Standard Fish Sampling Guidelines for Washington State Ponds and Lakes

by

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June 2000

Acknowledgments

This report would not have been possible without the expertise and reviews of many individuals. For their advice and reviews, we thank the staff from the Washington Department of Fish and Wildlife (WDFW) including Steve Caromile, Chris Donelly, Mark Downen, Doug Fletcher, Joe Foster, Ross Fuller, Robert Gibbons, Chad Jackson, Steve Jackson, John Long, Stacey Kelsey, Jeff Korth, Curt Kraemer, William Meyer, Karl Mueller, Mark Petersen, Larry Phillips, Jim Scott, Jack Tipping, and John Weinheimer. For statistical advice we thank Peter Hahn and Annette Hoffman (WDFW). Dick O'Connor and Terry Johnson (WDFW) developed mapping programs to provide survey maps. Colleen Desselle (WDFW) provided valuable help on the formatting and publication of this document. Expertise outside the department was critical for designing protocols which matched procedures used successfully in other areas. We thank Rick Crump (Smith-Root Incorporated); William Davies (Auburn University - Emeritus); Wayne Hubert (Wyoming Cooperative Fish and Wildlife Research Unit); Jeff Johnson (Smith-Root Incorporated); Leondro E. Miranda (Mississippi Cooperative Fish and Wildlife Research Unit); James Reynolds (Alaska Cooperative Fish and Wildlife Research Unit- Emeritus); Dennis Schupp (Minnesota Department of Natural Resources); Kerry Smith (Smith-Root Incorporated); Alan Temple (U. S. Fish and Wildlife Service National Conservation Training Center, Shepherdstown, West Virginia); and David Willis (University of South Dakota) for their advice and reviews. Any mistakes we made interpreting their procedures are our own, and not theirs. We especially thank Bill Zook (WDFW) for his advice, funding, and support of this study. This study was funded by Washington State Warmwater Enhancement Funds and Federal Aid to Fish Restoration Project Number F115-R-3.

Abstract

Standardized sampling is necessary to compare growth, condition, and population sizes of various lacusterine fish species among years and among lakes. Use of standard techniques allows biologists to concentrate resources on improving fish populations instead of routine monitoring considerations. We present methods for standardizing Washington lake and pond sampling statewide. These methods are based on those used successfully in other areas and modified for the Pacific Northwest. Included in this report are guidelines for conducting gill netting, fyke netting and electrofishing surveys; standards for equipment; and techniques for selecting sample sizes to meet certain objectives.

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Introduction

Standardized sampling and data comparison methodologies are used in a wide variety of fields such as medicine, finance, education and agriculture. Standardized sampling methodologies are also extremely important in fisheries and are required to evaluate how a fish population changes over time, or is functioning compared to an "average" in a state or a region. This allows the biologist to identify problem fish populations, discover populations with exceptional angling opportunities, set regulations, or apply various management strategies and monitor their effects.

The following gives a short synopsis of standardized sampling procedures proposed to survey warmwater lake–fish populations in Washington state. These procedures are based on those used in other areas and have undergone both regional and national review, both by warmwater sampling experts and statisticians. This publication gives a step–by–step description, with examples, of how to conduct a standardized survey and calculate sample sizes. For clarity, we do not justify standard procedures in the text. Justification of specific reasons for certain standardized procedures appear as footnotes. This updates material found in Fletcher *et al.* (1993). Any questions or comments on this standardized procedure should be directed to Inland Fisheries Investigations, WDFW, Olympia.

These methods were developed to capture the largest number of fish of various species in a majority of these waters.   It can be tempting to change sampling on a lake–by–lake basis to try to capture an even larger number of fish. However, the best results will be obtained by those biologists who adhere closely to standardized procedures so their data will be comparable to state averages where fish were collected in the a similar manner. Application of these techniques whenever possible, even when just determining species composition, will improve your ability to evaluate lakes, and build a robust state database for comparison purposes.

Standardized Survey Procedures

Timing the Survey[1]

- Time of survey can greatly affect sampling data (Bettross and Willis 1988, Guy and Willis 1991).
- Fall surveys—should occur between the last week of August and the first week of October.
- Spring surveys—should occur between the last week of April and mid–June.
- Choosing between Spring or Fall—Large largemouth bass can most easily be captured in the spring while they are staging for spawning[2]. However, yearling largemouth bass are still offshore during this time, and can be more easily captured in the fall. The biologist should determine which life history stage is of most interest and time the sampling accordingly. Never compare Spring to Fall samples and vice versa.

Initiating the Survey

- Obtain standardized survey equipment—Survey equipment will consist of an electrofishing boat, standardized gill net(s) and standardized fyke net(s)[3]. Consult Table 1 for net and electrofishing standards.

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1 Numerous surveys have found that CPUE of most warmwater species peaks in the spring and fall (Pope and Willis 1996). Betross and Willis (1988) concluded that largemouth bass surveys should occur between 16-22°C. Divens et al. (1996) compiled Washington Department of Ecology data from 90 Washington lakes and found that most Washington lakes had temperatures within this range during September and June. However, some species such as yellow perch caught in gill nets may have peaks in mid–summer.

2 This is based on monthly electrofishing surveys we conducted year–round on three Western Washington lakes over a two–year period.

3 Several researchers have tested the efficiency of various gear types for capturing the five most common warmwater fish species in Washington lakes: largemouth bass; bluegill; pumpkinseed; black crappie; and yellow perch. Electrofishing is most efficient for *centrachids* while gill netting is more efficient for yellow perch (Lewis et al. 1962, Hamley 1975, Hall 1986, Coble 1992, Divens et al. 1998) and fyke nets are efficient for crappie spp. (Willis' warmwater workshop notes from Warmwater fisheries sampling, assessment, and management). A combination of gears gives the greatest ability to sample all species effectively.

Table 1. Standardized sampling equipment for Washington State lake fish surveys.	
Sampling Equipment	**Standard for Washington State**
Electrofishing Boat	Smith-Root GPP 5 boats with a six dropper spider array on each boom, and a cable “whisker” cathode array in front.
Gill Net	150' by 8' variable mesh monofilament with the following mesh size and panel length: 0.5" square - 25', 0.75" square - 25'', 1" square - 50', 2" square - 50'.
Fyke Net	4' high, 3/8" diameter aluminum or stainless steel circular hoops with two 25' wings and up to an 100' lead. Mesh size is 0.25" (see Figure 1).

- Get map of the lake—this can be obtained from the WDFW GIS lakes database by contacting

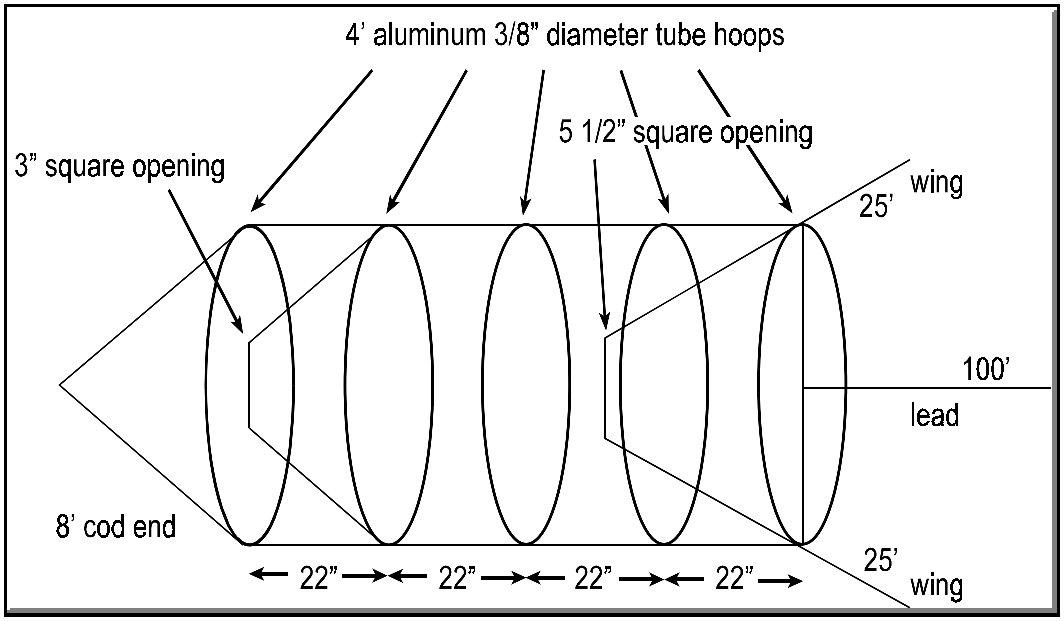

Figure 1. Standard fyke net measurements for Washington State warmwater fish surveys.

the warmwater database manager[4]; from several texts on Washington lakes including: Wolcott (1973); Dion et al. (1976); Sumioka and Dion (1985); or from the Washington Department of Ecology Lake Monitoring Program. Original full–sized maps of many lakes are also available from WDFW historical files (contact regional offices or the Inland Fisheries Division in Olympia). If no map is available, map the lake yourself using methods in a standard limnological methods text.

- Measure or obtain the shoreline perimeter—most easily available from maps of the lake printed out from the WDFW GIS lakes database, but can be obtained easily from a map of the lake with a scale.

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4 The Washington Department of Fish and Wildlife GIS lakes database contains of 40,000 lakes and ponds in Washington State. The database reports the perimeter and area of each lake or pond. Major lakes have the maximum depth.

- Randomly select a starting point on the lake.

- Decide if it is feasible to electrofish the entire shoreline during the time allotted for the survey.

  - **Entire shoreline *can* be sampled during the survey:** This is possible most often in small– and medium–sized lakes. Start from the randomly chosen starting point and move around the shore. Shock for 600 seconds, work up fish, shock again for 600 seconds, work up fish, and continue this procedure until the entire lake is covered. For the last section, cover the amount of distance to reach the starting point (e.g., 278 sec, 342 sec. etc.) and stop. Do not re–shock part of the first section again to get 600 seconds. For setting gill and fyke nets, randomly choose sites. On small lakes it is possible to have a substantial impact on the existing fish populations if enough gill net sets are placed to detect a certain percent change. The biologist should use judgement to decide when to stop setting gill nets if the population may be substantially impacted, with the understanding that change may not be detectable from the few gill net sets[5].

  - **Entire shoreline *cannot* be sampled during the survey:** This is likely in larger lakes. Use the following procedure:

    - Mark sampling points on map of lake—from that starting point, put a mark every 400 meters (1300 feet) along the shoreline perimeter on the map[6]. These will be the "sampling points" where you will *start* your electrofishing surveys and place nets. For a rough, but easy field estimate, take a piece of string, lay it on the map scale and mark it off at 400 m increments. Lay this string around the perimeter of the lake on the map and mark points on the map.

    - Choose to sample using simple random or stratified random sampling techniques[7].

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5 For small lakes or to measure small differences over time, it may be difficult to obtain enough CPUE samples to measure statistical differences. In these cases, the biologist may want to explore if a mark–recapture estimate of the actual population should be incorporated.

6 Four hundred meters was the maximum distance of electrofishing boats could travel and effectively sample during 600 second time limits on two Kitsap County lakes (S. A. Bonar, B. Bolding, and M. Divens, Unpublished Data).

7 Miranda et al. (1996) found that systematic sampling was useful in reservoirs showing a progressive change in littoral areas from the dam to the inflow(s). In these situations, simple random samples may be clustered near the inflow or the dam, and may not be representative of the whole reservoir. Simple random or stratified random sampling is more appropriate in waterbodies containing littoral areas with habitats that recur cyclically, such as in highly dendritic reservoirs with various similar arms. We chose simple or stratified random sampling because we felt that the former situation was not that common. However, in those instances where it does occur, the biologist should consider systematic sampling.

- **Simple Random:** Shoreline is not separated into different strata. Use this technique in the vast majority of lakes, such as those with homogenous shorelines or smaller lakes. (We have seen few lakes in western Washington that we would stratify; however, more in eastern Washington, especially in the Coulee areas). For number of sections (sampling points) to sample to obtain a catch per unit effort (CPUE) estimate with a specified degree of precision and confidence, refer to Appendix A[8].

- **Stratified Sampling:** Normally you should not stratify unless there are clearly major differences between CPUE in large sections of the lake. Some of the computational drawbacks will outweigh the advantages[9]. However, to reduce your variance and increase your ability to detect changes in CPUE, you can stratify the lake if it exhibits great differences in major habitat types. Larger lakes and those with wide variations in habitat such as cliffs, rocky rip–rap, and weedy coves are good candidates. If you decide to stratify, here are some guidelines:

[8] The first year of this program, we had no variances on Washington electrofishing and netting data. Therefore, we chose sample sizes (15 electrofishing samples, 8 net nights) based on surveys in other states (Miranda et al. 1996, D. Schupp, Minnesota DNR, personal communication). However, this year we have variances and can adjust our sample sizes accordingly.

[9] Stratification based on CPUE can lower CPUE variance for certain fish species. However, there are potential drawbacks that the biologist should consider before employing this technique. If there are several principal fish species, stratification based on the distribution of one may not lower the variance for another, since they may have different distributions. Also growth, condition, or length frequencies may vary between strata, especially in larger reservoirs (Mesa and Duke 1990). If more fish from one strata are sampled on another, these measures may be biased towards that one strata and not representative of the lake overall. In these situations, the researcher will want to test if these measures are significantly different between strata to determine if they can be pooled. If not, the researcher may want to report both these indexes and CPUE separately by strata, or use procedures described in Cochran (1977) or Scheaffer et al. (1986) to develop stratified random estimates for growth, condition, stock density indexes, as well as CPUE in the lake overall. Whatever the case, scales, weights, and lengths should be obtained from fish from both strata. Collection of five per cm group from just one strata may not represent the lake overall.

- Determine what fish specie(s) are of greatest interest or those which are the principal players.
- Determine how to stratify based on habitat where CPUE of the "principal player(s)" would probably be highest (e.g., weedy coves, largemouth bass; rock rubble, smallmouth bass, etc.).
- Designate strata locations on the map—for example ⅓ of shoreline is highlighted as cliff (where biologist feels that largemouth bass CPUE would be low) and ⅔ of shoreline is highlighted as weedy habitat (where biologist feels that largemouth bass CPUE would be high).
- Select needed sample size from Appendix A. These sample sizes are designed for simple random sampling and should, therefore, be more than adequate for stratified sampling.
- Use one of two types of allocation methods to assign sampling sections to strata.
  - If you or the regional biologists can make an educated guess about the ***degree*** catch rates will be higher in one strata versus the other, use ***nonuniform probability allocation*** based on the degree catch rates might be different. For instance, suppose you are most interested in largemouth bass. If you think samples taken in weedy habitats will have twice the catch rates of bass (fish/hour) as samples in cliff habitats, and you have a total needed sample size of 21-600 second sections, put 14 of the samples in weedy habitat and 7 in cliff habitat. Make sure there are at least two samples, preferably more, in the unpreferred habitat so strata variance can be calculated.
  - If you have no idea how much the catch rates will vary from one strata to another, ***proportionally*** allocate samples to strata based on size or "weight" of strata. For instance if ⅓ of shoreline is cliff and ⅔ of shoreline is shallow weedy habitat, put ⅓ of samples along the cliff shore in randomly chosen locations (i.e., the 400 m spaced sampling points discussed earlier) and ⅔ of samples in the weedy habitat in randomly chosen locations. This will ensure that the areas with high CPUE of the species of interest will be sampled[10].

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[10] Optimal allocation is not possible without a previous estimate of variance within strata for that particular lake. Therefore, two options are available for allocation in our lakes where previous surveying has not been conducted: proportional allocation and nonuniform probability sampling. Although nonuniform probability sampling is used most often in creel surveys, Mississippi researchers (L. E. Miranda, Mississippi State University, personal communication) are developing this for use in standardized electroshocking surveys. Expert opinion has been used to allocate samples for creel surveys in nonuniform probability sampling (Stanovick and Nielsen 1991). See Cochran (1977), Scheaffer et al. (1986), and Brown and Austen (1996) for general statistical procedures on stratification and proportional allocation. See Malvestuto et al. (1978) and Malvestuto (1996) for information on nonuniform probability sampling.

- **Special considerations for net sampling**—for net sampling, exclude those randomly–chosen sampling points where it is impossible to set nets (i.e., no sheer cliff faces, boat launches, areas where turbines are, etc.). Then randomly select other sampling points to make up for those excluded.

Standardizing Techniques on the Lakes

Gill Nets

- Gill nets should be set in the evening before electrofishing starts and retrieved the next morning;
- Nets should be set perpendicular to shore;
- Smallest mesh size should be closest to shore; and
- Although net–nights will be the unit of interest, record set time and pick up time.

Fyke Nets

- Fyke nets should be set perpendicular to shore;
- Nets should be set in the evening/late afternoon before electrofishing starts and retrieved the next morning;
- Record set time and pick up time; and
- Try to set the net so the top of the first hoop is no more than about 1 foot under the water's surface[11].

Electrofishing

- Electrofishing should be conducted with pulsed DC, high range 100-1000 volts, 120 cycles per second;
- Standardize power output of the electrofishing unit based on the conductivity of each lake (See Appendix C);

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[11] See Fletcher et al. (1993) and Hubert (1996) for fyke netting procedures. D. Willis, South Dakota State University (personal communication) knows of no depth standard on midwestern fyke net sets, although the "1 foot under the water approach" has worked well for him. However, Missouri Department of Conservation biologists sometimes set their modified fyke nets where 20 or 30 ft of water may be over the first frame. Their white crappie CPUE data seemed quite comparable to Kansas CPUE data collected in shallower sets. However, the age–0 CPUE values were much lower for the Missouri data than for the Kansas data.

- Electrofish starting at each randomly chosen sampling point for 600 seconds as measured by the timer on the electrofishing unit[12]. Always record on data sheets the actual number of seconds shocked (e.g., 578 sec, 600 sec, 605 sec, etc.);
- Electrofish in the same direction from the sampling point for all samples;
- Electrofish petal operations (continuous or intermittent) are at the discretion of the operator, and should be designed to capture the highest number of fish. Use intermittent shocking when approaching structure such as beaver lodges, downed trees, docks and weed patches. Stay off the pedal until close to structure, then hit the pedal;
- A minimum of two dippers and one driver should be in each electrofishing boat. **Dippers should go for everything, even young–of–year (YOY)**[13],[14];
- We have found that catch rates go down if you electrofish the same section over again. Never cover the same section that you have electrofished over again[15];
- Make sure that when fish are worked up, they are released back at the start of the section, and not near the end where they can stray into the next section to be electrofished again; and
- Electrofish at night to have the highest catch rates.

Processing the Catch

- **IMPORTANT: Data from each 600 second electrofishing section, and each net set should be recorded separately. DO NOT POOL DATA FROM DIFFERENT NET SETS OR ELECTROFISHING SECTIONS!**[16]

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[12] See Miranda et al. (1996) for a discussion of the length of electroshocking time sections on standardized lake surveys. He tested precision of electrofishing samples lasting from 300 seconds to 3600 seconds. They found that for sections spaced closer than 30 minutes apart travel time, shorter sections were more efficient than longer sections. We selected 600 second sections instead of 300 second sections because of the high likelihood of many “zero” measures of CPUE for individual sections in 300 second sections, skewing the data to a non–normal distribution and affected the ability to calculate confidence intervals.

[13] We found that non–standard, selective dipping of different sized fish or various species of fish was one of the major factors which made it difficult to analyze and compare historical WDFW warmwater fisheries data from over 60 Washington lakes.

[14] No question about it, YOY are inconvenient to sample. However, last year I found how important these data were when I examined first–year growth of YOY of various species. When we will conduct recruitment studies, YOY information will also be very important.

[15] During data collection on Bolding et al. (1998) and Bolding et al. (1997), it was found that electroshocking the same areas again resulted in lowered catch rates. Cross and Stott (1975) found that the effect lasted between 3 and 24 hours on roach and gudgeon after they had been electroshocked in English ponds.

[16] If all sample data are pooled, it would be impossible to calculate a variance.

- **Measure fish lengths**—Take **total** lengths to nearest mm, caudal fin compressed[17]. **Do this on ALL captured fish when possible**. It makes your later data analysis much cleaner and easier. When it is not feasible to measure all fish, such as when there are thousands of YOY or huge numbers of carp, measure a random subsample of these groups (30-50 fish) and count the rest.

- **Special note on lengths**—When preparing length-frequency histograms, fish should **not** be rounded off to the nearest cm, but rather should include fish from that cm length to the next. For example, the 10 cm group should include fish from 10.00 to 10.99 cm, **not** those from 9.50 to 10.49 cm[18].

- **Obtain needed sample sizes—**Note that 55 stock size fish are required for a workable PSD estimate and 100 "adult" fish are required to develop a useable length frequency (Table 2). To determine if a significant change has occurred in PSD, more stock size fish may be required. See Miranda (1993) and Willis' (1998) warmwater fisheries sampling, assessment, and management, Section H7, for needed sample sizes and calculations to detect significant differences in PSDs between years or lakes.

Table 2. Basic data to collect on principal fish species.

Data	Units	Use	Sample Size
Length	mm total length; Compress Caudal Fin	Stock Density Indices (PSDs etc.), Length Freq. Histograms, Wr, Growth, Relative Composition, Population Estimates	All fish—need to get at least 100 of the major species (for PSDs > 55 stock size)[a,b,c]. For measuring changes in stock density indexes, sample sizes may need to be larger. See Miranda (1993) and H7 in Willis' (1998) warmwater fisheries sampling, assessment, and management.
Weight	g	W*r*	Five fish sampled per cm group.
Scales	Number	Growth	Five to ten scales per fish, five fish sampled per cm group[d].
Electroshocking CPUE	Fish/hr	Electroshocking CPUE and C.I.	Shock in 600 second increments[e], working up fish between sections. If CPUE variance available, see Appendix A for sample sizes. If variance not available, use Appendix B.
Gill Net, Trap Net CPUE	Fish/net night	Gill Net, Trap Net CPUE and C.I.	Use net nights as the unit of interest. See Appendix A for sample sizes if CPUE variance available. If variance not available, use Appendix B.

[a] Anderson and Neumann 1996
[b] Gustafson 1988
[c] Divens et al. 1998
[d] DeVries and Frie 1996
[e] Miranda et al. 1996

17 Use of total length makes survey data comparable to historical data from and many other areas of the country. Measuring total length with a compressed caudal fin is the standard for North America (Anderson and Neumann 1996).

18 This method of grouping length data is recommended by Anderson and Neumann (1996) in Fisheries Techniques, 2nd edition, page 449, 4th paragraph.

- **For length frequencies, PSD estimates, and CPUEs do not combine samples from different gear types**[19].

- **Obtain weights on five fish from each cm length group**[20]**—**It does not matter which gear type caught the fish. If you obtained weights on five per cm group of pumpkinseed by electrofishing, you do not have to start over again with the nets and weigh an additional five per cm group. Once you have five per cm group of adult fish of a particular species, you can stop taking weight data on that species (Table 2). However, remember the exception to this when you stratify. If the strata in the lake have different growth rates or conditions (you can test to see if samples can be pooled), you will have to take a sample from each strata to obtain the mean estimate for the lake.

- Take scales on five fish of each species from each cm length group (these might be the same fish which were weighed). Use tally sheet to determine when enough scales have been obtained (Table 2). To validate scale readings, you may want to sacrifice a small number of fish for otoliths. On warmwater fish, otoliths may be easily obtained by snipping the isthmus caudal to the lower jaw and gills on the ventral side of the fish using a pair of dykes or wirecutters. The head is then popped back and the otoliths will be found in two pockets behind the head. For more information contact Inland Fisheries Investigations. Also, for stratified sampling, the biologist will need to take samples from each strata if strata length–at–age is significantly different (see 5 above).

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[19] See Ricker (1975), page 19, 2nd paragraph. Since each gear has its own individual bias, combining gear types when estimating stock density indexes and CPUE leads to estimates that usually cannot be compared among lakes. For instance, how does one compare a CPUE calculated using one hour of gill netting and one hour of electroshocking to another CPUE collected with two hours of electroshocking and one–half hour of gill netting? One would expect more littoral species such as largemouth bass in the second CPUE calculation than the first, which has nothing to do with management actions, habitat, or other factors. While studies can remain consistent if the same ratio of effort from one gear type to another is used, it is usually much easier to always make separate estimates for each gear type.

[20] Some of the reviewers in other areas of the country used this technique to ensure that a wide variety of weights were collected to represent the entire range of fish lengths.

Appendices

Appendix A. Using Sequential Sampling or Previous Year's Data to Calculate CPUE Sample Size During a Survey

To determine an appropriate sample size for the survey, first reach a decision about survey objectives. Is the survey purpose to get a point estimate of a value or to measure change? What degree of confidence is required in the results (e.g., 70%, 80%, 95%)? If change is to be measured, what degree of change should be detected? Then select a sample size for electrofishing, gill netting, and fyke netting which will be appropriate to meet these goals.

The best method to calculate CPUE sample sizes so they will be tailored to individual lakes is to use previous estimates of variance are available from the specific lake, taken at the same time of year. These estimates can be obtained either through sequential sampling or through previous year's sampling.

A. 1. Calculating a Sample Size to Estimate CPUE Within Certain Bounds

If the biologist wants to measure CPUE within certain bounds, use the following equation to calculate needed sample sizes: (from Willis' (1998) warmwater fisheries sampling, assessment, and management, also see Cochran (1977)).

$$n = \frac{(t^2)(s^2)}{[(a)(x)]^2}$$

Where:

n = sample size required
t = *t* value from a *t*- table at n-1 degrees of freedom for a desired sample size (1.96 for 95% confidence; 1.26 for 80% confidence; and 1.04 for 70% confidence)
s^2 = variance
x = mean CPUE
a = precision desired in describing the mean expressed as a proportion.

Simply plug in values obtained from last year's survey or while the survey is in progress to calculate how many samples are needed to get the precision required. This method can best be illustrated by the following example:

Example A.1.

The biologist samples six randomly chosen electroshocking sections over a two–day period in Black Lake. The next morning in the motel room, he counts up the largemouth bass per section, and figures the mean and variance with a pocket calculator. He finds that the average largemouth bass CPUE is 42 fish per hour with a variance of 999. He is interested in sampling enough sections to determine CPUE with 80% confidence limits which are $\pm$ 30% of the mean. Plugging these values in the above equation (t = 1.26, s^2=999, x = 42, a = 0.30) gives a needed sample size of 9.98 or 10 sections. Since 6 have been completed already, he only has to sample an additional 4. Of course, this assumes that enough of the fish have been captured for growth, length frequency, and relative weight sample size requirements (Table 2).

A. 2. Calculating a Sample Size for CPUE, Growth or Condition to Measure a Degree of Change

To determine if a certain percent change occurred in CPUE over time, more samples are needed. Parkinson *et al.* (1988) developed simple procedures to estimate changes in CPUE, growth, angling effort and fish age over time in small trout lakes in British Columbia. Basically, sample size can be calculated by:

$$n = \frac{100^2 k \left(\frac{s}{x}\right)^2}{A^2}$$

Where: n = sample size required

k= multiplication constant from Table A1
s = standard deviation (square root of the variance)
x = mean CPUE (could also be length-at-age, condition, etc.)
A = percent change to be detected.

These are sample sizes for independent one– and two–tailed t-tests, and are useful for measuring differences between two different times. One–tailed tests have lower required sample sizes and can be used if the direction of change can be predicted (up or down). Two–tailed tests should be used if the direction of change is not known. To include several different times in the analysis, use sample size calculations for one–way ANOVA presented in Zar (1984).

Both the power of the test and degree of confidence in the results are reflected in the "k" value (Table A.1.). We will not discuss the exact meaning of k and its derivation here; however, see Snedecor and Cochran 1980, Zar (1984), and Parkinson *et al.* (1988) for more information.

Power of the test is an important consideration. A test with low power has a good chance of not being able to detect differences, even if they occur. A test with high power is much better able to detect differences. We recommend a power ($1-\beta$) of 0.80 (therefore $\beta = 0.20$) for most warmwater surveys, but Table A.1. gives other alternatives also. Alpha (α) is simply the confidence in the results (e.g., 0.30, 0.10, 0.05 etc.).

Table A. 1. Values of *k* for various combinations of β and α for two–tailed tests. Values of *k* in parentheses are for one–tailed tests.

	α				
β	**0.30**	**0.20**	**0.10**	**0.05**	**0.01**
0.20	7.05 (3.73)	9.02 (5.67)	12.37 (9.02)	15.70 (12.37)	23.36 (20.07)
0.10	10.74 (6.52)	13.14 (9.02)	17.13 (13.14)	21.02 (17.13)	29.76 (26.04)
0.05	14.38 (9.41)	17.13 (12.37)	21.65 (17.13)	25.99 (21.65)	35.63 (31.55)

A very important point is, that while change can be documented between two surveys taken at different times, it is impossible to say that this change was definitively the result of the management action as opposed to environmental variability. Therefore, the biologist has to qualify his results after a two–point survey to say change occurred, and he suspects it was or was not related to the management action based on some other supporting evidence. Samples taken several years before and several years afterwards, to measure trends in both “treatment” and “control” lakes are necessary to statistically validate that the change was related to the management action. This is most definitely the preferred situation if money and manpower are available.

Example A. 2.

A slot limit will be put into effect on Black Lake in 2001. The biologist in the example above wants to be able to detect a 30% increase in CPUE with 80% confidence between 1999 and 2005. Plugging in values from the above example ($k = 5.66$ from Table A.1. for $\beta = 0.20$ and $\alpha = 0.20$; $s = 31.61$ (s^2=999); $x = 42$; $A = 30$,) gives a needed sample size of 35.62 or 36 sections for *each* survey. Since 6 have been completed already, he has to sample an additional 30. Of course, this assumes that enough of the fish have been captured for growth, length frequency, and relative weight sample size requirements (Table 2). Unfortunately, because of time constraints, the biologist realizes he cannot sample 36 samples in this lake. Therefore, he is willing to put up with 70% confidence ($\alpha = 0.30$) in the results, to measure a 50% increase in CPUE. He enters the values for 70% confidence and 50% increase into the equation and which gives a needed sample size of 8.46 or 9 samples. He has taken 6 already, so he needs an additional 3.

Appendix B. Sample Size Tables for CPUE

We recommend that sequential sampling or previous year's data from a particular lake be used to calculate sample sizes whenever possible (Appendix A). However, if this data is unavailable, the following tables can give a rough approximation of average sample sizes for varying degrees of confidence, power and precision. Fewer samples are needed to estimate CPUE within certain bounds (Tables B. 1.-B. 4.) than to measure a change in CPUE (Tables B. 5.-B. 8.). The following are average needed sample sizes for specific degrees of confidence. Those sample sizes for measuring change (Tables B. 5.-B. 8.) assume that the direction of change can be estimated (one–tailed test) and a power (1- β) of 0.80 is used. Sample sizes appearing in the tables were calculated based on 1998 data. The following examples show how the tables can be used to calculate sample sizes.

Example B. 1. Potholes Reservoir is receiving tiger muskies to control stunted yellow perch. The biologists expects that CPUE of yellow perch will go down following stocking, and he guesses that the change will be 50%. Therefore, the biologist looks at Table B. 8. to find the intersection between 50% change and 80% confidence intervals. A rough approximation of the needed number of net nights would be 23.

Example B. 2. The electrofishing CPUE of largemouth bass in Munn Lake is being calculated with 80% confidence intervals to compare to the state averages. The biologist wants to get his estimate within 30% of the actual mean. Therefore, he determines from Table B.1. that 15 samples would be reasonable.

Table B. 1. Median needed sample sizes (600 second sections) for mean CPUE, using simple random electrofishing sampling, for largemouth bass and bluegill in western Washington lakes. Sample sizes were calculated from variances provided from 1998 surveys. Biologists should choose sample size based on the level of confidence wanted in the results (usually 80% for management and 95% for research), and the precision desired in the CPUE estimate. Use of stratification will usually give biologists more precision with these sample sizes.

Precision Desired in Describing the Mean (%)	Confidence (%)		
	70	**80**	**95**
100	2	2	3
50	4	6	13
30	10	15	36
25	15	22	52
10	91	138	325

Table B. 2. Median needed sample sizes (600 second sections) for mean CPUE, using simple random electrofishing sampling, for largemouth bass and bluegill in eastern Washington lakes. Sample sizes were calculated from variances provided from 1998 surveys. Biologists should choose sample size based on the level of confidence wanted in the results (usually 80% for management and 95% for research), and the precision needed in the CPUE estimate. Use of stratification will usually give biologists more precision with these sample sizes.

Precision Desired in Describing the Mean (%)	Confidence (%)		
	70	**80**	**95**
100	2	2	3
50	3	4	10
30	8	12	29
25	12	18	42
10	73	112	262

Table B. 3. Median needed sample sizes (net nights) for mean CPUE, using simple random gill net sampling, for yellow perch in western Washington lakes. Sample sizes were calculated from variances provided from 1998 surveys. Biologists should choose sample size based on the level of confidence wanted in the results (usually 80% for management and 95% for research), and the accuracy needed in the CPUE estimate. Use of stratification will usually give biologists more precision with these sample sizes.

Precision Desired in Describing the Mean (%)	Confidence (%)		
	70	**80**	**95**
100	2	2	4
50	5	7	18
30	14	21	49
25	20	30	70
10	123	187	439

Table B. 4. Median needed sample sizes (net nights) for mean CPUE, using simple random gill net sampling, for yellow perch in eastern Washington lakes. Sample sizes were calculated from variances provided from 1998 surveys. Biologists should choose sample size based on the level of confidence wanted in the results (usually 80% for management and 95% for research), and the precision needed in the CPUE estimate. Use of stratification will usually give biologists more precision with these sample sizes.

Precision Desired in Describing the Mean (%)	Confidence (%)		
	70	**80**	**95**
100	2	2	2
50	2	4	9
30	7	10	24
25	10	15	35
10	61	92	217

Table B. 5. Approximate needed sample sizes (600 second sections) for detecting changes in mean CPUE, using simple random electrofishing sampling, for largemouth bass and bluegill in western Washington lakes. Sample sizes were calculated from variances provided from 1998 surveys. Biologists should choose sample size based on the level of confidence wanted in the results (usually 80% for management and 95% for research), and the percent change in CPUE needed to be detected. Use of stratification will give biologists the ability to detect a smaller change with these sample sizes.

	Confidence (%)		
Change Detected(%)	**70**	**80**	**95**
100	4	7	14
50	16	25	53
30	45	68	146
25	64	98	210
10	400	607	1310

Table B. 6. Approximate needed sample sizes (600 second sections) for detecting changes in mean CPUE, using simple random electrofishing sampling, for largemouth bass and bluegill in eastern Washington lakes. Sample sizes were calculated from variances provided from 1998 surveys. Biologists should choose sample size based on the level of confidence wanted in the results (usually 80% for management and 95% for research), and the percent change in CPUE needed to be detected. Use of stratification will give biologists the ability to detect a smaller change with these sample sizes.

	Confidence (%)		
Change Detected(%)	**70**	**80**	**95**
100	4	6	13
50	16	24	50
30	44	66	138
25	63	95	198
10	391	594	1235

Table B. 7. Approximate needed sample sizes (net nights) for detecting changes in mean CPUE, using simple random gill netting sampling, for yellow perch in western Washington lakes. Sample sizes were calculated from variances provided from 1998 surveys. Biologists should choose sample size based on the level of confidence wanted in the results (usually 80% for management and 95% for research), and the percent change in CPUE needed to be detected. Use of stratification will give biologists the ability to detect a smaller change with these sample sizes.

	Confidence (%)		
Change Detected(%)	**70**	**80**	**95**
100	4	6	14
50	16	24	53
30	44	67	146
25	64	97	210
10	396	601	1311

Table B. 8. Approximate needed sample sizes (net nights) for detecting changes in mean CPUE, using simple random gill netting sampling, for yellow perch in eastern Washington lakes. Sample sizes were calculated from variances provided from 1998 surveys. Biologists should choose sample size based on the level of confidence wanted in the results (usually 80% for management and 95% for research), and the percent change in CPUE needed to be detected. Use of stratification will give biologists the ability to detect a smaller change with these sample sizes.

	Confidence (%)		
Change Detected(%)	**70**	**80**	**95**
100	4	6	13
50	15	23	50
30	42	63	138
25	60	91	198
10	373	566	1235

Appendix C. Standardizing Electrofishing Boat Power Output

The amount of power transferred from the water to the fish has been described as the critical electrical factor affecting the behavior of fish (Kolz 1989, Kolz and Reynolds 1989). Power (watts) is equal to the product of amps and voltage. Variation in power output from electrofishing boats explained an average of 14.9% of the variance in night electrofishing catches in surveys on the Mississippi and Illinois Rivers (Burkhardt and Gutreuter (1995). This variation can be considerably reduced at no cost by standardizing power based on the conductivity of the water. Standardization of power is rapid and simple to conduct. The following is based on the procedures of Burkhardt and Gutreuter (1995) and Koltz et al (1998).

We recommend a specific power which should be the goal for each level of conductivity. To arrive at these power goals, we shocked using several different power settings in three Western Washington lakes with two Smith-Root GPP5 electrofishing boats. We selected the lowest power setting which rolled fish but did not cause spinal injury or hemorrhaging. Injury was determined by dissection and internal examination of salmonids (trout, coho salmon) captured using the various power settings. Salmonids were dissected instead of warmwater fish because of their higher susceptibility to electrofishing injury.

To standardize the power output of your boat, conduct the following steps. **REMEMBER TO BE EXTREMELY CAUTIOUS STANDARDIZING YOUR BOAT BECAUSE YOU ARE WORKING WITH POWERFUL CURRENT.**

1. To standardize, you will need the following: two biologists, a voltmeter, a conductivity meter, and the three tables in this appendix.

2. Launch the boat, and deploy droppers as if sampling.

3. Adjust tips of electroshocking booms so they are about one netting pole length apart (approximately 124").

4. Obtain specific conductance of the water (Conductivity of the water standardized for 25°C) using hydrolab or ambient conductivity using some other instrument.

5. If specific conductance was obtained, convert it to ambient conductivity (conductivity uncorrected for temperature) using Table C. 1.

6. Look on Table C. 2. to obtain power goal for the ambient conductivity of the lake.

7. Turn on the generator. Use your usual shocking settings (120 hz and high voltage).

8. If using a Smith-Root shockboat, open the fuse compartment on the front of the console.

9. You should see four jacks, two with black heavy duty wires, and two with red wires. These are the anode and cathode jacks.

10. **THIS IS A HIGH CURRENT AREA. BE VERY CAREFUL NOT TO TOUCH THE METAL ON THE JACKS WITH YOUR SKIN.** Pull one red and one black jack out slightly, so a small bit of metal on the jack is showing[21].

11. Touch the red lead to the red jack and the black lead to the black jack. Have voltmeter set on high (1000v). Read voltage.

12. Obtain amperage from meter on console.

13. Adjust percent of range knob until power goal (voltage x amperage) is obtained[22]. Table C. 3. can be used to find an appropriate amperage and voltage combination for the required power goal. The power output is now standardized.

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[21] A voltmeter can be wired in permanently to the jacks for convenience and safety.

[22] Peak power is the factor which has the most effect on fish behavior. Peak power is the product of peak amps and peak volts. Multiplying volts given by the multimeter (which is average volts) and amps given by the boat's ampmeter (which is average amps) does not provide an estimate of peak power. However, meters designed to measure peak volts and amps are quite expensive and not widely available. Using the boat's ampmeter and a multimeter, one can obtain an index which is highly correlated to the actual peak power. Based on field tests in a Washington lake, we found that the correlation between actual peak power determined by a peak voltmeter–peak ampmeter and the readings given by the boat's ampmeter and a voltmeter measuring average volts was r=0.99. The "power" goals presented in this manual were developed for average amps x average volts. If average power goals (peak volts x average amps) or peak power goals (peak volts x peak amps) are desired, other tables must be developed.

Table C. 1. Ambient conductivity (µs) at various specific conductance (µs) x water temperature (ºC) combinations.

	Specific Conductance (µs)																		
ºC ⇓	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**	**110**	**120**	**130**	**140**	**150**	**160**	**170**	**180**	**190**	**200**
1	11	17	23	28	34	40	45	51	57	62	68	74	79	85	91	96	102	107	113
2	12	17	23	29	35	41	47	52	58	64	70	76	81	87	93	99	105	111	116
3	12	18	24	30	36	42	48	54	60	66	72	78	84	90	96	102	108	114	120
4	12	18	25	31	37	43	49	55	62	68	74	80	86	92	99	105	111	117	123
5	13	19	25	32	38	44	51	57	63	70	76	82	89	95	101	108	114	120	127
6	13	20	26	33	39	46	52	59	65	72	78	85	91	98	104	111	117	124	130
7	13	20	27	33	40	47	53	60	67	73	80	87	93	100	107	113	120	127	134
8	14	21	27	34	41	48	55	62	69	75	82	89	96	103	110	116	123	130	137
9	14	21	28	35	42	49	56	63	70	77	84	91	98	105	112	119	127	134	141
10	14	22	29	36	43	50	58	65	72	79	86	94	101	108	115	123	130	137	144
11	15	22	30	37	44	52	59	66	74	81	89	96	103	111	118	126	133	140	148
12	15	23	30	38	45	53	61	68	76	83	91	98	106	114	121	129	136	144	151
13	16	23	31	39	47	54	62	70	78	85	93	101	109	116	124	132	140	147	155
14	16	24	32	40	48	56	63	71	79	87	95	103	111	119	127	135	143	151	159
15	16	24	32	41	49	57	65	73	81	89	97	106	114	122	130	138	146	154	162
16	17	25	33	42	50	58	66	75	83	91	100	108	116	125	133	141	149	158	166
17	17	25	34	42	51	59	68	76	85	93	102	110	119	127	136	144	153	161	170
18	17	26	35	43	52	61	69	78	87	95	104	113	121	130	139	147	156	165	173
19	18	27	35	44	53	62	71	80	89	97	106	115	124	133	142	151	159	168	177
20	18	27	36	45	54	63	72	81	90	100	109	118	127	136	145	154	163	172	181
21	18	28	37	46	55	65	74	83	92	102	111	120	129	139	148	157	166	175	185
22	19	28	38	47	57	66	75	85	94	104	113	123	132	141	151	160	170	179	188
23	19	29	38	48	58	67	77	87	96	106	115	125	135	144	154	163	173	183	192
24	20	29	39	49	59	69	78	88	98	108	118	127	137	147	157	167	176	186	196
25	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200
26	20	31	41	51	61	71	82	92	102	112	122	133	143	153	163	173	183	194	204
27	21	31	42	52	62	73	83	94	104	114	125	135	145	156	166	177	187	197	208
28	21	32	42	53	64	74	85	95	106	116	127	138	148	159	169	180	191	201	212
29	22	32	43	54	65	76	86	97	108	119	129	140	151	162	173	183	194	205	216
30	22	33	44	55	66	77	88	99	110	121	132	143	154	165	176	187	198	209	220

Table C. 1. Ambient conductivity (µs) at various specific conductance (µs) x water temperature (ºC) combinations (continued).

		Specific Conductance (µs)																			
ºC ⇓	F(T)	**210**	**220**	**230**	**240**	**250**	**260**	**270**	**280**	**290**	**300**	**310**	**320**	**330**	**340**	**350**	**360**	**370**	**380**	**390**	**400**
1	1.77	119	124	130	136	141	147	153	158	164	170	175	181	187	192	198	204	209	215	221	226
2	1.72	122	128	134	140	146	151	157	163	169	175	180	186	192	198	204	210	215	221	227	233
3	1.67	126	132	138	144	150	156	162	168	174	180	186	192	198	204	210	216	222	228	234	239
4	1.62	129	135	142	148	154	160	166	172	179	185	191	197	203	209	215	222	228	234	240	246
5	1.58	133	139	146	152	158	165	171	177	183	190	196	202	209	215	221	228	234	240	247	253
6	1.54	137	143	150	156	163	169	176	182	189	195	202	208	215	221	228	234	241	247	254	260
7	1.50	140	147	154	160	167	174	180	187	194	200	207	214	220	227	234	240	247	254	260	267
8	1.46	144	151	158	164	171	178	185	192	199	206	212	219	226	233	240	247	254	260	267	274
9	1.42	148	155	162	169	176	183	190	197	204	211	218	225	232	239	246	253	260	267	274	281
10	1.39	151	159	166	173	180	187	195	202	209	216	223	231	238	245	252	259	267	274	281	288
11	1.35	155	163	170	177	185	192	199	207	214	222	229	236	244	251	259	266	273	281	288	296
12	1.32	159	167	174	182	189	197	204	212	220	227	235	242	250	257	265	273	280	288	295	303
13	1.29	163	171	178	186	194	202	209	217	225	233	240	248	256	264	271	279	287	295	302	310
14	1.26	167	175	182	190	198	206	214	222	230	238	246	254	262	270	278	286	294	302	309	317
15	1.23	170	179	187	195	203	211	219	227	235	244	252	260	268	276	284	292	300	308	317	325
16	1.20	174	183	191	199	208	216	224	232	241	249	257	266	274	282	291	299	307	316	324	332
17	1.18	178	187	195	204	212	221	229	238	246	255	263	272	280	289	297	306	314	323	331	340
18	1.15	182	191	199	208	217	226	234	243	252	260	269	278	286	295	304	312	321	330	338	347
19	1.13	186	195	204	213	221	230	239	248	257	266	275	284	292	301	310	319	328	337	346	354
20	1.11	190	199	208	217	226	235	244	253	262	271	280	290	299	308	317	326	335	344	353	362
21	1.08	194	203	212	222	231	240	249	259	268	277	286	296	305	314	323	332	342	351	360	369
22	1.06	198	207	217	226	236	245	254	264	273	283	292	302	311	320	330	339	349	358	368	377
23	1.04	202	212	221	231	240	250	260	269	279	288	298	308	317	327	336	346	356	365	375	385
24	1.02	206	216	226	235	245	255	265	275	284	294	304	314	324	333	343	353	363	373	382	392
25	1.00	210	220	230	240	250	260	270	280	290	300	310	320	330	340	350	360	370	380	390	400
26	0.98	214	224	234	245	255	265	275	285	296	306	316	326	336	347	357	367	377	387	398	408
27	0.96	218	229	239	249	260	270	281	291	301	312	322	332	343	353	364	374	384	395	405	416
28	0.94	222	233	244	254	265	275	286	296	307	318	328	339	349	360	371	381	392	402	413	424
29	0.93	227	237	248	259	270	281	291	302	313	324	334	345	356	367	378	388	399	410	421	432
30	0.91	231	242	253	264	275	286	297	308	319	330	341	352	363	374	385	396	407	418	429	440

Table C. 2. Electrofishing power goals (watts) at various ambient conductivities (µs). Developed in western Washington.

Ambient Conductivity	Power Goal	Ambient Conductivity	Power
20	845	155	351
25	717	160	351
30	632	165	352
35	572	170	352
40	528	175	353
45	494	180	354
50	468	185	355
55	447	190	356
60	430	195	357
65	416	200	358
70	404	205	360
75	395	210	361
80	387	215	362
85	380	220	364
90	374	225	366
95	370	230	367
100	366	235	369
105	362	240	371
110	360	245	373
115	357	250	374
120	355	255	376
125	354	260	378
130	353	265	380
135	352	270	382
140	351	275	384
145	351	280	386
150	351	285	388

Table C. 3. Power at various volts x amps combinations.

	Volts										
Amps ⇓	**50**	**75**	**100**	**125**	**150**	**175**	**200**	**225**	**250**	**275**	**300**
1	50	75	100	125	150	175	200	225	250	275	300
1.5	75	113	150	188	225	263	300	338	375	413	450
2	100	150	200	250	300	350	400	450	500	550	600
2.5	125	188	250	313	375	438	500	563	625	688	750
3	150	225	300	375	450	525	600	675	750	825	900
3.5	175	263	350	438	525	613	700	788	875	963	1050
4	200	300	400	500	600	700	800	900	1000	1100	1200
4.5	225	338	450	563	675	788	900	1013	1125	1238	1350
5	250	375	500	625	750	875	1000	1125	1250	1375	1500
5.5	275	413	550	688	825	963	1100	1238	1375	1513	1650
6	300	450	600	750	900	1050	1200	1350	1500	1650	1800
6.5	325	488	650	813	975	1138	1300	1463	1625	1788	1950
7	350	525	700	875	1050	1225	1400	1575	1750	1925	2100
7.5	375	563	750	938	1125	1313	1500	1688	1875	2063	2250
8	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400
8.5	425	638	850	1063	1275	1488	1700	1913	2125	2338	2550
9	450	675	900	1125	1350	1575	1800	2025	2250	2475	2700
9.5	475	713	950	1188	1425	1663	1900	2138	2375	2613	2850
10	500	750	1000	1250	1500	1750	2000	2250	2500	2750	3000

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