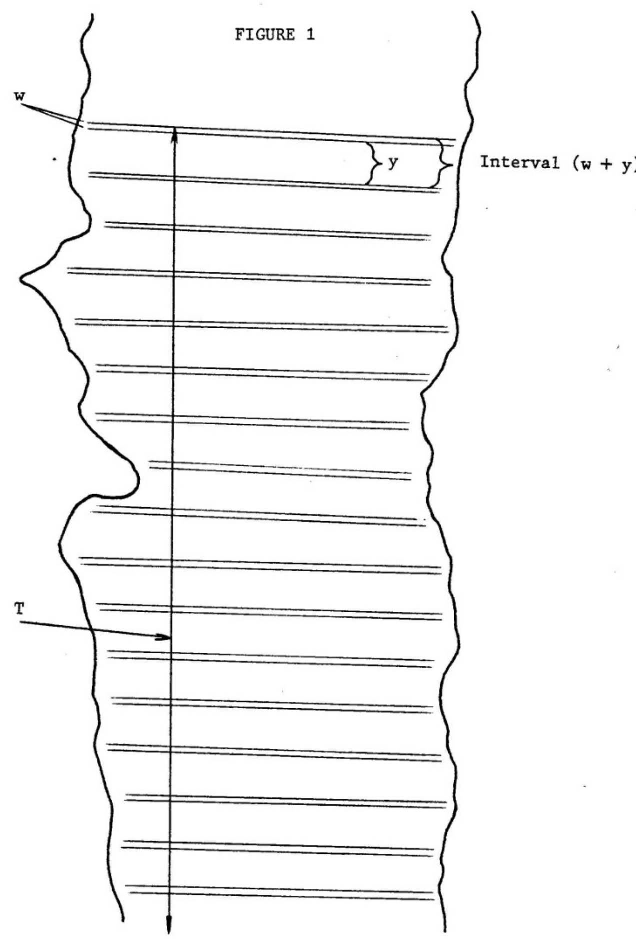
Estimated sampling interval (w + y) = 300 feet

Estimating 300-foot intervals, you count a total of 540 fish in 19 transects.

Checking later, you find from notes and a map that the kill area is one mile long. A 300-foot interval would only call for 17.6 transacts in a mile, so you must determine your actual interval for purposes of making calculations:

Actual (adjusted) interval (w + y)
= 5 ,280 /19 = 278 feet

Total fish in open water
= 278 / 20 X 540 = 7,506



Large Meandering Streams

Meandering, wide streams may pose difficult sampling problems that do not seem to match exactly those addressed by previously described methods. Nevertheless, if successive, non-overlapping segments can be set up (at least on a map) and sampled, it may be possible to adapt the methods for narrow streams that are completely or incompletely accessible. The boundary lines between adjacent segments should be perpendicular to the current. Designate segments, select a systematic sample with a random start, survey dead fish on the sample segments, and proceed with calculations appropriate for segments.

Multiple-Day Counts

Although this presentation has concentrated on single-day counts to this point, some investigators may find it necessary to make counts on more than one day. Counts restricted to a single day seriously underestimate the total number of dead fish. It is recommended that when multiple-day counts are made, each day's estimate should be based on a separate survey, carried out with approved methods so that each day's result can stand by itself. The investigator then may offer a professional opinion, based on experience and knowledge but unsupported by statistical procedure, about the probable grand total for the surveys. Otherwise, there is no obvious simple method of estimating the total number of individual fish killed. Multiple-day counts may be required in two situations: (1) when dead fish continue to float up from the bottom for several days at the same location, as in a lake, and (2) when a toxic plume of water moves down a stream killing the fish as it proceeds.

A plume of water can be so toxic that it kills fish for days as it progresses downstream. Dying fish may move downstream before they become entangled, sink, or strand on the bank. Little is known about the dynamics of this process. If the biologist waits for the kill to end, some dead fish in the upper stream will be removed by predators and scavengers, and others will decompose or drift downstream. The survey of dead fish should start as soon as possible after fish begin to die, and it should follow the kill downstream over successive, non-overlapping zones that together cover the area of the kill. Within any zone counts should be made at sample segments that are selected at random. Zone estimates may be made as single-day counts, or with suitable procedures, as multiple-day counts at the same location. To what degree estimates may be summed across days and across zones depends on the measurement and on the judgment of the biologist. It seems reasonable to sum counts of stranded fish if it can be assumed that they do not move, but not reasonable to sum directly the counts of floating fish across days. Sums across zones may have meaning in interpreting a multiple-day count, the professional judgment of the biologist at the site is important.

Drifting Fish in a Stream

Fish drifting downstream can cause potentially confusing problems. This movement is a flow of fish from one spot to another. The sampling surveys produce counts of the fish visible at the moment-that is, instantaneous counts. Drifting fish can be included only if they are counted the same way: instantaneously. Any drifting fish should be counted at the moment the observer passes the fish. In general, counts of drifting fish require correction because the water movement alters the effective area of the sample unit, not because the fish are moving.

When moving upstream:
Count all fish on the stream bank and, separately, count all floating fish, whether drifting downstream or not. Record the time it takes to finish the segment. Then, for an equivalent time, count all fish drifting past a stationary point at the upstream end of the segment. Correct the number of floating fish counted in the segment by subtracting the number of fish that drifted past the stationary point. If this correction results in a zero or a negative number, use the uncorrected count of floating fish in the sample segment. The corrected segment count is the number on the bank plus the corrected number floating.

When moving downstream:
Count the fish on the bank and also keep two counts of floating fish: (1) those that you pass, and (2) those that drift past you. Pay no attention to whether a particular fish has been seen before: count

each fish passage. Also record the time required to transit the segment. Then, count all fish drifting past a stationary point at the bottom of the segment for a period of time equal to the transit time. The corrected estimate of floating fish is the number of fish drifting past the fixed point, plus the number that you passed, minus the number that passed you during the stream transit. If the corrected number is zero or negative, use only the number of fish passing the fixed point. The corrected segment count is the number on the bank plus the corrected number floating.