Deepwater fisheries in Vanuatu (Oceania) : are usual tools adequate for the management of small insular artisanal fisheries?

E. Cillaurren and M. Simier
Laboratoire d'halieutique et écosystèmes aquatiques
Centre ORSTOM B.P. 5045
34032 Montpellier cedex 1

Abstract

The analysis of ten years of fishing effort and deepwaterfish catch in Vanuatu with statistic exploratory methods show specific reaction to the fishing pressure related to the fish habitats. For the *Etelis spp.* and the *Pristipomoïdes spp.* which habitats are well structured according to the depth, a yearly decreasing of the average length of the catches shows that these fish are the most harvested of the deep demersal stock. The intermediate depth species, like *Epinephelus spp.* or *Aphareus rutilans* appear less harvested. These species are concentrated in few fishing areas and therefore they are supposed to be more affected by local over-fishing. The management of the deep demersal fishery includes two approaches. The first one is focused on an evaluation of the quotas per species with a recommendation about the maintenance of a species diversity. The second ones identifies the fishing areas which need to be preserved from intensive fishing effort. These areas are situated in the southern island isolated by the 1000 m isobath which limits the extension of the resource and in the eastern islands of the archipelago where the sharp bottom-slope increases the vulnerability of the resource to the fishing effort.

Key words : Deep demersal fishing/ Space-time structure of fish population/ Vanuatu/ STATIS

Résumé

L'analyse avec des méthodes statistiques exploratoires de dix années d'effort et de prises provenant d'une pêcherie artisanale démersale à Vanuatu a montré une réponse spécifique de la ressource à l'effort de pêche en relation avec les habitats des poissons exploités. Pour les espèces des genres *Etelis spp.* et *Pristipomoïdes spp.* dont les habitats sont bien structurés selon la profondeur, la diminution sur l'ensemble des zones de la taille moyenne des captures montre que ces espèces sont les plus exploitées. Les espèces capturées à des profondeurs intermédiaires comme *Epinephelus spp.* et *Aphareus rutilans*, apparaissent dans la situation présente les moins exploitées. Toutefois concentrées dans quelques zones de pêche, elles sont susceptibles d'être exposées à l'intensification de l'effort de pêche. La gestion des pêcheries peut se faire selon deux approches. La première s'oriente vers la détermination de quotas par espèce avec des recommandations pour le maintien de la diversité spécifique. La seconde identifie des zones de pêche à préserver de l'exploitation intensive. Ces zones seraient situées dans l'île du sud isolée par l'isobathe 1000 qui limite l'extension géographique de la ressource et dans les îles de l'est caractérisées par l'étroitesse et la forte déclivité des pentes récifales qui contribuent ainsi à augmenter la vulnérabilité de la ressource.

Mots clés : Pêche démersale de profondeur/ Structure spatio-temporelle des populations de poissons/ Vanuatu/STATIS

1.INTRODUCTION

In fisheries management, the assessment of the fish stock uses to estimate the optimum fishing effort for the maximum substainable yield (M.S.Y.). Holistic or surplus production models use a time series of years of catch per effort unit with the assumption that the catches are proportional to the fishing effort and that the fish stock is a homogeneous biomass (Sparre 1989). Analytical models offer a more detailed description of the age structured fish stocks giving therefore more accurate estimations of the state of the stocks in response to the fishing pressure. The spatial structure of fish stock is not really accounted in both methods but some analyses like the swept area method for the biomass estimation try to compensate this lack (Gulland, 1975).

Furthermore, Munro and Thompson (1983) identify the relation of a stock to an area and relate the fishing effort and the catch to the exploited surface in the Fox model (1970). In Pacific islands and for Hawaiian artisanal demersal fisheries, Polovina (1989) is one of the first to include both multispecific and multiarea application in a forecast model for the management of demersal fisheries. In their study about deep reef slope fishery resources of the south Pacific, Dalzell and Preston (1992) also notice differences for the catch rate according to the structure of the island ; the variability of the catch rate is lower in the small high islands than in the large high islands as in the atolls. The idea that a space heterogeneity of the deep demersal fish resource should be taken into account for the stock assessment and, further, for the fisheries management is also present in this study.

We have set the present study in Vanuatu, archipelago in the north west of New Caledonia, between 13°S and 21°S of latitude and 166° W and 170°W of longitude, where the artisanal demersal fisheries activities have been developped and surveyed between 1982 and 1991. First estimations of the stock size evaluate from fishing experiments data the optimal harvest at 740 tons (Brouard and Grandperrin, 1984) giving an optimal yield of 1 kg per ha and per year. Analytical models application allow estimations of M.S.Y. per species, giving an estimation of 585 tons for all species mixed (Table 1) (Cillaurren *et al.*, 1998a).

As the surface areas for fish distribution are known, ie. the bottoms between 100 and 500 m depth, an estimation of a M.S.Y. per island is possible with the assumption of a constant availability of the resource in the whole harvested area.

Table 1 - Estimations of maximum substainable yields (M.S.Y.) for eleven deep demersal species caught in Vanuatu.

Species	Number of recruits	M.S.Y. in tons	Biomasse in tons
E. carbunculus	404,111	364	2,853
E. coruscans	26,218	18	87
E. radiosus	5,247	4	18
P. filamentosus	54,249	23	177
P. flavipinnis	53,834	15	57
P. multidens	30,817	14	77
E. magniscuttis	21,537	24	91
E. morrhua	5,241	3	15
E. septemfasciatus	2,907	4	7
L. malabaricus	323,485	110	563
A. rutilans	3,254	6	13
Total	930,900	585	3958

In this work we will consider this assumption through the study with exploratory methods of the time and space distribution of the fishing effort and of the average length of the catch. First, we will set the picture of the space-time movement of the fishing effort. Then we will study differences in the responses of the resource to the fishing pressure through the space and yearly fluctuation of average lengths given as a sensible index of the resource reaction to the fishing pressure. From these analyses we will discuss about the suitability of the surface estimation of the M.S.Y. for the fisheries management. Some developments including a space structuration of fish populations and therefore of fishing effort will be then conceived.

2. MATERIAL AND METHODS

2.1. Data type and origin

The demersal artisanal fishery was implemented by the Fisheries Department in Vanuatu in 1982 with the setting of fishing village associations under the control of the Village Fisheries Development Program. This program carried out the training of the villagers to the new fishing technique, ie. fishing with small (mean of 8,5 m) motorhead boats set with bandreels and vertical lines, and a technical assistance. From 1982 to 1991, a research program conducted by ORSTOM (Institut français de recherche scientifique pour le développement en coopération) set, in collaboration with the Fisheries Department, a database recording the fishing activities (fishing effort and catch) of the village associations, and the body length measurements of the main eleven species caught. About 11,000 fishing trips were recorded and 100,000 fish were measured. After correction and self-test evaluation a sample of about 30,000 fish lengths was kept in order to study the time and space distribution of the resource.

A series of yearly length frequencies has been recorded between 1983 and 1991 for eleven species on six islands or groups of islands ; a mean length was then estimated for each species by year and by fishing area. These fishing areas have been delimited according to their separation by the 500 isobath (Figure 1) which is the extension depth limit of the concerned demersal species. The eleven main species studied, from the *Lutjanidae* and *Serranidae* families usually caught between 100 and 500 m depth. These species compose about 80% of total catches (Brouard and Grandperrin, 1984 ; Cillaurren *et al.*, 1998a).

2.2. Methods

Given the space-time spreading of the fishing, the statistic exploratory methods have been considered to analyse the data. Usual methods like Principal Component analysis (PCA) or Correspondence analysis (CoA) are designed for description of large two-dimensional matrices containing values for many variables (columns) and individuals (rows). The information is decomposed into synthetic axes which define small dimensional projection spaces. The relations between variables and/or individuals are shown by their proximity or opposition in these spaces. CoA analysis has been used for the spatial and time study of the fishing effort .

More recent methods allow the simultaneous analysis of several matrices. Among them, the STATIS method (Thioulouse and Chessel, 1987) has been used for the study of the spatial and temporal variation of the average length recorded for the main eleven species. For this analysis, the data are organized into a three axis table which presents the space distribution of the yearly variation of the mean lenght for eleven species. This 3-D matrix is considered here as a series of 2-D matrices each corresponding to a fishing area. STATIS method first shows the general structure (common to the fishing areas) of the time evolution of mean length of the eleven species. This average figure is a compromise of the spatial time trend of the average length of eleven species. In addition, the projection of each matrix related to one area onto the compromise gives the trajectories of each species per island which actually represent the temporal variation specifically related to one island. Then the contribution of the space localisation to the time variation of the average length is highlighted.

3. RESULTS AND DISCUSSION

A simple CoA analysis is applied on the yearly fluctuation of the fishing effort deployed on six fishing areas (Figure 2). 57% of the total variability is represented by two axes. There is an opposition between the east part of Vanuatu, harvested in 1983 and 1984, and the rest of the country. The fishing effort is moving and in the same time increasing from the periphery of the archipelago, ie. Aoba, Maewo, Pentecost and Tanna to the center. The last years, the most intensive fishing effort is concentrated in Santo and Malekula.

Before using STATIS analysis, two fishing areas (Santo and Malakula) have been gathered. Then, the STATIS analysis is applied to a series of five tables corresponding to five fishing areas. For each table, the eleven species are the columns and the years are the rows. The number of years per island is not constant. The compromise gives the general trend of the temporal evolution of the mean length of the eleven species. Different projections can be done onto the compromise axis. One gives the rows image, i.e. the average length variation, all species included, along years and islands, and the other gives the columns image, i.e. the specific mean length variation among the islands. On figure 3, a general decrease of the average length is observed in the whole archipelago since 1986. The first axis accounting for 54% of the variability is explained by the year trend. There is a clear opposition between the first period of the fishing (1983 to 1985) and the second one (1987 to 1990) during which a development of the fishing village associations and therefore an intensification of the fishing effort have been observed. Despite the strong structure given by the years of fishing, a secondary influence is brought by the islands. Geographic variability of the mean length evolution is great in 1984, 1985 and 1986 during which a displacement of the fishing effort was noticed from the east and south part to the center of the archipelago. We can therefore conclude that the deep fish stock has in general a constant reaction related to the fishing pressure whatever are the species and the fishing area.

The image of the mean length variability around the compromise for eleven fish populations and for the five groups of islands is presented in figures 4 and 5. In figure 4, for each species, the mean position (from the compromise) is related to the 5 by-islands positions. The species from the *Etelis spp.* group and the *Pristipomoïdes spp.* respectively caught in the deepest and lowest depths (Brouard and Grandperrin, 1984 ; Cillaurren *et al.*, 1998b) bring the principal contribution to the first axis. The yearly variation of the mean length appears similar for both groups. This has been seen like a homogeneous response to the harvesting. The second axis (11%) is explained by intermediate species like *Epinephelus spp.* and specially *Aphareus rutilans*, opposed to *Lutjanus malabaricus* which actually is a species caught in the lowest depth. In figure 5 the cloud of 55 island-species values is separated in five pictures corresponding to the five islands or groups of islands. *Aphareus rutilans* is isolated from the other species in most islands. The similarity of the species mean length variability is remarkable in Santo and Malakula. Efate gives a close picture to the compromise. On the opposite, Tanna is distinguished by the contribution of *Lutjanus malabaricus* and the species caught in the intermediate depths. Opposition along the second axis between *E. carbunculus* et *E. coruscans* is also noticed in the east of the archipelago.

Three main features are highlighted by these analyses. The first and more trivial one is the evident change of the average lenght of deep demersal fish populations in response to the fishing pressure. The second one is the differences observed between species. For the most structured depth species like *Etelis spp* and *Pristipomoïdes spp.*, the variation of the mean lenght of the fish population is comparable in most of the islands. For the depth intermediate species like *Epinephelus spp.* and *Aphareus rutilans* , the variation of average lenght is less clear. These species appear then less harvested than the precedent and are actually less fished. These results confirm the differences in the vulnerability between the species according to their depth distribution as expected by Brouard and Grandperrin (1984). The third one is the influence of the geographic localisation on the yearly mean length evolution. It can be related to particular concentrations of *E. septemfasciatus* in Tanna, *E. coruscans* and *E. carbunculus* in the east and the decrease of *Lutjanus malabaricus* 's abundance from the north to the south of the archipelago.

Parrish (1987) and Shapiro (1987) remark that in contrast to the *Lutjanidae* group, the *Serranidae spp.* are solitary and territorial. Therefore it is not surprising that this behavior related with their distribution into the depth scale makes them more difficult to fish. Tanna, isolated from the other islands by the 1000 m depth, could also represent an area of aggregation for these species. For the *Etelis spp.*, principally harvested, their particular reaction to the fishing pressure in the east can be related to the high yields observed (Cillaurren *et al.*, 1998a). Biggest fishes have been probably caught around these islands. Indeed, the slope is the sharpest one of the archipelago and these reliefs are supposed to be favourable to the concentration of the deep demersal fish and therefore increase their vulnerability, as expected by Polovina *et al.* (1990). For *Lutjanus malabaricus* showing a clear geographical distribution related with physical parameters, ie. water temperature, the rare fishes caught in the south are probably old adults not usually harvested in the rest of the country.

The correlation indices of the five areas showing the adequation of each island space-time structure to the average lengths space-temporal variation estimated for the archipelago, are good (Table 2).

Table 2 - Correlation indice given by the STATIS operator averaging analysis and relation with the fishing surface are.

Fishing area	Years (rows)	Corr. to the compromise	Surface area in ha	M.S.Y in tons. *
Santo Malakula	From 1983 to 1990	0,74	244,314	188
Aoba Maewo Pentecost	From 1983 to 1990	0,70	70,311	65
Ambrym Epi, Paama Tongoa	From 1983 to 1989	0,83	148,516	126
Efate	From 1986 to 1990	0,84	95,330	73
Tanna	From 1984 to 1988	0,59	42,438	46

The space-time structure given by the compromise is representative to the evolution observed in each island or groups of islands.
The lowest correlations are however observed in Tanna and in the east part of the archipelago. Both areas are few exploited and are in the periphery of the archipelago. This could signify that a geographical effect ought also have an influence on the mean length in response to the fishing effort.As these islands are distinguished to the others by the strength of the slope or/and the proximity of used depth which limits the extension of the resource and therefore the available surface area for the deep demersal resource, we have supposed this topography has an influence on the catchability of the fish. We have then analyse the relation between the correlation index and the surface area (Figure 6). The best average picture is observed for fishing areas exceeding 100,000 ha (figure 6). For narrower surfaces, in Tanna and in the east, the variability of the reaction's resource to the fishing pressure is higher than in the other islands probably because the strong geographic localisation of some species helped by the sharply slopes in the east and the isolation of the southern island. In both areas the geographic extension of the deep demersal fish is probably uneasy and suggest difficulties in the renewal of the resource following the harvesting. For greater areas, like in Santo and Malekula, the constant reaction of all species to the fishing pressure gives a picture of an intensive harvesting and approach the optimal exploitation.

4. CONCLUSIONS

In Vanuatu, after ten years of fisheries, the deep demersal ressource remain under exploited . Reactions to the fishing pressure vary from one group of species to other. For depth strong structured species ie. *Etelis spp.* and *Pristipomoïdes spp.*, there is a clear response to the fishing pressure given by the time-decreasing of the average length. This effect is noticeable in the whole archipelago with a maximum for deepest species in the east represented by high islands (Maewo, Aoba and Pentecost) where the sharpness of the slope is supposed to reduce the available surface for the ressource extension. The decrease of the average lenght of the intermediate species , i.e. *Epinephelus spp.* and *Aphareus rutilans* is not clear. These species appear the be the less exploited in the group. Their mobility into the depth scale joined to their strong geographic localisation in few harvested islands in the present situation protects them from fishing.

The space structuration plays a predominant role in the fisheries activities as well as in the distribution of the resource. In Vanuatu the displacement of the fisheries obeys more to economic constraints (Cillaurren and David, 1995) than to the resource availability. This one varies also according to the space extension of their habitat. Then if application of quotas per species appears suitable, integration of a vulnerability index related to separate harvested areas may be useful. This index is probably higher in the east part of Vanuatu and in the south, where the localisation of some species is strong.

Future fishing management may include various scenarii. In a topic of integrated development of a small artisanal fishery, the harvesting will probably be developped in the center of the country. Therefore, regulation may be more focused on the conservation of the species diversity avoiding the intensive fishing in a particular depth and then the overexploitation of one group of species. For a project of licenses selling to industrial fishing boats, regulation should preserve areas presenting local abundances.

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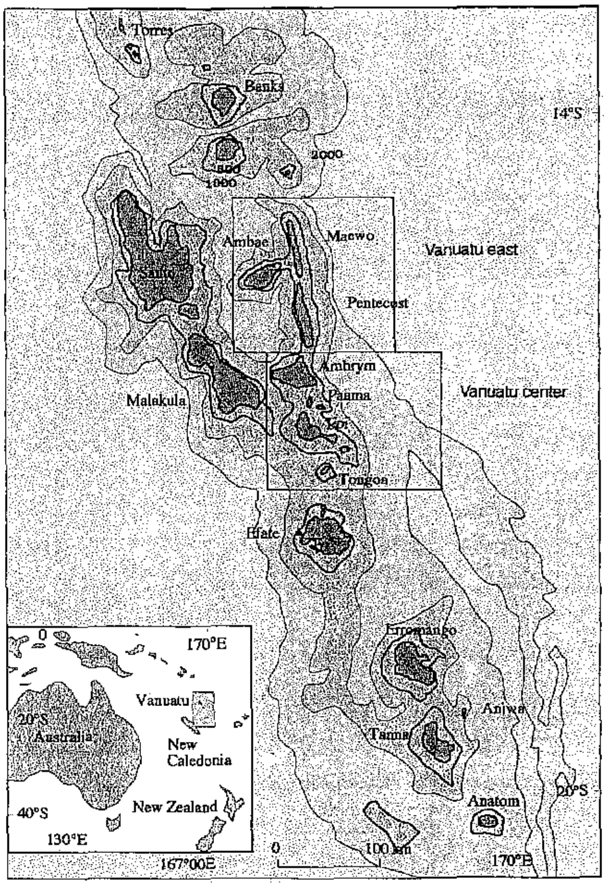

Figure 1 - The Vanuatu archipelago

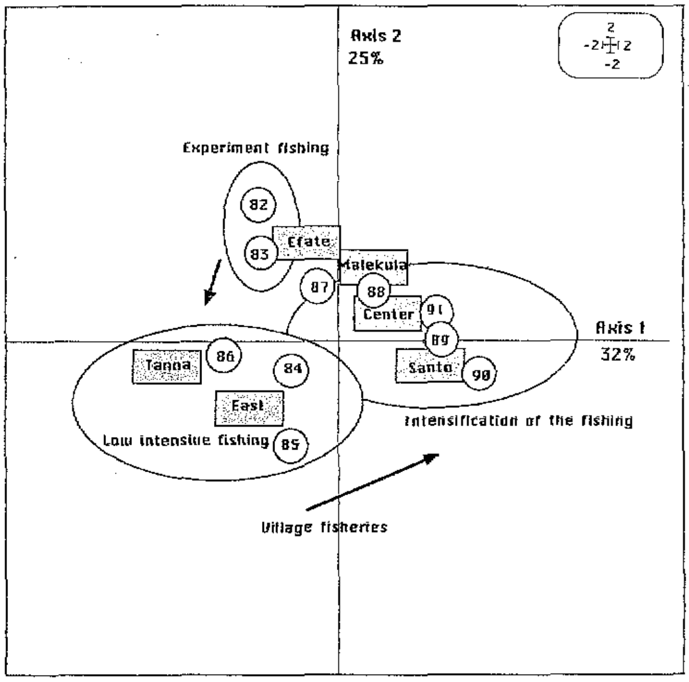

Figure 2 - Space-time variation of the fishing effort

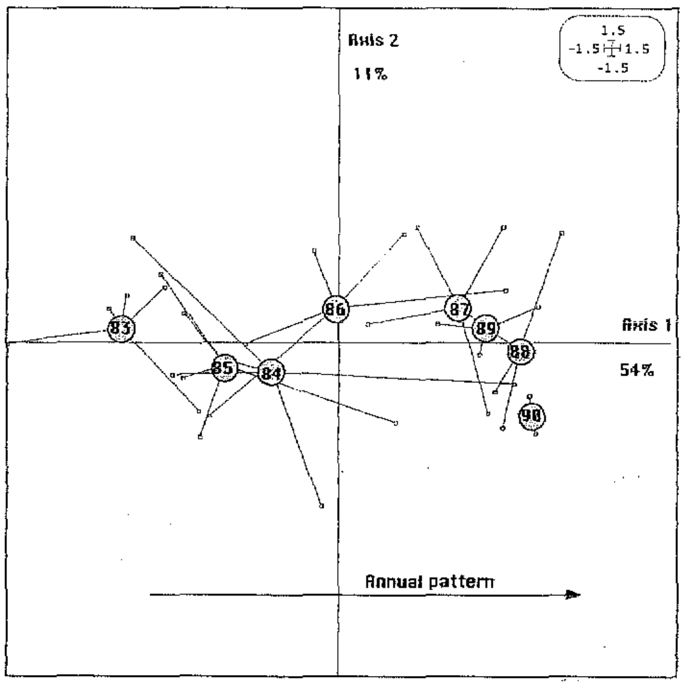

Figure 3 - General yearly trend of the average length of fish

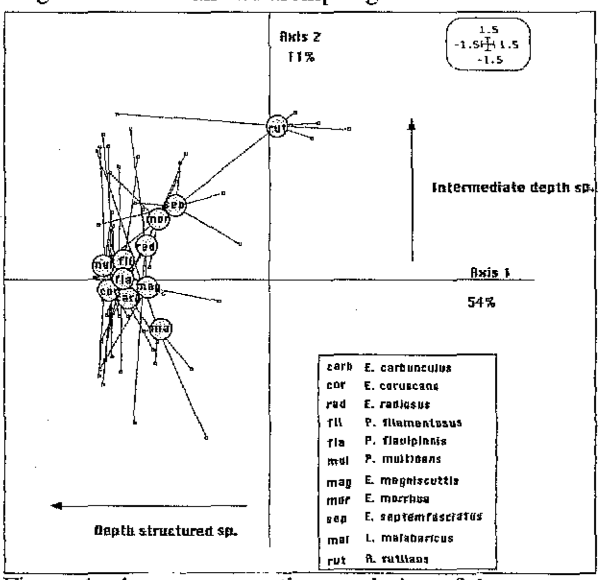

Figure 4 - Average space-time evolution of the mean length for the eleven main species

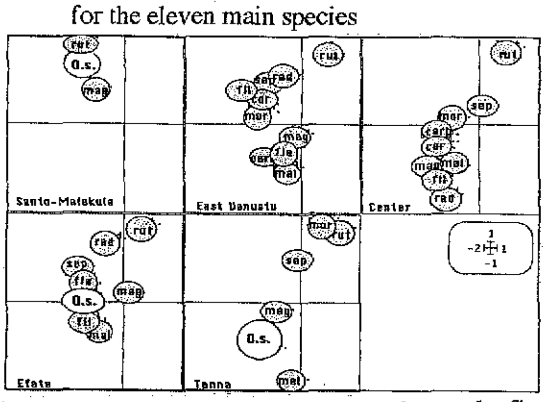

Figure 5 - Trajectories of the compromise on the five islands or groups of islands (O.s. : other species)

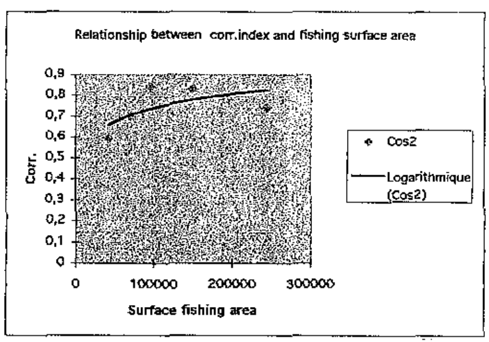

Figure 6 - Relationship between the correlation indices obtained with STATIS and the fishing areas