FISHERY RESEARCH

STANDARD FISH SAMPLING PROTOCOL FOR LOWLAND LAKES AND RESERVOIRS IN IDAHO

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IDFG Report Number 12-10
May 2012

INTRODUCTION

Standardized sampling methods for fisheries surveys are important for describing the status or detecting changes in fish communities. Standard sampling protocols provide consistent and measurable metrics of the fish community, such as catch-per-unit-effort (CPUE), species composition, size structure, or body condition. These metrics can then be validly compared over time, allowing managers to characterize attributes of individual species or bodies of water. The strength of a standardized protocol is that, when used properly, surveys are repeatable, estimated metrics are comparable between years and bodies of water, and precision and confidence bounds can be calculated, ensuring statistically defensible comparisons. Metrics estimated with standardized sampling protocols can be invaluable to identify underperforming populations, monitor population response related to management changes, communicate with the public regarding particular bodies of water or species, or provide direction for more in-depth assessments.

The Idaho Department of Fish and Game (IDFG) has been committed to using a standardized, multiple-gear, fish community sampling approach for lowland lakes and reservoirs since the early 1990s (Idaho Department of Fish and Game 1992), but the agreed upon sampling methods have not been updated in 20 years. The previously adopted survey methods included combining different sampling gear types into one “unit of effort.” Unfortunately, this approach precluded the estimation of variability within gear types, a requirement for valid statistical comparisons. The previous methods also based sample size requirements (e.g., number of nets or electrofishing sites) only on the size of the body of water, rather than observed variability in catch by gear. Procedures in this revised manual for sampling lakes and reservoirs include recommendations for field methods and assessing sample size requirements. The new approach is based on the original standardized methods (IDFG 1992), updated with those used in other states that have undergone regional and national review (e.g., Bonar and Divens 2000; Bonvechio 2009).

Obtaining estimates of fish population metrics such as abundance, relative abundance, species composition, and age/growth information from lakes and reservoirs is difficult (Murphy and Willis 1996). Commonly, a multiple-gear strategy is employed to sample the full complement of species and fish sizes in a body of water (Weaver et al. 1993; Fago 1998; Ruetz et al. 2007). Using multiple gears to sample fish populations may help overcome the inherent biases associated with individual gear types. For example, electrofishing is known to be biased toward capturing larger individuals (Beamesderfer and Rieman 1988; Ruetz et al. 2007), while fyke or trap nets capture smaller fish more successfully (Jackson and Bauer 2000; Shoup et al. 2003). Using multiple sampling gears will allow development of a composite generalization of the fish populations in a body of water (Bonar and Divens 2000).

The following protocol outlines different sampling gears, optimal time of year to perform surveys, proper sampling design, and field procedures for lentic waters in Idaho. Following the recommended protocol will aid biologists in generating indices of population metrics for each species sampled. Because of differences in individual gear bias (i.e., species and/or size selectivity), separate estimates for each gear type should be made (Ricker 1975). For example, calculating CPUE for each gear type will allow valid comparisons of CPUE estimates between years and bodies of water.

The protocol is intended to be a minimum survey to document general population status, with the methods designed to provide flexibility for biologists to tailor gear types and sampling effort to meet specific sampling objectives. Additional gear types, or additional effort with the standard gear types for more intense, species-specific sampling, are recommended when in-depth evaluation is required or the known species assemblage requires other gear (e.g., trawling in kokanee waters). Likewise, if the body of water to be sampled is not conducive to a gear type or a gear fails to sample fish, that gear may be excluded from the survey. However, when the object of the survey is to make general characterizations of the fish community, or compare fish communities among bodies of water, then standardized sampling using the following protocol is strongly recommended. Whether biologists use only standardized survey methods, combine them with additional methods, or use alternate methods due to unusual logistic or safety constraints, sampling should be conducted as consistently as possible, using the same gear types during the same time of year.

STANDARDIZED GEAR

The sampling gears for the IDFG's standard lowland lake and reservoirs survey are those that are already being used by IDFG fisheries staff, consisting of electrofishing, trap nets, and gill nets1.

Electrofishing

- A pulsed DC electrofishing boat with two boom-mounted electrodes with two netters and a driver. The sample unit should be a 600 s period of electrofishing2, measured from the electrofishing unit as "on-time." The number of fish captured during that period is the response variable, which should later be standardized to the number of fish captured/h. The CPUE is calculated by first dividing the number of fish captured by the number of seconds spent sampling (actual power-on time in seconds) and then multiplying by 3,600 to standardize the estimate to fish captured/h. The mean CPUE is then calculated by summing the CPUE (as fish captured/h) for the different transects and dividing by the number of transects sampled.

Trap Nets

- Standard IDFG trap nets should be constructed with a 75 ft lead, 3X6 ft (23 m lead, 0.9 X 1.8 m) frame with five hoops, crowfoot throats on first and third hoops, ¾" (1.9 cm) bar mesh, treated black. The CPUE is calculated by summing the number of fish captured across net sets and dividing by the total number of nights that nets were set.

Gill Nets

- Standard gill nets should be 150 ft long X 6 ft deep (45 m X 1.8 m) clear monofilament nets with 6 panels composed of ¾", 1", 1 ¼", 1 ½", 2", and 2 ½" (1.9, 2.5, 3.2, 3.8, 5.1, and 6.4 cm) bar mesh in floating and sinking configurations. Although a floating and a sinking gill net are often set as a pair, report separately and calculate CPUE for the individual nets regardless of whether gill nets are floating or sinking. The CPUE is calculated by summing the number of fish captured across net sets and dividing by the total number of nights that nets were set.

1These gears are very similar to the gears used by the State of Washington for standard surveys in lentic waters, which consist of electrofishing, fyke nets, and gill nets (Bonar and Divens 2000).

2 See Miranda et al. (1996) for discussion on length of electrofishing time per sample interval. Conclusions were that short-duration intervals (5-10 minutes) were best (i.e., produced lower variance) when travel time between sample survey reaches was <30 minutes, whereas long-duration intervals (30-60 minutes) were best only when travel time between reaches was long (>30 minutes) and CPUE was low. Bonar and Divens (2000) used this information to settle on 600 s sample intervals for standard surveying conducted by State of Washington field staff on lentic waters.

SURVEY TIMING

Lake and reservoir surveys should be conducted in the spring or fall as dictated by water temperatures. However, certain species and water-body dependant factors may also be considered as well as the timing of past surveys. The CPUE for most warmwater species peaks in the spring and fall (Pope and Willis 1996) when water temperatures are between 14-20°C and fish are more shoreline oriented.

The best months for conducting surveys during spring are May and June and in fall are September through mid-October, but water temperature should drive the actual sampling times if possible. Particular attention is required in early spring and late fall to ensure water temperatures are not so cold that fish are offshore, which usually occurs around 12-14°C for warmwater fish. Also, comparison of CPUE between a spring survey and fall survey is not recommended because of differences in the life stages of many species during the year.

VARIABILITY AND NUMBER OF SAMPLE SITES REQUIRED

Oftentimes, many prior years of sampling data exist that provide perspective on fish populations or trends in population metrics. Where previous survey data are available, analyze those data using the following procedures to ensure that adequate sampling was performed. If previous sampling provided useful information, then the prior survey approach should probably be repeated, with the same sites revisited where appropriate[3]. If the previous sampling proved to be inadequate or no data exists, the following guidelines should be used to determine sample sizes and allocate sampling effort.

To begin, determine whether the entire shoreline can be sampled in the time allotted for the survey, which is usually possible at bodies of water smaller than 100 ha. If the body of water is too large to survey the entire shoreline, use a simple randomized or stratified random design to select sample sites as described below. If the sampling was stratified in previous surveys, use the same strata to remain consistent. Otherwise, a body of water should be stratified for sampling purposes only if major differences occur in the morphology or habitats that potentially affect use by fish. When stratifying a body of water, sampling sites must be randomly chosen within each strata (Bonar and Divens 2000).

The appropriate sample size (number of sites) for each gear type will depend on the objectives of the survey. Whether the purpose is for general monitoring, comparing changes over time, or comparing surveys between bodies of water, biologists must decide the desired level of precision in a given parameter estimate, or alternatively, the ability to detect a prescribed difference in effect size for the parameter of interest (CPUE, abundance, etc.). An estimate of the variability for each sampling gear is necessary to 1) properly determine the sample size needed; 2) meet the desired level of precision; 3) describe attributes of the mean or level of change in the mean; and 4) estimate statistical power (1-β).

3 Whether to continue to use existing (usually non-random) survey reaches or whether to switch to new, randomly-distributed survey reaches does not have a clear-cut answer, as there are advantages and disadvantages to either decision. In general, if no surveys have been conducted, it is obviously best to select new reaches at random. However, continued use of existing survey reaches (originally selected non-randomly) that have been repeatedly visited over many years (perhaps decades) will probably be more informative than switching completely to randomly-based sampling, especially if one can assume the existing reaches are generally representative of the body of water being surveyed. Moreover, if the goal of your work is to compare CPUE over time at that particular body of water, rather than compare results to other bodies of water (which have been surveyed in a random manner), then the existing 'sentinel' sites should continue to be sampled. However, it is difficult to justify inferences from data gathered at non-randomly sampled reaches to the entire body of water.

Several ways exist to describe confidence level and statistical power. Confidence level (α) may be most clearly described as the probability of determining that a difference **exists** when, in fact, there is no difference (i.e., committing a type I error). Confidence level is usually set as $\alpha = 0.05$, although $\alpha = 0.10$ is probably more useful for many fisheries surveys conducted for research and management purposes. Statistical power (1-β) is described as the probability of determining that a difference **does not exist** when, in fact, there is a true difference (i.e., committing a type II error). Statistical power for biological comparisons is usually acceptable at $1-\beta = 0.8$, but the statistical power of a test is often overlooked and usually is much lower.

Another consideration that must be taken into account is whether to use one-tailed or two-tailed tests. Whenever you conduct any standard test of statistical significance, you must first decide whether the test should be one-tailed or two-tailed. Anytime you expect a relationship to be directional (i.e., to go one specific way), you should probably use a one-tailed test. For example, if you initiate a slot limit on a bass population to increase the mean size of fish in the population, you might want to test whether mean size (or Proportional Stock Density, etc.) increased a few years after the regulation was in place.

A two-tailed hypothesis predicts that there was a difference between groups, but would make no reference to the direction of the effect. In general, most standard lake surveys are conducted to compare populations over time, with no specific expectations of increasing or decreasing CPUE, fish size, or other population metrics. Therefore, in most cases, you would want to use a two-tailed test. Examples and tables herein provide one-tailed and two-tailed information to allow versatility in your comparisons.

If no previous surveys are available, use professional judgment to determine sample sizes for the initial survey, or use the suggested number of sampling units depending on the size of the body of water (Table 1). If the body of water is surveyed again, the variability from the existing data can be used to estimate statistical power and sample size. If variability estimates from previous surveys are available, estimate the number of sample sites per body of water or strata necessary to estimate CPUE within certain bounds from Table 2 or by using the following equation modified from Willis (1998)4:

$$n = \left(\frac{t}{a} \frac{SD}{\bar{x}} \right)^2$$

Where:
- n = sample size required
- t = 2-tail *t*-value from a t-table at n-1 degrees of freedom for a desired sample size (1.96 for 95% confidence; 1.65 for 90% confidence; 1.26 for 80% confidence; and 1.04 for 70% confidence)
- SD = standard deviation (square root of the variance)
- $\bar{x}$ = mean CPUE (or other parameter of interest)
- a = precision desired in describing the mean, expressed as a proportion

4 The standard deviation divided by the mean, also called the coefficient of variation (CV), is a common measure of variability in data (see Zar 1996). The mean and standard deviation can be calculated easily in the field and these equations can be used to verify the proper number of required samples.

Example:

Megallon Pond, a new 200 acre fishing pond was constructed three years ago and stocked with largemouth bass and bluegill. No official surveys have been completed. The local biologist wants a general overview of the largemouth bass population by determining the CPUE. The biologist believes the best sampling method is electrofishing, but is not sure how many sites to sample for a proper survey. Because no previous information exists, the biologist decides to electrofish five sites to estimate the level of variability to further determine the number of sample sites required to estimate CPUE with 95% confidence and a precision level of 25%. The biologist captures 123, 47, 55, 103, and 110 largemouth bass, respectively. The biologist uses a calculator to determine the mean ($\overline{x}$ = 87.6) and the standard deviation (SD = 34.3). The coefficient of variation (SD/ $\overline{x}$) is 0.39. Using the above equation:

t = 1.96, the t-value for 95% confidence
SD = 34.3, the calculated standard deviation
$\overline{x}$ = 87.6, the mean number of largemouth bass collected per electrofishing site
a = 0.25, level of precision desired in describing the mean (25%).

$$n = (\frac{1.96}{0.25}\frac{34.3}{87.6})^2$$
$$n = 9.42$$

The number of sites necessary to sample to meet the biologist's requirements with the measured variability is 9 or 10. The biologist could also look in Table 2 where SD/ $\overline{x}$ = 0.39 and go to the column for 95% confidence and a precision of 25% and find the number of sites necessary = 10.

If the purpose of the sampling is to measure a degree of change in the desired metric, then find in Tables 3-5 the number of samples required to estimate a mean with different levels of confidence (α), statistical power (1-β), and variability (coefficient of variation = SD/ $\overline{x}$), or use the following equation from Parkinson et al. (1988):

$$n = \frac{100^2 k (\frac{SD}{\overline{x}})^2}{A^2}$$

Where: *n* = sample size required

k = multiplication constant from Table 6

SD = standard deviation

$\overline{x}$ = mean CPUE (could also be length-at-age, condition, etc.)

A = percent change to be detected

The value of the constant *k* accounts for both the statistical power (1-β) of the test and the desired degree of confidence (α).

Example:

Five years have passed since the last survey of Megallon Pond. A new biologist wants to perform a survey and compare the current estimate of CPUE for the population of largemouth bass with the estimate from the last survey. The biologist wants the ability to detect a difference in the mean CPUE of 25%, at a 90% confidence level and 80% power. The final variability (SD/ $\overline{x}$) estimated from the previous survey was 0.50. Looking at Table 4 (for 90% confidence, 2-tail) the biologist finds 0.50 in the SD/ $\overline{x}$ column, then moves over to the column for 80% power and a 25% detectable difference and finds that 36 sample sites are required to meet the objectives the biologist desires. Being realistic, the biologist understands that 36 sample sites may not be reasonable for a small pond, but looking at Table 4 further, finds that 9 sites will provide the ability to detect a 50% difference and provide 80% power with 90% confidence.

SAMPLE SITE LOCATIONS

Electrofishing and Trap Nets

- After estimating the proper number of sites to sample, randomly choose a starting point on the body of water.
- Determine the shoreline length and divide it into *x* number of 500 m increments. The distance of 500 m is approximately the maximum length of shoreline that can be electrofished during one unit of sampling (see example below). Randomly select, from all available 500 m sections, the number of sites determined above.
- You may use these sites to place trap nets also, or randomly choose new sites following the same procedure.
- If you decide to use the same sites, place trap nets a reasonable distance5 (at least 100 m) from the starting point of electrofishing in the opposite direction to avoid electrofishing through the net.
- If the body of water is small enough that the entire shoreline can be electrofished, randomly choose sites for the trap and gill nets. While electrofishing, be careful to avoid shocking within a reasonable distance of nets, keeping at least 100 m between the electrofisher and the net location.
- If the body of water is stratified, randomly assign sample sites following the procedures outlined previously for each stratum.

Example:

Big Lake has a shoreline distance of 10,000 m, which results in 20, 500 m sections. Based on the variance from previous surveys, five sites must be sampled to achieve the desired precision. From the 20 possible sites, you randomly choose sites 4, 7, 13, 15, and 17. For the first site, beginning at the starting point, measure 4, 500 m sections (2,000 m) along the shoreline. Mark the point on the map which will be the first sample site. Continue for each corresponding site.

5 The purpose of staying a reasonable distance away from nets along shore is to avoid changing (because of the electrofishing) the behavior of fish with the potential to be captured in the net. If 100 m appears to be too close or far away, then increase or decrease the distance.

Gill Nets

- Gill nets may be placed near locations chosen for electrofishing and trap net sites. However, if pelagic species are present in the body of water, sites for gill nets should be chosen from throughout the body of water.
- The recommended method of placing gill net sites is to use a map and grid system made up of squares that overlay the body of water. Determine the number of squares and randomly select, from all available squares, the number of sites required as calculated previously.
- The recommended size of the squares are 100 X 100 m (1 hectare) on bodies of water up to 5,000 ha and 500 X 500 m squares on bodies of water over 5,000 ha.[6]
- Placing a grid on a map is simple using map software such as TOPO! or All Topo. Map applications allow you to enter the size of the grid pattern and overlay the grid on the map. If map software is unavailable, use the scale from a printed map and draw a grid over the body of water.
- Once the squares for sampling have been identified using map software, place a point in the center of the squares on the map. Points can then be downloaded or entered by hand into a Global Positioning System (GPS) unit to locate the site in the field.
- Set a floating and a sinking gill net at the predetermined site. If curtain or suspended gill nets were used in previous surveys, the same type of net should be used for subsequent sampling.

SAMPLING PROCEDURES

Electrofishing

- Begin electrofishing shortly after dusk for the highest catch rates. Beginning at the predetermined site, electrofish the shoreline in one direction for 600 s measured from the timer on the electrofishing boat. Always record the actual number of seconds shocked on datasheets.
- Operation of the pedal to activate the electric field during electrofishing is the one action that has the greatest influence on the number of fish captured during a sampling event, yet can vary greatly between operators. Operating the pedal consistently from survey to survey will ensure the comparability between surveys.
- While electrofishing, operate the pedal to activate the electric field in a manner that maximizes catch; do not just keep the pedal on for 600 s. In bodies of water with relatively steep sides, let off the pedal while maneuvering the boat in water that is too deep for effective shocking, and re-activate the electricity when approaching shore to drive and hold fish in shallower water where they can be netted. Likewise, if there is structure that may hold fish, activate the electricity when the probes are over the structure for maximum effectiveness. Approaching cover with the electric field activated may drive fish away. If the body of water has large areas of relatively shallow water such as flats or bays, the pedal can be activated most of the time, but having the electricity on

6 In Florida, a grid pattern is used to randomly choose sites in pelagic areas of water bodies (Bonvechio 2009). The use of 100 m and 500 m grids are easiest to use in TOPO! software, but any size could be used. Using a grid is recommended, but any method that provides random sites can be used.

constantly may cause fish to flee, whereas cycling the electricity on and off will likely increase catch (Bonar and Divens 2000).

- Net EVERYTHING, even young-of-year fish. Selective netting of different sizes or species of fish may invalidate comparisons made with the data. If selective netting is conducted, record how it was done so future comparisons can be made accordingly.
- After shocking 600 s, stop and process fish. Be sure to release fish offshore or away from the sampled area. Do not release fish near trap nets or gill nets. The 600 s of electrofishing is the sample unit, and the fish captured during the 600 s is the response variable for statistical purposes, expanded to fish/h for CPUE.
- Only electrofish an area one time during a sampling event. Sampling the same area repeatedly may result in a biased catch and would likely invalidate comparisons with surveys where sections were electrofished once.
- At bodies of water where the entire shoreline can be electrofished, choose a starting point and shock in one direction. Shock for 600 s, stop and process fish, then continue shocking from the stopping point. As you approach the beginning, only shock to the location where you started, then stop. Record the seconds spent shocking in the final section.

Trap Nets

- Set trap nets at the location by anchoring the lead to shore and pull the trap box perpendicular to shore with a weight attached to the cod end of the trap. Set the net so the lead and trap box are stretched taut to keep the box upright. Attach a float line to either the cod end or to the top of the box frame. Use your best judgment when deciding how deep the trap box is set. The preferred depth is within a meter of the surface; however, up to 5 m is acceptable. If the bank is steep, shorten the lead and pile the excess on shore so the trap box sits in shallower water.
- Record the set and pick-up time.
- Fish the nets overnight for a minimum of 12 hours, then process and record fish information from each net separately.
- If trap netting more than one night, move nets to different locations each night. Ten trap nets per night is usually reasonable given space available for transport in vehicles and on boats, the time required to set and move nets, time to process fish, and the size of the body of water.

Gill Nets

- Set gill nets at randomly chosen locations. **If sites are near shore, set nets perpendicular to shore with the smallest mesh closest to the bank.**
- Record the set and pickup time.
- Fish gill nets overnight for a minimum of 12 hours, then process and record fish information from each net separately (not as a pair).
- Like trap nets, after fishing one location overnight, move gill nets to the next location.

- If excessive numbers of certain species are expected to be captured in gill nets, use your best judgment to balance the needs of the survey with the available time and manpower when deciding on the number of gill nets to use.
- If the body of water is stratified, sites should be located separately for each strata.

FISH PROCESSING

- **Record and report fish information separately for each 600 s electrofishing period, each trap net fished for a night, and each individual gill net fished for a night. DO NOT pool data from different electrofishing sections, net sets, or gears.** Pooling data for electrofishing sections or net sets precludes the calculation of variance estimates necessary for comparisons to other surveys. Likewise, pooling data between gears will invalidate any comparisons between years or bodies of water because of the catch bias associated with the individual gears.
- Identify all fish to species. Create booklets with keys, identifying features, diagrams, or photos of the species that reside in the bodies of water to aid identification in the field. Identification materials are especially helpful to inexperienced workers. If positive identification cannot be made, save several individuals in formalin or alcohol to preserve them for later identification in the lab.
- Measure the total length of all fish captured (mm). When excessive numbers of similarly sized fish (usually young-of-year) of the same species are captured, measure at least 50 and count the rest.
- Weigh at least five fish per 10 mm length group. It does not matter what gear type caught the fish.
- If age estimates for fish are to be made, obtain aging structures from 5-10 fish per 10 mm length group. Remove the structure that is most effective. Usually, otoliths provide the most accurate age estimates, but scales (centrarchids) or fin rays (ictalurids) may be used for some species. Only otoliths should be used for salmonids.
- Make sure to bring materials (i.e., scale envelopes, micro vials for otoliths, dissection tools, etc.) for removal and storage of age structures in the field. If you plan to bring fish to the lab, have storage bags, coolers, and ice to preserve the fish until they can be processed or frozen.

PHYSICAL DATA

Several other metrics should also be collected as a measure of the overall conditions during a survey:

- Air temperature (°C).
- Water temperature (°C; surface).
- Conductivity (µS/cm).
- Secchi depth. Make three measurements and calculate the average.
- GPS coordinates for the individual sample locations of electrofishing transects, trap nets, and gill nets. Lat/Long in decimal degrees.

- Electrofishing boat settings. Include hertz, pulses, voltage, amps, or watts if available.
- Weather conditions. Wind direction, cloudy/clear, etc.
- Body of water storage capacity, reservoir level.
- If you have the measuring equipment, collect other water chemistry metrics, such as dissolved oxygen, pH, total dissolved solids, and chlorophyll a, or measure the full water column profile.
- When deemed necessary, collect zooplankton samples to calculate zooplankton ratio (ZPR) and zooplankton quality index (ZQI).
- When conducting a focused survey, collect any additional information required.

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Table 1. Suggested number of sample sites for different sized-bodies of water.

		Number of sample units/night		
Body of water Size (ha)	**Nights**	**Electrofishing (600 s)**	**Trap Net**	**Gill Net (pair)**
1 - 50	1	Entire shoreline	5	2
51 - 100	2	Entire shoreline	5	2
101 - 500	2 - 3	6	10	5
501 - 1000	3	6	10	5
> 1000	3+	6 - 10	10	5

Table 2. Sample sizes required to estimate a mean for different confidence levels (2-tail and 1-tail tests) at a desired precision (5%, 10%, 25%, 50%, 100%, and 200%) using different levels of variability (SD/ $\bar{x}$; coefficient of variation).

	Confidence																	
	80% (2-tail); 90% (1-tail)						90% (2-tail); 95% (1-tail)						95% (2-tail); 97.5% (1-tail)					
	Precision (%)						Precision (%)						Precision (%)					
SD/ $\bar{x}$	5	10	25	50	100	200	5	10	25	50	100	200	5	10	25	50	100	200
0.1	7	2	0	0	0	0	11	3	0	0	0	0	15	4	1	0	0	0
0.15	15	4	1	0	0	0	24	6	1	0	0	0	35	9	1	0	0	0
0.2	26	7	1	0	0	0	43	11	2	0	0	0	61	15	2	1	0	0
0.25	41	10	2	0	0	0	68	17	3	1	0	0	96	24	4	1	0	0
0.3	59	15	2	1	0	0	97	24	4	1	0	0	138	35	6	1	0	0
0.35	81	20	3	1	0	0	133	33	5	1	0	0	188	47	8	2	0	0
0.4	105	26	4	1	0	0	173	43	7	2	0	0	246	61	10	2	1	0
0.45	133	33	5	1	0	0	219	55	9	2	1	0	311	78	12	3	1	0
0.5	164	41	7	2	0	0	271	68	11	3	1	0	384	96	15	4	1	0
0.55	199	50	8	2	0	0	327	82	13	3	1	0	465	116	19	5	1	0
0.6	237	59	9	2	1	0	390	97	16	4	1	0	553	138	22	6	1	0
0.65	278	69	11	3	1	0	457	114	18	5	1	0	649	162	26	6	2	0
0.7	322	81	13	3	1	0	530	133	21	5	1	0	753	188	30	8	2	0
0.75	370	92	15	4	1	0	609	152	24	6	2	0	864	216	35	9	2	1
0.8	421	105	17	4	1	0	693	173	28	7	2	0	983	246	39	10	2	1
0.85	475	119	19	5	1	0	782	196	31	8	2	0	1110	278	44	11	3	1
0.9	533	133	21	5	1	0	877	219	35	9	2	1	1245	311	50	12	3	1
0.95	593	148	24	6	1	0	977	244	39	10	2	1	1387	347	55	14	3	1
1	657	164	26	7	2	0	1082	271	43	11	3	1	1537	384	61	15	4	1
1.05	725	181	29	7	2	0	1193	298	48	12	3	1	1694	424	68	17	4	1
1.1	795	199	32	8	2	0	1310	327	52	13	3	1	1859	465	74	19	5	1
1.15	869	217	35	9	2	1	1431	358	57	14	4	1	2032	508	81	20	5	1
1.2	947	237	38	9	2	1	1559	390	62	16	4	1	2213	553	89	22	6	1
1.25	1027	257	41	10	3	1	1691	423	68	17	4	1	2401	600	96	24	6	2
1.3	1111	278	44	11	3	1	1829	457	73	18	5	1	2597	649	104	26	6	2
1.35	1198	300	48	12	3	1	1973	493	79	20	5	1	2801	700	112	28	7	2
1.4	1289	322	52	13	3	1	2122	530	85	21	5	1	3012	753	120	30	8	2
1.45	1382	346	55	14	3	1	2276	569	91	23	6	1	3231	808	129	32	8	2
1.5	1479	370	59	15	4	1	2435	609	97	24	6	2	3457	864	138	35	9	2
1.55	1579	395	63	16	4	1	2600	650	104	26	7	2	3692	923	148	37	9	2
1.6	1683	421	67	17	4	1	2771	693	111	28	7	2	3934	983	157	39	10	2
1.65	1790	447	72	18	4	1	2947	737	118	29	7	2	4184	1046	167	42	10	3
1.7	1900	475	76	19	5	1	3128	782	125	31	8	2	4441	1110	178	44	11	3
1.75	2013	503	81	20	5	1	3315	829	133	33	8	2	4706	1176	188	47	12	3
1.8	2130	533	85	21	5	1	3507	877	140	35	9	2	4979	1245	199	50	12	3
1.85	2250	562	90	22	6	1	3705	926	148	37	9	2	5259	1315	210	53	13	3
1.9	2373	593	95	24	6	1	3908	977	156	39	10	2	5547	1387	222	55	14	3
1.95	2500	625	100	25	6	2	4116	1029	165	41	10	3	5843	1461	234	58	15	4
2	2630	657	105	26	7	2	4330	1082	173	43	11	3	6147	1537	246	61	15	4
2.05	2763	691	111	28	7	2	4549	1137	182	45	11	3	6458	1614	258	65	16	4
2.1	2899	725	116	29	7	2	4773	1193	191	48	12	3	6777	1694	271	68	17	4
2.15	3039	760	122	30	8	2	5003	1251	200	50	13	3	7103	1776	284	71	18	4
2.2	3182	795	127	32	8	2	5239	1310	210	52	13	3	7437	1859	297	74	19	5
2.25	3328	832	133	33	8	2	5480	1370	219	55	14	3	7779	1945	311	78	19	5
2.3	3478	869	139	35	9	2	5726	1431	229	57	14	4	8129	2032	325	81	20	5
2.35	3631	908	145	36	9	2	5978	1494	239	60	15	4	8486	2122	339	85	21	5
2.4	3787	947	151	38	9	2	6235	1559	249	62	16	4	8851	2213	354	89	22	6
2.45	3946	987	158	39	10	2	6497	1624	260	65	16	4	9224	2306	369	92	23	6
2.5	4109	1027	164	41	10	3	6765	1691	271	68	17	4	9604	2401	384	96	24	6

Table 3. Sample sizes required with 80% confidence (2-tail) or 90% confidence (1-tail) to detect a desired difference (10%, 25%, 50%, 100%, and 200%) in a mean using different levels of variability (SD/$\bar{x}$; coefficient of variation) and power (80%, 90%, and 95%).

	80% Power						90% Power						95% Power					
	Detectable difference (%)						Detectable difference (%)						Detectable difference (%)					
SD/$\bar{x}$	10	25	30	50	100	200	10	25	30	50	100	200	10	25	30	50	100	200
0.1	9	1	1	0	0	0	13	2	1	1	0	0	17	3	2	1	0	0
0.11	11	2	1	0	0	0	16	3	2	1	0	0	21	3	2	1	0	0
0.12	13	2	1	1	0	0	19	3	2	1	0	0	25	4	3	1	0	0
0.13	15	2	2	1	0	0	22	4	2	1	0	0	29	5	3	1	0	0
0.14	18	3	2	1	0	0	26	4	3	1	0	0	34	5	4	1	0	0
0.15	20	3	2	1	0	0	30	5	3	1	0	0	39	6	4	2	0	0
0.16	23	4	3	1	0	0	34	5	4	1	0	0	44	7	5	2	0	0
0.17	26	4	3	1	0	0	38	6	4	2	0	0	50	8	6	2	0	0
0.18	29	5	3	1	0	0	43	7	5	2	0	0	56	9	6	2	1	0
0.19	33	5	4	1	0	0	47	8	5	2	0	0	62	10	7	2	1	0
0.2	36	6	4	1	0	0	53	8	6	2	1	0	69	11	8	3	1	0
0.21	40	6	4	2	0	0	58	9	6	2	1	0	76	12	8	3	1	0
0.22	44	7	5	2	0	0	64	10	7	3	1	0	83	13	9	3	1	0
0.23	48	8	5	2	0	0	70	11	8	3	1	0	91	14	10	4	1	0
0.24	52	8	6	2	1	0	76	12	8	3	1	0	99	16	11	4	1	0
0.25	56	9	6	2	1	0	82	13	9	3	1	0	107	17	12	4	1	0
0.26	61	10	7	2	1	0	89	14	10	4	1	0	116	19	13	5	1	0
0.27	66	11	7	3	1	0	96	15	11	4	1	0	125	20	14	5	1	0
0.28	71	11	8	3	1	0	103	16	11	4	1	0	134	21	15	5	1	0
0.29	76	12	8	3	1	0	111	18	12	4	1	0	144	23	16	6	1	0
0.3	81	13	9	3	1	0	118	19	13	5	1	0	154	25	17	6	2	0
0.31	87	14	10	3	1	0	126	20	14	5	1	0	165	26	18	7	2	0
0.32	92	15	10	4	1	0	135	22	15	5	1	0	175	28	19	7	2	0
0.33	98	16	11	4	1	0	143	23	16	6	1	0	187	30	21	7	2	0
0.34	104	17	12	4	1	0	152	24	17	6	2	0	198	32	22	8	2	0
0.35	110	18	12	4	1	0	161	26	18	6	2	0	210	34	23	8	2	1
0.36	117	19	13	5	1	0	170	27	19	7	2	0	222	36	25	9	2	1
0.37	123	20	14	5	1	0	180	29	20	7	2	0	235	38	26	9	2	1
0.38	130	21	14	5	1	0	190	30	21	8	2	0	247	40	27	10	2	1
0.39	137	22	15	5	1	0	200	32	22	8	2	0	261	42	29	10	3	1
0.4	144	23	16	6	1	0	210	34	23	8	2	1	274	44	30	11	3	1
0.41	152	24	17	6	2	0	221	35	25	9	2	1	288	46	32	12	3	1
0.42	159	25	18	6	2	0	232	37	26	9	2	1	302	48	34	12	3	1
0.43	167	27	19	7	2	0	243	39	27	10	2	1	317	51	35	13	3	1
0.44	175	28	19	7	2	0	254	41	28	10	3	1	332	53	37	13	3	1
0.45	183	29	20	7	2	0	266	43	30	11	3	1	347	56	39	14	3	1
0.46	191	31	21	8	2	0	278	44	31	11	3	1	362	58	40	14	4	1
0.47	199	32	22	8	2	0	290	46	32	12	3	1	378	61	42	15	4	1
0.48	208	33	23	8	2	1	303	48	34	12	3	1	395	63	44	16	4	1
0.49	217	35	24	9	2	1	315	50	35	13	3	1	411	66	46	16	4	1
0.5	226	36	25	9	2	1	329	53	37	13	3	1	428	69	48	17	4	1
0.51	235	38	26	9	2	1	342	55	38	14	3	1	446	71	50	18	4	1
0.52	244	39	27	10	2	1	355	57	39	14	4	1	463	74	51	19	5	1
0.53	253	41	28	10	3	1	369	59	41	15	4	1	481	77	53	19	5	1
0.54	263	42	29	11	3	1	383	61	43	15	4	1	500	80	56	20	5	1
0.55	273	44	30	11	3	1	397	64	44	16	4	1	518	83	58	21	5	1
0.56	283	45	31	11	3	1	412	66	46	16	4	1	537	86	60	21	5	1
0.57	293	47	33	12	3	1	427	68	47	17	4	1	557	89	62	22	6	1

Table 3. Continued.

	80% Power						90% Power						95% Power					
	Detectable difference (%)						Detectable difference (%)						Detectable difference (%)					
$SD/\bar{x}$	10	25	30	50	100	200	10	25	30	50	100	200	10	25	30	50	100	200
0.58	303	49	34	12	3	1	442	71	49	18	4	1	576	92	64	23	6	1
0.59	314	50	35	13	3	1	457	73	51	18	5	1	596	95	66	24	6	1
0.6	325	52	36	13	3	1	473	76	53	19	5	1	617	99	69	25	6	2
0.61	336	54	37	13	3	1	489	78	54	20	5	1	637	102	71	25	6	2
0.62	347	55	39	14	3	1	505	81	56	20	5	1	658	105	73	26	7	2
0.63	358	57	40	14	4	1	522	83	58	21	5	1	680	109	76	27	7	2
0.64	369	59	41	15	4	1	538	86	60	22	5	1	702	112	78	28	7	2
0.65	381	61	42	15	4	1	555	89	62	22	6	1	724	116	80	29	7	2
0.66	393	63	44	16	4	1	572	92	64	23	6	1	746	119	83	30	7	2
0.67	405	65	45	16	4	1	590	94	66	24	6	1	769	123	85	31	8	2
0.68	417	67	46	17	4	1	608	97	68	24	6	2	792	127	88	32	8	2
0.69	429	69	48	17	4	1	626	100	70	25	6	2	816	130	91	33	8	2
0.7	442	71	49	18	4	1	644	103	72	26	6	2	839	134	93	34	8	2
0.75	507	81	56	20	5	1	739	118	82	30	7	2	964	154	107	39	10	2
0.8	577	92	64	23	6	1	841	135	93	34	8	2	1096	175	122	44	11	3
0.85	652	104	72	26	7	2	949	152	105	38	9	2	1238	198	138	50	12	3
0.9	731	117	81	29	7	2	1064	170	118	43	11	3	1388	222	154	56	14	3
0.95	814	130	90	33	8	2	1186	190	132	47	12	3	1546	247	172	62	15	4
1	902	144	100	36	9	2	1314	210	146	53	13	3	1713	274	190	69	17	4
1.05	994	159	110	40	10	2	1449	232	161	58	14	4	1889	302	210	76	19	5
1.1	1091	175	121	44	11	3	1590	254	177	64	16	4	2073	332	230	83	21	5
1.15	1193	191	133	48	12	3	1738	278	193	70	17	4	2265	362	252	91	23	6
1.2	1299	208	144	52	13	3	1892	303	210	76	19	5	2467	395	274	99	25	6
1.25	1409	226	157	56	14	4	2053	329	228	82	21	5	2677	428	297	107	27	7
1.3	1524	244	169	61	15	4	2221	355	247	89	22	6	2895	463	322	116	29	7
1.35	1644	263	183	66	16	4	2395	383	266	96	24	6	3122	500	347	125	31	8
1.4	1768	283	196	71	18	4	2575	412	286	103	26	6	3357	537	373	134	34	8
1.45	1896	303	211	76	19	5	2763	442	307	111	28	7	3602	576	400	144	36	9
1.5	2030	325	226	81	20	5	2957	473	329	118	30	7	3854	617	428	154	39	10
1.55	2167	347	241	87	22	5	3157	505	351	126	32	8	4115	658	457	165	41	10
1.6	2309	369	257	92	23	6	3364	538	374	135	34	8	4385	702	487	175	44	11
1.65	2456	393	273	98	25	6	3577	572	397	143	36	9	4664	746	518	187	47	12
1.7	2607	417	290	104	26	7	3797	608	422	152	38	9	4951	792	550	198	50	12
1.75	2762	442	307	110	28	7	4024	644	447	161	40	10	5246	839	583	210	52	13
1.8	2922	468	325	117	29	7	4257	681	473	170	43	11	5550	888	617	222	56	14
1.85	3087	494	343	123	31	8	4497	720	500	180	45	11	5863	938	651	235	59	15
1.9	3256	521	362	130	33	8	4744	759	527	190	47	12	6184	989	687	247	62	15
1.95	3430	549	381	137	34	9	4996	799	555	200	50	12	6514	1042	724	261	65	16
2	3608	577	401	144	36	9	5256	841	584	210	53	13	6852	1096	761	274	69	17
2.05	3791	607	421	152	38	9	5522	884	614	221	55	14	7199	1152	800	288	72	18
2.1	3978	636	442	159	40	10	5795	927	644	232	58	14	7554	1209	839	302	76	19
2.15	4169	667	463	167	42	10	6074	972	675	243	61	15	7918	1267	880	317	79	20
2.2	4366	699	485	175	44	11	6360	1018	707	254	64	16	8291	1327	921	332	83	21
2.25	4566	731	507	183	46	11	6652	1064	739	266	67	17	8672	1388	964	347	87	22
2.3	4772	763	530	191	48	12	6951	1112	772	278	70	17	9062	1450	1007	362	91	23
2.35	4981	797	553	199	50	12	7257	1161	806	290	73	18	9460	1514	1051	378	95	24
2.4	5196	831	577	208	52	13	7569	1211	841	303	76	19	9867	1579	1096	395	99	25
2.45	5414	866	602	217	54	14	7887	1262	876	315	79	20	10282	1645	1142	411	103	26
2.5	5638	902	626	226	56	14	8213	1314	913	329	82	21	10706	1713	1190	428	107	27

Table 4. Sample sizes required with 90% confidence (2-tail) or 95% confidence (1-tail) to detect a desired difference (10%, 25%, 50%, 100%, and 200%) in a mean using different levels of variability (SD/ $\bar{x}$; coefficient of variation) and power (80%, 90%, and 95%).

	80% Power						90% Power						95% Power					
	Detectable difference (%)						Detectable difference (%)						Detectable difference (%)					
SD/ $\bar{x}$	10	25	30	50	100	200	10	25	30	50	100	200	10	25	30	50	100	200
0.1	12	2	1	0	0	0	17	3	2	1	0	0	22	3	2	1	0	0
0.11	15	2	2	1	0	0	21	3	2	1	0	0	26	4	3	1	0	0
0.12	18	3	2	1	0	0	25	4	3	1	0	0	31	5	3	1	0	0
0.13	21	3	2	1	0	0	29	5	3	1	0	0	37	6	4	1	0	0
0.14	24	4	3	1	0	0	34	5	4	1	0	0	42	7	5	2	0	0
0.15	28	4	3	1	0	0	39	6	4	2	0	0	49	8	5	2	0	0
0.16	32	5	4	1	0	0	44	7	5	2	0	0	55	9	6	2	1	0
0.17	36	6	4	1	0	0	50	8	6	2	0	0	63	10	7	3	1	0
0.18	40	6	4	2	0	0	56	9	6	2	1	0	70	11	8	3	1	0
0.19	45	7	5	2	0	0	62	10	7	2	1	0	78	13	9	3	1	0
0.2	49	8	5	2	0	0	69	11	8	3	1	0	87	14	10	3	1	0
0.21	55	9	6	2	1	0	76	12	8	3	1	0	95	15	11	4	1	0
0.22	60	10	7	2	1	0	83	13	9	3	1	0	105	17	12	4	1	0
0.23	65	10	7	3	1	0	91	14	10	4	1	0	115	18	13	5	1	0
0.24	71	11	8	3	1	0	99	16	11	4	1	0	125	20	14	5	1	0
0.25	77	12	9	3	1	0	107	17	12	4	1	0	135	22	15	5	1	0
0.26	84	13	9	3	1	0	116	19	13	5	1	0	146	23	16	6	1	0
0.27	90	14	10	4	1	0	125	20	14	5	1	0	158	25	18	6	2	0
0.28	97	16	11	4	1	0	134	21	15	5	1	0	170	27	19	7	2	0
0.29	104	17	12	4	1	0	144	23	16	6	1	0	182	29	20	7	2	0
0.3	111	18	12	4	1	0	154	25	17	6	2	0	195	31	22	8	2	0
0.31	119	19	13	5	1	0	165	26	18	7	2	0	208	33	23	8	2	1
0.32	127	20	14	5	1	0	175	28	19	7	2	0	222	35	25	9	2	1
0.33	135	22	15	5	1	0	187	30	21	7	2	0	236	38	26	9	2	1
0.34	143	23	16	6	1	0	198	32	22	8	2	0	250	40	28	10	3	1
0.35	152	24	17	6	2	0	210	34	23	8	2	1	265	42	29	11	3	1
0.36	160	26	18	6	2	0	222	36	25	9	2	1	281	45	31	11	3	1
0.37	169	27	19	7	2	0	235	38	26	9	2	1	296	47	33	12	3	1
0.38	179	29	20	7	2	0	247	40	27	10	2	1	313	50	35	13	3	1
0.39	188	30	21	8	2	0	261	42	29	10	3	1	329	53	37	13	3	1
0.4	198	32	22	8	2	0	274	44	30	11	3	1	346	55	38	14	3	1
0.41	208	33	23	8	2	1	288	46	32	12	3	1	364	58	40	15	4	1
0.42	218	35	24	9	2	1	302	48	34	12	3	1	382	61	42	15	4	1
0.43	229	37	25	9	2	1	317	51	35	13	3	1	400	64	44	16	4	1
0.44	239	38	27	10	2	1	332	53	37	13	3	1	419	67	47	17	4	1
0.45	250	40	28	10	3	1	347	56	39	14	3	1	438	70	49	18	4	1
0.46	262	42	29	10	3	1	362	58	40	14	4	1	458	73	51	18	5	1
0.47	273	44	30	11	3	1	378	61	42	15	4	1	478	77	53	19	5	1
0.48	285	46	32	11	3	1	395	63	44	16	4	1	499	80	55	20	5	1
0.49	297	48	33	12	3	1	411	66	46	16	4	1	520	83	58	21	5	1
0.5	309	49	34	12	3	1	428	69	48	17	4	1	541	87	60	22	5	1
0.51	322	51	36	13	3	1	446	71	50	18	4	1	563	90	63	23	6	1
0.52	334	54	37	13	3	1	463	74	51	19	5	1	585	94	65	23	6	1
0.53	347	56	39	14	3	1	481	77	53	19	5	1	608	97	68	24	6	2
0.54	361	58	40	14	4	1	500	80	56	20	5	1	631	101	70	25	6	2
0.55	374	60	42	15	4	1	518	83	58	21	5	1	655	105	73	26	7	2
0.56	388	62	43	16	4	1	537	86	60	21	5	1	679	109	75	27	7	2
0.57	402	64	45	16	4	1	557	89	62	22	6	1	703	113	78	28	7	2

Table 4. Continued.

	80% Power						90% Power						95% Power					
	Detectable difference (%)						Detectable difference (%)						Detectable difference (%)					
$SD/\bar{x}$	10	25	30	50	100	200	10	25	30	50	100	200	10	25	30	50	100	200
0.58	416	67	46	17	4	1	576	92	64	23	6	1	728	117	81	29	7	2
0.59	431	69	48	17	4	1	596	95	66	24	6	1	754	121	84	30	8	2
0.6	445	71	49	18	4	1	617	99	69	25	6	2	779	125	87	31	8	2
0.61	460	74	51	18	5	1	637	102	71	25	6	2	806	129	90	32	8	2
0.62	476	76	53	19	5	1	658	105	73	26	7	2	832	133	92	33	8	2
0.63	491	79	55	20	5	1	680	109	76	27	7	2	859	137	95	34	9	2
0.64	507	81	56	20	5	1	702	112	78	28	7	2	887	142	99	35	9	2
0.65	523	84	58	21	5	1	724	116	80	29	7	2	915	146	102	37	9	2
0.66	539	86	60	22	5	1	746	119	83	30	7	2	943	151	105	38	9	2
0.67	555	89	62	22	6	1	769	123	85	31	8	2	972	155	108	39	10	2
0.68	572	92	64	23	6	1	792	127	88	32	8	2	1001	160	111	40	10	3
0.69	589	94	65	24	6	1	816	130	91	33	8	2	1031	165	115	41	10	3
0.7	606	97	67	24	6	2	839	134	93	34	8	2	1061	170	118	42	11	3
0.75	696	111	77	28	7	2	964	154	107	39	10	2	1218	195	135	49	12	3
0.8	792	127	88	32	8	2	1096	175	122	44	11	3	1386	222	154	55	14	3
0.85	894	143	99	36	9	2	1238	198	138	50	12	3	1564	250	174	63	16	4
0.9	1002	160	111	40	10	3	1388	222	154	56	14	3	1754	281	195	70	18	4
0.95	1116	179	124	45	11	3	1546	247	172	62	15	4	1954	313	217	78	20	5
1	1237	198	137	49	12	3	1713	274	190	69	17	4	2165	346	241	87	22	5
1.05	1364	218	152	55	14	3	1889	302	210	76	19	5	2387	382	265	95	24	6
1.1	1497	239	166	60	15	4	2073	332	230	83	21	5	2620	419	291	105	26	7
1.15	1636	262	182	65	16	4	2265	362	252	91	23	6	2863	458	318	115	29	7
1.2	1781	285	198	71	18	4	2467	395	274	99	25	6	3118	499	346	125	31	8
1.25	1933	309	215	77	19	5	2677	428	297	107	27	7	3383	541	376	135	34	8
1.3	2091	334	232	84	21	5	2895	463	322	116	29	7	3659	585	407	146	37	9
1.35	2254	361	250	90	23	6	3122	500	347	125	31	8	3946	631	438	158	39	10
1.4	2425	388	269	97	24	6	3357	537	373	134	34	8	4243	679	471	170	42	11
1.45	2601	416	289	104	26	7	3602	576	400	144	36	9	4552	728	506	182	46	11
1.5	2783	445	309	111	28	7	3854	617	428	154	39	10	4871	779	541	195	49	12
1.55	2972	476	330	119	30	7	4115	658	457	165	41	10	5201	832	578	208	52	13
1.6	3167	507	352	127	32	8	4385	702	487	175	44	11	5542	887	616	222	55	14
1.65	3368	539	374	135	34	8	4664	746	518	187	47	12	5894	943	655	236	59	15
1.7	3575	572	397	143	36	9	4951	792	550	198	50	12	6257	1001	695	250	63	16
1.75	3788	606	421	152	38	9	5246	839	583	210	52	13	6630	1061	737	265	66	17
1.8	4008	641	445	160	40	10	5550	888	617	222	56	14	7015	1122	779	281	70	18
1.85	4234	677	470	169	42	11	5863	938	651	235	59	15	7410	1186	823	296	74	19
1.9	4466	714	496	179	45	11	6184	989	687	247	62	15	7816	1251	868	313	78	20
1.95	4704	753	523	188	47	12	6514	1042	724	261	65	16	8232	1317	915	329	82	21
2	4948	792	550	198	49	12	6852	1096	761	274	69	17	8660	1386	962	346	87	22
2.05	5198	832	578	208	52	13	7199	1152	800	288	72	18	9098	1456	1011	364	91	23
2.1	5455	873	606	218	55	14	7554	1209	839	302	76	19	9548	1528	1061	382	95	24
2.15	5718	915	635	229	57	14	7918	1267	880	317	79	20	10008	1601	1112	400	100	25
2.2	5987	958	665	239	60	15	8291	1327	921	332	83	21	10479	1677	1164	419	105	26
2.25	6262	1002	696	250	63	16	8672	1388	964	347	87	22	10960	1754	1218	438	110	27
2.3	6544	1047	727	262	65	16	9062	1450	1007	362	91	23	11453	1832	1273	458	115	29
2.35	6831	1093	759	273	68	17	9460	1514	1051	378	95	24	11956	1913	1328	478	120	30
2.4	7125	1140	792	285	71	18	9867	1579	1096	395	99	25	12470	1995	1386	499	125	31
2.45	7425	1188	825	297	74	19	10282	1645	1142	411	103	26	12995	2079	1444	520	130	32
2.5	7731	1237	859	309	77	19	10706	1713	1190	428	107	27	13531	2165	1503	541	135	34

Table 5. Sample sizes required with 95% confidence (2-tail) or 97.5% confidence (1-tail) to detect a desired difference (10%, 25%, 50%, 100%, and 200%) in a mean using different levels of variability (SD/ $\bar{x}$; coefficient of variation) and power (80%, 90%, and 95%).

	80% Power						90% Power						95% Power					
	Detectable difference (%)						Detectable difference (%)						Detectable difference (%)					
SD/ $\bar{x}$	10	25	30	50	100	200	10	25	30	50	100	200	10	25	30	50	100	200
0.1	16	3	2	1	0	0	21	3	2	1	0	0	26	4	3	1	0	0
0.11	19	3	2	1	0	0	25	4	3	1	0	0	31	5	3	1	0	0
0.12	23	4	3	1	0	0	30	5	3	1	0	0	37	6	4	1	0	0
0.13	27	4	3	1	0	0	36	6	4	1	0	0	44	7	5	2	0	0
0.14	31	5	3	1	0	0	41	7	5	2	0	0	51	8	6	2	1	0
0.15	35	6	4	1	0	0	47	8	5	2	0	0	58	9	6	2	1	0
0.16	40	6	4	2	0	0	54	9	6	2	1	0	67	11	7	3	1	0
0.17	45	7	5	2	0	0	61	10	7	2	1	0	75	12	8	3	1	0
0.18	51	8	6	2	1	0	68	11	8	3	1	0	84	13	9	3	1	0
0.19	57	9	6	2	1	0	76	12	8	3	1	0	94	15	10	4	1	0
0.2	63	10	7	3	1	0	84	13	9	3	1	0	104	17	12	4	1	0
0.21	69	11	8	3	1	0	93	15	10	4	1	0	115	18	13	5	1	0
0.22	76	12	8	3	1	0	102	16	11	4	1	0	126	20	14	5	1	0
0.23	83	13	9	3	1	0	111	18	12	4	1	0	137	22	15	5	1	0
0.24	90	14	10	4	1	0	121	19	13	5	1	0	150	24	17	6	1	0
0.25	98	16	11	4	1	0	131	21	15	5	1	0	162	26	18	6	2	0
0.26	106	17	12	4	1	0	142	23	16	6	1	0	176	28	20	7	2	0
0.27	114	18	13	5	1	0	153	25	17	6	2	0	189	30	21	8	2	0
0.28	123	20	14	5	1	0	165	26	18	7	2	0	204	33	23	8	2	1
0.29	132	21	15	5	1	0	177	28	20	7	2	0	219	35	24	9	2	1
0.3	141	23	16	6	1	0	189	30	21	8	2	0	234	37	26	9	2	1
0.31	151	24	17	6	2	0	202	32	22	8	2	1	250	40	28	10	2	1
0.32	161	26	18	6	2	0	215	34	24	9	2	1	266	43	30	11	3	1
0.33	171	27	19	7	2	0	229	37	25	9	2	1	283	45	31	11	3	1
0.34	181	29	20	7	2	0	243	39	27	10	2	1	300	48	33	12	3	1
0.35	192	31	21	8	2	0	257	41	29	10	3	1	318	51	35	13	3	1
0.36	203	33	23	8	2	1	272	44	30	11	3	1	337	54	37	13	3	1
0.37	215	34	24	9	2	1	288	46	32	12	3	1	356	57	40	14	4	1
0.38	227	36	25	9	2	1	304	49	34	12	3	1	375	60	42	15	4	1
0.39	239	38	27	10	2	1	320	51	36	13	3	1	395	63	44	16	4	1
0.4	251	40	28	10	3	1	336	54	37	13	3	1	416	67	46	17	4	1
0.41	264	42	29	11	3	1	353	57	39	14	4	1	437	70	49	17	4	1
0.42	277	44	31	11	3	1	371	59	41	15	4	1	458	73	51	18	5	1
0.43	290	46	32	12	3	1	389	62	43	16	4	1	481	77	53	19	5	1
0.44	304	49	34	12	3	1	407	65	45	16	4	1	503	81	56	20	5	1
0.45	318	51	35	13	3	1	426	68	47	17	4	1	526	84	58	21	5	1
0.46	332	53	37	13	3	1	445	71	49	18	4	1	550	88	61	22	5	1
0.47	347	55	39	14	3	1	464	74	52	19	5	1	574	92	64	23	6	1
0.48	362	58	40	14	4	1	484	77	54	19	5	1	599	96	67	24	6	1
0.49	377	60	42	15	4	1	505	81	56	20	5	1	624	100	69	25	6	2
0.5	393	63	44	16	4	1	526	84	58	21	5	1	650	104	72	26	6	2
0.51	408	65	45	16	4	1	547	87	61	22	5	1	676	108	75	27	7	2
0.52	425	68	47	17	4	1	568	91	63	23	6	1	703	112	78	28	7	2
0.53	441	71	49	18	4	1	590	94	66	24	6	1	730	117	81	29	7	2
0.54	458	73	51	18	5	1	613	98	68	25	6	2	758	121	84	30	8	2
0.55	475	76	53	19	5	1	636	102	71	25	6	2	786	126	87	31	8	2
0.56	492	79	55	20	5	1	659	105	73	26	7	2	815	130	91	33	8	2
0.57	510	82	57	20	5	1	683	109	76	27	7	2	844	135	94	34	8	2

Table 5. Continued.

	80% Power						90% Power						95% Power					
	Detectable difference (%)						Detectable difference (%)						Detectable difference (%)					
SD/$\overline{X}$	10	25	30	50	100	200	10	25	30	50	100	200	10	25	30	50	100	200
0.58	528	85	59	21	5	1	707	113	79	28	7	2	874	140	97	35	9	2
0.59	547	87	61	22	5	1	732	117	81	29	7	2	905	145	101	36	9	2
0.6	565	90	63	23	6	1	757	121	84	30	8	2	936	150	104	37	9	2
0.61	584	93	65	23	6	1	782	125	87	31	8	2	967	155	107	39	10	2
0.62	604	97	67	24	6	2	808	129	90	32	8	2	999	160	111	40	10	2
0.63	623	100	69	25	6	2	834	133	93	33	8	2	1032	165	115	41	10	3
0.64	643	103	71	26	6	2	861	138	96	34	9	2	1065	170	118	43	11	3
0.65	663	106	74	27	7	2	888	142	99	36	9	2	1098	176	122	44	11	3
0.66	684	109	76	27	7	2	916	147	102	37	9	2	1132	181	126	45	11	3
0.67	705	113	78	28	7	2	944	151	105	38	9	2	1167	187	130	47	12	3
0.68	726	116	81	29	7	2	972	156	108	39	10	2	1202	192	134	48	12	3
0.69	747	120	83	30	7	2	1001	160	111	40	10	3	1237	198	137	49	12	3
0.7	769	123	85	31	8	2	1030	165	114	41	10	3	1274	204	142	51	13	3
0.75	883	141	98	35	9	2	1182	189	131	47	12	3	1462	234	162	58	15	4
0.8	1005	161	112	40	10	3	1345	215	149	54	13	3	1663	266	185	67	17	4
0.85	1134	181	126	45	11	3	1519	243	169	61	15	4	1878	300	209	75	19	5
0.9	1272	203	141	51	13	3	1703	272	189	68	17	4	2105	337	234	84	21	5
0.95	1417	227	157	57	14	4	1897	304	211	76	19	5	2346	375	261	94	23	6
1	1570	251	174	63	16	4	2102	336	234	84	21	5	2599	416	289	104	26	6
1.05	1731	277	192	69	17	4	2317	371	257	93	23	6	2865	458	318	115	29	7
1.1	1900	304	211	76	19	5	2543	407	283	102	25	6	3145	503	349	126	31	8
1.15	2076	332	231	83	21	5	2780	445	309	111	28	7	3437	550	382	137	34	9
1.2	2261	362	251	90	23	6	3027	484	336	121	30	8	3743	599	416	150	37	9
1.25	2453	393	273	98	25	6	3284	526	365	131	33	8	4061	650	451	162	41	10
1.3	2653	425	295	106	27	7	3552	568	395	142	36	9	4392	703	488	176	44	11
1.35	2861	458	318	114	29	7	3831	613	426	153	38	10	4737	758	526	189	47	12
1.4	3077	492	342	123	31	8	4120	659	458	165	41	10	5094	815	566	204	51	13
1.45	3301	528	367	132	33	8	4419	707	491	177	44	11	5464	874	607	219	55	14
1.5	3533	565	393	141	35	9	4730	757	526	189	47	12	5848	936	650	234	58	15
1.55	3772	604	419	151	38	9	5050	808	561	202	51	13	6244	999	694	250	62	16
1.6	4019	643	447	161	40	10	5381	861	598	215	54	13	6653	1065	739	266	67	17
1.65	4274	684	475	171	43	11	5723	916	636	229	57	14	7076	1132	786	283	71	18
1.7	4537	726	504	181	45	11	6075	972	675	243	61	15	7511	1202	835	300	75	19
1.75	4808	769	534	192	48	12	6437	1030	715	257	64	16	7959	1274	884	318	80	20
1.8	5087	814	565	203	51	13	6810	1090	757	272	68	17	8421	1347	936	337	84	21
1.85	5373	860	597	215	54	13	7194	1151	799	288	72	18	8895	1423	988	356	89	22
1.9	5668	907	630	227	57	14	7588	1214	843	304	76	19	9382	1501	1042	375	94	23
1.95	5970	955	663	239	60	15	7993	1279	888	320	80	20	9883	1581	1098	395	99	25
2	6280	1005	698	251	63	16	8408	1345	934	336	84	21	10396	1663	1155	416	104	26
2.05	6598	1056	733	264	66	16	8834	1413	982	353	88	22	10922	1748	1214	437	109	27
2.1	6924	1108	769	277	69	17	9270	1483	1030	371	93	23	11462	1834	1274	458	115	29
2.15	7257	1161	806	290	73	18	9716	1555	1080	389	97	24	12014	1922	1335	481	120	30
2.2	7599	1216	844	304	76	19	10174	1628	1130	407	102	25	12579	2013	1398	503	126	31
2.25	7948	1272	883	318	79	20	10641	1703	1182	426	106	27	13157	2105	1462	526	132	33
2.3	8305	1329	923	332	83	21	11120	1779	1236	445	111	28	13749	2200	1528	550	137	34
2.35	8670	1387	963	347	87	22	11608	1857	1290	464	116	29	14353	2296	1595	574	144	36
2.4	9043	1447	1005	362	90	23	12108	1937	1345	484	121	30	14970	2395	1663	599	150	37
2.45	9424	1508	1047	377	94	24	12617	2019	1402	505	126	32	15600	2496	1733	624	156	39
2.5	9813	1570	1090	393	98	25	13138	2102	1460	526	131	33	16244	2599	1805	650	162	41

Table 6. 2-tail (1-tail in parenthesis) *k*-values used to calculate sample sizes to detect a desired difference in a mean with differing levels of confidence and power. From Bonar and Divens (2000).

		Confidence level (α)			
Power (1-β)	**70%**	**80%**	**90%**	**95%**	**99%**
80%	7.05 (3.73)	9.02 (5.67)	12.37 (9.02)	15.70 (12.37)	23.36 (20.07)
90%	10.74 (6.52)	13.14 (9.02)	17.13 (13.14)	21.02 (17.13)	29.76 (26.04)
95%	14.38 (9.41)	17.13 (12.37)	21.65 (17.13)	25.99 (21.65)	35.63 (31.55)

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