Planning of additional experiments for the BACOMA project

This note contains the report of the power analyses conducted as part of the planning of the additional experiments within the BACOMA project. The purpose of this pre-analysis is to provide information that can be used for making optimal decisions on numbers of hauls to be conducted and their allocation between the vessels.

Introduction

The power of an experiment is the probability of detecting a change. Power depends on

- magnitude of the detectable difference
- total variance (within- and between-hauls)
- number of hauls.

Under ideal circumstances the power analysis proceeds in three steps:
First a decision is made about what changes are of interest and with what probability this change should be detected if exist. Next, information about the variation is retrieved either from a pilot study or from previous comparable experiments. Finally the specification of change-of-interest and the variance are combined to calculate the minimum number of repetitions (hauls and sampling sizes) required to meet the specifications. Practical considerations such as financial limitations and logistic constraints prevents however often this approach. In that case a reverse and more pragmatic approach is to optimize the amount of information that the allowable resources permit.

The objective of the present study is to measure the selectivity of different codends using two vessels **K**ungsö and **V**ingarö.

Assumptions:
All codends have the same total variance for both vessels.
The amount of fish that will be measured are similar for all hauls and all codends and similar to the amount measured in the previous experiment.

Material and Methods

In addition to specification of a significance level (the risk of rejecting a true hypothesis or equivalently that a confidence region does not contain the true parameter) a proper experimental plan should also specify the risk of accepting a false hypothesis (error of type II). By convention it is common to set this risk to 10% or 20%. A lower level requires more experimental effort and the type II error is considered less serious than the type I error).

The two vessels, Kungsö and Vingarö, that have been selected for the trials have previously been used within the BACOMA project. Information about the selectivity parameters and the variances are thus available and can be used as sensible input for power analysis. The REML estimates of the mean selectivity parameters are

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Vessel	L50	SR
Kungsö	36.30	10.05
Vingarö	37.96	10.08

The estimates of the variance matrices are listed in the table below. The estimates of the "within-haul" variance are the mean values taken over all hauls with each of the two vessels.

Vessel	Within-haul	Between-haul	Total
Kungsö	$\begin{pmatrix} 0.1546 & -0.06033 \\ -0.06033 & 0.2006 \end{pmatrix}$	$\begin{pmatrix} 18.2519 & -7.6188 \\ -7.6188 & 4.2456 \end{pmatrix}$	$\begin{pmatrix} 18.4065 & -7.6792 \\ -7.6792 & 4.4462 \end{pmatrix}$
Vingarö	$\begin{pmatrix} 0.1293 & -0.03668 \\ -0.03668 & 0.1898 \end{pmatrix}$	$\begin{pmatrix} 4.5961 & -1.2533 \\ -1.2533 & 4.5128 \end{pmatrix}$	$\begin{pmatrix} 4.7253 & -1.2900 \\ -1.2900 & 4.7026 \end{pmatrix}$

Technical stuff

The power analysis of codend selectivity arise from normal test theory.
Comparison of two different gear types used with the same vessels can be concluded by testing a hypothesis of the form

$$\begin{array}{ll} H_0 & \theta_1 = \theta_2 \\ H_1 & \theta_1 \neq \theta_2 \end{array}$$

where θ denotes the selectivity parameter vector $(L_{50}, SR)^T$ Even though the experiments involve more gear types, the comparisons can be performed pair-wise and the argument maintains. Assume that H hauls is taken with each gear type and that the estimates from the individual hauls are maximum likelihood estimates with (asymptotic) distribution

$$\hat{\theta}_{i,h} \sim N_2(\theta_i; \Sigma)$$

i=1,2 index the gear type and h=1… H index the hauls. This implies

(1) $$\bar{\theta}_i = \frac{1}{H}\sum_h \hat{\theta}_{i,h} \sim N_2\left(\theta_i; \frac{1}{H}\Sigma\right)$$

The test is performed by referring

(2) $$F = \frac{(2H-3)}{4(H-1)} T^2 = \frac{(2H-3)}{4(H-1)} \frac{H}{2} \left(\bar{\theta}_1 - \bar{\theta}_2\right)^T S^{-1} \left(\bar{\theta}_1 - \bar{\theta}_2\right)$$

to a F(2,2H-3,0) distribution. Here S^{-1} is an unbiased estimate of Σ.

The power of the test is defined by

(3) $$Power = 1 - \beta = P\left[F(2,2H-3,\phi) > F_{1-\alpha}(2,2H-3,0)\right]$$

where the non-centrality parameter is

$$\phi = \frac{H}{2} \left(\theta_1 - \theta_2\right)^T \Sigma^{-1} \left(\theta_1 - \theta_2\right).$$

For planning purpose Σ can be substituted by an estimate of the total variance obtained from previous trials or from a pilot study.

If $\theta_1 - \theta_2$ is regarded as the smallest difference of interest, the power analysis now proceeds by using (3) to find the minimum *H* for which the experiment attains the specified level of power 1-β.

By (1) it is (not surprisingly) seen that more hauls allows θ_i to be determined with higher precision and hence smaller confidence regions, which can be derived from (2). Specifying the maximum allowable size of the confidence regions and varying the number of hauls until the requirements are met leads to an alternative planning approach which does not involve power.

Results

This planning involves two different vessels which have shown different variability structures in a previous trials period. Due to this difference it is not possible to achieve equal power between the two vessels for both *L50* and *SR*.

It is seen that *L50* and *SR* are much less correlated for Vingarö (-0.274) than for Kungsö (-0.849) and that V has more narrow confidence limits for *L50* than K has, see figure 1. On the other hand K appears to be more precise in measuring *SR* than V does. Consequently the planning depends on what the main interest of the experiment is. If the focus is on *L50* and the two vessels should measure these with similar precision then the number of hauls taken with K should be larger than the number of hauls taken with V. If, on the other hand, it is of concern also detect differences in *SR*, then the conclusion is somewhat opposite.

In the table below is listed the minimum number of hauls required to detect differences in $L_{50\%}$ as listed in the first column. Note that these numbers are calculated under the assumption of no difference in *SR*.

Delta	Hauls required	
$L_{50\%}$	Kungsö	Vingarö
2.00	27	23
2.17	23	20
2.33	20	18
2.50	18	16
2.67	16	14
2.83	14	13
3.00	13	12
3.17	12	11
3.33	11	10
3.50	10	9
3.67	10	8
3.83	9	8
4.00	8	8
4.17	8	7
4.33	8	7
4.50	7	6
4.67	7	6
4.83	7	6
5.00	6	6
5.17	6	5
5.33	6	5
5.50	6	5
5.67	5	5
5.83	5	5
6.00	5	5

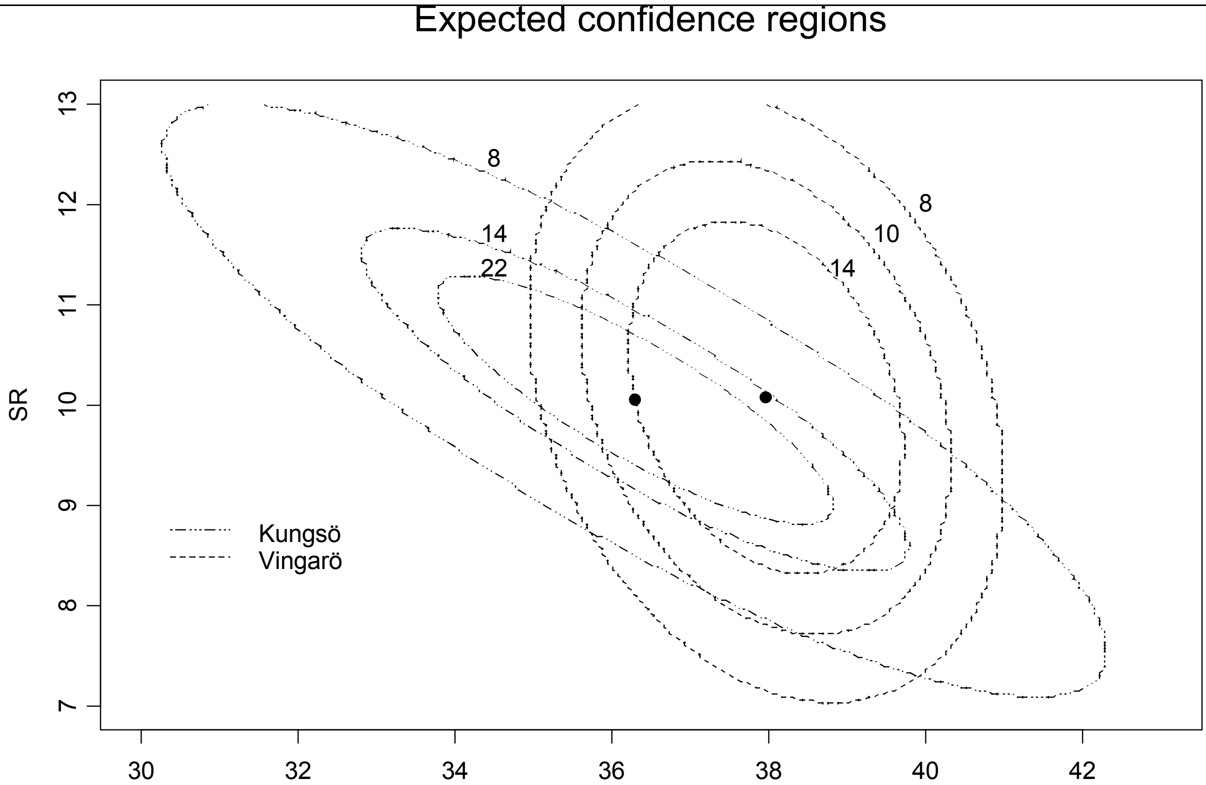

Fig. 1: 95% confidence regions for different number of hauls

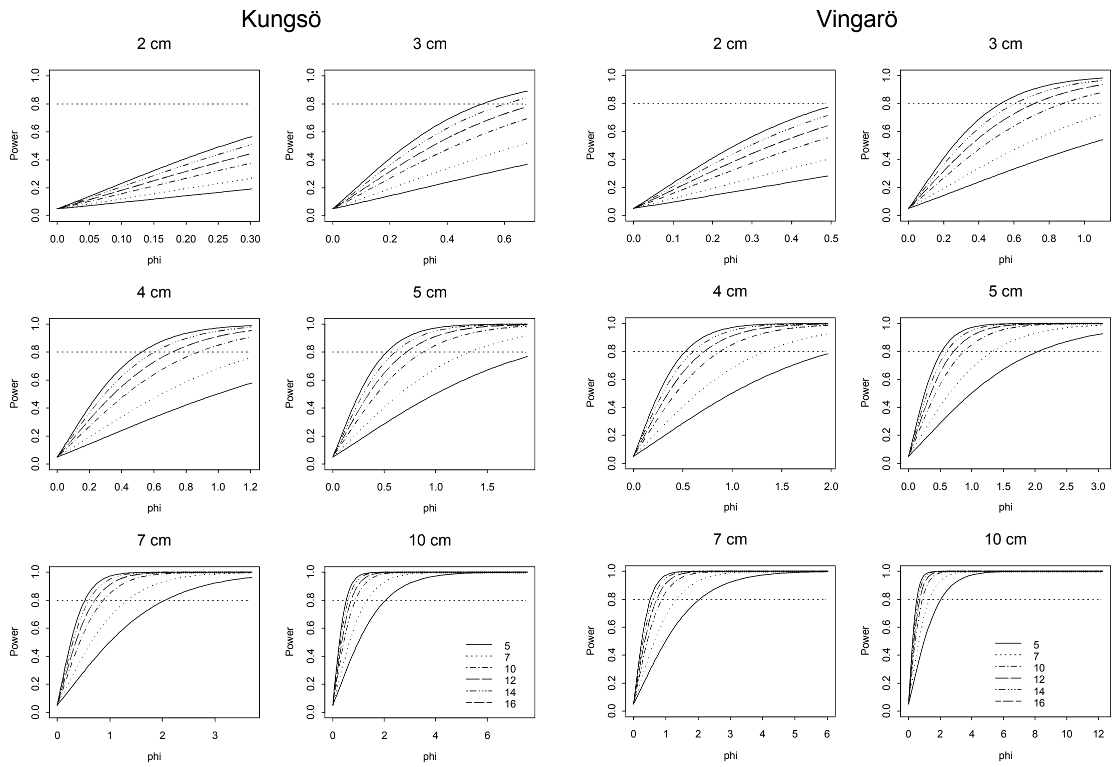

Fig. 2: Power curves for varying detectable Delta *L50*'s and different number of hauls

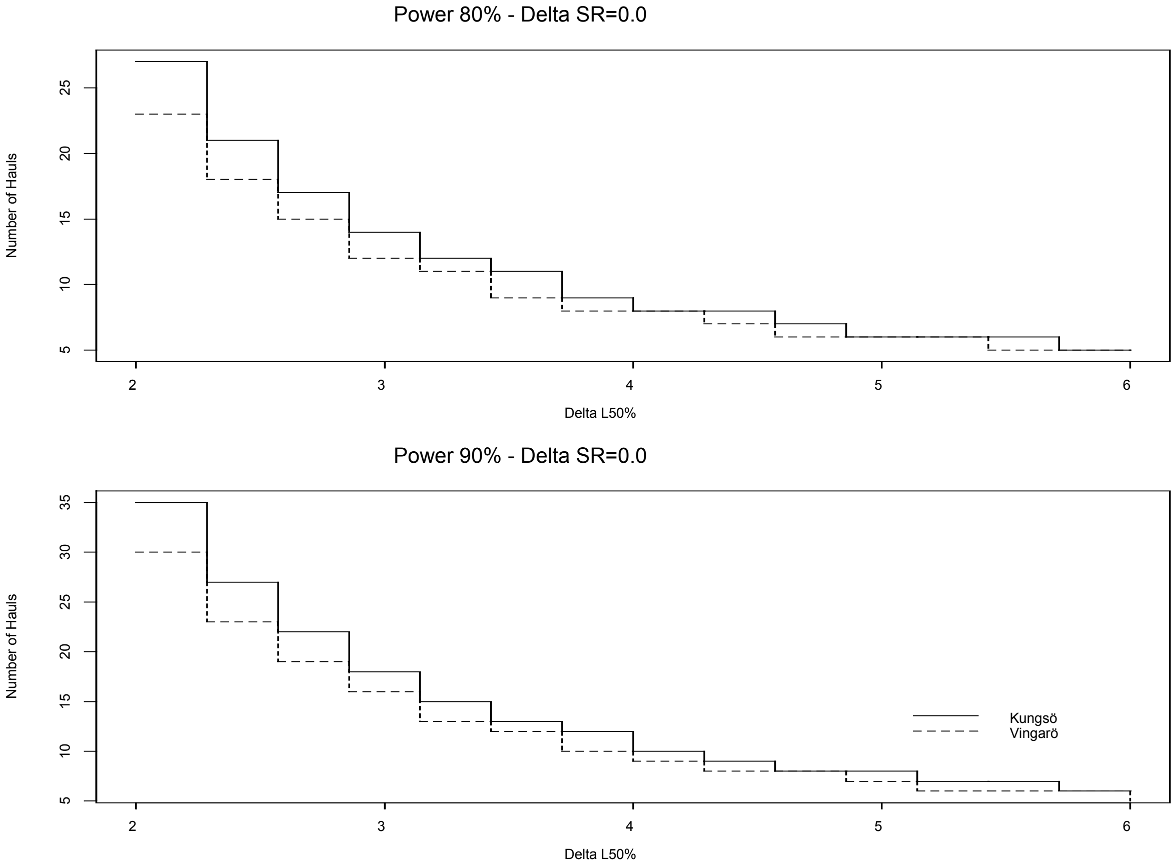

Fig. 3: Minimum number of hauls vs detectable *L50*. Delta *SR*=0

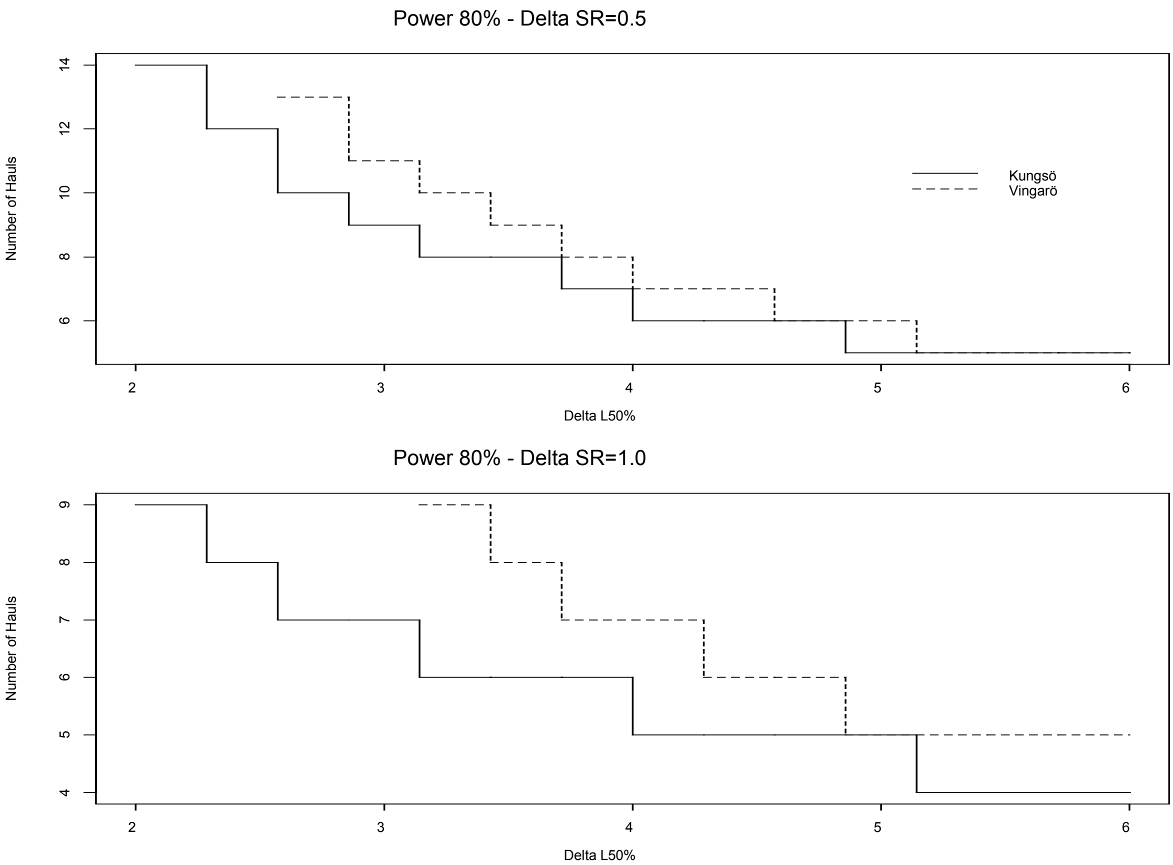

Fig. 4: Minimum number of hauls vs detectable *L50*. At two levels of Delta *SR*

References:

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Millar, R.B. and R.J. Fryer (1999) Estimating the size-selection curves of towed gears, traps, nets and hooks. Reviews in Fish Biology and Fisheries 9: 1-28.