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Monitoring ecosystems using research surveys; maximizing information and minimizing cost

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Abstract

Indices or estimates of abundance generated by research vessel surveys are becoming ever more important for assessing marine resources. Most often survey abundance indices are used in conjunction with commercial catch data to estimate fishing mortalities and stock size. However, for short-lived species (e.g. capelin) survey indices provide the only reliable information on stock development and even for long-lived species (e.g. cod), it has been shown that calibrated survey estimates tracked recent abundance trends more accurately than catch-based estimates. Multipurpose research surveys provide information on the spatial and temporal patterns of environmental and biological variables, which has enhanced our understanding of ecosystem interactions, assessment and management. The information needed for the ecosystem approach to management is increasing the importance of conducting multipurpose surveys, which is affecting vessel configuration and survey design. In this paper we examine the survey design and sampling routines for some IMR surveys and suggest ways to improve their efficiency, i.e. the utilization of vessel time.

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An Extended Abstract

Precision and effort

A substantial part of the research vessel effort at IMR (and in ICES) aims at monitoring ecosystem characteristics; that is updating and maintaining time series of various variables (physical, chemical and biological) in order to reveal temporal changes. Estimates used for monitoring are as a rule aggregates, indices or mean values of a large number of spatially distributed observations. The precision of such estimates depends on the number of observations and thus on the effort used to collect them as indicated in Fig. 1. Quantified relationships of this type are useful tools in effort planning, particularly regarding the number of observations needed, and relationships should thus be established for all the variables of interest.

Figure 2. The efficiency of the sampling allocation for a three-stage sampling scheme of commercial catches.

Figure 3. Precision of the age distribution versus the number of fish aged per catch.

Acoustic surveys

Aglen (1989) investigated the precision in acoustic surveying as a function of the research vessel effort. He established the formula

$$CV = a / \sqrt{d} \quad (1)$$

where d = sailed distance/ $\sqrt{area}$ is the degree of coverage, and estimates of a are between 0.4 and 0.8 for a variety of species and areas. Equation (1) is thus an empirical result which is helpful for evaluating the effort needed to achieve a desired level of precision. Figure 4 shows the relationship (1) for values of a = 0.4 and a = 0.8.

Simmonds (1995) asked the question: How should we divide the allocated time (vessel days) of the North Sea herring survey into time for acoustic coverage (number of transects) and time for trawling (number of trawl stations). He found that the precision of the abundance estimate remained constant (cv ≈ 0.2) over a wide range of combinations of transects and trawl stations.

Swept area surveys

Trawl surveys provide estimates of the abundance or relative abundance of fish as well as estimates of the relative frequency of various population characteristics, such as length, age and stomach contents. During the last decade a number of studies have been carried out to evaluate how fish sampling should be performed in order to increase survey efficiency (see Pennington et al. 2002 for references). In particular, tows of short duration (say 10 minutes) are more efficient than long tows (e.g., 30 minutes), it is best to measure a few fish from as many locations as possible, and the cruise tracks for random surveys are generally shorter, on average, than the cruise tracks for uniform surveys (e.g., systematic surveys).

Figure 5. Survey precision and tow duration.
Figure 6. Precision versus the number of fish measured per station.
Figure 7. Length of cruise track and survey design – uniform or random surveys.

IMR's research vessel capacity and effort

When the new research vessel "G.O. Sars" replaces 2 of the older vessels, IMR's total research vessel capacity will be reduced from about 900 to 700 vessel days per year. To some extent the greater cruising speed of the new vessel may compensate for this loss. Yet, a loss of almost 20 percent in terms of vessel days per year seems realistic. Is it possible to use the IMR vessels in a way so that this loss of capacity or effort does not significantly/substantially affect the quality of information gathered from the research cruises?

In the past IMR's research vessels to a large extent have been used for specialized cruises, i.e. cruises or surveys focusing on indices of abundance of one or two fish species, or on fish larvae and plankton, or on determining hydrographic indices. Table 1 and Fig. 6 depict IMR's research vessel effort in the Barents Sea in late summer – early autumn 2001. The time series of indices from these surveys are among the most important data for the evaluation of the state of the Barents Sea ecosystem; i.e. trends in stock sizes of important species, interaction studies, environmental development etc.

Table 1 indicates that the efficiency of the total effort is rather low. That is the average number of trawl stations per vessel day is, 529 / 165 = 3.2, which is about half the mean value commonly adopted when these surveys are planned.

Judging from Figure 8 (map) and table 1, considerable time must have been spent in sailing to and from the investigation areas in order to change scientific staff, although the areas show a high degree of overlap among cruises/surveys. Also the degree of coverage seems quite high. For the capelin cruise, from which the acoustic estimates of abundance are directly used to estimate next years fishing quota, the degree of coverage is between 25 and 30 and the question whether or not such effort is needed for stock assessment purposes should be carefully addressed. As for the 0-group survey, a reduction in the number of trawl stations by 20 percent would increase the CV of the 0-group cod abundance index about 3-4 percent. Taking into consideration that the dynamic range of the year-to-year variation of the abundance index is an order of magnitude (10:1), such a reduction in precision is insignificant.

Planning of surveys

The finding above indicate that:

- Empirical knowledge of the relationship between precision and vessel effort should be established and <u>used</u> in the allocation of vessel time.
- Multi-purpose surveys are preferred so that a variety of observations at various levels are measured at each observation point.