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MONTANA DEPARTMENT OF FISH, WILDLIFE & PARKS

Fisheries Division

# A Computer System to Compile Fish Population Statistics

By

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# DESCRIPTION OF SYSTEM

The computer system consists of five programs to do the calculations (excluding production rates) described in Richard Vincent's papers, "River Electrofishing and Fish Population Estimates" (Prog. Fish Cult., Vol. 33, No. 3, July 1971: 163-169) and Addendum (Prog. Fish Cult., Vol. 36, No. 3, July 1974: 182).

## Capabilities

The capabilities of this system are:

1. Estimates fish population number and biomass point estimates along with eighty (80) percent confidence intervals (i.e., point estimates $\pm$ 1.282 standard deviations) for individual length groups specified by the fisheries investigator. An optional printout of point estimates by the age analysis interval (standard = 1/2 inches) is available.
2. Gives total counts of those fish caught in the marking and recapture run as well as the number of marked fish recaptured.
3. Keeps track of record counts for each computer program in various categories so errors can be detected.
4. Produces condition factors and eighty (80) percent confidence intervals for those fish five (5) inches and longer within individual length groups.
5. Apportions number, length, and weight of the fish estimates among age classes when age data is provided. Average lengths and weights for each age class are also calculated.
6. Calculates mortality rates between this and a prior collection if the investigator provides the previous number estimates for the appropriate age classes.
7. Determines percent of composition of fish population estimates for number, length and weight of each age class within the given length groups.
8. Provides average weight of fish for each 1/10 inch class represented in the data.

The computer system can be used for data analysis even if no estimate is being made. Average lengths, weights and/or condition factors can be calculated for each length group provided. Sorted listings of data by fish length can be obtained to facilitate plotting histograms.

The edited data from the electrofishing and age sheets along with the information from the parameter cards are stored on tape. Thus an estimate that has been run in a previous year can be recomputed using the same parameters (since Jan. 1980). However, the computer system is not a data bank. No attempt is made to store all fisheries data collected. Only those collections that have been processed will be stored.

# PROCEDURES FOR USING SYSTEM

The following is the standard operating procedure for using the computer system.

1. Information from individual fish are entered on electrofishing sheets and, if age data is included, on age data sheets.
2. A collection code is obtained from: Eunice Nelson
   Cooly Lab, MSU
   Bozeman, MT 59717
   Phone: 994-2360

It is a unique six (6) digit code assigned to data provided from a single river section or lake during a specific time period. It is simple in concept. The first digit is the region; the next two, the year; and the last three, a serial collection code. The information needed when requesting a collection code is: stream name, section name, month of marking run, species either caught or planned on being taken.

3. The electrofishing sheets are coded at the top with the appropriate information. Stream and section name are needed only on the first sheet. The species code and collection code are needed on all sheets. The species code is our standard code number (see Fisheries Field Handbook), except an alphabetic prefix is added: W for wild, H for hatchery, and U for unknown or undesignated. This allows for separate estimates for hatchery fish when applicable.
4. Electrofishing sheets are sent in for key punching. If age data is available and scales have been read they can be sent at this time. It is preferred that the electrofishing sheets be sent for key punching as soon as the electrofishing has been completed. This means that age data and electrofishing data will be sent in separately. Be sure to send in the Fish Population Parameter Keypunch Form with cards one and two filled out for each species. (See Procedures for Filling Out Parameter Cards) These cards provide the headings for all listings. Note only one parameter card keypunch form has to be sent if both electrofishing and age data are sent together.
5. Electrofishing sheets, parameter card form and keyed data listings are returned to the investigator. It is the investigator's responsibility to check the listings against the raw data and to note on the listings in red any discrepancies. Only those pages with discrepancies need be sent in for correction.

Data on these listings are sorted as follows:

| Mark-recapture Data Listing | Age Data Listing |
|---|---|
| 1. Species | 1. Species |
| 2. Trip type (mark = 1 or recapture = 2) | 2. Length of fish in ascending order. |
| 3. Mark code (marked = 1 or unmarked = 0) | |
| 4. Length of fish in ascending order. | |

This systematic arrangement will enable you to readily cross-check with your field data. Mistakes will be avoided if you check your original field data against copies.

Be sure to check the following items:

1. Total count. You will note that on the listings for both mark-recapture and age data a total has been entered at the end of each species. This is a count for the number of entries and should be checked against the number of entries for this species on your data sheets. Also, you should count the number of recaptured fish on your field data sheets and check this total against the number of entries (mark code 1) on the data listings.

2. If weight estimates are to be made, each entry with a mark code "0" (unmarked or new fish) must have a weight. Otherwise zero weight will be used in computing the average. Weights of 0.00 are acceptable if appropriate. Generally, each entry for mark code "1" (marked or recaptured fish) will be blank (not 00000). However, a weight is allowed and may be keypunched and filed for future use, but will not be used with this particular system. If you have not been entering weights, you should check those fish with mark code "0" and no weight or those fish with mark code "1" and a weight to see if a mark code error has occurred.

3. The mark code for all fish on marking trips (trip type "1) must be "0". Checking this should also help insure that trip type is punched correctly.

4. Scan all weights and lengths to see none are obviously wrong. Generally most invalid lengths are at the head of the listing for each species.

5. On the age data listing, blank ages are permissible, but check to make sure they are intended to be left as blanks. Weights can be entered on age data but aren't mandatory. Every fish length in the age data listing should match a fish length in the mark-recapture listing. When one doesn't, this is called an "unmatched length" and is printed on a report. This length cannot have an average weight assigned from the length weight table. So it is not used in determining weight estimates by age. There are two solutions to the problem. The first is to make sure all age data "matches" all mark-recapture data. The other solution is to enter weights for all age data. If the age data "matches" it will use the average weight for that length of fish, ignoring the keyed weight. However, if it doesn't match then the program will use the keyed weight.

A paper entitled "Mark-Recapture Efficiencies by Inch Class" will be furnished with mark-recapture data listings. These efficiencies are simply (R/M)*100 and (R/C)*100 ("Procedure for Selecting Length Groups").

6. The age data and Fish Population Parameter Card keypunch form with cards one and two filled out (you can use the same one sent in with the electrofishing data) are sent in for keying. Be sure all collection and species codes are filled in. On age data sheets regenerated scales

do not have to be deleted. The computer program ignores those fish with no age assigned, but they are listed as output apart of a report for a double-check.

7. The age data, parameter card form and keyed data listings are returned to the investigator. It is the responsibility of the investigator to carefully check the keyed data listings against the raw data to see if all has been entered correctly. If discrepancies are encountered they should be made on the listing in red.

8. Fish population parameter cards three through eleven can now be filled out (see "Procedure for Selecting Length Groups" and "Procedures for Filling Out Fish Population Parameter Key Punch Form"). The completed form along with any discrepancies in either the electrofishing of age data are then sent to Dick Vincent at Region 3 headquarters in Bozeman. Dick will review the parameter card form to see if a valid estimate is being made. These forms will then be forwarded to Helena.

9. The parameter card form, electrofishing data, and age data will be edited for various parameters. The investigator may be called at this point to verify or correct any discrepancies. After the edit report has been satisfactorily corrected, the various computer programs are run and the estimates produced (see "Detailed Description of a Computer System to Compute Fish Population Statistics").

10. After the estimates, parameter card form, and any keyed listings that had errors are returned, it is the reponsibility of the investigator to check record counts, invalid and unusable records to see that all were correct and intended.

11. It is the responsibility of the investigator to keep computer listings and program printouts on file for at least five years. The feasibility of storing these on microfiche is being explored.

A short synopsis on the chronological events in making an estimate are as follows:

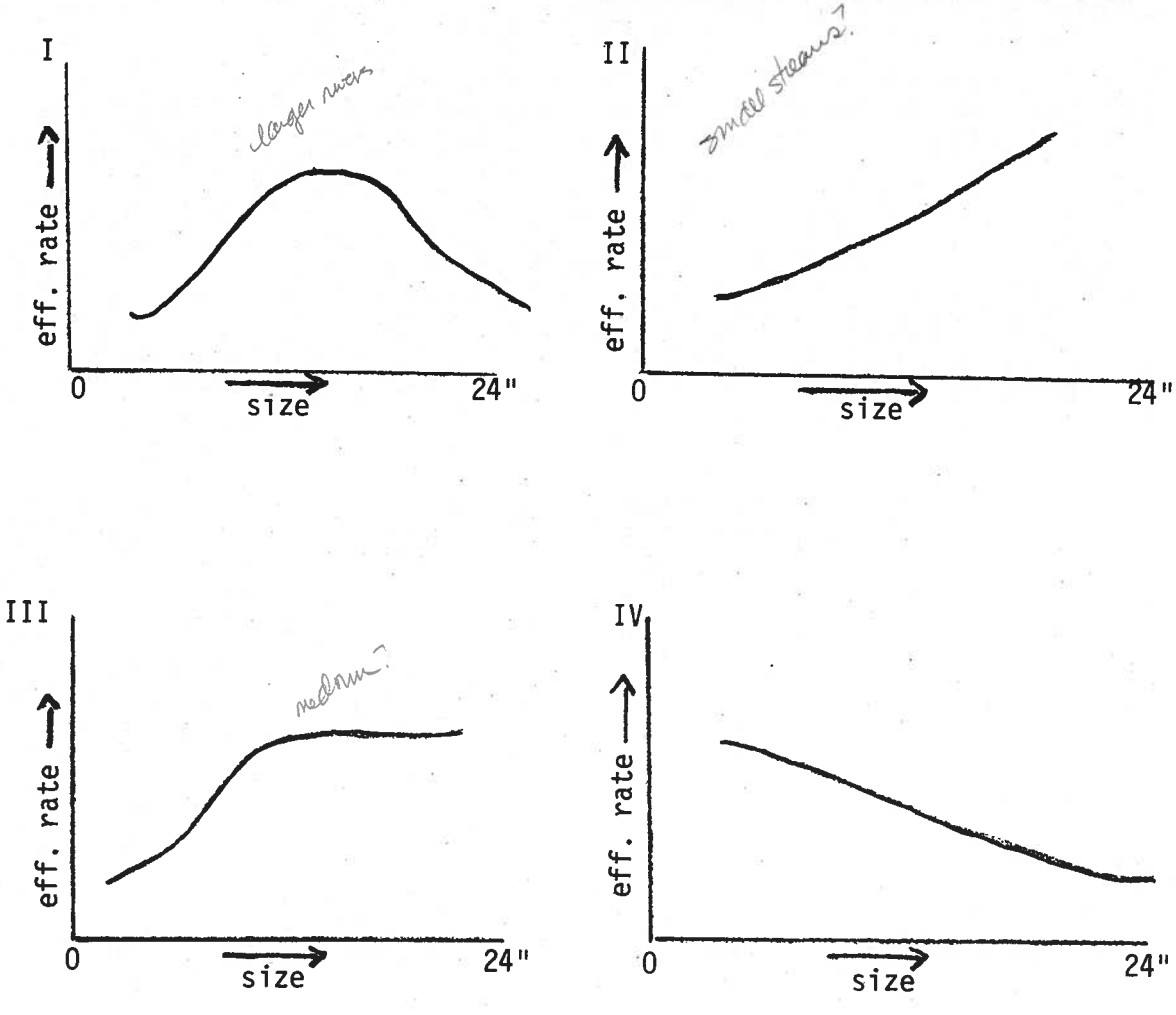
1. Send in electrofishing sheets along with parameter card form with cards one and two filled out.
2. Check computer listings and make corrections in red.
3. Send in age data along with parameter card form with cards one and two filled out.
4. Check computer listings and make corrections in red.
5. Fill out parameter cards five through eleven.
6. Send parameter card form and corrections to Dick Vincent. — send corrections to Borrell.
7. Edit report may have to be corrected or verified by phone.
8. Check estimate printout for correct counts and unusable or invalid records.
9. Keep records for five years.
10. send mark + recapture + age data at same time, only one parameter card necessary

## PROCEDURES FOR SELECTING LENGTH GROUPS

The actual mechanics of making a fish population estimate are done only after the mark-and-recapture plus the fish aging process have been completed. Both must be done in order to produce estimates of age structure and mortality.

First, the efficiency sheet on the mark-and-recapture printout is used to determine what the proper size groupings are for individual estimates. It is essential that the proper size group is chosen in order to produce the most accurate estimate of numbers, biomass, age structure and mortality rates. The main concern is to arrange 0.5 inch groups in such a manner to have at least four recaptures (preferrably seven) per size group, and to maintain equal efficiencies within each size group. Each stream, section and fish species has its own characteristic efficiency pattern which is usually associated with size and/or age, as shown by the following four examples.

Examples (1):



Since each stream or section will have its own unique efficiency curve, one should determine what general curve applies to the fish in that section. Once you know this, then fish can be grouped accordingly into appropriate size groups. The following example (2) of a rainbow trout mark-recapture efficiency sheet shows efficiencies by 0.5 inch groups.

Example: 2

Montana Department of Fish, Wildlife & Parks
RPT 1189.3 Mark-Recapture Efficiencies
December 29, 1980

Madison River - Pine Butte - 3.0 Miles
Collection 380040 Marked 09/30/80 Species 001W

| Size Class | M | C | R | Efficiency R/M |
|---|---|---|---|---|
| 4.5 - 4.9 | 3 | 2 | 0 | 0% |
| 5.0 - 5.4 | 16 | 14 | 1 | 6% |
| 5.5 - 5.9 | 37 | 25 | 1 | 3% |
| 6.0 - 6.4 | 43 | 46 | 2 | 5% |
| 6.5 - 6.9 | 59 | 50 | 3 | 5% |
| 7.0 - 7.4 | 57 | 45 | 4 | 7% |
| 7.5 - 7.9 | 49 | 46 | 2 | 4% |
| 8.0 - 8.4 | 33 | 22 | 4 | 12% |
| 8.5 - 8.9 | 25 | 20 | 3 | 12% |
| 9.0 - 9.4 | 24 | 18 | 3 | 13% |
| 9.5 - 9.9 | 33 | 25 | 2 | 6% |
| 10.0 - 10.4 | 33 | 30 | 3 | 9% |
| 10.5 - 10.9 | 42 | 26 | 4 | 10% |
| 11.0 - 11.4 | 29 | 27 | 0 | 0% |
| 11.5 - 11.9 | 46 | 34 | 2 | 6% |
| 12.0 - 12.4 | 39 | 39 | 5 | 13% |
| 12.5 - 12.9 | 44 | 31 | 2 | 5% |
| 13.0 - 13.4 | 45 | 33 | 3 | 7% |
| 13.5 - 13.9 | 39 | 34 | 2 | 4% |
| 14.0 - 14.4 | 23 | 17 | 0 | 0% |
| 14.5 - 14.9 | 21 | 18 | 4 | 19% |
| 15.0 - 15.4 | 8 | 5 | 1 | 13% |
| 15.5 - 15.9 | 7 | 2 | 0 | 0% |
| 16.0 - 16.4 | 2 | 2 | 0 | 0% |
| 16.5 - 16.9 | 1 | 2 | 0 | 0% |
| 17.0 - 17.4 | 1 | 0 | 0 | 0% |
| TOTAL | 759 | 613 | 52 | 7% |

more splits
separate more accurate estimate

Example (3) shows a correct way to combine the sizes so each grouping fits on an efficiency curve. In this example, the proper curve is probably similar to No. III.

Example 3

Rainbow Trout

| | Size Group | M | C | R | (Eff) | Pop$^n$ Est. |
|---|---|---|---|---|---|---|
| 1 | 4.8 - 6.9 | 158 | 137 | 7 | ( 5.1%) | 2743 |
| 2 | 7.0 - 7.9 | 106 | 91 | 6 | ( 6.6%) | 1406 |
| 3 | 8.0 - 9.4 | 82 | 60 | 10 | (16.7%) | 460 |
| 4 | 9.5 - 11.4 | 137 | 108 | 9 | ( 8.3%) | 1504 |
| 5 | 11.5 - 13.4 | 174 | 137 | 12 | ( 8.8%) | 1858 |
| 6 | 13.5 - 17.4 | 102 | 80 | 8 | (10.0%) | 927 |
| | | 759 | 613 | 52 | 7% | 8898 |

Once the size groups have been selected, then individual population estimates can be made for each size group as shown in Example 3. After this has been done, then the next step is to estimate the number of fish for each age group. This is done as follows.

How computer arrives at .5" length group - proportion of new fish due to similar efficiencies

| | Size Group | No. of New Fish | Percent of Total for Group | No. Estimate For Size Group | Percent Each Age | No. For Each Age |
|---|---|---|---|---|---|---|
| 1 | 4.8 - 6.9 | -- | | 2743 | I - 100% | I - 2743 |
| 2 | 7.0 - 7.9 | -- | -- | 1406 | I - 100% | I - 1406 |
| 3 | 8.0 - 8.4 | 51 | 38.6 | 136 | I - 87.5 | I - 119 |
| | | | | | II - 12.5 | II - 17 |
| | 8.5 - 8.9 | 42 | 31.8 | 146 | I - 58.3 | I - 85 |
| | | | | | II - 41.7 | II - 61 |
| | 9.0 - 9.4 | 39 | 29.6 | 178 | I - 40 | I - 71 |
| | | | | | II - 60 | II - 107 |
| | | 132 | | | | |
| 4 | 9.5 - 9.9 | 56 | 23.7 | 356 | II - 100% | II - 356 |
| | 10.0 - 10.4 | 60 | 25.4 | 382 | II - 85.7 | II - 327 |
| | | | | | III - 14.3 | III - 55 |
| | 10.5 - 10.9 | 64 | 27.1 | 410 | II - 56.3 | II - 210 |
| | | | | | III - 43.7 | III - 200 |
| | 11.0 - 11.4 | 56 | 23.8 | 356 | II - 50.0 | II - 178 |
| | | | | | III - 42.9 | III - 153 |
| | | | | | IV - 7.1 | IV - 25 |
| | | 236 | | | | |
| 5 | 11.5 - 11.9 | 78 | 26.0 | 484 | II - 17.6 | II - 85 |
| | | | | | III - 58.8 | III - 285 |
| | | | | | IV - 23.6 | IV - 114 |
| | 12.0 - 12.4 | 73 | 24.4 | 453 | III - 73.3 | III - 332 |
| | | | | | IV - 26.7 | IV - 121 |
| | 12.5 - 12.9 | 73 | 24.4 | 453 | III - 86.7 | III - 393 |
| | | | | | IV - 13.3 | IV - 60 |
| | 13.0 - 13.4 | 75 | 25.2 | 468 | III - 81.9 | III - 383 |
| | | | | | IV - 19.1 | IV - 85 |
| | | 299 | | | | |

(continued on next page)

| | Size Group | No. of New Fish | Percent of Total for Group | No. Estimate For Size Group | Percent Each Age | No. For Each Age |
|---|---|---|---|---|---|---|
| 6 | 13.5 - 13.9 | 70 | 40.2 | 373 | III - 21.4 | III - 80 |
| | | | | | IV - 71.4 | IV - 266 |
| | | | | | V - 7.2 | V - 27 |
| | 14.0 - 14.4 | 40 | 23.0 | 213 | III - 12.5 | III - 27 |
| | | | | | IV - 75.0 | IV - 159 |
| | | | | | V - 12.5 | V - 27 |
| | 14.5 - 14.9 | 35 | 20.1 | 186 | IV - 60 | IV - 112 |
| | | | | | V - 40 | V - 74 |
| | 15.0 - 15.4 | 12 | 6.9 | 64 | IV - 40 | IV - 26 |
| | | | | | V - 60 | V - 38 |
| | 15.5 - 15.9 | 9 | 5.2 | 48 | IV - 16.7 | IV - 8 |
| | | | | | V - 83.3 | V - 40 |
| | 16.0 - 17.4 | 8 | 4.6 | 43 | V+ - 100 | V+ - 43 |
| | | 174 | | | | |

| AGE | STRUCTURE Fall Est. | Previous Est. Spring | Summer Mortality |
|---|---|---|---|
| I | 4424 | -- | -- |
| II | 1341 | 2364 | 43% |
| III | 1898 | 3308 | 43% |
| IV | 976 | 1869 | 48% |
| V | 249 | 749 | 67% |

The importance of proper size group arrangement cannot be over-emphasized, for example, using the same data only making just one size group (M=759 x C=613 ÷ R=52), the estimation of age group numbers and biomass varies significantly. The numbers and biomass of yearling and two-year-olds decreased 16-17% while the older four and five-year-olds increased 17-25%. The overall estimation was only 1% lower in numbers, but 6% higher in biomass. These differences are even greater in estimates where greater differences in efficiencies exist.

Occasionally, fish population estimates are ruined by estimates being made during fish spawning movements. Generally, this inflates the estimate for those ages involved in the spawning activity. The following example from two spring estimates made on the Gallatin River for rainbow trout illustrates this situation. The first estimate was made prior to spawning and the second during active spawning.

Example: Gallatin River - Rainbow Trout

Prior to Spawning

First Population Estimate

| Size | Est. | Eff. |
|---|---|---|
| 5.0 - 8.4" | 4410 | 3.8% |
| 8.5 - 10.4" | 2171 | 7.8% |
| 10.5 - 11.9" | 1240 | 8.3% |
| 12.0 - 19.9" | 1003 | 9.1% |

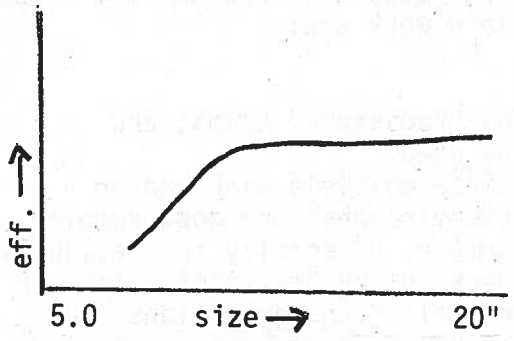
10 to 14 day difference

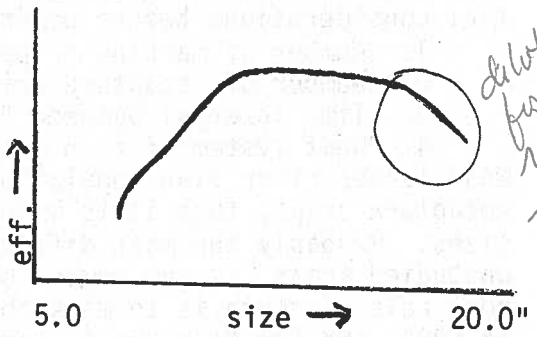
During Spawning

Second Population Estimate

| Pop$^n$ Est. | Eff. | Difference |
|---|---|---|
| 4512 | 6.0% | + 2.3% |
| 2142 | 14.0% | - 1.3% |
| 1283 | 15.1% | + 3.4% |
| 1412 | 12.2% | +29.0% |

does indicate which age groups are spawning




deletion of fish as a result of movement

As you can see, the population estimates for trout under 11.9 inches were similar only varying 1.3-3.4%, while the estimate of rainbow over 12.0 inches was 29% higher. The efficiency chart below the estimate also showed a drop for the 12.0 inch and larger rainbow during the spawning period. This reflects both and movement into the study section of unmarked trout as well as movement out of the section of marked trout. Estimates made during spawning periods almost always result in an inflation of the population estimate.

## PROCEDURES FOR GATHERING FIELD DATA

In order to insure quality fish population estimates, collection of field data such as the raw mark-recapture information and fish scale samples should be done with accepted techniques.

First, all mark-recapture data should be recorded in a legible manner on special mark-recapture forms made especially for ease in keypunching. This will insure more accurate transposing of raw data to computer sheets. A special "rite in the rain" paper is used and contains proper spaces for stream name, section, species code, date, collection codes, code for trip type (marking - 1, recapture - 2) and a code for unmarked (0) and marked (1) fish. The latter is used during the recapture trips.

Second, fish scale sample data should be taken with care so lengths recorded on the scale envelopes should match lengths in the mark-recapture data. Fish scale samples should be taken from only new fish with approximately 20 samples per inch group. Scale samples should be taken randomly within the same size interval as the age analysis interval. For example, if the age analysis interval is 0.5 inch, then at least 10 samples should be taken randomly with each 0.5 inch group for each fish species sampled. A good way to insure an adequate sample for each 0.5 inch group is to set up a tally sheet initially and check off groups as they become filled during the electrofishing operation.

Third, the most vital data is the actual mark-recapture information. Essential considerations before beginning the field work are:

1. Number of marking trips;
2. Number of recapture trips;
3. Time interval between "marking" and "recapture" trips; and
4. What system of fish marks are to be used.

Most larger river fish population work requires multiple mark and/or recapture trips, thus it is important to determine what are good sample sizes. Probably the most difficult to determine, especially in previously unstudied areas, is the number of fish to mark in the "marking" trips. A good rule of thumb is to mark about 20% for small fish populations (up to 500); 15% for fish populations from 500-5,000; and 10% for populations greater than 5,000. Since in many cases the population size is unknown initially on large rivers, approximately three "marking" trips should be planned. If the marked sample size appears to be on the low side, it can be later compensated for in more recapture trips.

The determination of the correct amount of recapture trips can be more accurately measured using numbers of marked recaptures. To do this predetermined size groups similar to those chosen in Section IV are set up before the recapture period begins. Recapture trips can then cease when the last size group receives at least seven (7) recaptures or in some cases four (4) -- see Section IV. This will insure a good population estimate and you won't find yourself six months later saying, "I sure need more recaptures for a good estimate."

tally recaptures on each run - usually prob in smallest and largest groups.

emphasis should be placed on achieving sufficient recaptures in length groups of particular importance; i.e., 16+ important groups if have special regs trying to increase this size group.

The time interval between the "marking" and "recapture" trips depends on the size of the stream, species of fish and the size of the fish. When all of the fish are randomly remixed within the unmarked fish in the population, the recapture period can begin. One way in the field to determine this is during the first recapture trip. The investigator notices "clumping" of marked fish. Then more time must elapse before recapturing can begin. This "clumping" (more marked fish at certain release point than one would expect) generally occurs with smaller fish, which take longer to redistribute than larger fish. They tend to stay near points of release longer and estimates made during this condition tend to underestimate these sizes. With trout it is most common with 0 or one year old trout or those under 10 inches and generally during colder water periods. A good rule of thumb is to wait 10-14 days after marking before recapture begins. If the period is too long (more than one month), fish may grow, destroying marks and altering size groups.

Generally, in marking fish, a temporary fin clip or fish tag is used. During the multiple marking runs, the fin clip can involve the same fin. But, during recapture trips, different marks should be used. Population estimates can be made either by:

1. The sampling with replacement method, or
2. The sampling without replacement method.

Using the replacement method, any fish sampled and marked during the first recapture trip can be recounted in the second or third trips. The same is true for those sampled and marked during the second recapture trip. This is probably the best method as you retain the highest possible sample size. Using the sampling without replacement method, all fish sampled and marked in any recapture run cannot be used again in the estimate.

Field mark-recapture data should not be submitted for key punching unless:

1. Data is legible;
2. All codes have been properly filled out;
3. One species per data sheet; and
4. All mark and recapture trips have been completed.

In submitting age data, there should be ages for every 0.5 or 1.0 inch groups included in the final population estimate. It may be necessary on the age data to use the "90" system. This designation is given those fish in which you cannot tell how old a fish is because:

1. The edge of the scale is too eroded, or
2. The outer portion is unreadable.

For example, because of this difficulty you decide a fish is at least IV years old but you are certain it is older, therefore you assign it a 94. The problem with assigning ages in this manner is that you can no longer estimate the number of fish in any age group older. In this case it is age IV. Thus a 94 age fish would allow an estimate of the numbers I, II, III and IV and older, but would not allow a V year old estimate. If a 92 is used, then only one-year-old and two-year-old and older fish

but fish are aged - cannot make age estimate for I year class - even if fish aren't worked but you know they are there you still cannot estimate I.

can be estimated with no estimates possible for individual age groups of III, IV and V.

Note: two major constraints in the mark-recapture system are:
1. No population estimates can be made where any size group has less than four (4) recaptures.
2. No age group estimates can be made for any group older than the youngest "90" age designation.

multiple recapture runs

| 3M | 1R | 2R | 3R |
|---|---|---|---|
| LCC | AC | LP | RP |

law of diminishing return w/ consecutive day recapture.

3-4 day intervals between recapture days.

mark days - should be consecutive

look up replacement method.
changes confidence intervals
helps larger ~~size~~ size fish w/ small sample size.

tally M C R every day of recapture keeping track of how you are doing.

movement by olfaction - placement downstream from territory will allow fish to easily move back to natural territory.

problems arise when place fish upstream from territory olfactory system cannot work properly.

upstream movement by olfaction

# PROCEDURES FOR FILLING OUT FISH POPULATION PARAMETER KEY PUNCH FORM

Parameter cards give instructions to the computer on how data is to be treated. Although this form appears complicated, it is easily filled out once one gets the knack of it. Use a separate form for each species. The following instructions refer to the attached example.

## Parameter Heading

Enter collection code and species (for explanation of codes, see Procedures for Using System). These are entered only once but are keyed at the beginning of each card. This enables the computer to select the proper parameter cards for the correct collection. Fill in the name and date. Note that the name given is where all reports and questions will be sent or directed.

## Parameter Card 01*

Enter stream or lake name, section name or number, and section length. Your entry will appear as the heading on the computer printout. Section length should be in terms as 4450 feet, 1 mile, 1805 meters or 2 kilometers.

Entire entry should be centered. Dashes, commas and roman numerals can be used. This card can also be used for comments if space allows.

## Example Card 01

SUPER CREEK - GOOD SECTION - 1100 FEET (ESTIMATE OF AGE ONES NOT MADE)

## Parameter Card 02

1. Species Name. Print the common name of the fish species for which this form pertains.
2. Last Marking Date. Enter as designated. Since the estimate is made on the last day of the marking run, this is the date that should be entered.
3. Metric Data. The letters 'METRIC' are entered in these spaces if metric measurements (millimeters and grams) were used on lengths and weights. If metric data is used, the mark-recapture and age listings will be in metric units. The efficiency sheet will be in English units. The parameter card must be filled out in English units. The future plans are for a metric report.

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*Parameter card numbers are given in columns 89 and 90 on the form.

Parameter Card 03

1. Length Groups. Enter into columns one and two (1-2) the number of groups you will use (on the example in the Appendix this was 5). Up to 10 groups can be entered. Fill in the length groups that you will use. For detailed information on determining length groups, see the section entitled "Procedure for Selecting Length Groups." No break can occur between groups. In the example the first group was from 4.8 inches to 6.9 inches. The second group has to start at 7.0 inches and goes to 7.9 inches. Note that if one group ends at 7.9 inches, the next group has to start at 8.0 inches.

2. Constraints on Length Groups. There is no restriction on the minimum length in the group breakdown insofar as the program is concerned. In other words, the parameter cards can call for an absolute minimum of three inches even though the smallest fish is six inches. There is a restriction on the maximum length. The maximum length on the parameter card cannot exceed the .9 decimal of the inch group that encompasses the largest fish in the collection. That is, if the largest fish in the collection is 17.4 inches, the largest size on the parameter card cannot exceed 17.9 inches. As a matter of philosophy, the maximum size entered on the parameter card should be the maximum collected on all runs. The minimum should either be the minimum collected on all runs, or the minimum size in the youngest age class for which a valid estimate can be made. If the span of length groups do not cover the entire span of lengths in the collection, those fish outside the length groups will be listed on the estimate report as unusable lengths.

3. Age Analysis Group Printout. Coding a one (1) into this space will produce a report that gives the point estimates of number of fish by the length given in the age analysis interval (standard = 1/2 inch). This can be very useful in determining number of fish over or under a certain size. If your length groups were 6.5 - 7.9, 8.0 - 12.4, 12.5 - 15.9, 16.0 - 22.4, but you wanted to know the number of fish over and under 18 inches, you could use this printout to get the point estimate.

4. Age Analysis Interval. (Applicable if age class estimates or printout of estimates by age analysis interval are desired). The "0" in column 85 and "5" in column 86 indicate that the age analysis interval has been set at 1/2 inch (0.5 inch). Instead it could be set at .6, .7, 1.0, 2.0 or 3.0 inches or whatever suits the study. This interval is the unit of lengths of an analysis class. Analysis classes, in turn, are length classes employed when the length frequency of aged fish is reconstituted to approximate the natural length frequency of the fish population under study. For best accuracy in analyzing your data, the recommended age analysis interval is 1/2 inch (0.5 inch).

Parameter Card 04 (Use only if you want population estimates broken down by age classes).

1. Oldest Ages Shown. Enter the oldest age specifically listed in the age composition of length groups. In the example this was age 5.

2. Age Composition of Length Groups plus "And Older" Option. Here are designated the age classes that are associated with the individual length groups. All ages should be entered regardless if an estimate of that age is made. There is an arbitrary limit of three age classes per length group so you will have to adjust the limits of each length group accordingly.

In our example length group one and two contain age 1; group three contains ages 1, 2; and so forth through all length groups. The "and older" option is filled out with the Length Group number that you want those aged fish older to be calculated. In our example "6" was entered into column 13. This means that the oldest age class will be "5 and older". In making the computation the computer will, in fact, combine all fish aged 5, 6, 7, 95, etc. for the age data that are within the 13.4 - 17.4 inch length range. If column 73 were left blank (preferably to a zero), the oldest fish on the printout would be age 5 and fish older than 5 would be ignored. When you have fish aged in the 90 series (for explanation of 90 series see Procedure for Gathering Field Data), the lowest age of this series takes precedence. For example, if the fifth length group contains fish aged 3, 93, 4, 95 and 5, then age 3 is the oldest that can be designated.

3. Print Age Estimate. Enter a "1" for each age group estimate desired. Extreme care should be taken in making an estimate of ages 0, 1 and 2. When making an estimate of these age groups, the investigator should make sure his data covers the entire length span for that age. A common mistake is to set the first length too high to include all aged one fish and then to ask for an estimate of age ones. For example, suppose the ones in the population run from 4.8 to 6.9 inches. The investigator, to estimate ones, must make sure his first group does not start above 4.8 inches. If his first group was 5.9 to 7.4 inches, then he could not estimate ones. This same philosophy should be followed for age 0 and 2 fish.

Parameter Card 11

Previous Estimates by Age Class. These spaces on the Parameter Card Keypunch Form are used only if we want mortality rates based on an earlier population estimate. It is strongly suggested that, if you are going to use mortality data, you let the computer system make these calculations. This will ensure arithmetic procedure.

Special care should be taken to ensure the data is correct, particularly the year, since the computer will compare this "previous marking date" to the "current recapture date" which you entered earlier on the form. If the dates are in the same year, the program will determine mortalities by comparing age class 1 estimates from the current collection to age class 1 estimates from the previous collection; age class 2 to age class 2; 3 to 3, etc. On the other hand, if previous recapture date is from an earlier year, age classes from the earlier year will be compared to appropriate age classes of the current year.

Care also must be used if a mortality rate estimate is wanted for the maximum age class represented in the study. There are four situations in which it is valid to calculate such an estimate using this program. These are represented below in tabular form.

| SITUATION | PREVIOUS STUDY | | CURRENT STUDY | |
|---|---|---|---|---|
| | Year | Maximum Age Class | Year | Maximum Age Class |
| 1 | x | n | x | n |
| 2 | x | n & older | x | n & older |
| 3 | x-1 | n-1 | x | n |
| 4 | x-1 | n-1 & older | x | n & older |

If ages are represented by n, n + 1, n +2, etc., the number of fish n & older can be obtained by adding the number in each of these. Likewise, the number of fish n - 1, n, n + 1, etc., can be summed to obtain the number n - 1 and older.

EXAMPLE

| Spring 1981 | | | Fall 1981 | |
|---|---|---|---|---|
| Age | No. of fish | | Age | No. of fish |
| I | 830 | compare | I | 824 |
| II | 427 | compare | II | 420 |
| III | 132 | compare | III | 120 |
| IV | 55) | | IV & older | 52 |
| V & older | 8) 63 | compare | | |

Note: here n - age class 4

The words "RIGHT JUSTIFY" simply mean that the right-hand space is the units position. If this space is left blank the computer will consider it a zero. Thus referring to the sample, if 830 were incorrectly entered in spaces 15, 16 and 17, the computer would consider this 830,000.

A suggestion on rounding - round decimals from 0.1 to 0.4 down to the next lower whole number and round 0.5 to 0.9 up to the next higher whole number. For example, 8.5 should be rounded to 9.0.

Mortality Codes. Your entries in this section will determine which age classes from the current data are used in making mortality estimates.

# CHECKLIST FOR INVESTIGATOR USING MARK RECAPTURE SYSTEM

___ Obtain collection code(s).

___ All pertinent information coded onto electrofishing sheets.

___ Parameter cards one and two filled out for each collection and species.

___ Parameter card and electrofishing data sent to Helena for key punching.

___ Mark-recapture data computer listings checked for errors and corrections made in red.

___ Age data and parameter cards 1 and 2 sent to Helena for key punching.

___ Age data computer listings checked for errors and corrections made in red.

___ Parameter cards 3-11 filled out correctly:

- ___ No gaps between length groups.
- ___ Number of groups entered.
- ___ Age analysis Printout enter "1" if desired.
  - ___ Age analysis Interval entered.
- ___ Oldest age shown correctly entered.
  - ___ Age Analysis Interval entered.
- ___ Each length group has those ages shown.
- ___ "And Older" group designated if desired.
- ___ Age class estimates desired have a "1" entered.
- ___ Mortalities desired - fill out card 11.

___ Send parameter card form, mark-recapture corrections and age corrections to Dick Vincent.

___ Estimate reports reviewed for correct counts and valid length and age exclusions.

Collection Code: Region 3, Year 80, Collection Number 040
Species Code: Alpha —, Numeric 001

MONTANA DEPARTMENT OF FISH AND GAME
FISH POPULATION PARAMETER CARD KEYPUNCH FORM

JOB NUMBER 04-132 — FISHERIES DIVISION
PREPARED BY: Duke Vincent — DATE 9-29-81

Better other type of space i.e. age I estimate not valid

11/79

PUNCH ON PINK STRIPE CARDS

Stream Name - Section Name - Length (Centered) → BLANK
MADISON RIVER - PINE BUTTE - 3.0 MILES 01

USE FOR SPECIES IF REQUIRED ← Species Name
RAINBOW TROUT — BLANK — Blank — LAST MARKING DATE: MARKED 09/30/80 — BLANK — ENTER "METRIC" if metric measurements were used 02

NUMBER OF GROUPS — LENGTH GROUPS

| Group 1 Low | Group 1 Hi. | Group 2 Low | Group 2 Hi. | Group 3 Low | Group 3 Hi. | Group 4 Low | Group 4 Hi. | Group 5 Low | Group 5 Hi. | Group 6 Low | Group 6 Hi. | Group 7 Low | Group 7 Hi. | Group 8 Low | Group 8 Hi. | Group 9 Low | Group 9 Hi. | Group 10 Low | Group 10 Hi. | Blank | GROUP INTERVAL | Blank | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 06 | 04 | 8 | 06 | 9 | 07 | 0 | 07 | 9 | 08 | 0 | 09 | 4 | 09 | 5 | 11 | 4 | 11 | 5 | 13 | 4 | 13 | 8 | 17 | 4 | | | 1 | 05 | 03 |

Will be done automat

OLDEST AGE SHOWN — AGE COMPOSITION OF LENGTH GROUPS

| Group 1 1st Age | Group 1 2nd Age | Group 1 3rd Age | Group 2 1st Age | Group 2 2nd Age | Group 2 3rd Age | Group 3 1st Age | Group 3 2nd Age | Group 3 3rd Age | Group 4 1st Age | Group 4 2nd Age | Group 4 3rd Age | Group 5 1st Age | Group 5 2nd Age | Group 5 3rd Age | Group 6 1st Age | Group 6 2nd Age | Group 6 3rd Age | Group 7 1st Age | Group 7 2nd Age | Group 7 3rd Age | Group 8 1st Age | Group 8 2nd Age | Group 8 3rd Age | Group 9 1st Age | Group 9 2nd Age | Group 9 3rd Age | Group 10 1st Age | Group 10 2nd Age | Group 10 3rd Age | AND OLDER GROUP NO. | PRINT AGE ESTIMATE: Enter "1" for estimate. Leave blank for no estimate. | | | | | | | | | Blank | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 05 | 01 | | | 01 | | | 01 | 02 | | 02 | 03 | 04 | 02 | 03 | 04 | 03 | 04 | 05 | | | | | | | | | | | | 6 | 1 | 1 | 1 | 1 | 1 | | | | 09 |

PREVIOUS RECAPTURE DATE — Mo. Spec. Stat. — Dy. Spec. Stat. — Yr.

Previous Estimates by Age Class

Right Justify - Round to Whole Numbers - No Decimals

| 0 | I | II | III | IV | V | VI | VII | VIII | IX | MORTALITY CODES Enter "1" for estimates or blank for no estimates for each age class in current collection | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | 0 | H | H | H | H | H | | | | | 11 |

Code number of previous collection

- See over -

if you have 4 age classes in one length group - put that group # in "and older" column.
put 1st length group "and older" occurs + [illegible] "and older"

bias

$Y_i = \mu + \beta + \varepsilon_i$

$\varepsilon_i$ = element of random variation

sources of bias in mark + recapture method

1. marks become unrecognizable
2. variability in catchability between marked and unmarked fish
   - a. mortality
   - b. improper distribution
3. coding of data - transcription of data / inaccurate measurement.
4. keypunch error.
5. $\frac{(M+1)(C+1)}{R+1} - 1$
   - a. $MC > 4N$
     Bias < 2%
   - b. $R \geq 7$
     bias ≤ 5%

M = fixed
C = fixed
R = random