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# Conservation & Management of Freshwater Mussels II

## *Initiatives for the Future*

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Cover: Background photo — freshwater mussels (*Leptodea fragilis, Obovaria olivaria*) from the Wabash River, Illinois. Inset photo — *Lampsilis fasciola*. Photos by Kevin S. Cummings.

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# Assessing Unionid Populations With Quadrats and Timed Searches

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**Abstract.** We assessed unionid populations at 53 sites on wadable streams between New Hampshire and North Carolina by conducting timed searches and by searching 0.25-$m^2$ quadrats placed in adaptive cluster designs. Timed searches were inexpensive and successfully detected even sparse (<0.01/$m^2$) populations. Timed searches done with mask and snorkel had higher catch rates and detected more species than searches done on foot. Quadrats detected far fewer species per hour than timed searches. The time required to place and search quadrats varied with experience of the field crew and mussel density. Nevertheless, quadrats were surprisingly inexpensive to use (<5 min/quadrat under most conditions), and produced reasonably precise estimates of population densities of abundant species. In contrast, estimates of the population density of sparse species (<0.1/$m^2$) had large errors. Catch rates from timed searches were well correlated with actual population densities of mussels, but also had large errors, suggesting that timed searches provide only a very approximate index of population density, even if applied under carefully defined conditions. Neither quadrats nor timed searches have enough power to detect differences in populations of rare mussels under most conditions.

## Introduction

Assessing and monitoring mussel populations require suitable measures of population size. Such measures should be fast and simple to apply in various field situations, robust against changes in observers or conditions, have an acceptably small error and bias, and be closely related to the absolute size of the mussel population. None of the methods commonly used to assess mussel populations meets all of these criteria.

Commonly, an experienced observer informally surveys an area of interest, often on foot or snorkeling, and assesses the mussel population in terms like "good" or "poor," or simply "present" or "absent." Such an approach requires relatively little time in the field and allows a knowledgeable biologist to integrate field conditions, habitat quality, and mussel species biology into the final assessment. Unfortunately, there is no standardization among observers, and we are not aware of any tests of the relationship between such qualitative assessments and actual population size, which may be poor.

Alternatively, some biologists report catch-per-unit-effort (CPUE) statistics as indices of mussel populations (e.g., Hoeh and Trdan 1985; Mackie and Topping 1988; Strayer and Ralley 1991). The same informal search methods are used as in qualitative assessments, but the number of living mussels encountered in a given time is reported. Typically, neither search methods nor search times are standardized across observers. Again, the relationship between population density and CPUE has not been tested extensively, nor have the factors that might influence this relationship (e.g., observer experience, search method, field conditions, mussel species) been examined (but see Vaughn et al., this volume).

Finally, mussels sometimes are sampled using conventional quantitative methods (e.g., quadrats or grabs) deployed in various designs (e.g., Miller and Payne 1988, 1993; Strayer et al. 1994). If appropriate sampling devices are used, the resulting data are quantitative and repeatable and can be related to actual population size. Nevertheless, these quantitative methods usually are viewed as too time-consuming, too insensitive to rare species, too prone to large estimation errors, and too poorly suited to field conditions for widespread use.

In this paper, we evaluate the costs, sensitivity, and precision of two commonly used sampling methods (timed searches and quadrats) as carried out under a wide range of field conditions. Based on these results, we make preliminary recommendations for use of these methods, and highlight remaining questions that need to be answered to develop better sampling designs for monitoring and assessing mussel populations.

Our data were collected as part of a rangewide assessment of populations of *Alasmidonta heterodon*, an endangered species. Further details about this work were given by Strayer et al. (1996).

## Methods

We established 1-9 study sites on each of 13 streams between New Hampshire and North Carolina, a total of 53 study sites. Streams ranged in width from 2.5 m to 150 m, and included a wide range of conditions (depth, turbidity, current speed, substratum, etc.). Study sites typically encompassed the entire width of the stream and ran for 100 m (large streams) to 200 m (small streams). The midchannel of one stream (the Connecticut River) was too deep to examine by our methods, so work on this river was confined to areas within 15 m of the shore.

At each site, we conducted two timed searches without prior knowledge of mussel distribution at the site. First, one of us (DLS) carried out a timed search for mussels while wading. This search usually took about 1 hour, and included both visual and tactile searches, as appropriate. All live mussels encountered were identified and counted. At the end of the search, we made a subjective estimate of visibility at the site using a 1-10 scale, where 10 indicates that 100% of the bottom was clearly visible and 1 indicates that about 10% of the bottom was clearly visible. At a few sites, the timed search while wading was omitted because of time limitations or because we felt that so much silt would be stirred up that a timed search while snorkeling (see following text) would be impossible.

Following the timed search while wading, one researcher (DLS) put on a mask and snorkel and repeated a timed search of the study site. During this search, which usually took about an hour, we identified and counted all living mussels encountered. At the end of the search, a subjective index of visibility (1-10 scale, as above) was chosen. Timed searches while snorkeling were not done at some sites because of excessive turbidity.

In addition to the timed searches, we estimated mussel population density using 0.25-$m^2$ quadrats, which were searched by sight and, where necessary, by feel. Sediment within the quadrats was not excavated. We used an adaptive cluster sampling design (Thompson 1992), stratified at some sites into nearshore and midchannel strata. Typically, we placed 30 to 100 primary quadrats at random, then sampled additional quadrats following the requirements of adaptive cluster sampling. Values for the condition (the criterion for additional sampling) varied among sites, and was set based on information gathered in the timed searches. The estimator

$\hat{\mu}_2$ $\hat{x}_2$ was used for the mean (Thompson 1992).

All estimates and statements in this report refer to mussels that were visible at the sediment surface. Young animals (i.e., less than ca. 25 mm and 3 years old) were rarely seen and presumably buried out of sight beneath the sediment surface. In addition, in at least some unionid populations, substantial numbers of adults are buried beneath the sediment surface (Amyot and Downing 1991). All of our estimates therefore omit this buried part of the population.

To assess the sensitivity of the two sampling methods, we plotted the probability of detecting at least one animal of a species against the population density of that species. For quadrats, we used the results of Green and Young (1993). For timed searches, we used our regression of catch rates on population density (equation 2) to predict the mean number of animals encountered in the search. We then assumed that the actual catches of rare species (i.e., those near the detection threshold) follow a Poisson distribution (cf. Green and Young 1993) and calculated the probability of not detecting the species as $e^{-M}$, where M is the mean number of animals encountered. Because there is error associated with our estimate of catch rates, simply using equation 2 to calculate detectability would introduce a bias and overestimate the sensitivity of timed searches. We therefore used resampling methods (Bruce 1993) to calculate the full range of expected catch rates around equation 2 (n = 1000 runs per density), from which detection probabilities were estimated.

## Results

### *Costs*

At the average site, we spent 48 minutes on timed searches on foot and 56 minutes on timed searches while snorkeling. At sites where both search methods were used, combined effort averaged 101 minutes. We spent much more time (5.2 person-hr/study site) setting up and searching quadrats. This cost is inclusive, and takes into account the time required to set up the study site, place the quadrats in position, search them for unionids, and record data. The mean number of quadrats searched during this time was 76 (61 primary quadrats plus 15 quadrats in clusters), giving a mean cost/quadrat of 4.1 minutes. The cost/quadrat varied widely across sites, from 1.2 minutes to 10 minutes, and was strongly affected by our experience and by the density of mussel populations (Figure 1). Based on our results, a modestly experienced field crew might expect to spend 2-4 minutes setting up and searching a quadrat.

### *Detectability*

Sampling with quadrats detected fewer species per hour than timed searches. Density-detectability curves for randomly placed quadrats, based on a speed of 4.1 minutes/quadrat (see previous text) are shown in Figure 2. Populations sparser than 0.01-0.1 $m^{-2}$ may escape detection for efforts of 1-10 person-hours, using randomly placed quadrats. (Of course, if an efficient stratified or adaptive design is used, detection probabilities will rise). Timed searches were capable of detecting even very sparse populations: a 1-hour timed search can be expected to detect a population of *Elliptio complanata* about 1,000 times sparser than that detectable in 1 hour of quadrat sampling. Timed searches done while wading detected 25% fewer species than those done while snorkeling.

***Precision***

Estimates of mussel densities obtained from quadrat samples were encumbered with large errors (Figure 3), despite the relatively large effort spent on these samples. The precision (standard error/mean) of quadrat samples was readily predicted ($r^2$=0.95, $p<0.0001$) from the mean number of mussels per quadrat (m) and the number of quadrats searched (n) as:

$$\text{equation 1: s.e./mean} = 1.69\ m^{-0.28}\ n^{-0.55}$$

Equation 1 is not significantly different (at p=0.05) from the relationship proposed by Downing and Downing (1992) (s.e./mean=$m^{-0.25}\ n^{-0.5}$). Although both stratification and adaptive sampling designs sometimes greatly increase precision (e.g., Thompson, 1992), neither the use of stratification nor the number of clusters encountered at a site significantly affected the precision of our results (ANCOVA, p>0.25). Figure 4 shows the expected precision of density estimates based on equation 1 and a cost estimate of 4.1 minutes/quadrat (see above). Except for high densities or high sampling efforts, errors are expected to be substantial.

The appropriate error term for timed searches depends on the purpose of the study. Our study was designed to evaluate differences among populations across sites (as opposed to following trends at a single site over time), so the appropriate error term is derived from the variance around the density-CPUE regression. All three timed search data sets (on foot, snorkeling, and combined searches) give essentially the same results against actual population densities, so we present only one data set (snorkeling searches) here.

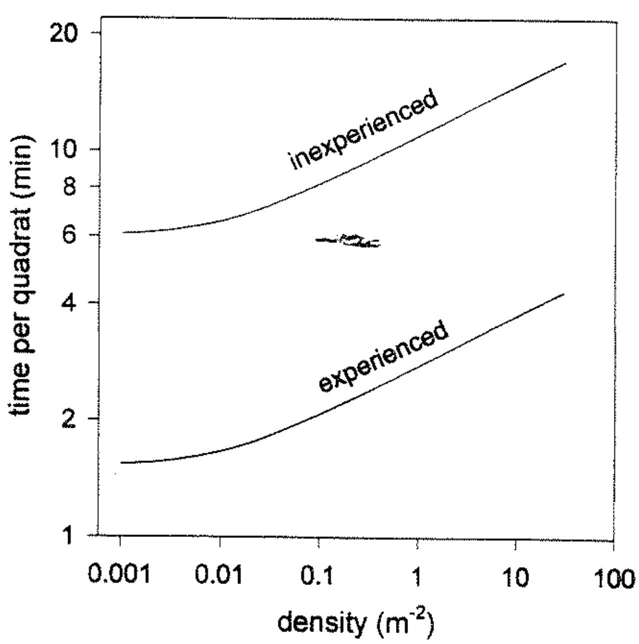


**Figure 1.** Mean time required to place and search a 0.25-$m^2$ quadrat, as a function of mussel density, for a crew with no experience or a summer's experience.

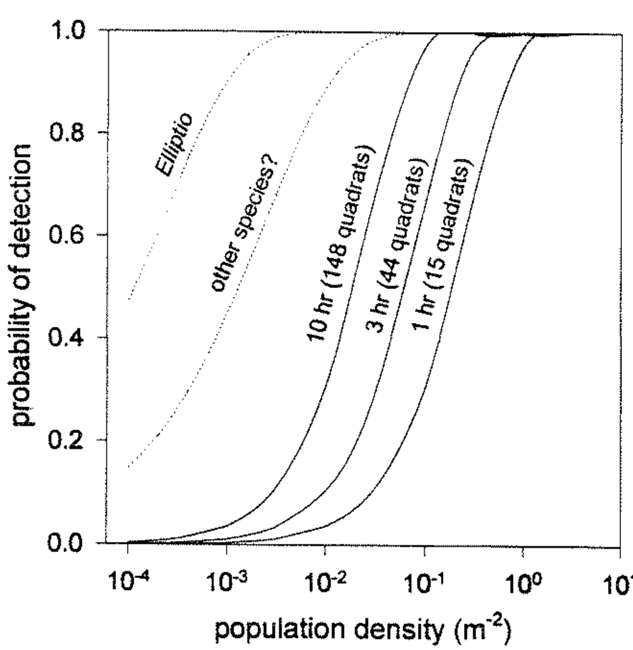


**Figure 2.** Probability of detecting at least one individual of a mussel species, based on its mean density. Solid lines are for quadrats, based on Green and Young (1993), assuming a cost of 4.1 minutes per quadrat. Dotted lines are for 1-hour timed searches while snorkeling. Line for "other species" was constructed by assuming catch rates one-third of those for *Elliptio* (cf. Figure 5).

For *Elliptio complanata* (we use this name broadly here for all nonlanceolate *Elliptio*, pending clarification of the taxonomy of the genus), CPUE is related ($r^2$=0.57) to actual population density (Figure 5) by:

$$\text{equation 2: } CPUE = 126D^{0.573}$$

where CPUE is catch per hour and D is density per $m^2$. There is considerable scatter around this regression: the 95% confidence interval spans about a 35-fold difference in catch rates (Figure 5). Including our assessment of visibility at the sampling sites improves the fit of the regression slightly (partial F=7.2, p=0.01; $r^2$ rises to 0.63). It appears that *E. complanata* is more visible than the other mussel species in our study (Figure 5), but our data set does not allow a rigorous assessment of the effects of species on CPUE.

Conversely, if we try to predict density of *E. complanata* from CPUE (Figure 5), the 95% confidence interval spans a range of about 175-fold.

Catches from the two kinds of timed searches are tightly correlated ($r^2$=0.88), with catches from snorkeling searches a little higher (Figure 6). These higher catches may result from better visibility while snorkeling, but they may also reflect that we had prior knowledge about the site when we did the snorkeling searches. The relationship between snorkel-CPUE and wading-CPUE is not improved (p>0.05) if the difference in visibility estimates (i.e., visibility wading minus visibility snorkeling) is added to the model.

## Discussion

We draw three conclusions from our study. First, the suitability of quadrats and timed searches for assessing mussel populations depends on the specific goals of the study and the resources available to the investigator. Although we have shown that quadrat sampling can be relatively inexpensive, timed searches are far less expensive. Therefore, if time is very short, quadrat sampling may be impractical. Furthermore, under the conditions of our study, timed searches (especially those done by snorkeling) offered excellent detection of rare species. Quadrat sampling was much less efficient in detecting rare species (see also Vaughn et al., this volume).

Both sampling methods can be used to estimate mussel population density, given more or less serious qualifications. Estimates of population density from timed searches are fraught with very large errors, and it is not clear how much these

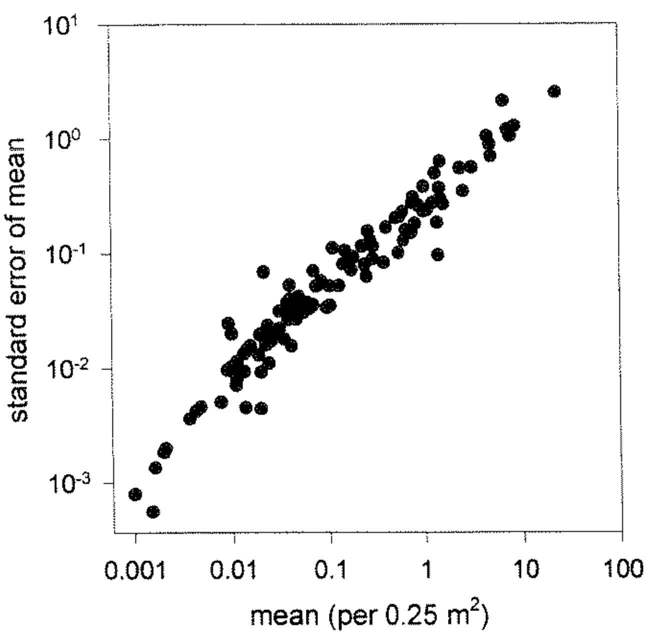


**Figure 3.** Precision of estimates of population density from quadrat samples in our study. Each dot represents one species at one site.

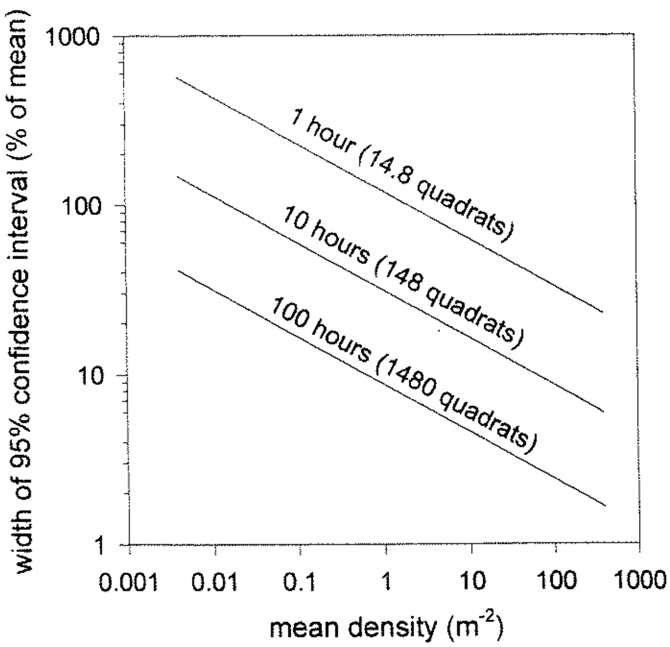


**Figure 4.** Estimated precision of estimates of population density from quadrat samples as a function of effort and population density. Based on equation 1 and a cost of 4.1 minutes per quadrat.

errors can be reduced through improvements in methodology (see following text). Thus, results from timed searches can be used for only the grossest comparisons among sites. Furthermore, it is possible to convert CPUE to absolute population densities only if an extensive calibration study is done (e.g., Figure 5).

Although quadrats can give acceptably precise estimates of population densities of dense populations from modest sampling efforts (Figure 4; see also Downing and Downing 1992; Miller et al. 1993), enormous effort must be expended to achieve precise estimates for sparse populations. Unfortunately, it is just these sparse populations that we often are most interested in monitoring. Neither timed searches nor quadrats give acceptably precise results for these sparse populations at present. As a result of this low precision, quadrat sampling as usually applied (the typical study surveyed by Downing and Downing used only 16 quadrats per site) has little ability to detect even large differences between populations of rare mussels (Figure 7). If two mussel populations have densities below 1 $m^{-2}$ and differ by less than 50%, most quadrat-based sampling designs will not detect the difference.

This brings us to our second point: the power of a proposed sampling scheme should be compared with the goals of the study before the study begins. We have shown that 95% confidence intervals around population estimates often span an order of magnitude or more, given densities of interest and resources available to mussel biologists. In our experience, mussel biologists often are interested in detecting modest differences (e.g., 10-25%) between sites or times. These two observations obviously are incompatible (cf. Figure 7). Three options are available to resolve this problem: (1) greatly increase the sampling effort (which may be too costly or too disruptive to the mussel population being studied), (2) adopt less ambitious goals (e.g., detecting a threefold change in density), or (3) adopt less stringent statistical criteria for determining if a difference exists (i.e., $\alpha$ = 0.10 or even 0.25 instead of the customary 0.05). These options may not be palatable but need to be adopted if we are to design realistic monitoring programs.

Third, we think that more research into sampling designs might help malacologists discover

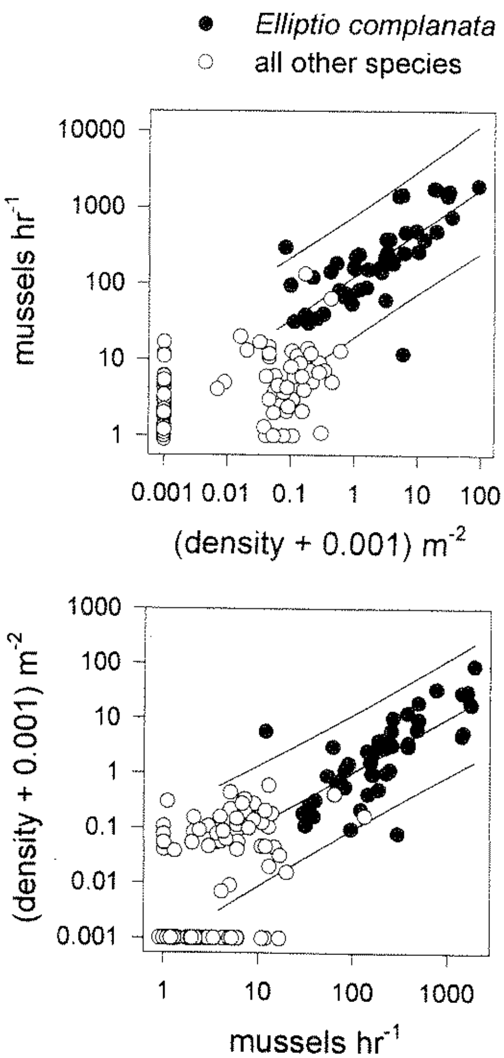


**Figure 5.** Upper: CPUE (searches while snorkeling) as a function of actual population density. Lines show the regression and the 95% prediction intervals on individual observations for *Elliptio complanata*. Lower: Inverse of upper figure.

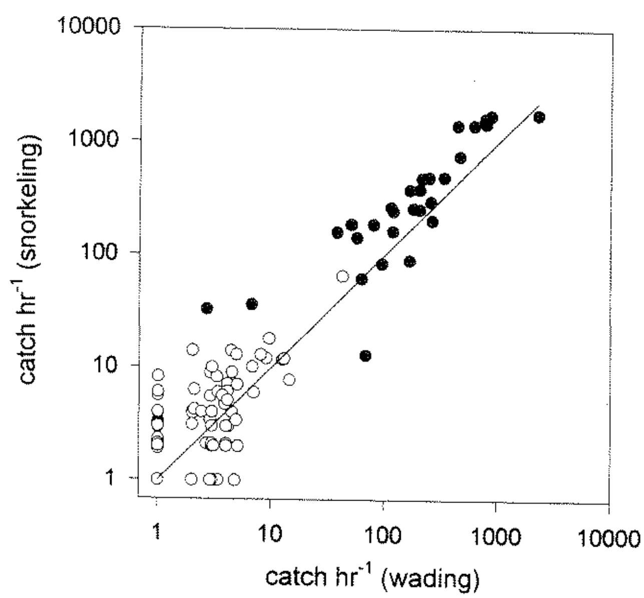


**Figure 6.** Relationship between CPUE generated by the two search methods. The line indicates equal catch rates.

more efficient ways to assess mussel populations. The abilities of quadrats deployed in a simple random design to sample mussel populations are known (e.g., Downing and Downing 1992; Green and Young 1993). Designs that use information about the population to direct sample placement (e.g., stratification, adaptive designs, and multistage sampling; see Thompson 1992 for a review) can be much more powerful than simple random sampling, especially where mussel populations are very heterogeneous (e.g., Strayer et al. 1994). In particular, research on rules (based on the spatial structure of real mussel populations) for setting the value of the condition (for adding adjacent quadrats to the sample) in adaptive designs to minimize variance would be especially welcome.

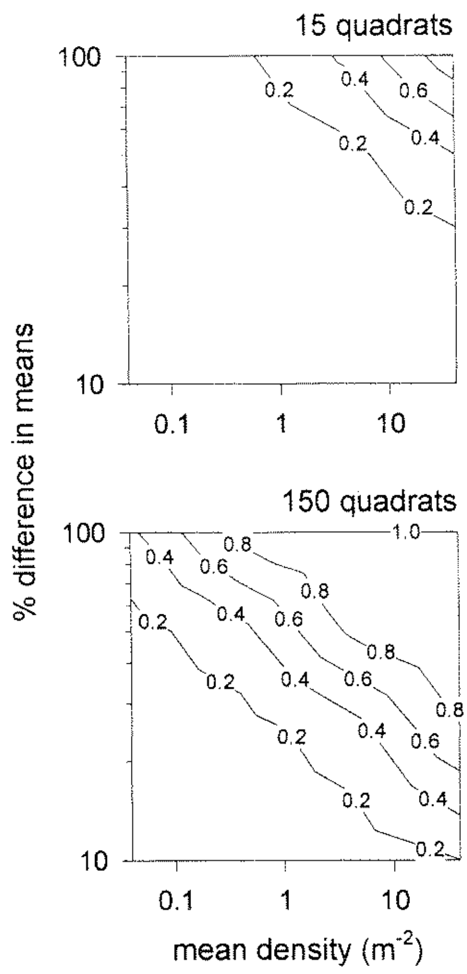


**Figure 7.** Statistical power of quadrat sampling to detect density differences between two mussel populations, as a function of population density, size of the difference, and sampling effort. Contours show the probability of detecting a significant difference in density between the two populations with a two-tailed t-test and $\alpha = 0.05$. Calculated with Borenstein and Cohen (1988), based on equation 1.

Much remains to be learned about the potential for timed searches to produce repeatable, quantitative assessments of mussel populations. Variance in CPUE statistics can arise from many sources, few of which have yet been quantified. The considerable variance we found between CPUE and mussel density arose from day-to-day differences in observer efficiency and search strategy and site-to-site differences in search conditions and mussel behavior. Additional variation can arise from differences among observers, differences in apparency among species, longer-term variation in efficiency of a single observer, and increasing catch rates resulting from familiarity gained during repeated visits to a single site for assessment of temporal trends in a mussel population. Variation from these uninvestigated sources may be substantial. Depending on the purpose to which the CPUE data are applied (e.g., temporal trends at one site, cross-site comparisons, cross-species comparisons), some of the sources of variance may be relevant. These problems will have to be addressed through further research on timed-search methodology before we can know how timed searches can be used rigorously to assess mussel populations.

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