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Causes of variations of two temporal series of hake's abundance indicators in the golfe du Lion (Mediterranean sea) obtained independently by commercial fishing data and by experimental survey data

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Abstract : The interest of the calibration of two chronological series of abundance index obtained from experimental and commercial fishing is useful because they are acquired in an independent manner one to each other, and in consequence, the sources of uncertainties and bias are different in these two experiences. In experimental fishing, the main source of mistake is linked to the small size of the sample. The sampled surface is very small, and moreover, the spatial heterogeneity of abundance index into the strata is important. In this case the imprecision of abundance index and their annual variability is higher than in the other case. In commercial fishing, fishermen tend to smooth the variations of abundance. The CPUE vary less quickly than the true variations of abundance. This bias is a general rule. Moreover, the yields are dependant of the variations of two factors : the catchability coefficient and the biomass. After having extracted of the yields the influence of the factors that have an effect on the catchability, the analysis shows that the common change of annual indicators of hake abundance reflects a stock change, in particular in the recruitment which depends on the environmental conditions.

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1. Introduction

The activity of trawling is characterised by the presence of numerous sources of variability. Biodiversity is particularly important and the fishing gear isn't selective, so much so that numerous species are exploited simultaneously. The gears and fishing techniques are also various. Finally, the areas concerned by the species and cohorts exploited are vast and variable from one cohort to the other and one season to the other. Yet the observation of such a fishery shows that these are always the same boats that use a particular gear to search for such particular target species in a given sector. The activity of the trawlers and the exploited stocks are structured therefore spatially and seasonally and this structure reproduces from one year to the other without change in situation. This variability in the modes of exploitation of a fishing resource lays down methodological complications in relation to the simple case where fishes as the units of effort are distributed on a random basis (see Laurec and Le Guen, 1981). The solution adopted to this general problem is to measure the variability of the catchability coefficient q[1] in all directions, in relative value to a situation of reference, in order to obtain a composite coefficient q, stable in the time, which is annually reproducible. In the case where the influence of some factors cannot be measured, it is necessary to take the precaution to keep from one year to the other the same conditions of fishing, in order to make relative comparisons of catches. Then, from data of fishing yields, it is possible, according to these conditions, to obtain a chronological set of yearly index of abundance. It is that we are going to make from data of fishing catches by experimental fishing, and by commercial fishing on the other hand.
The bottom trawl is a fishing gear that the boat drags behind it along the ground and catches the species that live on the bottom or close to it. A fraction of this resource escapes, the one that is situated in the zones that are inaccessible, in particular the hard bottom. Many factors can influence its fishing power. One can mention the shape and the measurements of the trawl, the size of the mesh, the shape and the measurements of the rigging, the speed of the trawler, but also, as external factors to the gear, the speed and the direction of the currents, the nature of the sediment, the depth, the hour of the day without forgetting the behaviour of fish that depends for part of the environmental conditions.
All these factors, which are external or internal to the gear, or which are linked to the behaviour of fish, have an effect on the catchability coefficient q. If all these factors are common to the experimental and commercial fishing, these two types of activity are otherwise very different in the pursued purpose and the implementation of strategies to reach them.
In experimental fishing, the spatial distribution of the hauls is independent of the distribution of the populations exploited. The purpose is to cover the geographical distribution of the studied species, that is to say the demersal and

[1] q : proportion of the stock taken by one unit of fishing effort.

benthic species of the golfe du Lion. The sampling method used is the spatial stratification. The studied zone is divided in strata which must be the most homogeneous possible in abundance variations, and must be the most heterogeneous possible between them. The abundance index and the associated variances are calculated taking into account the surfaces swept by the trawl during the hauls and also the ratio between the strata surfaces. A first difficulty appears here because the spatial distribution of abundance is not identical from one species to the other or from one cohort to the other. A compromise must be found in the spatial stratification of a lot of heterogeneous variables.

In the golfe du Lion, the spatial stratification is determined taking into account the depth, between the depths 10 and 800 m : 10-50 m, 50-100 m, 100-200 m, 200 - 500 m, and finally 500-800 m. Then, each of these strata is divided in two parts of which the limit of separation is located in the middle of the golfe du lion, to the longitude of 4°w, in order to respect at best the homogeneity intra stratum.

Once fixed the limits of the strata, it remains to determine the procedure of sampling of the hauls inside every stratum. A sampling respecting the conditions of an simple random sampling is achieved inside every stratum and the number of hauls by stratum is defined in proportion to the surface of the considered stratum. In fact, for convenient reasons, the strategy of sampling adopted is the one of a systematic sampling. The hauls are positioned on straight lines perpendicularly to the coast and equidistant between them. This strategy has the advantage to cover uniformly all of the studied zone. It is a technique of sampling which gives more effective results than the random sampling but that raises difficulties of variance evaluation. A manner to raise these difficulties is to use in this case the classic formulas of the simple random sampling that provide in these conditions, according to Cochran (1977), an upper limit to the variance.

The main source of uncertainty of this assessment method is linked to the small size of the sample. On the one hand the sampled surface is very small, on the other hand the spatial heterogeneity of abundance in the strata is strong. Imprecision waited of the results can be compensated in part by the realisation of a great number of hauls (Frontier, 1983).

In commercial fishing, the ships don’t cover all the area of distribution of the species, they only exploit the sectors reputed of stronger abundance. Besides, the catchability coefficient q varies according to several factors. The composition of the species in the catches of the trawlers depends on various factors among which it is necessary to mention the area and the season of fishing, the choice of species, and the type of gear used. The combination of these various factors defines what it is suited to call a *metier* (anon.,1987). It’s the reason of which we have to, first of all, define the practised metiers and to classify the trawlers in these various metiers. The approach is based on typologies of fishing operations involving multivariate descriptive methods like factorial analyses and classification techniques (Pelletier and Ferraris, 2000). Every boat has the choice thus to distribute its effort between one or several metiers. The difficulty that one meets in the definition of the metiers is to find

the discontinuities which permits to discriminate the activity of fishing. To distinguish too little metiers includes an activity to a level that denatures the reality and that brings only qualitative indications. On the contrary, a fine typology gives too much details, to characterise the different types of fishing. In these descriptive typologies, one can also get some difficulties to bring together isolated elements on the one hand - that can be important of the point of view of the dynamics of the whole - and on the other hand to define some borders between continuous elements in order to separate them.
Inside of a metier, the catchability coefficient varies according to several factors. It depends on the boat which fishes, the spatial and seasonal stratum where it takes place and the class of size to which belongs the considered fish. The retained approach consists to standardise the variations of catchability : for every factor, one chooses, among the possible modes, a mode of reference. Then the catchability of different modes are calculated relatively to the catchability of the reference mode. One constructs a new theoretical stock in which the coefficient of catchability is equal to the one that would have got the boat of reference if it had fished in the spatial and seasonal stratum of reference an individual of identical size to the reference size. The fundamental equations apply therefore to the modes of reference and the factor of catchability is a standard factor. The forecasting of catch are made in these standard conditions.
The complementary aspect between the two temporal series of abundance index is especially successful when the sources of uncertainties and bias according to one and the other approach are very different. Nowadays many authors work to the calibration of the experimental and commercial fishing data. For example, one can mention the works of Richards and Schnute (1986), Kulbicki and Wantiez (1990), Krieger (1992), Adams and al. (1995), Fox and Star (1996), and Abella and Violani (2000), etc.

2. Results

2.1. Results of the experimental fishing

The MEDITS trawl survey programmes in the Mediterranean achieved with the oceanographic vessel L'EUROPE began in 1994 and continue in a recurrent way at the rate of one cruise per year, in the spring. The densities observed, measured in weight and number of individuals by length class, are nowadays available (Bertrand and Relini, 1998). The exploitation of the MEDITS data collected from 1994 to 1999 surveys are made by calculating abundance indices : the sampling scheme, the method used to calculate indices and the computer program are presented by Souplet (1996). Results of yearly index of hake's abundance are presented in the table 1 below :

Year	Abundance index	Standard error	Variation's coefficient (%)
mean	38.94 (kg/km²)	-	-
1994	1.117	0.125	11.22
1995	1.047	0.153	14.61
1996	0.610	0.068	11.09
1997	0.433	0.048	11.15
1998	1.685	0.136	8.05
1999	1.107	0.163	14.77

Table 1 : Hake's abundance series obtained from experimental fishing (MEDITS survey).

2.2. Classification of trawlers in various metiers

Although, even today, no system for collecting data on fishing in the French Mediterranean exists, nevertheless it is possible to obtain CPUE because fishing in the golfe du Lion is not mixed with other fishing areas and the catch per trip is only sold at one auction. Furthermore the duration of fishing trip is always one day. In these conditions, the quantities of fish sold by the trawlermen of the golfe du Lion in one of six auctions are analysed like cpue, one day of sale by one trawler in an auction is equivalent to one unit of fishing effort. The data analysed are those of sales by French trawlermen in auctions in the golfe du Lion from 1994 to 1999.
The inter-auctions network is charged for the Direction of Fishing Administration of data collection which circulate by the auctions. Informations that circulate by this network are informed with details of production landed by ship and by fishing trip. They contain the day and place of sale, the identifier of the ship, species sold, their size, edibility, presentation, quality, type of transaction, and of course, the weight and price of each item sold. The network is responsible for the veracity of the information transmitted by auctioneers. It operates by comparing data received with previously established reference files. The data base is explained in detail in Pérodou (1999).

The activity of every trawler is described by the proportions of various species which are sold in auction during one year. The retained species, to the number of 16, are the following : sardine, anchovy, hake, poor-cod, anglerfish, skate, red mullet, octopus, cuttlefish, sole, red squid, common pandora, axillary sea bream, bogue, sea bass, and gilt-head sea bream.
The analysis is driven to the yearly scale then reiterated every year in order to show a possible long-term tendency in the various metiers practised by the trawlers.

All this information are gathered in a table R with n rows and p columns where the element r(i,j) corresponds, to the scale of the year, to the proportion of the j^{th} species in weight made by the i^{th} boat in one year. The description of this table of data is made by the technique of the Principal Component Analysis (PCA) that provides a descriptive graph of the activity of the trawlers, and a classification of these trawlers in the various metiers[2].

This exploration of the data by the technique of the PCA permits us to draw up a balance of the resemblance between boats and to determine some of the homogeneous groups of boats, in parallel to draw up a balance of the resemblance between percentages by species and to show some homogeneous groups of variables, and finally to superpose the two previous typologies in order to characterise one by the other.

In definitive, three metiers are characterised of the following way:

1) **the metier I ("small pelagic fishes")** is a group well differentiated, and is composed of boats that fish as target species the blue fish (sardine, anchovy), and secondarily the hake.
2) **the metier II ("inshore demersal species")** is composed of a few trawlers that rather fish some inshore groundfish species like sole, red mullet, octopus, cuttlefish, and of other groups of species which migrate between the sea and the lagoon. like the sea bass and the gilt-head sea bream.
3) **the metier III ("offshore demersal species")** is composed of trawlers which exploit as target species the **hake** and offshore groundfish species as the anglefish, the poor cod and the squid.

This typology is identical to the one found by Taquet and al. (1997) who analyses the data of Sete's fleet during the year 1989. In mean, 12 trawlers belong to the metier **III**. More precisely, its yearly evolution, whose tendency is to decrease, is the following :

[2] In a precedent study (Pérodou, 2000) the factors which are likely to explain the differences seen in the fishing power between boats have been researched, factors as their technical characteristics (length, engine power, etc.). Engine power did not appear to be a major factor in the difference noticed in fishing power of each boat. Two other explanatory factors are shown as evidence. They are the port where the catch is landed and the type of trawl, the bottom trawl (CF) and the trawl with the large vertical opening (GOV).It's the reason why we selected the trawlers of Sète that use a high vertical opening trawl (GOV). In this group, we also have eliminated the trawlers having landed in auction small yearly quantities, the threshold of elimination chosen is less than 500 kg per boat and per year. Finally, the fleet includes 30 vessels on yearly average, the extreme values being of 28 and 31.

Year	Number of trawlers
1994	16
1995	14
1996	12
1997	12
1998	10
1999	11
mean	12

Table 2 : Annual number of trawlers included in the metier **III**.

2.3. Evaluation of the yearly and monthly abundance of hake.

2.3.1. Model used and underlying hypothesis

Although it was Gulland (1956) who introduced the first linear model for studying factors affecting yields of fishing boats, it was Robson (1966) who is recognised as the inventor of this method. Many authors have since contributed to the spread of this method of statistical analysis : Laurec (1977), Gavaris (1980), Kimura (1981), Large (1992), Hilborn and Walter (1992), etc. The model used assumes a priori that there is no interaction between explanatory variables and looks at one species at the time.

A group of boats numbered i=1 to N_b is looked at. Fishing power of the boat i is P_i. According to the three factors model, many years are considered separating the annual effect and the seasonal effect. Years are numbered k=1 to N_y and seasonnal strata j=1 to N_s. Respective apparent abundance are labelled D_k and A_j. Each observation U is a CPUE. It is indexed by l =1 to N_o. With this notations, the three factors model is written :

$$U_l = D_{k(l)} \cdot P_{i(l)} \cdot A_{j(l)} \cdot E_l$$

Fishing power and apparent abundance are relative values. By convention one assumes :

$$\prod_{i=1}^{N_b} P_i = 1$$

$$\prod_{j=1}^{N_s} Q_j = 1$$

The general circumstances in which this model is applied is when there is consistency from one year to another in the fishing power of boats and in the apparent abundance of seasonnal strata. It is the principal hypothesis which is called reproductibility of structures. Furthermore the annual component D_k of apparent abundance is held to be constant in a year k and the same for all the boats.

Finally, abundance are said to be apparent in order to not forget that they correspond to a combination of three factors : the actual density of fish, the behaviour of the fishermen towards a certain species and the efficiency of the fishing gear.

2.3.2. Adjustement

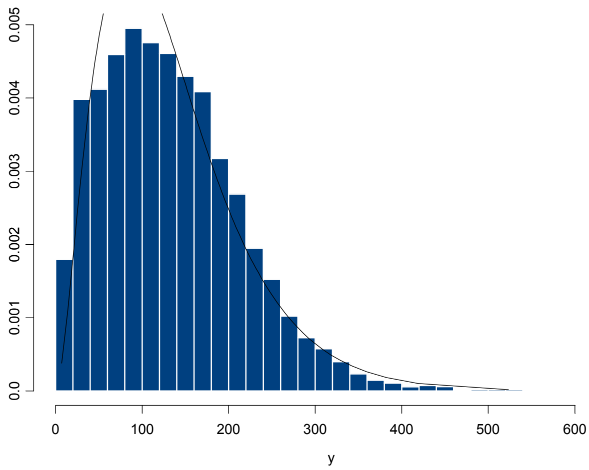
A better adjustement is obtained by the use of a General Linear Model (GLM) (Mc. Gullagh and Nedder, 1989) instead of a Linear Model. The use of GLM is recommended by several authors such Hilborn and Walters (1992), Large(1992), Stefanson (1996), etc.

The frequency distribution of hake CPUE is skewed and the variances are not independents from the means. The results indicate that a gamma distribution is adequate because the variance is proportional nearly to the square of the mean. The gamma density function is expressed within GLM' s in terms of the mean μ and the parameter v that determines the shape of the distribution. The parameter v, assumed constant for all observations, is σ^{-2}, where σ is the coefficient of variation. The gamma variance $V(\mu) = \mu^2/v$ and a logarithmic-link log(u) function is used to related the expected CPUE to the predictors.

2.3.3. Exploration of the data, previously to the modelling

The fishing trips of boats which belong to the metier **III** represent a sum of 12 017 trips on the initial base of 165 000 trips. As a supplement to this selection process, the data lower than 10 kg of hake by fishing trip have been

removed, which correspond in general to the incidental catches, and also data where boats are present just one or two years on the 6 years which constitute the present base have been removed. In definitive, it is a set of 9 918 trips that we selected on a base of 12 017 fishing trips belonging to the metier **III**.
The usual statistics that we can withdraw from this data set is the following : the extreme values go from 10 kg/day to 636 kg/day. The median value is equal to 123 kg/day and the mean equal to 134 kg/day with a standard deviation of 81 kg/day. The distribution of the CPUE is close to a gamma law as is shown in the histogram below :



<u>Figure 1</u> : Frequency distribution of hake's CPUE from metier **III** of trawlers.

Before examining results it is worthwhile looking at a number of simple plots. We are interested in the graphic highlight of possible interactions between factors, interactions that would contradict the principal hypothesis of independence of the explanatory factors. On the figure 2 below, we note an almost-parallel evolution of the yearly means of the different trawlers belonging to the metier **III**. Two ships - from an initial number of 12 - are excluded because of a divergent evolution of their yearly mean (they are not represented on the graph). We can conclude therefore at the absence of interactions between these two factors, that is, let's not forget, a necessary condition to the good application of our model.

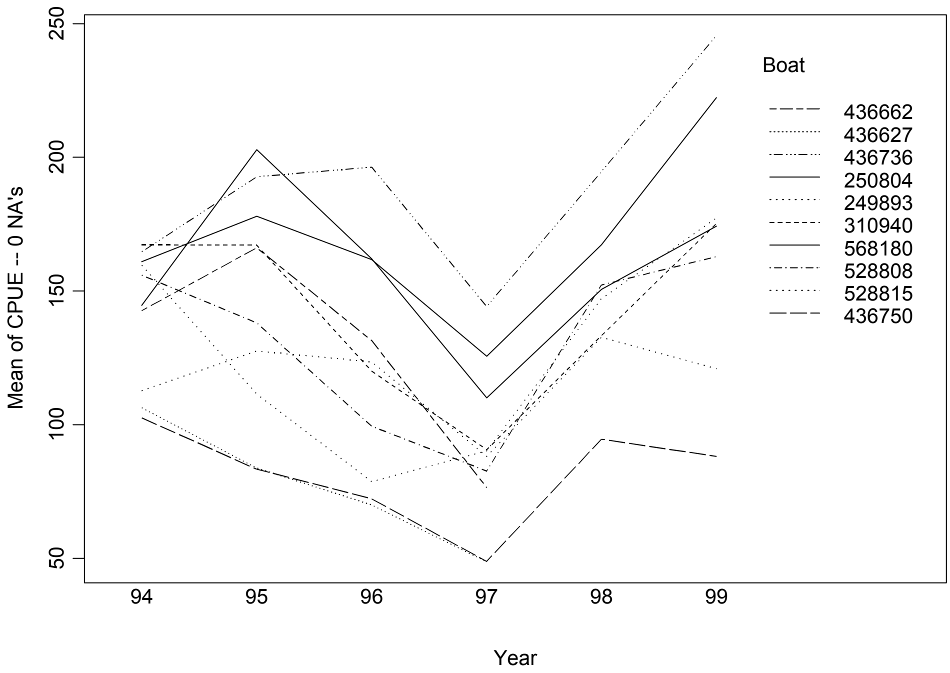


Figure 2 : Monthly mean yield (kg/day) of hake caught by trawlers belonging to metier **III**.

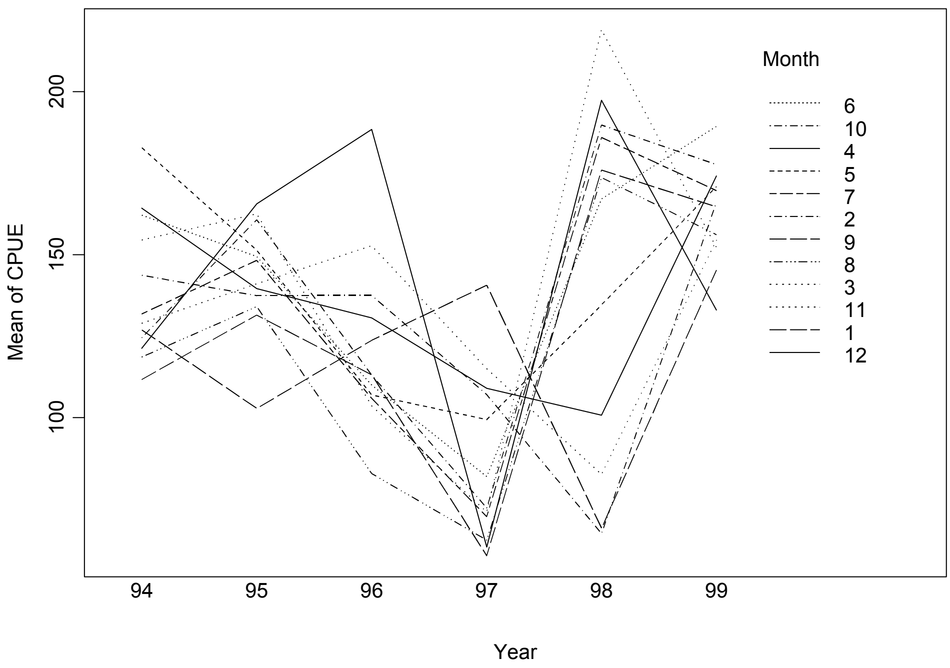


Figure 3 : Monthly mean yield (kg/day) by year of hake caught by trawlers belonging to metier **III**.

On the contrary, the next figure 3 of interactions between the factors years and months presented above highlights interactions between these two factors, which means that the annual repetition, of the spatial and seasonal biologic phases (recruitment, reproduction, seasonal migrations) are not assumed from one year to the other. This result contradicts the main hypothesis of the model used, the reproducibility of the structures from one year to the other, or as says previously, the independence of the explanatory factors.

2.3.4. Results

The table 3 of deviance analysis, below, indicates that this three factors model without interaction explains 21.6% of the total variance of the data set, either 13.8% for the boat factor, 6.9% for the year factor and 0.8% for the month factor. The interaction between the factors year and month now explains 11.5% of the total variance of the data and is classified therefore in second position, the values of the three primary factors remaining unaltered.

	Degree of freedom	Explained variance (%)
Null	9917	100
Trawler	9	13.8
Year	5	6.9
Month	11	0.8
Year:Month	55	11.5

Table 3 : Analyse of deviance from a model of hake's CPUE as a function of boat, year, month, and with month and year interactions.

Results of yearly coefficients are presented in the table 4 and 5 below :

Year	Coefficient	Standard error	Variation's coefficient (%)
Intercept	127.3278 (kg/day)	0.7025	0.55
1994	1.1032	0.0123	1.11
1995	1.0963	0.0126	1.15
1996	0.9069	0.0105	1.16
1997	0.6884	0.0085	1.23
1998	1.0826	0.0135	1.25
1999	1.2250	-	-

Table 4 : Intercept and coefficients of the year factor of a GLM where hake's CPUE in metier **III** is modelled as a function of year, month and boat.

Year	Coefficient	Standard error	Variation's coefficient (%)
Intercept	122.8175 (kg/day)	0.6410	0.52
1994	1.1269	0.0117	1.04
1995	1.1358	0.0122	1.07
1996	0.9392	0.0101	1.08
1997	0.6322	0.0081	1.28
1998	1.0429	0.0121	1.16
1999	1.2617	-	-

Table 5 : Intercept and coefficients of the year factor of a GLM where hake's CPUE in metier **III** is modelled as a function of year, month, boat, and with interaction between month and year.

To take interactions between the two variable month x year into account increases the predictive value of the model : the part of the variable explained increases strongly, which is not negligible, but it decreases its explanatory and operative value. Indeed, if the crossed effects are significant, the simple effects have little meaning separately. The effect of the interactions affects in the order of **3 to 4%** the values of the annual index of abundance as it is shown in the graph of comparison of the values below.

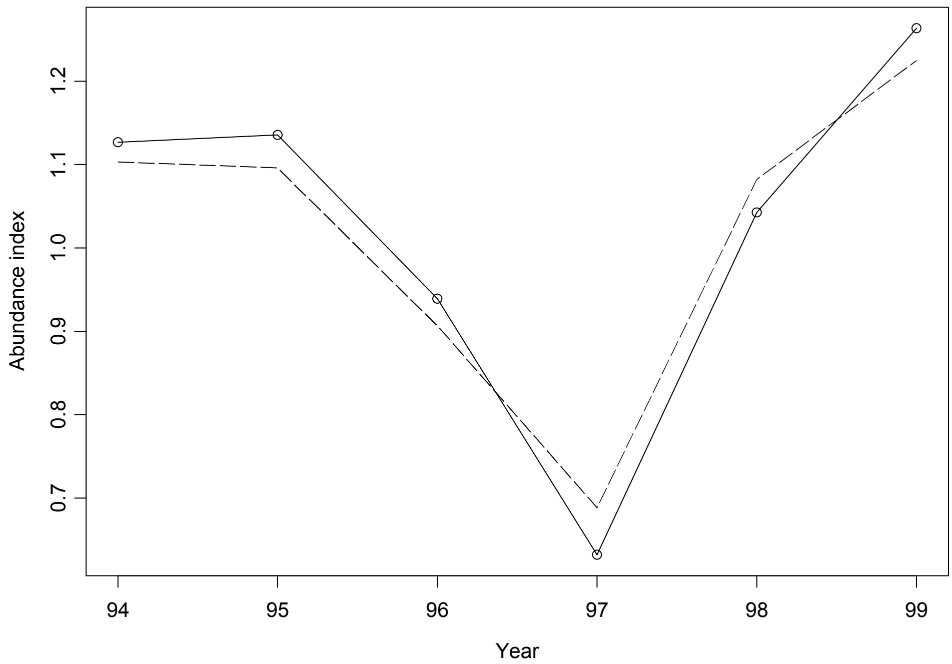


Figure 4 : Abundance index series without interactions month x year (dotted line) and with interactions month x year (solid line).

3. Comparison of two temporal series of hake abundance in the golfe du Lion obtained independently by commercial fishing data and by experimental survey data.

Indices obtained by two temporal series of hake's abundance are presented below in the table 6 and figure 5.

YEAR	**COMMERCIAL FISHING (without interaction)**	**Standard deviation**	**EXPERIMENTAL FISHING**	**Standard deviation**
Intercept	127.3278 kg/day	0.7025	38.94 kg/km²	**-**
1994	1.1032	0.0123	1.117	0.125
1995	1.0963	0.0126	1.047	0.153
1996	0.9069	0.0105	0.610	0.068
1997	0.6884	0.0085	0.433	0.048
1998	1.0826	0.0135	1.685	0.136
1999	1.2250	-	1.107	0.163

Table 6 : Hake's abundance series obtained from commercial and experimental fishing.

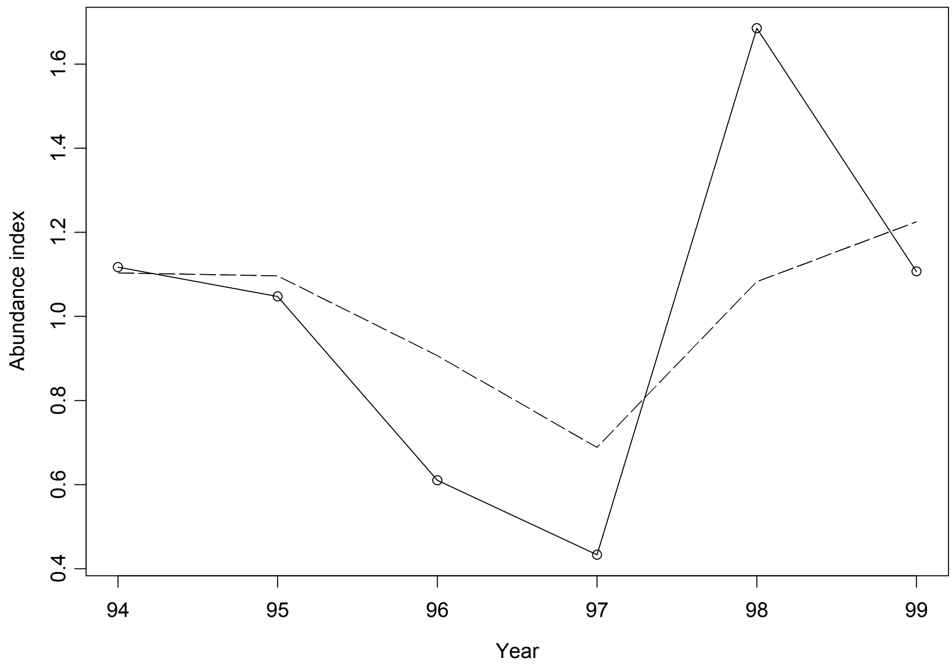


Figure 5 : Hake's abundance index from commercial data (dotted line) and experimental data (solid line).

3.1. How to interpret these differences ?

In experimental fishing, the main source of mistake of this method is linked to the small size of the sample. On the one hand the sampled surface is very small, on the other hand the spatial heterogeneity of abundance in the strata is important. Moreover, the seasonal variability isn't separated from the total variability and is incorporated in the long-term variability. Imprecision expected of the results is therefore increased, we can only collect a series with a great variability, that, in the case of one short period of observation as ours, can hide the real tendency of the biomass evolution. Imprecision expected of the results can be compensated in part by the validation of a great number of hauls.

In commercial fishing, on the other hand, fishermen tend to smooth the variations of abundance. Indeed, in case of abundance reduction, fishermen tend to report their effort in the research of others species, and, therefore, the yearly indication decreases less quickly than a real reduction of abundance that is leads to bias which is especially bigger than the biomass is smaller.

This bias exists also in case of increase of abundance but for another reason : in this case, the selling price decreases and the fishermen tend to abandon the species to the profit of other more lucrative species.

It is necessary to deduct that, in a general manner, the CPUE vary less quickly than the real variations of abundance. Otherwise an inverse relation exists between the catchalility coefficient and the true abundance, relation which should not exist according to the main hypothesis of our general model.
The existence of such bias that absorbed the fluctuations of abundance that we tire to measure is reinforced for another reason : the boats are not distributed at random in the strata but assemble in groups around the best concentrations of fishes. Therefore, the model used provides rather an indication of density inside the concentrations of fish than an indication of the real abundance of the fish stock, and this indication of density inside the concentrations varies less quickly than the real abundance of the stock. Therefore, it would be as interesting to measure the size and the number of fish concentrations as to calculate a mean inside the concentrations.
Thus, the observed differences between the two techniques of relative measure of abundance are explained logically and can be predicted in the case of hake. Similar studies should be carried out for other species to validate this first results.

3.2. importance to understand the fishermen's behaviour

Research catches are more apt to reflect actual fish distribution whereas commercial data are more greatly influenced by the fishermen's behaviour. The dynamics which govern fishermen‘s behaviour are probably as complex as those of the fish populations and understanding fishermen's behaviour is of equal importance for the successful management of a fishery. It is suggested that monitoring segments of the fleets exploiting a ground fish resource like the hake may suffice to obtain representative abundance indices. To corroborate this point, longer series of standardised catch rates should be compared to abundance indices derived from surveys

3.3. Importance of the climate and the hydrodynamic forces in the factors responsible for the yearly variations of hake's abundance

The variations observed in the yearly evolution of the indications of hake abundance reflect a real change in the state of the stock and more precisely a change in the recruitment of hake's juvenile (groups 0, 1 and 2), which is a major reason of abundance fluctuation of this type of population characterised by a strong relation between the environment and the recruitment. The recruiting period of hake is spread on all year with one preferential period from April to October. Analysis of area-month-year interactions show that seasonal fluctuations are differed by years, but also by areas as it's shown by Alvarez and al. (2001) on the comparative analysis of the hake's yields in north-western Mediterranean trawl fisheries regions (south and north of Ebro river, the golfe du Lion, and the northern Thyrrenian sea). These results suggest that factors affecting recruitment are local phenomena rather than major forces occurring at large geographic scale. Recruitment processes of European hake are poorly understood, and Sandy and Gill (2000) showed that processes of recruitment lead to well defined patches of juveniles in localised areas of the continental shelf. On the point of view of its biologic productivity the golfe du Lion appears to be a particularly productive system because of the following factors : a large continental shelf, a river with a strong flow (the Rhône), a Liguro - Provencal current carrying away the waters of the Rhône toward the golfe du Lion, finally and especially the action of powerful winds as the Mistral or the Tramontane causing the ascent of waters along the coasts (upwelling). Thus, the simple most influential factors for determining year class strength are probably the strength of prevailing currents and the upwelling caused by the wind.

3.4. Importance to analyse the spatial structure in fish distribution

It would be indispensable to acquire the information which takes into account of the strategies of occupation of the space by the resource but also by the fleet.

Indeed, in the face of the aggregated character of the resource, it is necessary to understand how the individuals distribute themselves between the different habitats. The fishermen know how to use this heterogeneity to achieve high catches. Therefore the yields of commercial fishing correspond to a *not random sampling* very linked to the spatial and temporal structure of the resource which doesn’t respect the basic conditions of the sampling theory. It is one of the reasons for which the variations of abundance from commercial yields are biased.

Another factor responsible for bias comes from what the calculation corresponds to the situation for which one doesn’t have any information on the precise localisation of the CPUE. To solve this problem one could conceive to use a spatial information. Beverton and Holt (1957) consider already the problem of non uniform spatial distributions for the fish and the fishing effort, and they show that the CPUE for the fleet will be an index of fish abundance provided that it is calculated as sum over all spatial regions of the CPUE values in each region.

Moreover if the area A of extension of the stock sustains systematic variations in relation with the abundance of the stock, a bias results from it in the CPUE taken like indication of abundance of the hake. The simulations achieved by Gauthiez (1997) show that the distance to the linear relation between CPUE and abundance is small when the occupation of the space by the resource is governed by a model to proportional density (with A constant). On the contrary the model with constant density (with A variable) leads to high variations of the catchability from the moment that the distribution of the effort is heterogeneous. The catchability is then a decreasing function of abundance.

So the acquirement of spatial CPUE would permit to fill this lack of information and to increase the quality and the precision of the available data base very distinctly for the assessments of hake stock.

3.5. Improvement of the stratification of the resource in experimental fishing

The mode of spatial occupation of the resource, notably in its density-dependence aspect, has a decisive influence on the relation between the catch and abundance. In the framework of the spatial distribution analysis of the resource, it would be desirable to put in relation these structures with the structure of the environment, notably the abiotic factors. Thus, increasing the sample size in experimental survey is often not realistic, the only alternative is to stratify the sampling more effectively rather than simply on the base of depth. Better stratification can come only from a greater understanding of the biological factors responsible for fish distributions. An adequate understanding would include the association of fish with microhabitat and the biological behaviour of fishes which leads to patchiness. Surveys could then be stratified on the basis of areas where fish are occurring at background levels and in large patches. New biological information could lead to the biological understanding necessary to achieve more efficient stratification designs.

3.6. Replacement of the monospecies model by a multispecies model better adapted to the activity of trawling.

The catch achieved during a fishing operation is composed of several cohorts and several species. To take into account this heterogeneous character of the resource, it would be desirable in the procedure previously used of standardisation of the catchability coefficient to pass from a monospecies model to a plurispecies model that can write itself with the following notations:

- y for the year ;
- s for the seasonal and spatial stratum ;
- a for the year class (or the length class) of a given species ;
- m for the métier ;
- b for the boat ;
- l for l th observation.

$$U_{(l)} = \sum_{a=1}^{A} U_{a(l)} = P_{bm} \cdot \left(\sum_{a=1}^{A} D_{ya} Q_{sa} E_{ysbma(l)} \right)$$

with three supplementary hypotheses :

- *P_{bm} doesn't depend on a ;*
- *D_{ya} doesn't depend on m ;*
- *Q_{sa} doesn't depend on m.*

For the adjustment of such a model which is not linear one can use the procedure followed by Laurec and Pérodou (1987) or to use the least square method generalised as indicated by Gauthiez (1997).

4. Conclusion

The complementary aspect between the two temporal series of abundance index is especially successful than the sources of uncertainties and bias according to one and the other approach are very different : imprecision linked to the small samples in the experimental fishing, tendency to level the abundance variations in the commercial fishing.

Our results indicate that data collected from research cruises and commercial fishery are complementary rather than contradictory and the synthetic method may be very useful in stock assessments. Probably neither method does a particularly good estimation of fish abundance for species which are patchily distributed. A great deal of variation due to patchiness in fish distribution remains.

In conclusion, a complete information on the localisation of commercial catches is not sufficient to absorb the bias inherent to these observations, contaminated by the active research lead by the fishermen to localise the resource. If, in the stock assessments, the long-term projections are based on the VPA methods, on the other hand, the short-term projections depend on indications of abundance issued from the commercial fishing data and the hypothesis of a linear relation between the fishing effort and the coefficient of fishing mortality. And this short-term diagnostic would be confirmed by the results of data issued from experimental survey which are the only ones that bring indications of abundance non biased and whose precision would be improved by a better knowledge of the spatial structure of the exploited resources.

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