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Choosing survey time series for populations as part of an ecosystem approach to fishery management

Verena M. Trenkel[1,a] and John Cotter[2]

[1] Ifremer, Département EMH, BP 21105, 44311 Nantes, France
[2] CEFAS Lowestoft Laboratory, Pakefield Road, Lowestoft, Suffolk NR33 0HT, UK

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Abstract – Ecosystem assessments of fisheries based only on survey data will often have to use surveys that were designed historically for special purposes, e.g. for assessing abundances of two or three target species, or for tuning VPAs. An important question then is whether the previously collected data can provide informative time series of abundance indices and other state indicators for a wider range of target and non-target species. Some potential shortcomings of existing data series are treated in this paper leading to four questions which can guide the user to determine the suitability of an existing time series: did the survey cover the stock of each species adequately? Did survey catchability vary significantly between length or age classes? Did survey catchabilities vary significantly in space or time? Was the sampling effort sufficient? Simple methods for investigating these questions are proposed and illustrated with examples.

Key words: Indicators / Survey-based methods / Bias

1 Introduction

Survey based stock assessment and management approaches will in many cases be using existing time series data collected during surveys set up originally with specific objectives, for example the collection of recruitment indices for tuning analytical stock assessment models. Fundamental requirements for using survey CPUE data in these, or any other ways, are that

- design of the survey is consistent from year to year (ICES 2004, 2007);
- trawl gear is carefully standardised (ICES 2006a);
- codends are made of small mesh netting such that selectivity can be assumed to be reasonably constant for all fish larger than the selection range.

When broadening the use of a survey to an ecosystem-based assessment involving a wide range of species and indicators, it is important to know that the survey is adequate for each case, especially if there are no other data to support the assessment, e.g. on commercial landings or discards. The species of interest should have been identified and treated consistently in all years (Francis et al. 2003). For rare or non-commercial species, reliable species identification can be wanting, as pointed out by Daan (2001) for the International bottom trawl survey data for the North Sea. Although intercalibration studies can help to accommodate changes in survey gear or vessel, precise conversion estimates are usually only obtained for more abundant species (Pelletier 1998), hence it is advisable to keep any such changes to a minimum. For commercial species which are the main targets of analytical stock assessments, landings and discards data can help to check whether survey CPUE series can be considered proportional to abundance. However this is no longer possible when the data are also going to be used for non-commercial species. In addition, many survey trawls are not designed to reliably catch very small or very large individuals.

Yoccoz et al. (2001) stress the point that for monitoring (sampling) programs to be successful, the questions of why sample, what to sample and how to do it need to be considered together. Clearly, in the case of survey based approaches, the three questions are still relevant, but now the crucial issue is whether the existing data allow one to address the additional objectives of an ecosystem-based assessment.

The type of data collected determines the indices that can be calculated. If body size has not been measured, which has been the case for many non-commercial species in the past, no length–based indicators are available. Quantity may have been poorly estimated for rare species so that analyses may have to be restricted to presence-absence data. Other biological indicators may have specific requirements, e.g. season of sampling for maturity staging. Further details on a range of biological indicators can be found in Cotter et al. (2009) and Rochet and Trenkel (2003). The sampling design impacts the precision of estimated indices. Issues surrounding survey design have been extensively discussed by ICES (2004) but mainly in relation to

[a] Corresponding author: Verena.Trenkel@ifremer.fr

Table 1. Methods for identifying potential unsuitability of survey time series for given species.

Issue	Methods
Survey area ≠ stock area	• year class curves • ratio of abundance estimates of succeeding ages of a cohort • density maps
Variable catchability across length/age classes	• comparison of abundance estimates or length/age frequency distributions for different data series
Variable catchability in space or time	• checking consistency of survey protocol
Sampling effort not sufficient	• occurrence limit • density limit

target species. Precision for non-target species may not be as good.

There are several issues that need to be considered for each species of interest before using a survey time series as the unique data source for carrying out a survey-based stock assessment (Mesnil et al. 2009), for generating ecologically informative indicators and, more generally, for providing management recommendations (Trenkel et al. 2007). Some important issues leading to bias or unduly large uncertainties regarding the evolution of a stock are

- surveyed area or depths did not encompass the stock;
- survey catchability varied strongly between size or age classes;
- survey catchability varied strongly in space and time;
- sampling effort was too small given rareness of the resource.

In the next sections we examine each point in turn, indicating methods (Table 1) which might be used for investigating whether the issue makes a given survey series unusable for a species of interest, and illustrating the methods with some examples.

2 Did the survey cover the stock?

There are various reasons why survey areas might not encompass stock areas, in addition to the problem of stock boundaries not being well known, or survey areas varying between years. The simplest reason is that part of the stock, or certain age classes, live outside the survey area or in the part of the water column not sampled by a given observation method. No single survey will cover the whole stock area for geographically widespread species such as hake in the northeast Atlantic; a single stock probably extends from Norway to Mauritania (see overview in ICES 2006b, p. 48). For other species the problem might be that certain age groups are too deep to be trawlable, or too shallow for the survey vessel to access them, they live in midwater above most trawl headlines, or they are not accessible to the survey gear because their habitat is, for example, too rough to be trawlable. Three easy methods might allow one to check for consistency in stock coverage: i) year class curves (Cotter et al. 2007), ii) the ratio of abundance estimates for age $a + 1$ in year $t + 1$ to those of age a in year t and iii) density maps (Table 1).

Anchovy in the Bay of Biscay is an example of a species with a variable proportion of recruits too close to the coast and thus in waters too shallow to be reached by the survey vessel being used. The measurable effect of this is that estimated numbers at age 2 (derived from acoustic survey information and identification trawl hauls (Massé 1996)) can be higher than estimated numbers at age 1 in the previous year (Fig. 1a). Similar results can be found for cod in the North Sea using International Bottom Trawl (IBTS) survey data. The ratio of abundance at age 2 in year $t + 1$ to abundance at age 1 in year t is larger than 1 in most years (Fig. 1b). In the older age groups, e.g. $\mathrm{age5}_{1990}/\mathrm{age4}_{1989}$ this effect may be caused by small sample sizes. However, the effects described above can also be caused by size selectivity or changing geometry of the trawl with depth so that in each case it is necessary to find the most plausible explanation.

The map of the density of lesser weever individuals in the Bay of Biscay indicates that there might be two hot spots in the distribution (Fig. 2). The offshore one might not have been covered completely by the survey, given the highest density values are at the edge.

In addition to the above issues, species might move out of, or into the survey area in response to changing environmental conditions. Diel migrations or other changes in activity patterns can also lead to variability in availability to the survey gear (Godø 1994; Benoît and Swain 2003). This issue is related to changes in catchability treated below.

3 Did survey catchability vary significantly between length or age classes?

Many scientific surveys have been designed as young fish surveys. For example, what is called today IBTS started off as the *International Young Herring Survey* (IYHS), then became the *International Young Fish Survey* (IYFS) before finally obtaining its current name (Heessen et al. 1997). The change in objectives reflected in the varying names did not imply any change in design, rather a modification of the list of species for which information was collected. Hence in response to the initial objectives, a sampling trawl (GOV 36/47) designed for catching young fish is still used today. The time of year of the survey was decided for the same reasons.

The consequence of designing surveys to target recruits is that there can be the problem of size classes not being

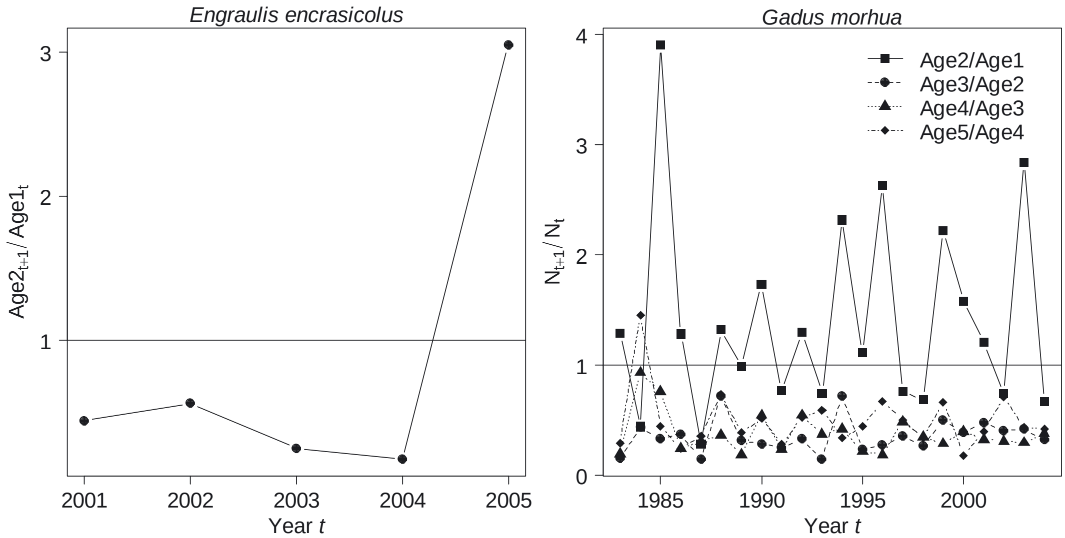

Fig. 1. Checking spatial coverage of survey data series. a) Ratio of acoustic survey abundance estimates for age2/age1 anchovy (*Engraulis encrasicolus*) in Bay of Biscay; b) Ratio of bottom trawl abundance estimates for successive ages for cod (*Gadus morhua*) in North Sea. Ratios > 1 might be caused by abundance-related migrations into the survey area or changing selectivity with age.

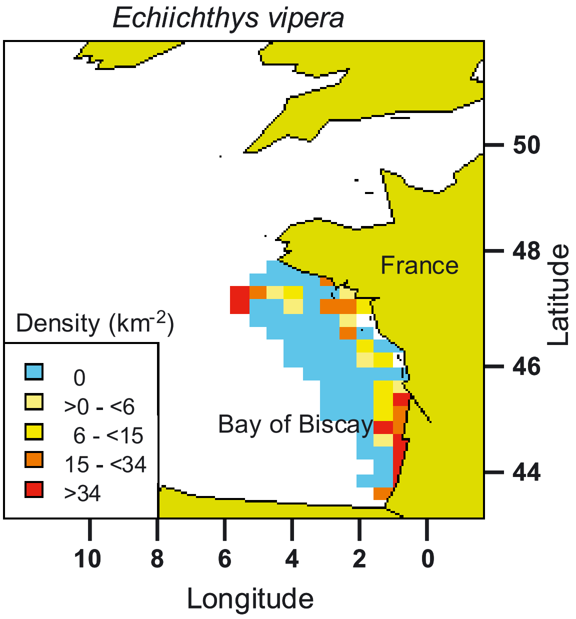

Fig. 2. Checking spatial coverage of survey data series. Average density per km^2 for lesser weever in the Western IBTS groundfish survey (1987-2006). Categories are quantiles.

represented in the survey catches in the same proportions as they are in the stock. This can be due to the rigging of the survey gear being used (escapement of larger indiviudals or herding), the vessel speed, or of course an area mismatch dealt with above. If several survey series are available, for example at different times of the year or with different trawls, a simple way of investigating the coherence of the series is to compare abundance-at-age estimates (Beare et al. 2002) or length distributions (Trenkel et al. 2004) (Table 1).

As an example, consider the relationship between survey abundance estimates for a selection of species in the central Celtic Sea obtained in autumn and spring using the same bottom trawl (Fig. 3a) and two different types of bottom trawls (Fig. 3b). For hake (*Merluccius merluccius*) all abundance series are positively correlated. In contrast, for horse mackerel (*Trachurus trachurus*), there is a negative relationship between GOV derived abundance estimates in autumn and PHHT (Portugues high headline trawl) estimates in the following spring, while no relationhip is seen between autumn and spring PHHT indices. For Argentinidae, there is some evidence for negative relationships for both comparisons while for Norway pout (*Trisopterus esmarkii*), spring and autumn estimates based on the same trawl are negatively related, while using different trawls give positively related estimates. Given these differences, it is not surprising that detected time trends in log-abundance estimates for these species depend on the survey series being used (Table 5 in Trenkel et al. 2004b). A practical rule might be that if different survey series lead to similar time trend estimates, the stock most likely was sampled such that catchability q was constant across length classes. In that case, any one of the series is suitable for survey-based stock assessments.

4 Did survey catchability vary significantly in space or time?

A range of factors can make survey catchability vary between hauls and interannually even when the survey gear remains the same (Godø 1994; Hjellvik et al. 2002; Francis et al. 2003). Between-haul variability due to sampling error and spatial variations in population densities will most likely reduce the precision of survey indices while interannual variation in catchability might bias estimates and affect time trends. The latter might be called a year-effect in survey catches. A study of the potential year-effect in survey catches for the Western IBTS autumn groundfish survey taking place in the Bay of

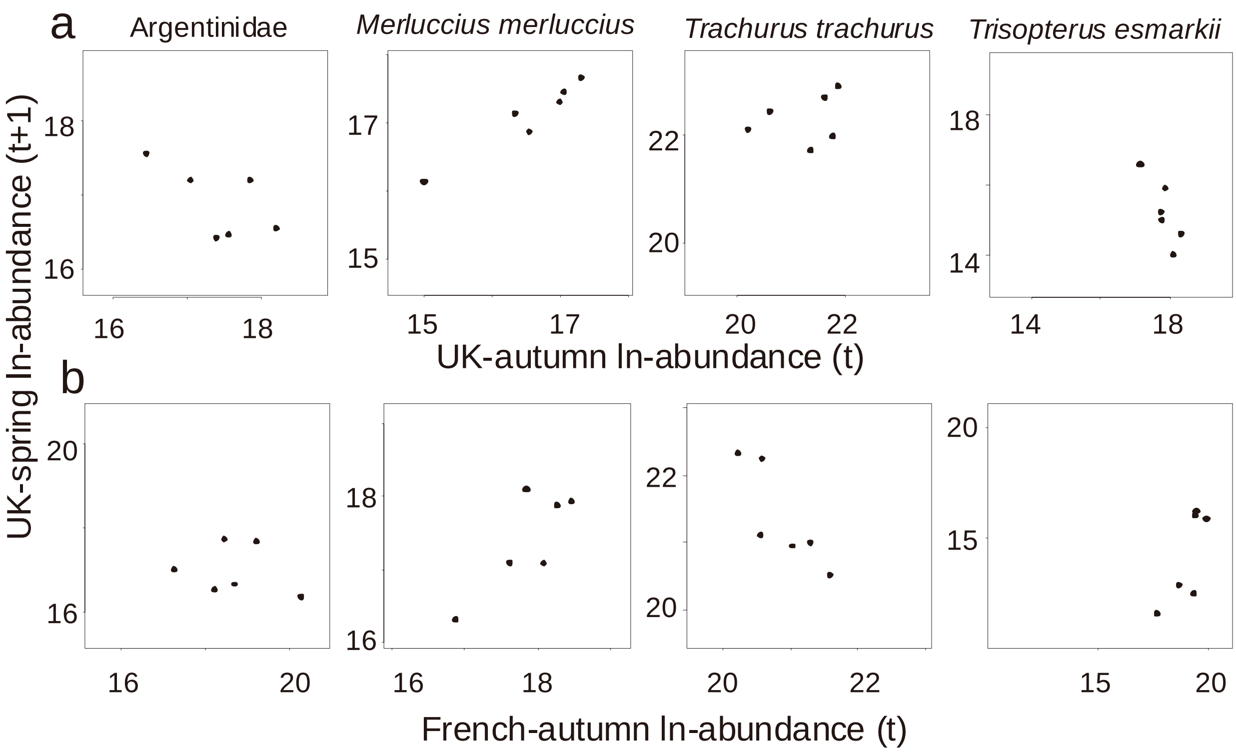

Fig. 3. Checking stock coverage of survey data series. Comparison of survey log-abundance estimates for Celtic Sea based on UK (1991, 1992, 1998-2001) and French survey series (1990, 1991, 1997-2000) (a) autumn (year t) with spring (year $t+1$) using same bottom trawl (Portuguese high headline trawl, PHHT); (b) autumn (year t) with spring (year $t+1$) using different bottom trawls (PHHT and GOV).

Biscay showed that, on average, 20% of interannual variation in abundance indices could be explained by survey conditions (wind strength, starting date,...) for benthic species, 11% for demersal, and none for pelagic species (Poulard and Trenkel 2007). In contrast, survey conditions explained a smaller and decreasing part of the interannual variability in the coefficients of variations of these abundance indices and in species mean weight. In the same study it was found that correcting for survey conditions using a multiple regression could alter time trends in species' abundance indices and, as a consequence, influence stock assessments based solely on survey information.

A range of biological processes might also influence survey catchability. For example, Swain et al. (1994) found evidence that the catchability of older cod was density dependent. However, clearly distinguishing shifts in survey catchability from random variation is very difficult in practice. A first step to detecting possible large changes in catchability is to carefully examine the consistency of the used survey protocol over the time series in terms of sampling method or gear, sampling design (number of stations and their spatial distribution) and sampling period (Table 1).

5 Was the sampling effort sufficient?

When using existing survey time series for a given species, various *ad hoc* rules have been used to decide whether sampling effort was sufficient. In addition to criteria regarding species identification, sampling area and gear selectivity, Francis et al. (2003) considered the percentage of tows where the species was present (occurrence) and the quantities that were caught (Table 1). Based on empirical trials, Rochet et al. (2005) excluded species with occurrence <5% on average in survey tows across the time series and <5 individuals per km^2 on average. The limits to be used will clearly depend on the survey and the species' biology but also its spatial distribution and the minimum density that might be estimable reliably with the given sampling effort, e.g. 100 hauls.

Consider the annual percentage occurrence (percentage of hauls where species was present) of Hollowsnout grenadier (*Coelorinchus coelorincus*) and pollack (*Pollachius pollachius*) in the Western IBTS bottom trawl survey data (Fig. 4a). In certain years the occurrence of both species was above the 5% exlusion limit, but on average it was below or even zero. The reasons why the two species occurred rarely in the trawl samples differ. Hollowsnout grenadier mainly occurs in deeper waters outside the sampled area. For pollack the survey area represents the southern geographic limit of the distribution hence when population abundance increases, the species might extend its southern limit and occur in larger numbers in the survey.

Instead of an occurrence minimum, a density limit (individuals per km^2 by species) can be used for selecting those species for which the sampling effort was sufficient. The histogram for the average density for 127 species found in the Western IBTS bottom trawl data is shown (Fig. 4b). The inset is a blow up for small densities. By excluding species with <5

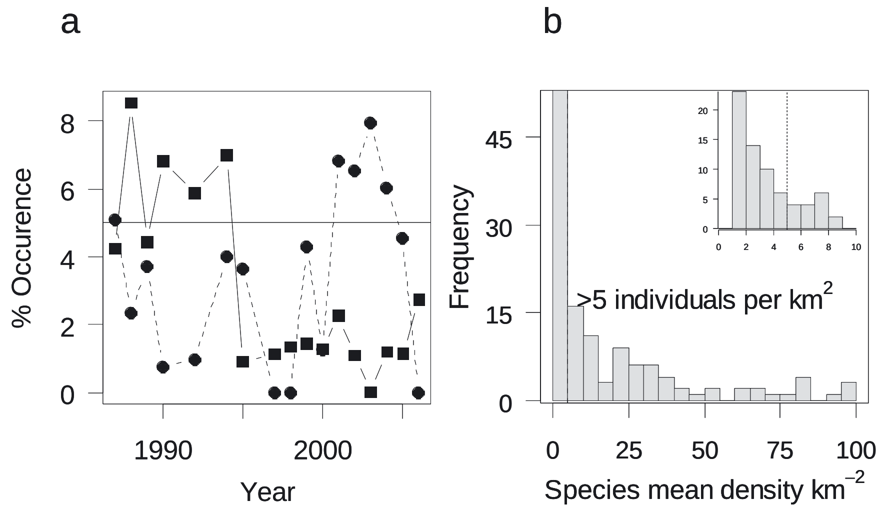

Fig. 4. Checking sufficiency of sampling effort of survey data series. Occurrence and average densities in Western IBTS bottom trawl survey data for the Bay of Biscay (1992-2006). a) the hollowsnout grenadier, *Caelorinchus caelorincus* (squares) and pollack, *Pollachius pollachius* (circles); b) mean density (km^{-2}) for 127 fish and shellfish species. The horizontal (a) and vertical (b) bars indicate the selection criteria of a minimum occurrence in 5% of trawl hauls and a minimum density of 5 individuals per km^2. The inset in (b) shows an enlargement for smaller densities.

individuals per km^2, 54 species would be removed from further analysis, 61 species if the minimum density was at least 7 individuals per km^2 and 69 species would be excluded in the case of a minimum density of at least 10 individuals per km^2. Thus for this survey series, the actual density limit is not important as the number of species with average densities between five and seven individuals per km^2 is small. As a consequence, the number of species for which the time series is deemed suitable changes little if a density limit between 5 and 7 individuals per km^2 is used. However, no hard and fast rules can be given, and a plot such as in Figure 4 should be inspected for any survey series to decide for which species it might be used.

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