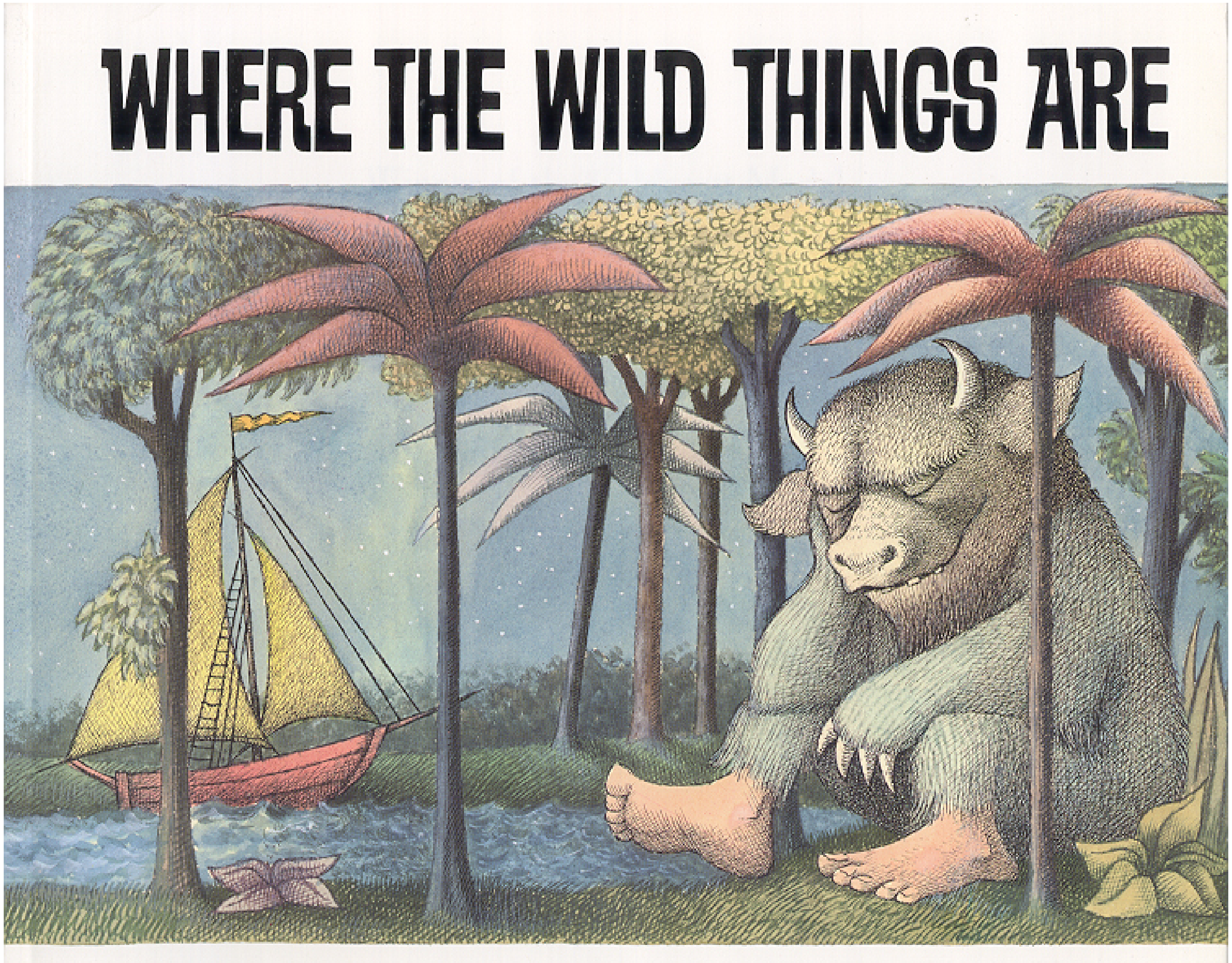
Survey Design



M. Sendak

Survey Planning

1. Set survey objectives
2. Determine sampling parameters including: detection thresholds, EDSU, bottom tracking, ping rate (given the maximum depth), transmit pulse width, single-target detection, and echo integration.
3. Design transect layout and identify GPS waypoints for transect start and end points and for CTD casts

Use survey objectives and analytic approach to define data requirements

Objectives

- resource assessment (i.e. how many?)
- impact assessment (i.e. impact vs control)
- monitor change (time, space)
- map distribution
- behavior (time, space)

Survey Design Steps

1. Define limits (space, time, operational, data)
2. Estimate time needed given desired sample density
3. Calculate time available
4. Choose sample strategy and type of cruise track
5. Lay out cruise track

MacLennan and Simmonds 1992

Sampling Principles

Collect:

- data that is representative of the population or area
- data that can be used to estimate abundance in areas not sampled
- data that can be used to estimate total abundance
- data that can be used to estimate precision of a survey

Design Choices

1) Balance between direct sampling and acoustic track
2) Sample stratification
3) Random or systematic designs
   - Random sampling within the domain
   - Systematic, regular with fixed or random start
4) Systematic or Adaptive design

Elementary Distance Sampling Unit

- the length of cruise track where acoustic measurements are averaged to give one sample

Possible EDSU's

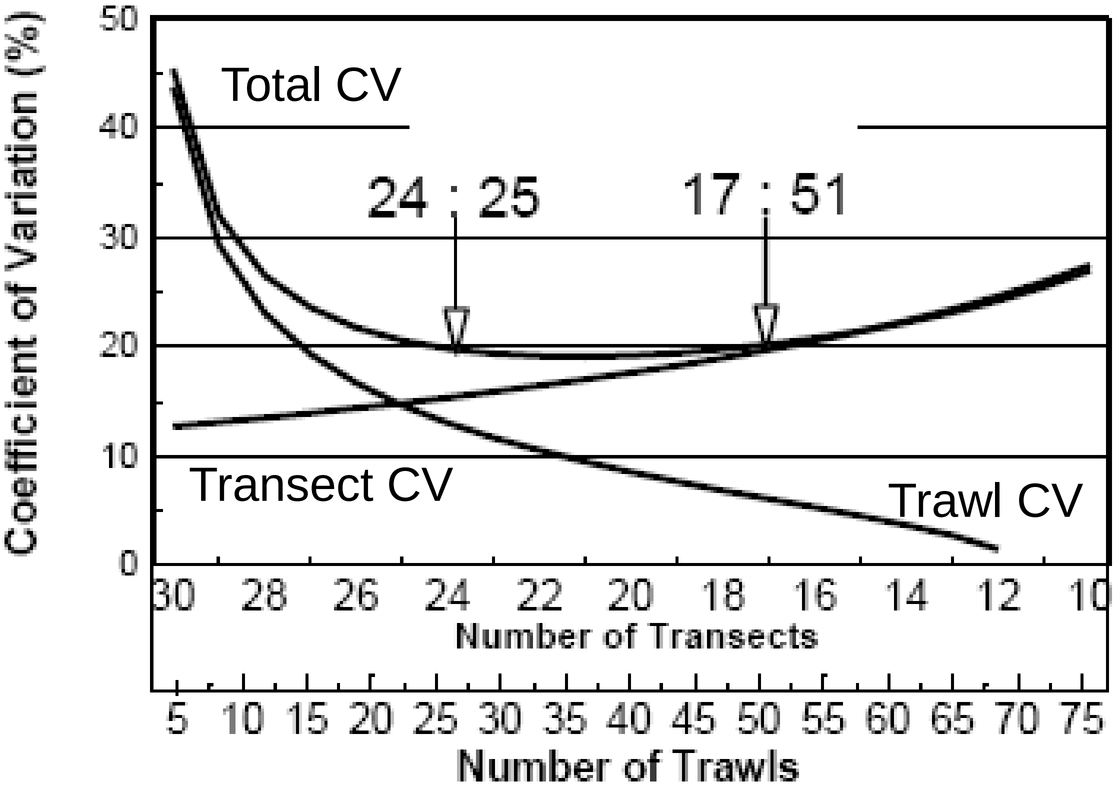
- collection of pings (arbitrary temporal or spatial averaging unit **OR** autocorrelation lag distance, variogram sill value **OR** something else)
- whole transect (may be limited by bathymetry or topography)

Does each location have equal probability of being sampled?

Proportion of Time for Sampling

$$cv = \frac{\sigma}{\mu}$$

North Sea Herring



In a 3 week survey:

24:25 1/6 time

17:51 1/3 time

Choose 1/5 time for single species, ¼ time for mixed species

Amount of Survey Trackline?

Estimate a baseline distance or start with CV and work backwards

Degree of Coverage Λ

$$\Lambda = \frac{D}{\sqrt{A}}$$

where
D is cruise track length
A survey area

Coefficient of variation (CV)

$$CV = \frac{0.5}{\sqrt{\Lambda}}$$

Aglen 1989

Sample Transect Layout

1. Random

   - assumes independent samples
   - provides more precise estimate of precision

2. Stratified Random

   - depth, habitat
   - proportions effort to variance to minimize variance of series

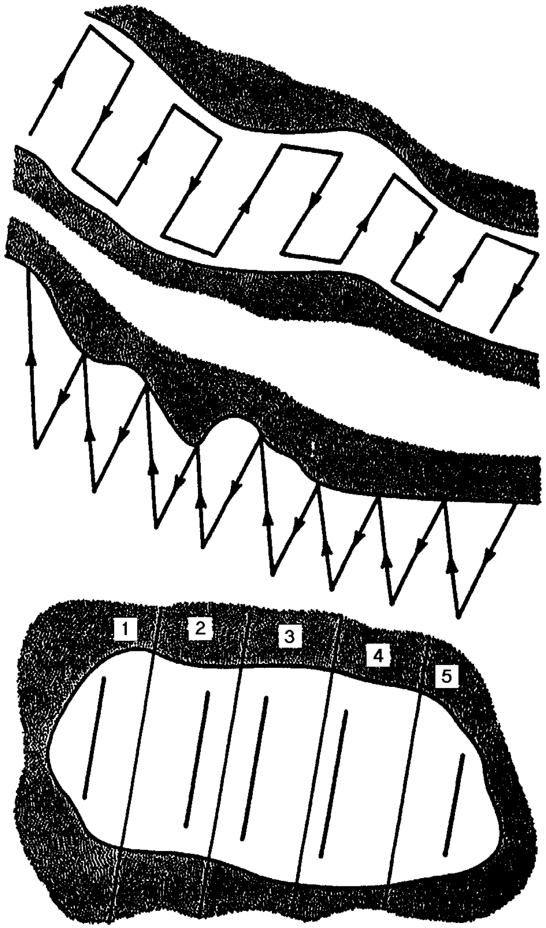
3. Systematic

   - grid, boustrophedont, zigzag
   - trade-off between independence of samples & series variance
   - provides best distribution map
   - may change sampling unit relative to other designs
   - requires autocorrelation measure to estimate percision

4. Adaptive

   - allocate effort proportional to variance as sampling is underway

Transect Layouts: Coastal

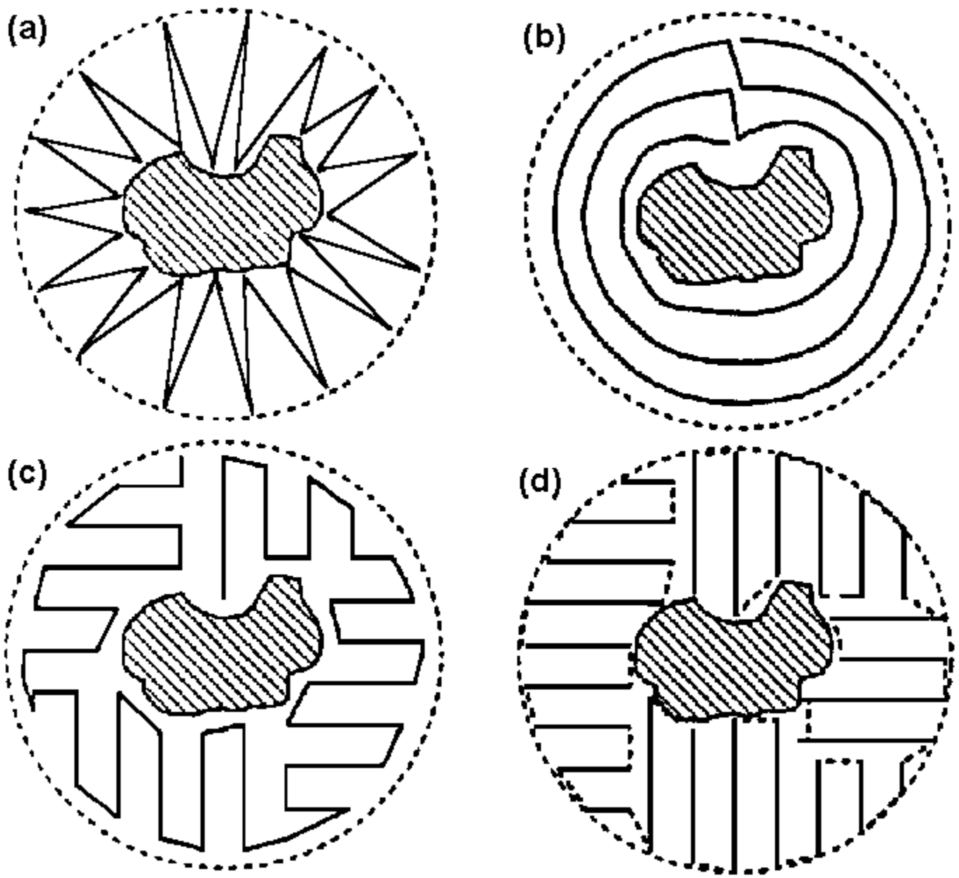


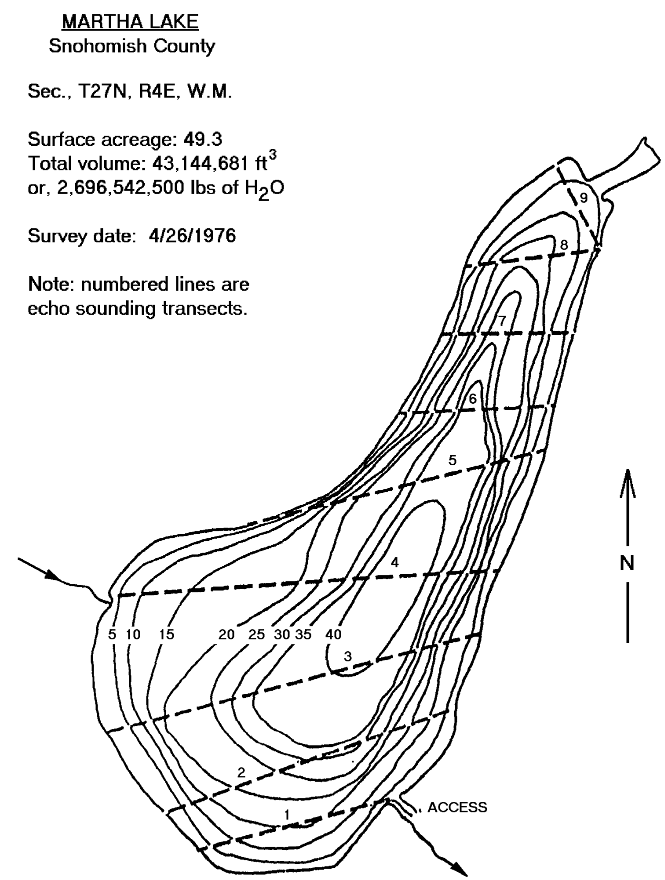
Parallel grid, boustrophedont
- transect : area$^{1/2}$ = 6
- suitable when transect length > 2x transect spacing

Zig-zag
- transect apex to area boundary

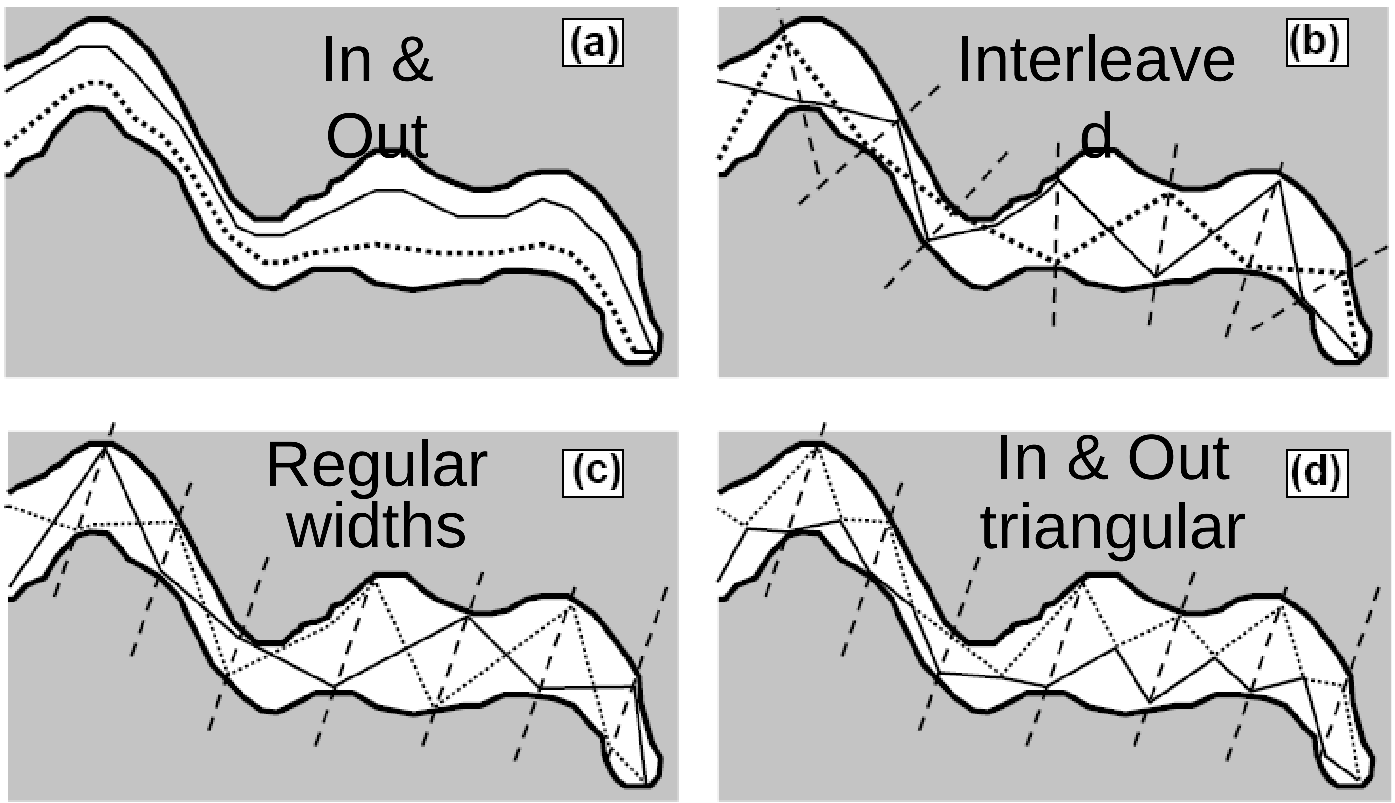
Random or stratified random

Transect Layouts: Islands & Lakes





Transect Layouts: Constricted Areas



Transect Direction

Anisotropy

– in an anisotropic field, variance is reduced if sampling is along the line with greatest rates of change

Migration

– for unknown migration directions, minimizing time between transects minimizes bias

– spiral designs may help (but difficult to run)

– for known migration directions, surveys with and against the direction of migration reduces bias

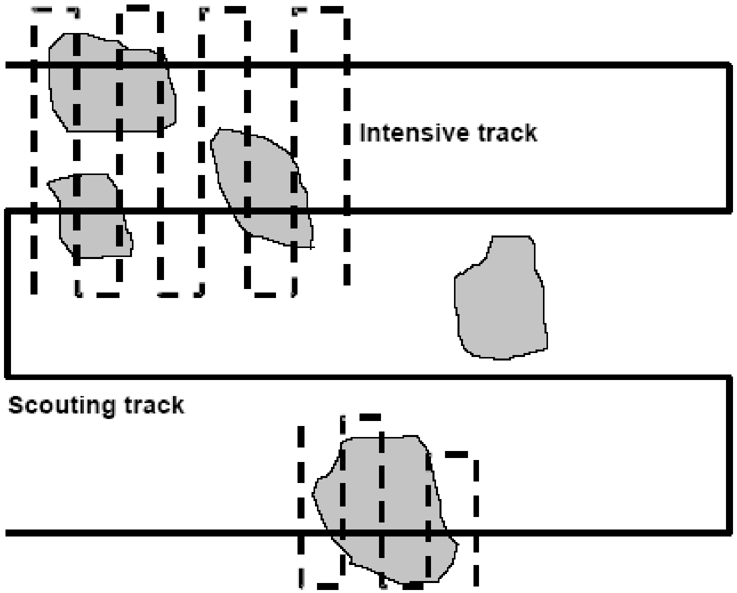
Efficiency of Transect Layout

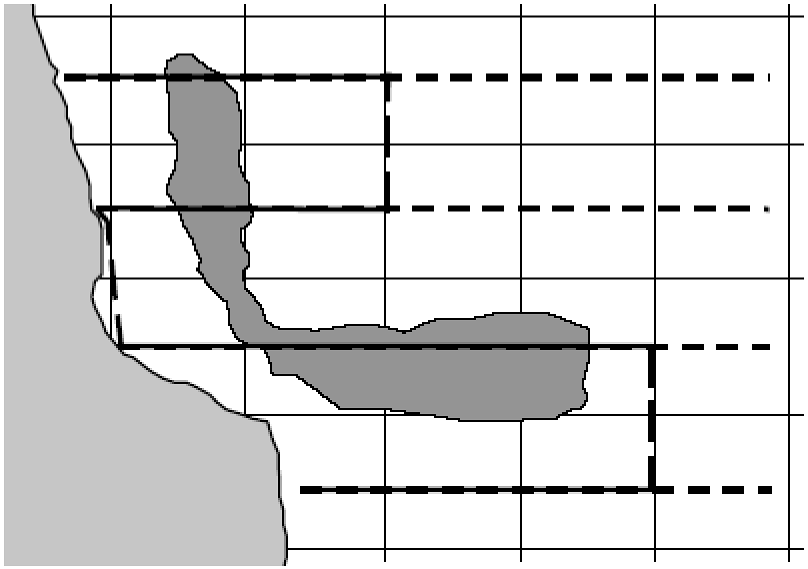
1. Random parallel sampling least efficient
2. Zig-zag sampling most efficient if low densities
3. Stratified parallel sampling most efficient if high densities
4. Fish school configuration influences density estimates
5. Increasing sampling effort reduces variance due to schooling

Kimura and Lemberg (CJFAS 38:1141-1152, 1981)

Adaptive Sampling

- combines coarse and fine resolution sampling
- different sampling intensities analyzed separately
- effort proportional to variance (how to allocate effort?)





Survey Design: Magnification Factor

Magnification Factor:

- representative fraction of a sample
- interpolation (within) or extrapolation (among) transects to include the area or volume of interest

$$MF = \frac{\text{area or volume of ecosystem}}{\text{total samples} * \text{volume of 1 sample}}$$

Example: Iron Hypothesis

- iron limits primary production in tropical ocean (John Martin)
- add iron, increase primary production, reduce atmospheric CO_2, reduce global warming

Sampling Activity: 10^4 samples

1 sample = 10 cm^3 test tube, total area to sample = 10^{20} cm^3

MF of each sample = 10^{15} $ecosystem^{-1}$

Sources of Variance

Distributional, Acoustical, Biological

Distributional: precision due to sampling

- unmet assumptions of sample layout
- degree of survey coverage

Acoustical: accuracy due to potential for bias

- equipment calibration and sensitivity
- change in transducer position during mobile surveys
- noise from acoustic system or electrical supply
- hydrographic conditions (e.g. temp and sal on c, bubbles, thermoclines, other critters)

Sources of Variance

Biological: accuracy due to potential for bias

- species composition (single or mixed aggregations)

- density changes

- distributional changes (space or time)

- behavior (tilt, feeding, ship avoidance)

- physiological (feeding, gonad development)

- ontogeny (non-linear growth, development)

Cruise Time Budget

Work time available W = Total (T) - Loading (L) - Steaming (S) - Calibration (C) - Hydrography (H):

$$W = (T - L - S - C - H)$$

P is proportion of day for survey: P = fraction of day for work

F is proportion allocated to fishing, t is time for acoustic track:

$$t = W \times P \times (1 - F)$$

Distance covered:

Distance = Time (t) x Speed (s): $d = t \times s$

Area coverage

- Uniform sampling (within a strata)
- Approximate transect spacing given by
- Spacing = Survey Area / Distance: $S = A / d$

Time Overhead Costs

– Loading and unloading equipment

– Steaming to and from survey area

– Calibration

– Direct sampling (e.g. trawling) for biological samples and trace identification

– Any other Oceanographic sampling

– Day / night limitations

– Contingency for weather

Two Analytic Approaches (that influence design)

Classic

- assumes random, independent distributions
- samples are representative of area domain

Geostatistical

- incorporates distribution, autocorrelation, and stocasticity
- transect spacing is important, can be a constraint

Geostatistics

set of methods to characterize spatial structure and incorporate space in estimations (e.g. quantity in a region, variance, value at a point, mapping)

Why estimate? partial knowledge of spatial variable

How to estimate? use a model of the phenomenon

3 Steps: Data Scrutiny, Structural Analysis, Estimation

cf. Rivoirard et al. (2000), Ch. 2&3

Geostatistic Methods

Transitive, Intrinsic

Transitive: variable confined to a finite domain, known or unknown

- tends to 0 outside of domain
- hypotheses about sampling design
- global estimation
- tool: covariogram

Intrinsic: variable can be described within domain and independent of domain geometry

- properties of stationarity
- probabilistic basis

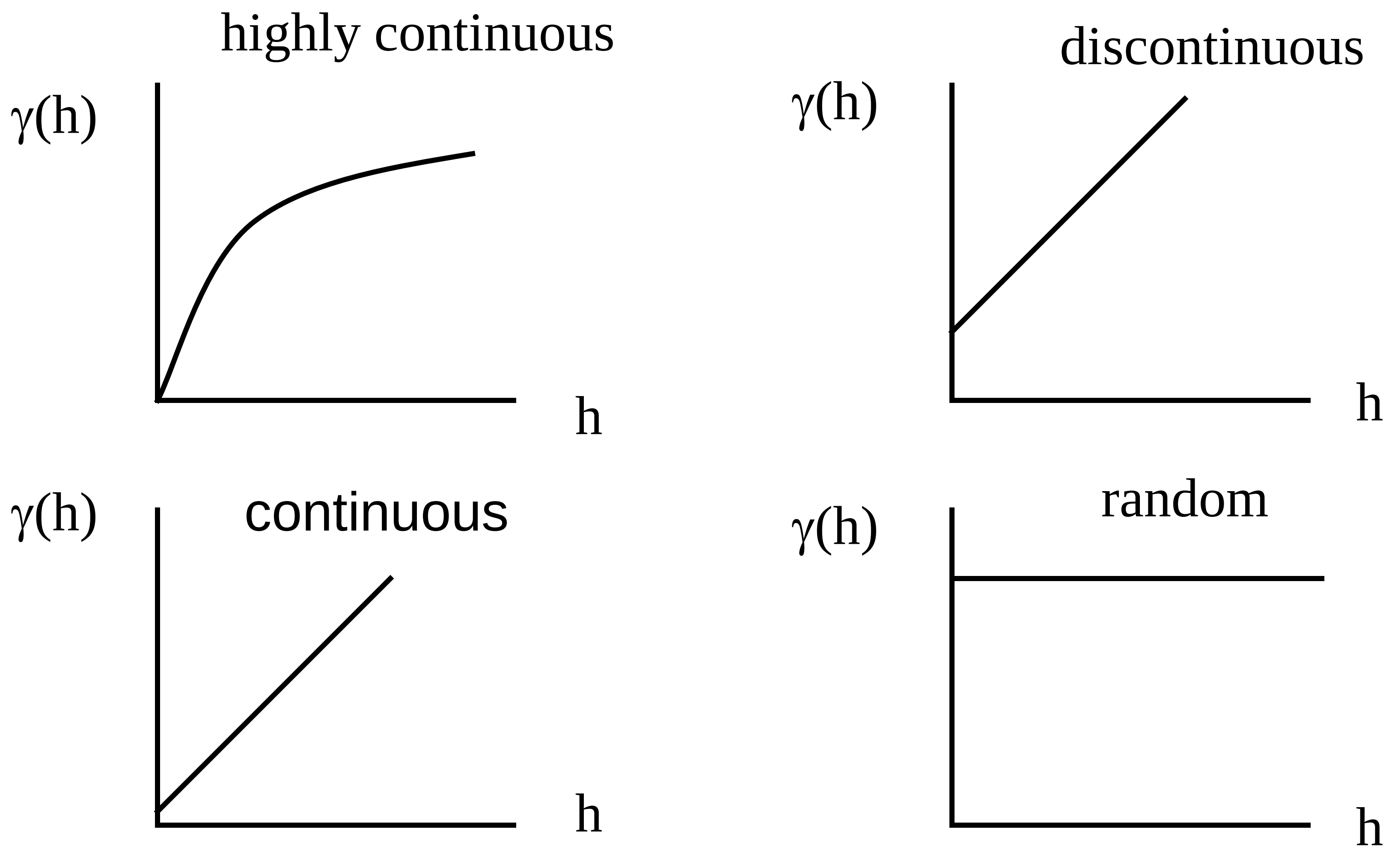
Variogram

$$\gamma(h) = 0.5\frac{1}{N(h)}\sum\left[z(x) - z(x+h)\right]^2$$

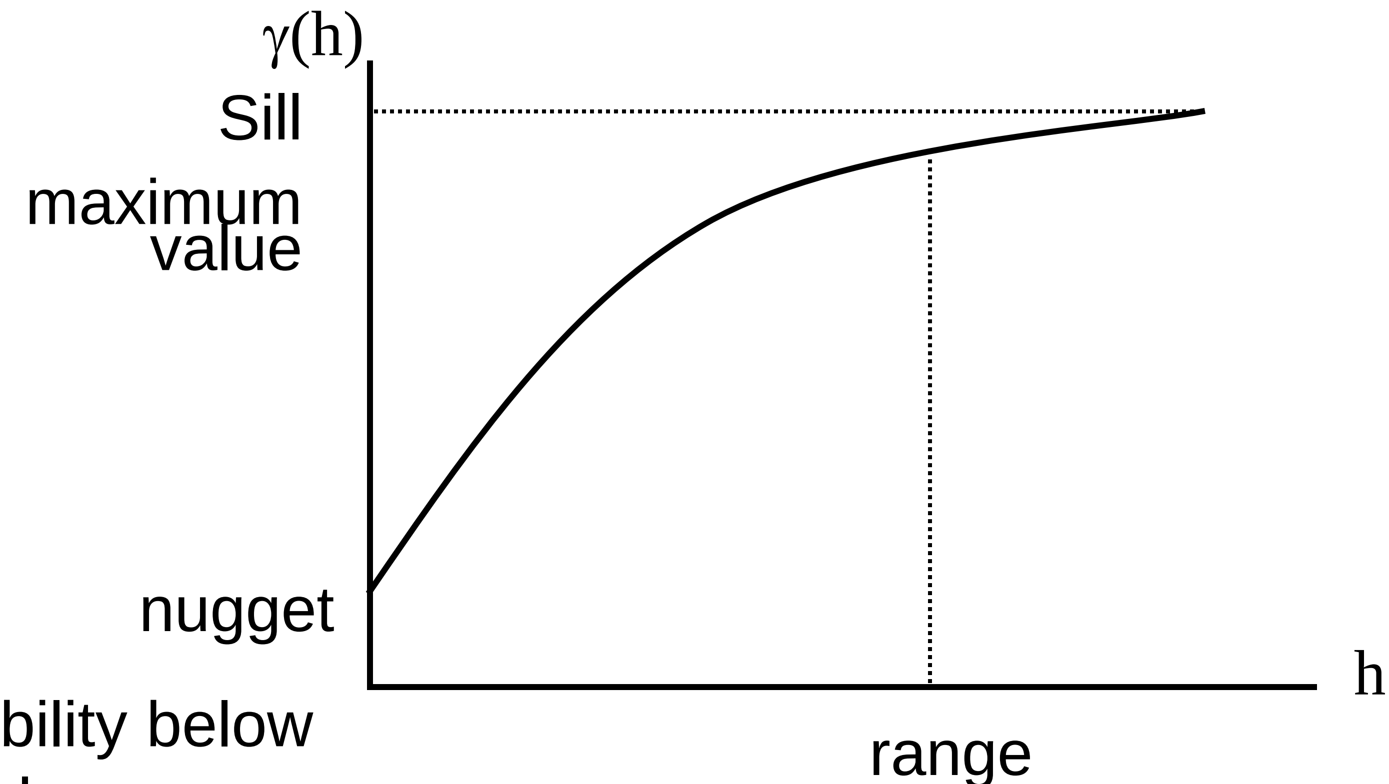
where: h = distance, N = number of point pairs, z = variable, x = position

units are the same as variance (i.e. quantity squared)

Distribution Properties from Variogram



Zones of Influence



variability below
sample
resolution

where correlation
vanishes

Variogram Models

1. Nugget effect
2. Spherical model
3. Exponential model
4. Gaussian model
5. Power model
6. Linear model

Applications: used to characterize spatial variance; can be used to ‘parameterize’ distributions (e.g. kriging)

Example software: EasyKrig by D. Chu on website

http://globec.whoi.edu/software/kriging/easy_krig/easy_krig.html

Geostatistical Abundance Estimate

1. Determine spatial independence among samples using variogram
2. Determine horizontal sampling frequency using Nyquist (min. R/2)
3. Determine spatial independence using variogram
4. Impose exterior boundary around region
5. Examine for and remove trends (depth, lat, long) if warranted
6. Krig backscatter data, replacing trend if warranted

Equipment Check List

ECHOSOUNDER FIELD GEAR LIST - LAKE WASHINGTON - OCTOBER 2015 CLASS TRIIP
FISHERIES ACOUSTICS RESEARCH - UW SCHOOL OF AQUATIC & FISHERIES SCIENCES
BOX 355020 - SEATTLE WASHINGTON, 98195-5020
(206) 221-6864 OR (206) 221-6890 OR (206) 221-5459

NAME: DATE: LOCATION:

CHECKLIST:

- CTD Crate
  - CTD
  - Download cable
  - Distilled water
  - tubing
- Towfish pod w mount bolts/PI bolts
- Black Shockmount Case
  - Simrad EK-60: 38 kHz GPT - serial 199 - IP 157.237.14.101
  - Simrad EK-60: 70 kHz GPT - serial 545? - IP 157.237.14.102
  - Simrad EK-60: 120 kHz GPT - serial 203 - IP 157.237.14.103
  - Simrad EK-60: 200 kHz GPT - serial 718? - IP 157.237.14.104
  - Ethernet Switch
  - 10A and 2A fuses
  - Power strip
  - Long orange ethernet cable
- Action Packer 1
  - Extra Ethernet cables: 25', 14', 3'
  - Power strip x 2
  - Ratchet straps
  - Flat clipboard
  - Dummy plugs for GPTs (2)
  - Nonskid mats
  - Ethernet switch
  - Tape: electrical, labeling
  - Ground cable
  - Headlamps
  - Nobeltec software
  - ER software
  - GPS splitter including
    - Serial cables
    - Gender benders

Parameter Log Sheet

Serial Numbers

GPS source

Environment

Echosounder Settings

Recording depth

University of Washington - Fisheries Acoustics Research Lab
EK-60 Parameter Log

Date:________________ Vessel: __________________________

Survey Location:____

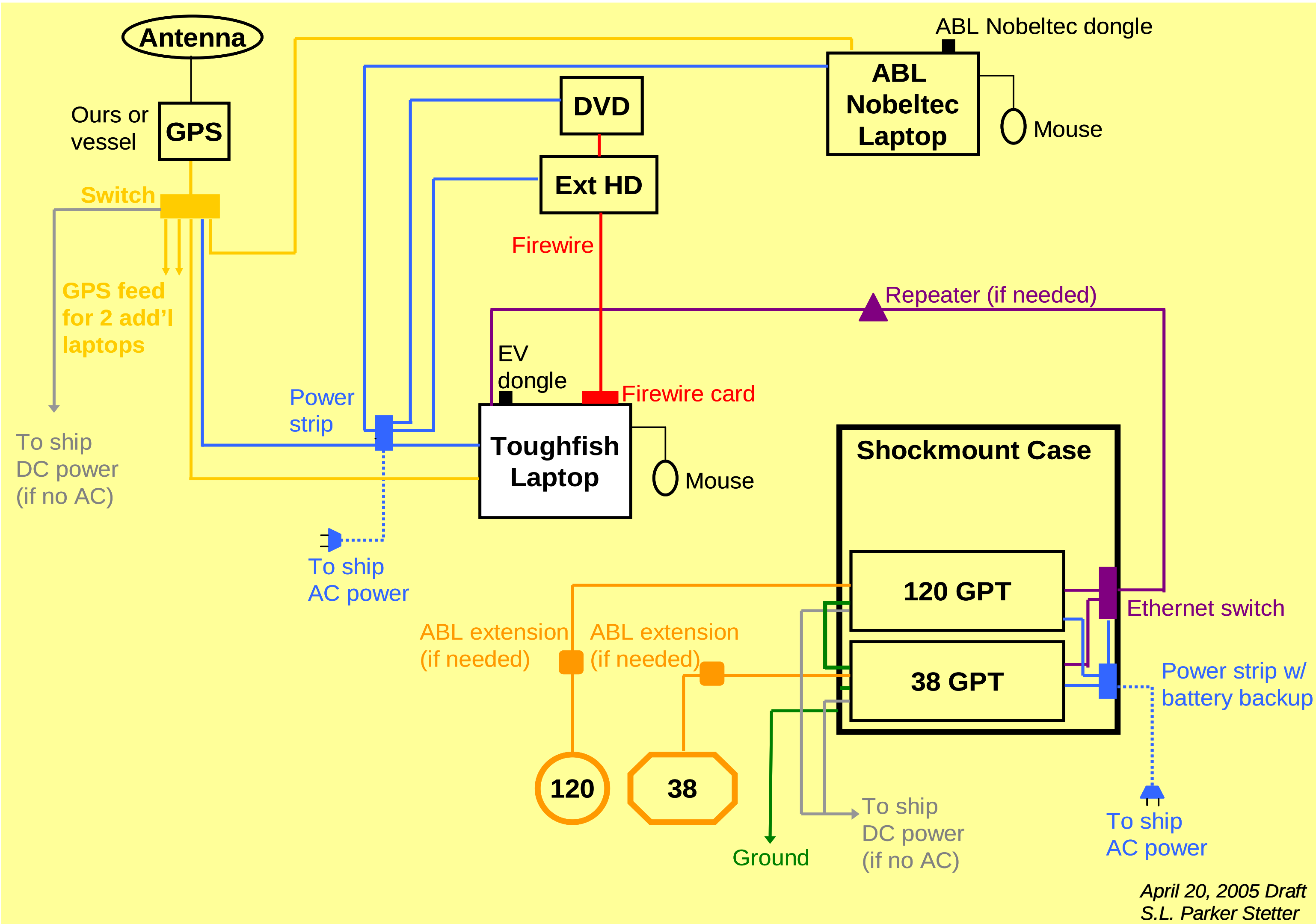
Personnel:____

Weather:____

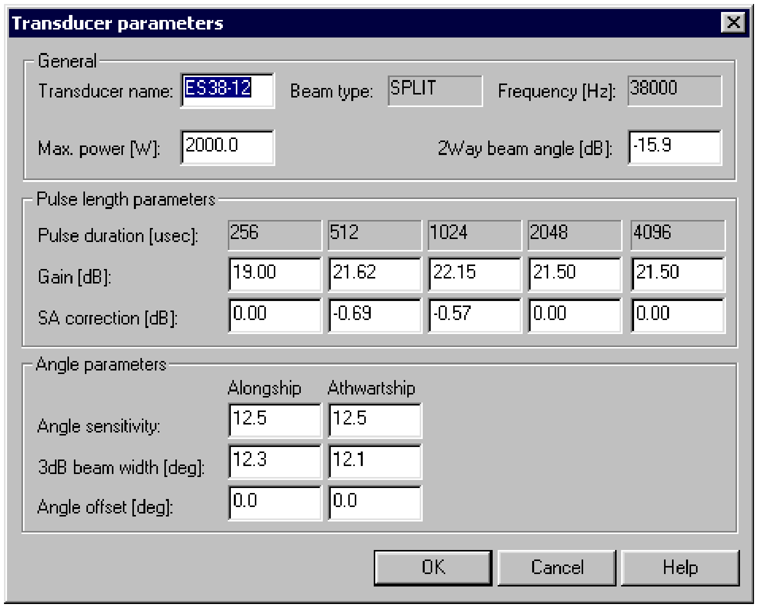
Parameter	***38 kHz***	***70 kHz***	***120 kHz***
Transducer serial number			
Transducer depth (m)			
GPS (boat or independent?)			
Water temperature (°C)			
Salinity (ppt)			
Sound speed ($m \cdot sec^{-1}$)			
Absorption ($dB \cdot m^{-1}$)			
Transmit power (W)			
Ping rate ($\cdot sec^{-1}$)			
Pulse duration (ms)			
Sample interval (m)			
Gain (dB)			
S_a Correction (dB)			
2-Way Beam angle (dB)			
3 dB Beam width – Along (°)			
3 dB Beam Width – Athwart (°)			
Angle offset – Along (°)			
Angle offset – Athwart (°)			
Raw data depth (m)			

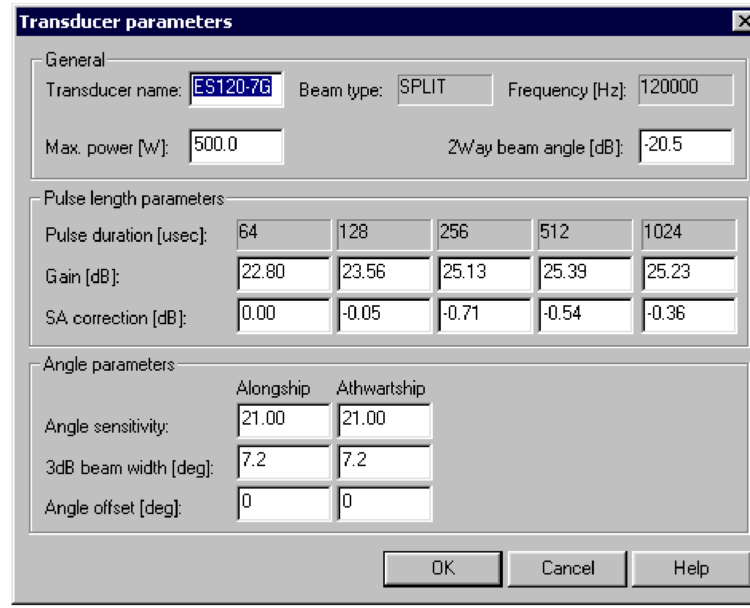
Comments / Notes:

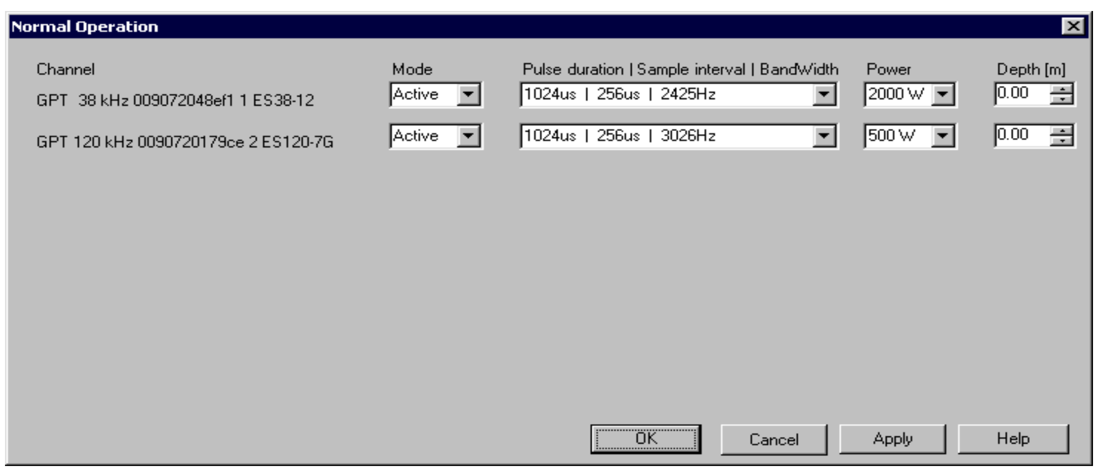
Equipment Schematic



Parameter Settings Screen Capture







Initial Sequence of Events
Lab this afternoon

1) Agree on survey goals
2) Decide on equipment configuration using knowledge of survey area and targets of interest.
3) Set up transect survey lines and activity budget given area to be covered and time available.
4) Log all data collection parameters and survey design information prior to start of survey.

Advice from E.J. Simmonds

- Check that your design matches your objectives
- Think about the analysis you will do to match your design
- Always try to follow the logic of how your samples will relate to the whole
- If you’re not sure of the logic of what you are doing it may not be correct