Recommended Designs Based on Common Objectives

Common Objectives

- Determine species present
  - Surveillance
  - Biological assessment prior to impact
  - A comment on application to multiple sites
- Estimating density or abundance
  - Single site
  - Multiple sites
- Some uncommon objectives
  - Estimating survival
  - Estimating spatial distribution within a site (mapping)

A rigorous sampling protocol should

- Have clear and specific objectives,
- Be designed to gauge precision of estimates,
- Ensure adequate spatial distribution of sampling effort,
- Be readily repeatable, and
- Have adequate quality assurance and quality control.

Estimation based on incomplete counts

- Relationship between the expected count (E[C]) from a survey and abundance (T)
  - $E(C) = \alpha\beta T$
  - where α is the fraction of the statistical population sampled (*sampling fraction*) and β is the fraction of the individuals within the sampled area that are detected (*detectability* or *detection efficiency*).
- Statistical sampling includes methods to know or estimate sampling fraction (α) and detectability (β)

Common name for sampling technique	Fraction of site searched or sampling fraction (α)	Detectability (β)	Survey result
Qualitative	Unknown	Unknown	Incomplete count with expectation: $E(C) = \alpha\,\beta T$
Semi-quantitative	Known	Unknown	Incomplete count within searched area with expectation: $E(C) = \beta T$
Quantitative	Known	Known or estimated	Abundance estimate: $\hat{T} = C \big/ \left(\alpha \cdot \hat{\beta}\right)$

Species presence: surveillance

- Objective: Determine species present without measurable degree of success
- Description of protocol
  - Qualitative sampling, Unconstrained search
  - Limited time or search site until adequately covered
- Sampling units
  - None
- Sampling design
  - Informal
- Advantages
  - Least cost
  - For fixed time, more individuals and species will be detected
- Disadvantages
  - No way to gauge if search time was sufficient to find uncommon and rare species
  - Can’t compare across sites or time without untestable assumptions
  - Absence of detection is not strong evidence that species was absent

Species presence: biological assessment

- Objective: Determine species present with measurable degree of success
  - Example: Determine the presence of a rare species with 85% probability, given that its density ≥ 0.01/ m^2. Alternatively, objective could specify abundance (e.g., given that abundance ≥ 100).
- Description of Protocol
  - Semi-quantitative sampling, Constrained search
  - Area to be searched determined by detectability, minimum density, and desired probability of detecting species
- Sampling units
  - 0.5 or 1 m wide transects
  - Oriented perpendicular to thalweg or shore
- Sampling design
  - Search area distributed around site to achieve good spatial coverage
  - Stratification or double sampling could be used to help distribute search area
- Advantages
  - Provides measure of probability of species detection
  - Absence can be used to infer maximum density at a site
- Disadvantages
  - Costs more in time and labor than qualitative sampling
  - Relies on estimates of detectability or use a conservative approximation

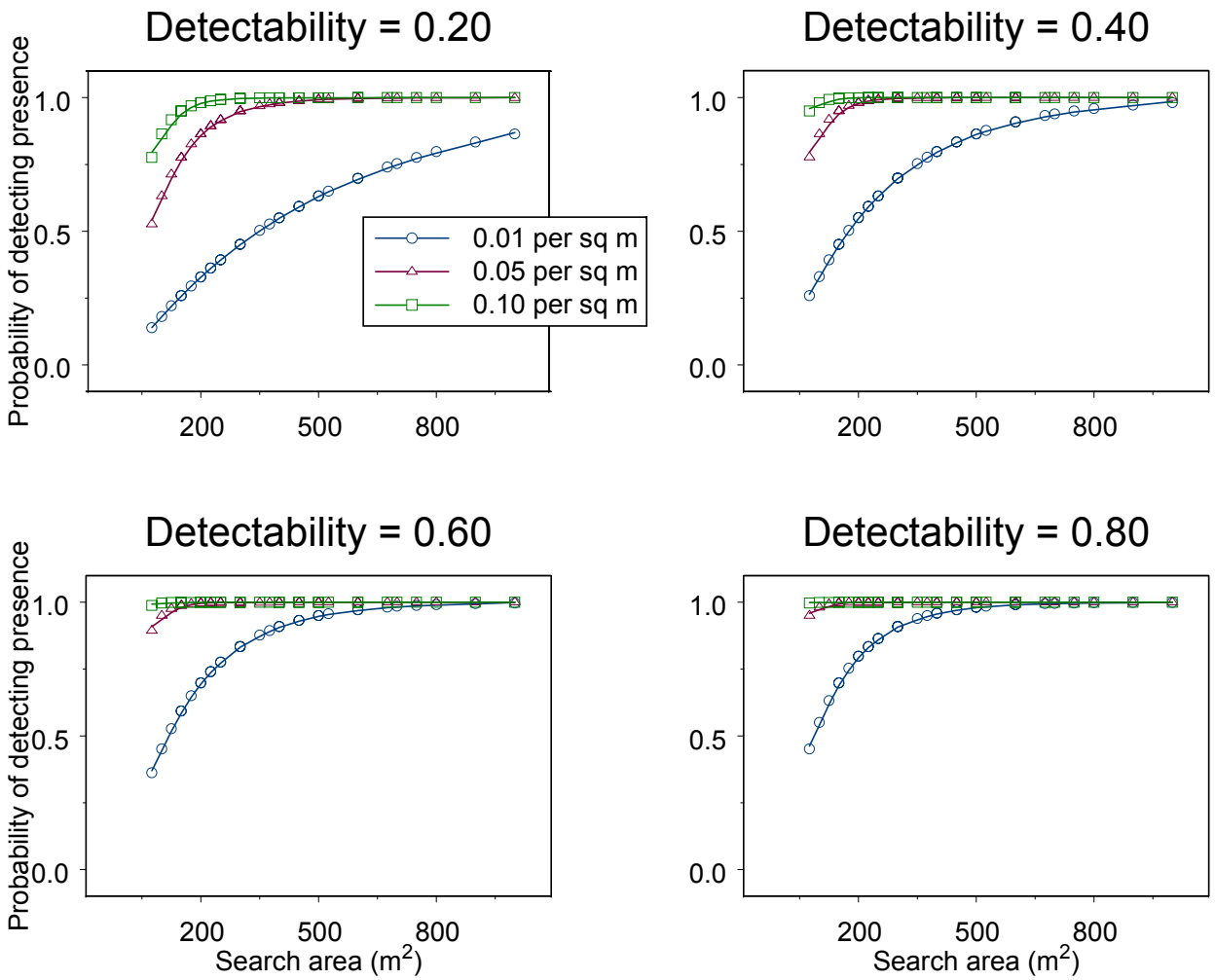
Probability of species detection (adapted from Green and Young (1993))

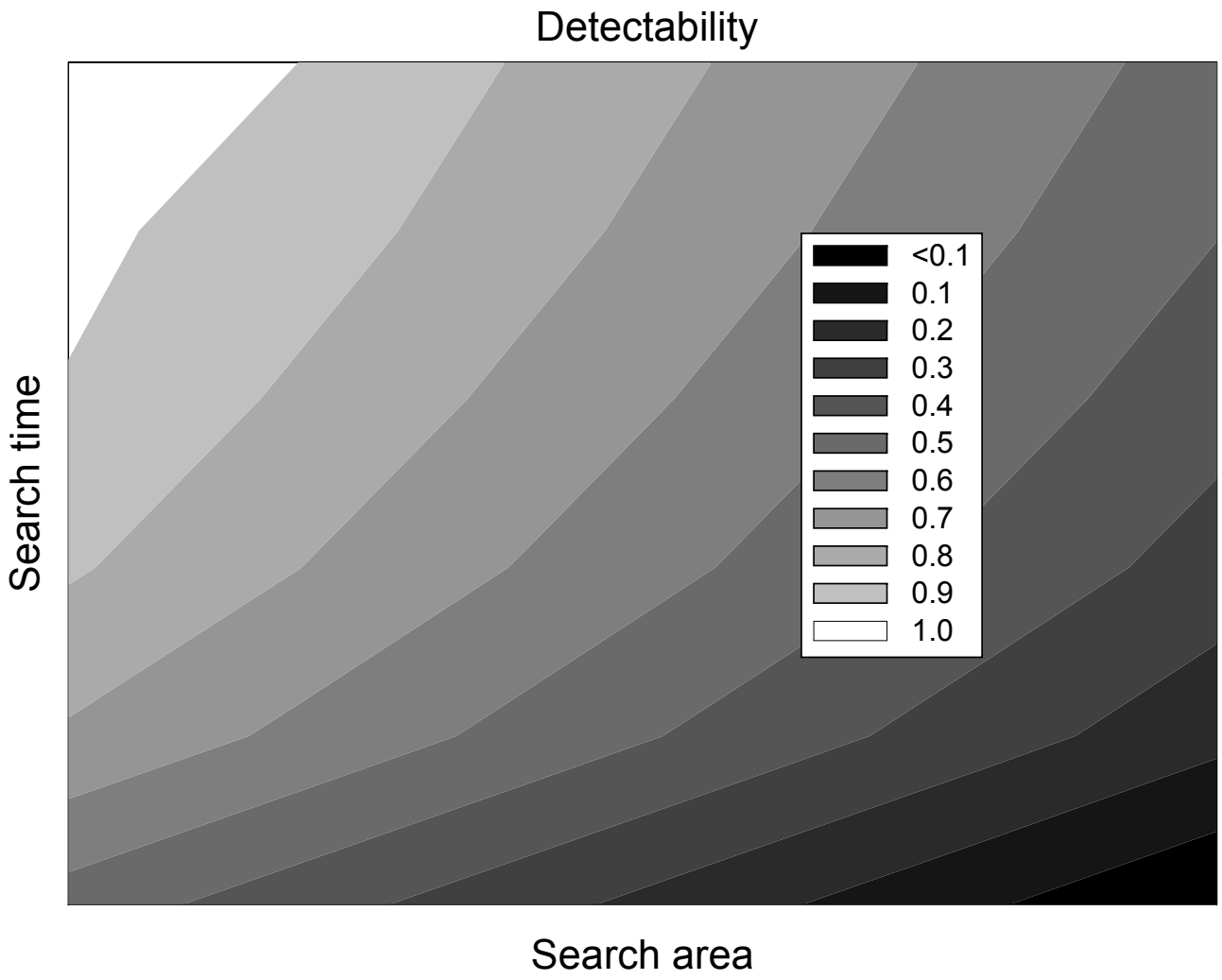
$$\text{Prob}(\text{detecting at least one individual}) = 1 - e^{-\alpha \cdot \beta \cdot T}$$

$$= 1 - e^{-\frac{a}{A}\beta T},$$

where α is sampling fraction, β is detectability or detection efficiency, *a* is area searched, *A* is area of site, and *T* is abundance.

Species presence: biological assessment




Detectability
Search time
Search area
<0.1
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0

			Search area (m^2)								
Study site area (m^2)	Detection efficiency	Population size	100	200	300	400	500	600	700	800	900
16,000	0.2	100	0.12	0.22	0.31	0.39	0.46	0.53	0.58	0.63	0.68
		200	0.22	0.39	0.53	0.63	0.71	0.78	0.83	0.86	0.89
		300	0.31	0.53	0.68	0.78	0.85	0.89	0.93	0.95	0.97
		400	0.39	0.63	0.78	0.86	0.92	0.95	0.97	0.98	0.99
		500	0.46	0.71	0.85	0.92	0.96	0.98	0.99	0.99	1.00
	0.4	100	0.22	0.39	0.53	0.63	0.71	0.78	0.83	0.86	0.89
		200	0.39	0.63	0.78	0.86	0.92	0.95	0.97	0.98	0.99
		300	0.53	0.78	0.89	0.95	0.98	0.99	0.99	1.00	1.00

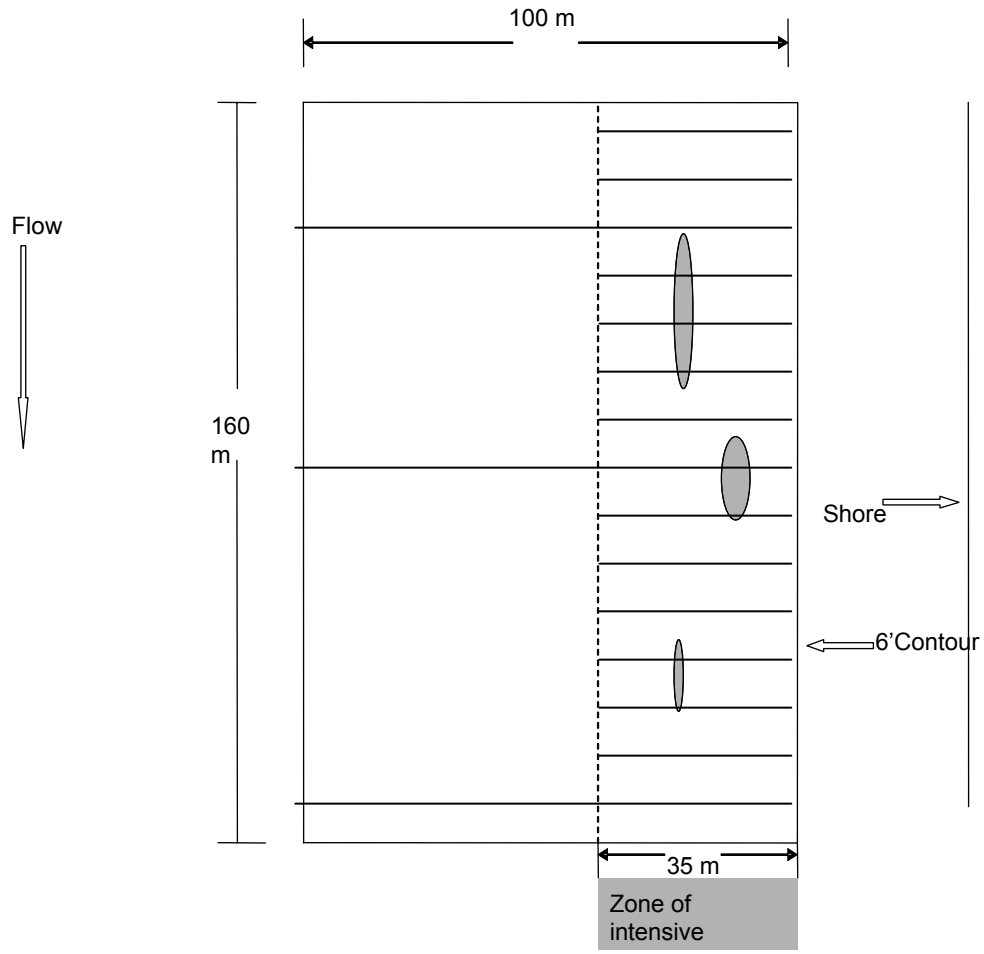


Figure 2. Hypothetical example of a 100m x 160m section of river showing locations of of potential mussel habitat (gray areas), zone of intensive sampling, and transects.

720 m of search area

Example protocol for biological assessment:

- Developed for assessment prior to dredge permitting on Allegheny and Ohio Rivers
- Draft protocol work product from an expert panel: Bob Carline, Dick Neves, Drew Miller, Gerry Dinkens, and myself
- Final report due to be issued soon
- Two phases of sampling
  - First phase is surveillance of site to stratify site by areas of habitat or density categories
  - Second phase is an ‘area-searched’ approach

Species presence: multiple sites

- Objectives:
  - Establish total species list in an area
  - Delineate species range
- Sampling within a site could follow either of the previous protocols
- Site selection important
  - Bridge crossing are disturbed sites and not representative
  - For total species list, reasonable to first sample known high density sites
  - However, for monitoring there should be a probability-based site selection (stratified random, systematic)

Example protocol for species presence at multiple sites:

- On large scale survey of Allegheny River (60 sites)
- Sites (100 m long) selected randomly within river sections
- 12 – 1 m transects oriented across river
- Results from transects used to stratify for later quantitative sampling
- Two-phase design (discussion to follow)

Estimating density or abundance: single site

- Objective: Estimate density or abundance of one or more species in a site with desired level of precision
- Description of protocol
  - Quantitative
  - Sample size depends on density
- Sampling units
  - 0.25 m^2 quadrats, (possibly 1 m^2 quadrats if large deep site)
  - Some excavation necessary (use double sampling)
- Sampling design
  - Probability-based, spatially balanced
  - Systematic sampling with multiple random starts
  - Could incorporate stratification (e.g., by depth contour)

Estimating density or abundance: multiple sites

- Objective: Estimate density or abundance for one or more species in a river, drainage, watershed with desired precision
- Description of protocol
  - Quantitative applied to multiple sites
  - Multiple stages of sampling (select sites, then subsample sites)
  - Two-phase sampling is useful so that quantitative sampling can be applied to only a subset of sites
- Sampling units
  - Large units: river segments, sites
  - Small units: quadrats, transects
- Sampling design
  - Two-phase sampling
  - The auxiliary variable (x_i) is a 'quick and dirty', approximate measure
  - Quick count of organisms (pitfall traps, point count)
  - Remotely sensed measure of forest composition
- The variable of interest (y_i) is a 'gold standard' measure
  - Statistical estimate of abundance (M-R, Distance Sampling)
  - Forest composition measured by site visits

Two-phase sampling: Basic approach

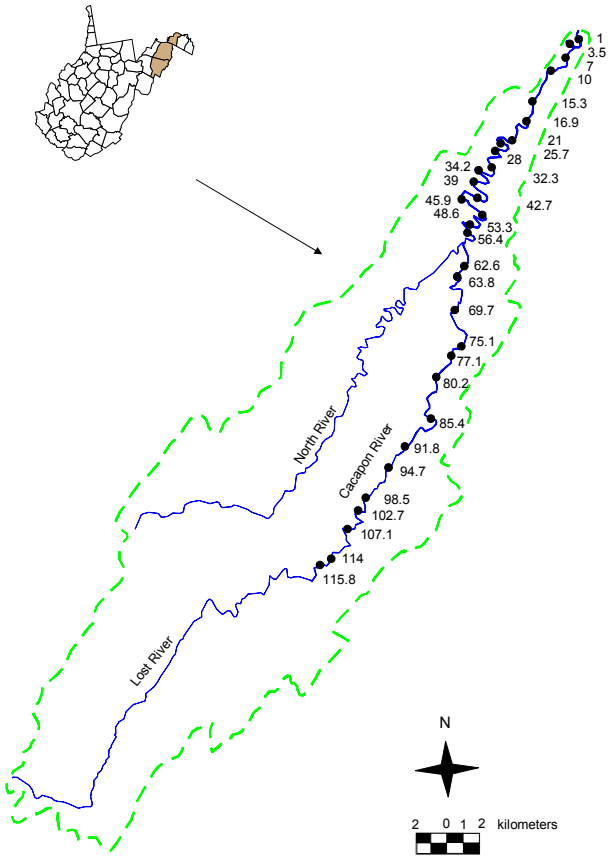
- Survey a large sample of sites using a rapid method such as qualitative or semi-quantitative sampling
- Subset of those sites is also surveyed using intensive methods to determine actual density
- Ratio of the mean count on those sites (using the rapid method) to the mean actual density (as determined by the intensive searches) is used to adjust (calibrate) results from all sites

Two-phase sampling: Basic approach

- In stratified sampling the relative proportion of units within each strata must be known, i.e., $W_h = N_h/N$ for the hth stratum is known
- However, sometimes units can't be classified until the site is visited. For example, when strata are defined by density.
- Approximate methods are used to stratify sites
- $w_h = n'_h/n'$ is an estimate of W_h
- Intensive methods can vary by strata

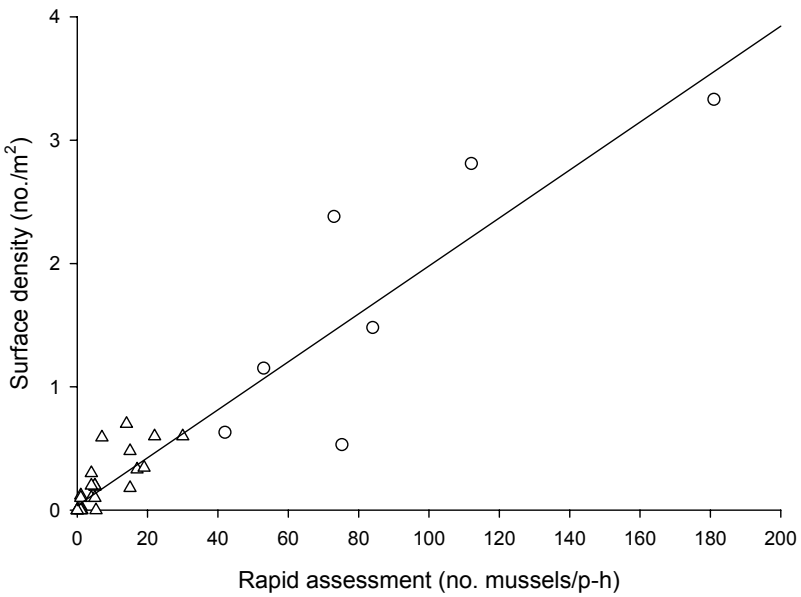
Two-phase Sampling of a River (Villella and Smith 2005)

- Objective to estimate riverwide density of freshwater mussels
- Don't want to spend much effort at reaches where mussels aren't present
- Timed search conducted at all sample reaches
- Reaches stratified based on timed-search results
- Quantitative sampling methods depend on strata



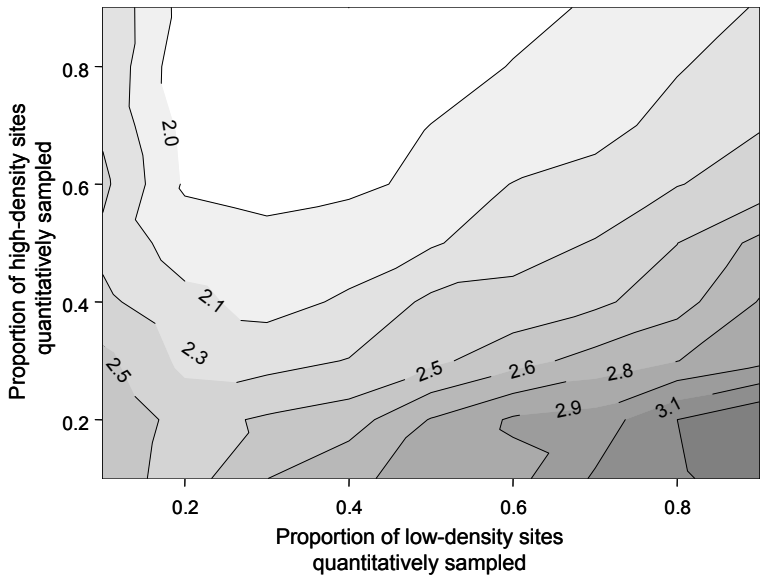
Two-phase Sampling of a River

- Timed search linearly related to density
- Most sites were classified in ‘low’ density stratum
- Adaptive sampling applied in low-density stratum
- Conventional quadrat sampling in high-density stratum



Two-phase Sampling of a River

- Minimizing variance and cost leads to optimal allocation
- Best to quantitatively sample a low to moderate proportion of low-density reaches
- And a high proportion of high-density reaches



Estimating survival, recruitment, and population growth

- Tagging study
- Individually marked tags
- Double tagging to estimate/account for tag loss
- Open population mark-recapture models
- Software available, e.g., Program MARK
- Temporary emigration is a potential problem