Swath Mapping of the Seafloor and its Application to Deep-Bottom Fisheries in New Caledonia

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Abstract. A bottom longline fishery operated in the EEZ of New Caledonia from 1988 to 1991. Fishing focused on five seamounts with summits at depths ranging from 500 to 750 m. The target species was alfonsino, *Beryx splendens*. As the soundings available from marine charts were not detailed enough, the fishing masters had to make their own charts in order to set the gear in the right location. A series of 11 scientific cruises devoted to a research program on alfonsino was launched in late 1991. During the first scientific cruises, several days were spent mapping the seabed to improve the existing knowledge of the topography of three seamounts by coupling the EDO echosounder depth measurements to the GPS positions. As this procedure is slow, it is applicable to limited areas or, if a wider grid is used, to large zones to locate major structures such as ridges and seamounts. The emergence of the multibeam echosounder has greatly improved seabed mapping performance. This tool seems to fit the requirement of exploratory deep-bottom fishing particularly well, as it covers large areas while providing details of the bottom. The EM 12 was used to obtain bathymetry and imagery of the SE portion of the EEZ of New Caledonia, covering an approximate area of 70,000 km^2 in two weeks. For depths ranging from 500 to 4,500 m, the results were impressive. They confirmed the known major features and provided greater topographical detail, revealing fine unknown structures. They also provided information on the type of substratum, information which might influence the fishing strategy. Finally, they made it possible to obtain an accurate estimate of the exploitable area which in turn led to new stock estimates.

Background

This paper reports on the development of bathymetric mapping of New Caledonia, from the early days of commercial fishing charts, through more detailed data collection during fisheries research cruises, to swath mapping. The seafloor topography of the EEZ of New Caledonia is complex. Its major geo-morphological characteristic is a succession of ridges and basins (Figure 1). The ridges feature several seamounts, most of whose accurate position and detailed shape are uncertain. When their summit is not deeper than a few hundreds meters, seamounts are well-known to provide good fishing grounds for deep-bottom fish and pelagic fish. To assess the bottom fishery potential of the EEZ of New Caledonia, an exploratory cruise was carried out in 1980 by the Japanese trawler *Kaimon Maru* (Figure 1). At that time, the only soundings available were those on marine charts. As they were not detailed enough to allow trawling in safe conditions, long hours were spent exploring the topography of the bottom before each haul, using echosounder (Barro, 1981). However, the catch rates of the *Kaimon Maru* were good in some places. For 12 fishing days and 43 hauls, the total catch was 160 tons of commercial species, mainly alfonsino (*Beryx splendens*), deep red snapper (*Etelis carbunculus*, *E. coruscans*) and pelagic armorhead (*Pseudopentaceros richardsoni*), particularly on the seamounts of the south-eastern part of the EEZ. From these results, a bottom longline fishery was initiated, which operated from February 1988 to July 1991 (Grandperrin and Lehodey, 1993).

First Acquisitions of Bathymetric Data During Commercial and Scientific Cruises

Commercial bottom longline fishing focused on five seamounts (B, C, D, J and K) located on the Norfolk and South Loyalty ridges (Figure 1). The summits of these seamounts range from 500 to 750 m. Alfonsino was the target species. This species has a worldwide distribution and is fished by bottom trawling or bottom longlining. In New Caledonia, it is mainly found at depths between 450 and 800 m (Lehodey, 1994). As for the survey made by the *Kaimon Maru*, the soundings available from marine charts were not detailed enough to set the gear properly. Therefore, the fishing masters had to make their own charts by plotting echosounder depths at recorded GPS positions (Figure 2). The longliners focused their fishing effort on previously located seamounts and for economic

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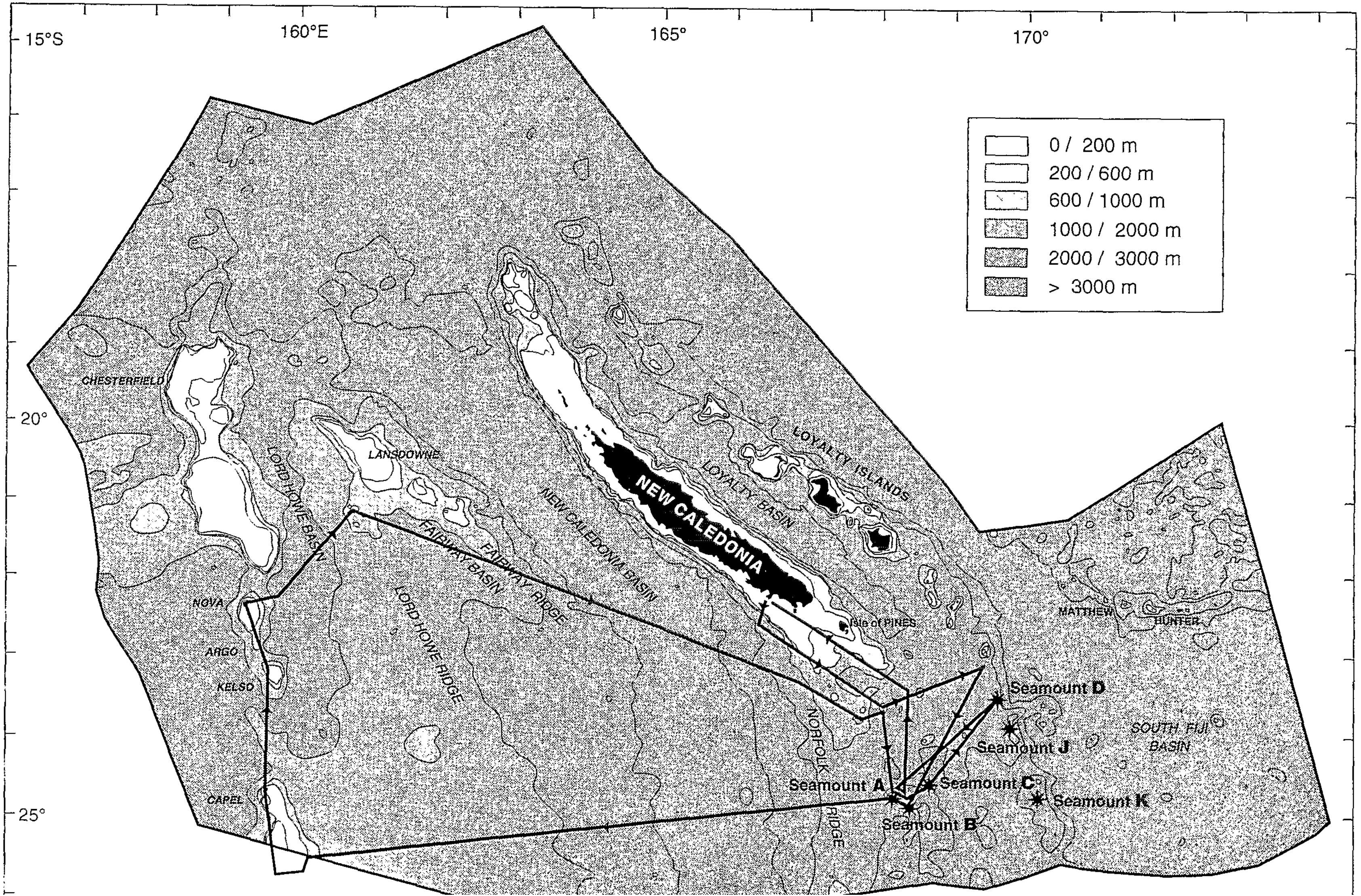
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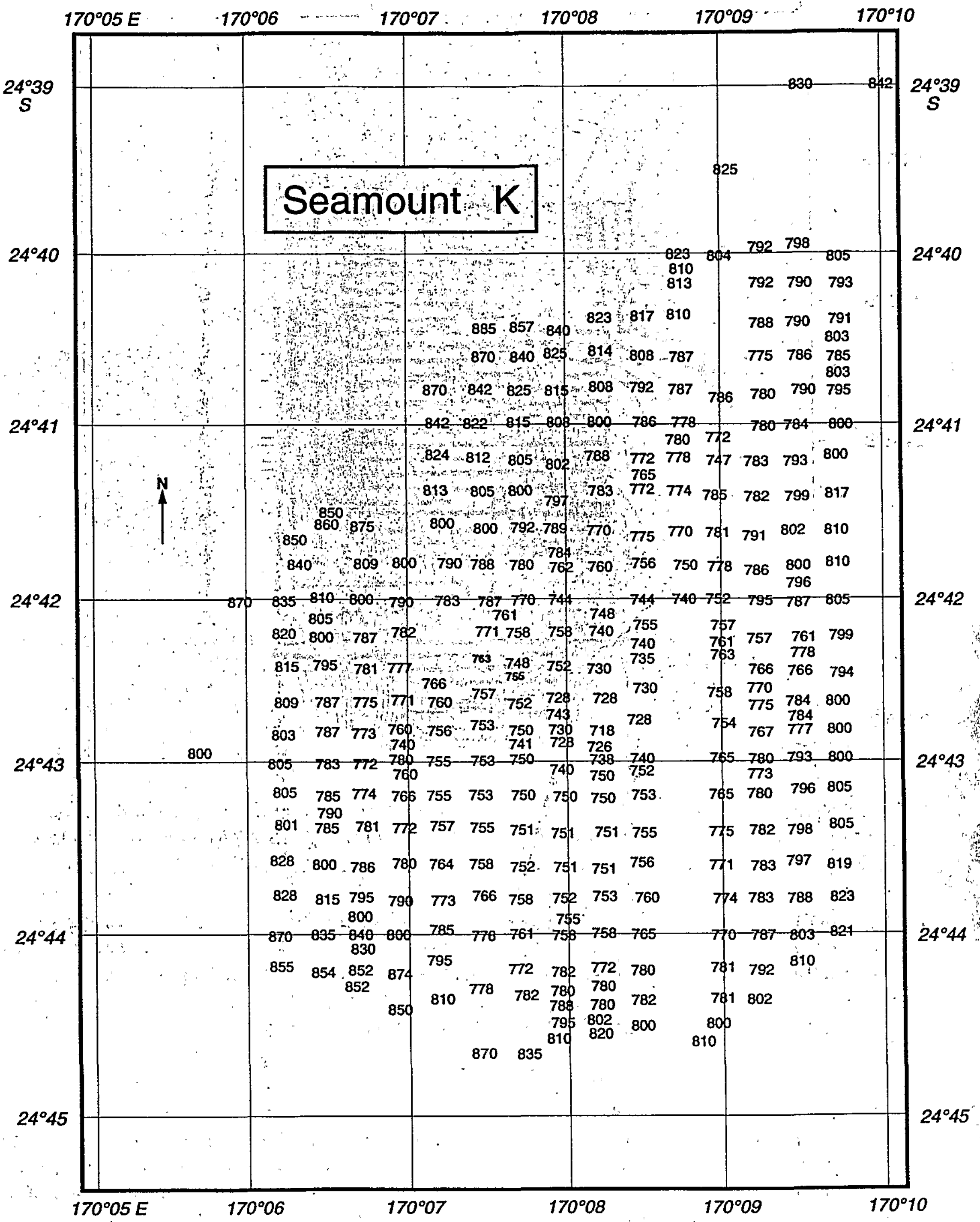

Fig. 2. Bathymetric chart of seamount K, made by the fishing masters of the commercial bottom longliners (soundings in meters).

reasons did not spend much time looking for new uncharted fishing grounds.

In 1991, 11 scientific cruises were conducted to determine the biological parameters essential to the management of the alfonsino fishery. Sampling was made using a bottom longline and various types of trawls. Among the five seamounts extensively fished by the commercial fishery, three (seamounts B, D and K) were

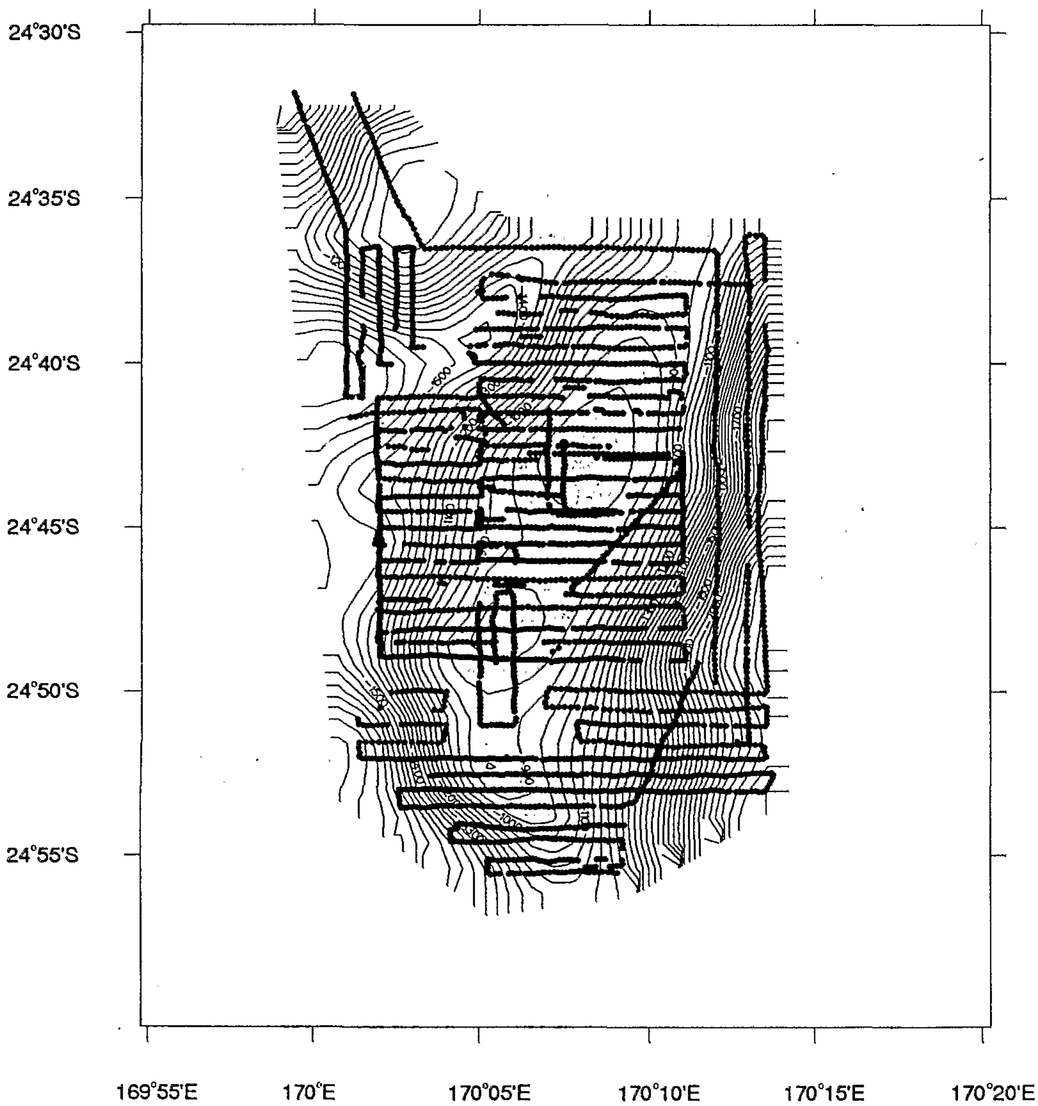

Fig. 3. Seabed mapping of seamount K by the RV *Alis*; 55 hours for 3,304 pairs of depth-position data.

selected to sample the alfonsino populations. At the beginning of the program, the depth data available were those of the marine and GEBCO (Monahan and Falconer, 1984) charts, as well as the charts previously produced by the fishing masters during commercial fishing operations (Figure 2). To facilitate fishing operations and analysis of biological and hydrological data, during the first eight scientific cruises, a total of 120 hours were spent recording detailed depth and navigation information each minute using an EDO echosounder and a Global Positioning System (GPS). These data were used to produce depth contours and subsequent three-dimensional representations of the seabed. As an example, the topography map of seamount K (Figures 3 and 4) included 3,304 depth-position data pairs. A minimum of 55 hours were necessary to cover about 1,000 km^2 with a ship speed of 5 knots. From the depth contours of seamount K and the positions of the terminal anchors of the commercial bottom longlines (Figure 5), it appears that the fishery did not exploit the whole seamount summit. Successful scientific sets were made in areas of the summit previously unknown to the fishermen. As this method of bathymetric data acquisition is slow, it is only applicable to limited areas. However, with a wider grid, it may be useful for locating major structures such as ridges

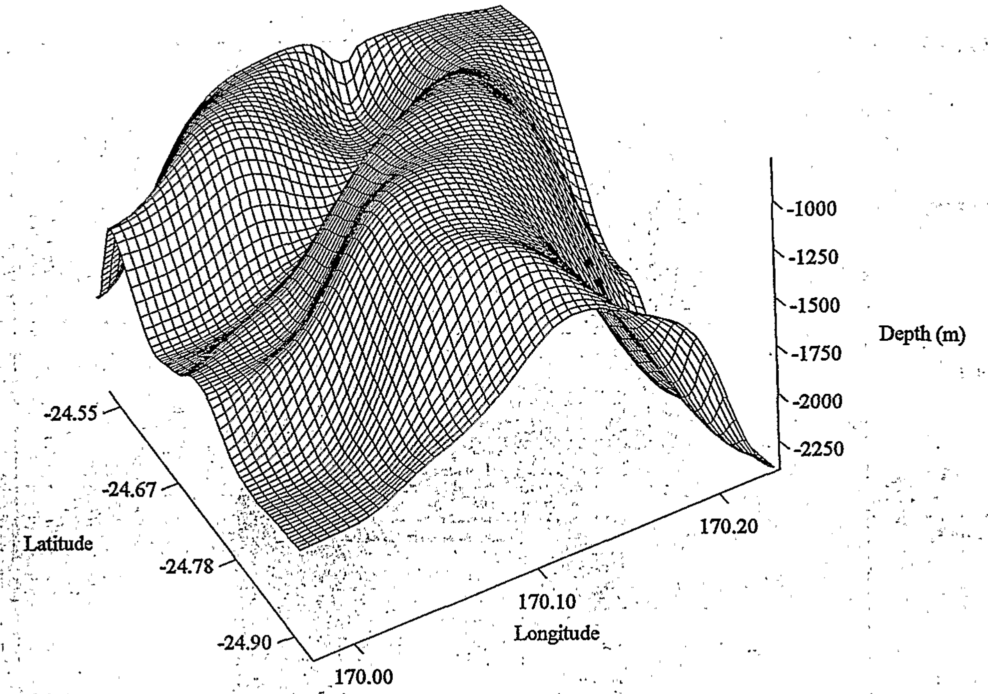

Fig. 4. Tridimensional diagram generated by seabed mapping of seamount K using an EDO echosounder and a Global Positioning System (GPS) on board the RV *Alis*; 55 hours for 3,304 depth-position data pairs.

and seamounts. Such a procedure was used by the Department of Marine Geology of the Noumea ORSTOM Centre during the "ZOE" mapping programme, and resulted in a chart of the EEZ of New Caledonia (Missègue *et al.*, 1992). About 70,000 depth-position pairs were recorded during 47 days, and an approximate area of 500,000 km^2 was covered; this information was combined with bathymetric data generated by previous French and foreign marine geology cruises (Missègue *et al.*, 1992).

The Interest of Swath Mapping for Deep Demersal Fisheries

Exploration and fishing strategy

The emergence of new bathymetric surveying techniques (e.g. SeaMARC II, Sea Beam multibeam echosounder, EM 12) has greatly improved seabed mapping. They are particularly useful in exploratory deep-bottom fishing, providing details of the bottom over large areas. A dual EM 12 multibeam echosounder was used on board the RV *L'Atalante* during the ZoNéCo 1 cruise (25 June–16 July 1993) which was devoted to the assessment of the marine resources of New Caledonia (Anonymous, 1993). This gave topography and bottom imagery of the south-eastern portion of the EEZ of New Caledonia, covering an approximate area of 70,000 km^2. About 7,500,000 depth-position data pairs were recorded for depths ranging from 500 to 4,500 m. The results were impressive. They confirmed the known bathymetric trends and provided greater topographical detail, revealing small unknown structures (Figure 6) compared with GPS-EDO data coupling method (Figure 4). Because of the wide swath of the EM 12, it took only 10 hours to sweep the entire seamount K (500,761 depth-position data pairs) when 55 hours had been necessary with the GPS-EDO coupling method (3,304 depth-position data pairs).

In addition to bathymetric data, the EM 12 gives a seafloor reflection index providing an image of the bottom (Figure 7) that can be interpreted to determine its nature, e.g. rock or sediments. This information is of great interest for future exploratory fishing cruises when choosing the type of gear to be used. Furthermore, as each species occupies a preferential ecological

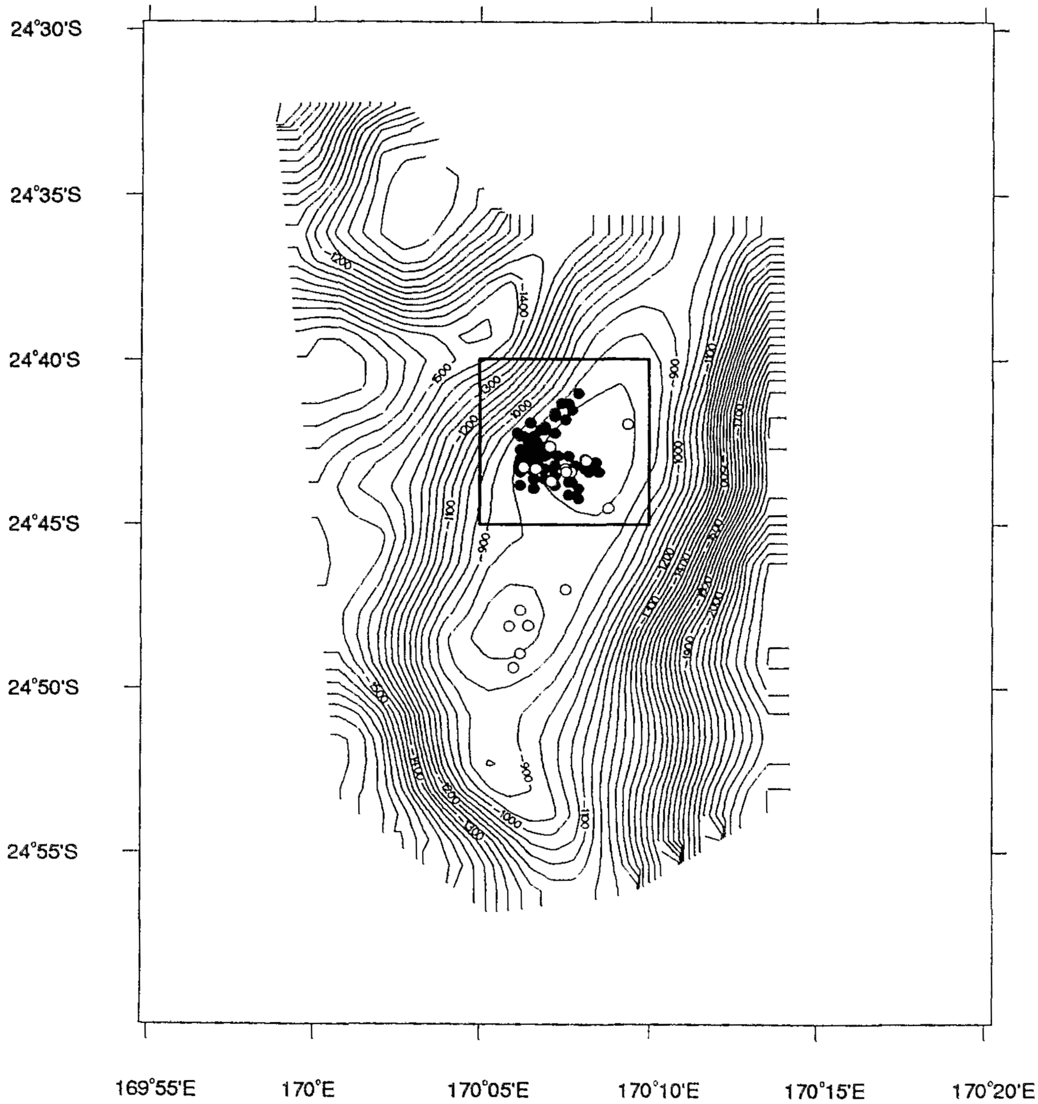

Fig. 5. Seamount K depth contours and scientific (O) and fishing stations (●). The box is the zone commercially fished and charted by fishing masters.

niche, the knowledge of the type and morphology of the substratum will influence both the fishing strategy and the distribution of target species.

Stock assessment

In the Pacific, commercial fisheries on seamounts are relatively recent. The first one started in 1967 on the seamounts of the Emperor Chain. The target species was the pelagic armorhead, with a trawl catch reaching 133,400 tons between December 1969 and July 1970 (Uchida and Tagami, 1984). In some hauls, alfonsino represented a third of the catch. The fishery collapsed in the late 1970's due to too large and uncontrolled a fishing effort. Because of the undeveloped or recently developed nature of the deep-bottom fisheries in the Pacific islands Countries and Territories, no long-term time series of catch and effort data are available, and production models cannot be used. However, rough estimation of virgin biomass (Bo) and maximum sustainable yield (MSY) can be made by extrapolating the actual Bo and MSY values calculated for a given species on a limited known fishing ground to larger unknown areas. However, such an extrapolation sup-

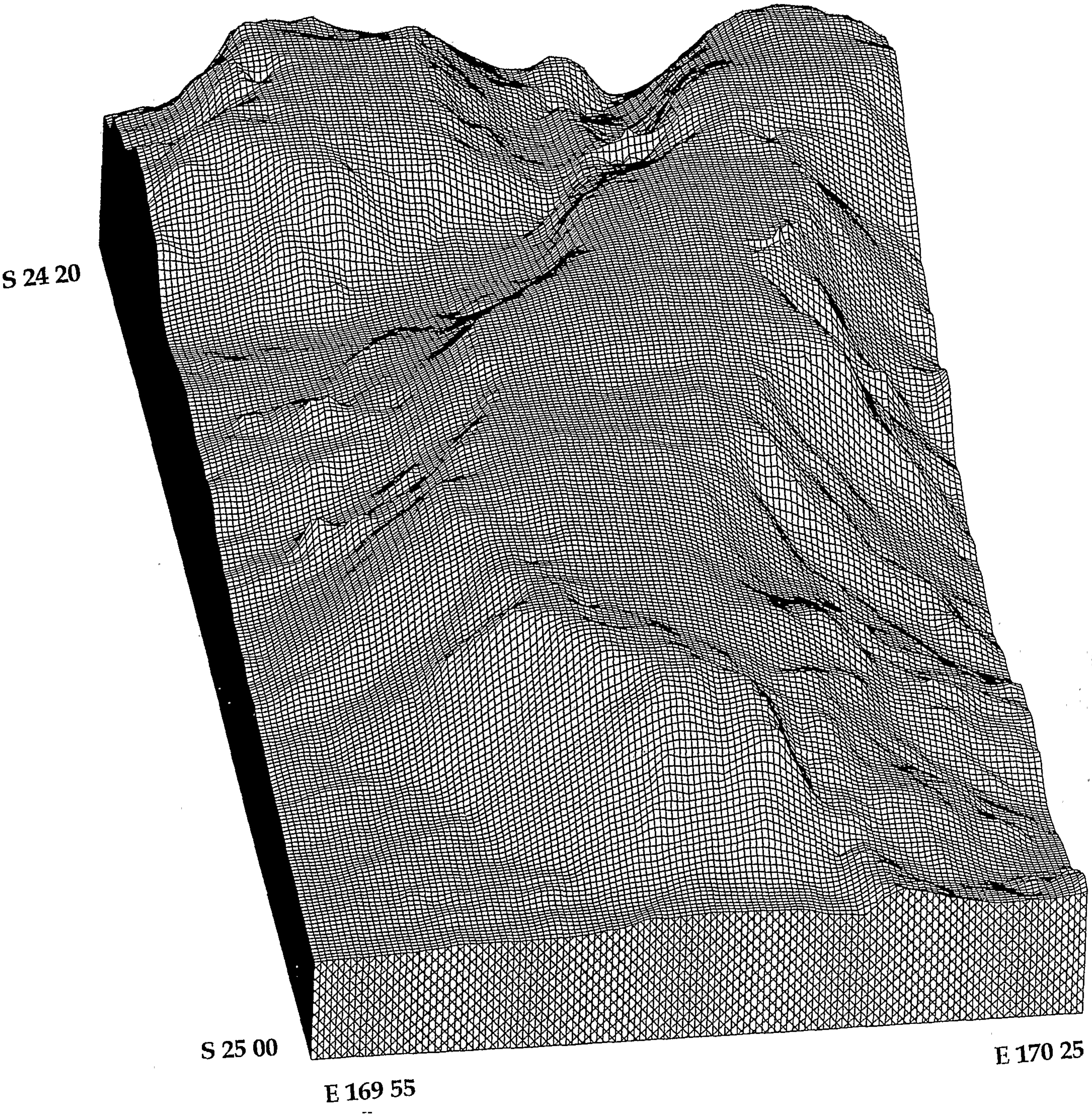

Fig. 6. Tridimensional diagram generated by seabed mapping of seamount K using the EM 12 on board the RV *L'Atalante* during the cruise ZoNéCo 1; 10 hours for 500,761 depth-position data pairs (vertical exaggeration: 5; resolution: 200 m).

pose that the environmental conditions (hydrological parameters, depth, nature of the substrate, standing fauna...) in the unknown areas are similar to the ones prevailing in the known fishing ground. In these conditions, only the areas where at least the depths and the type of substrate are the same as those inhabited by the concerned species, must be kept for the extrapolation. Therefore, the better the knowledge of the bathymetry

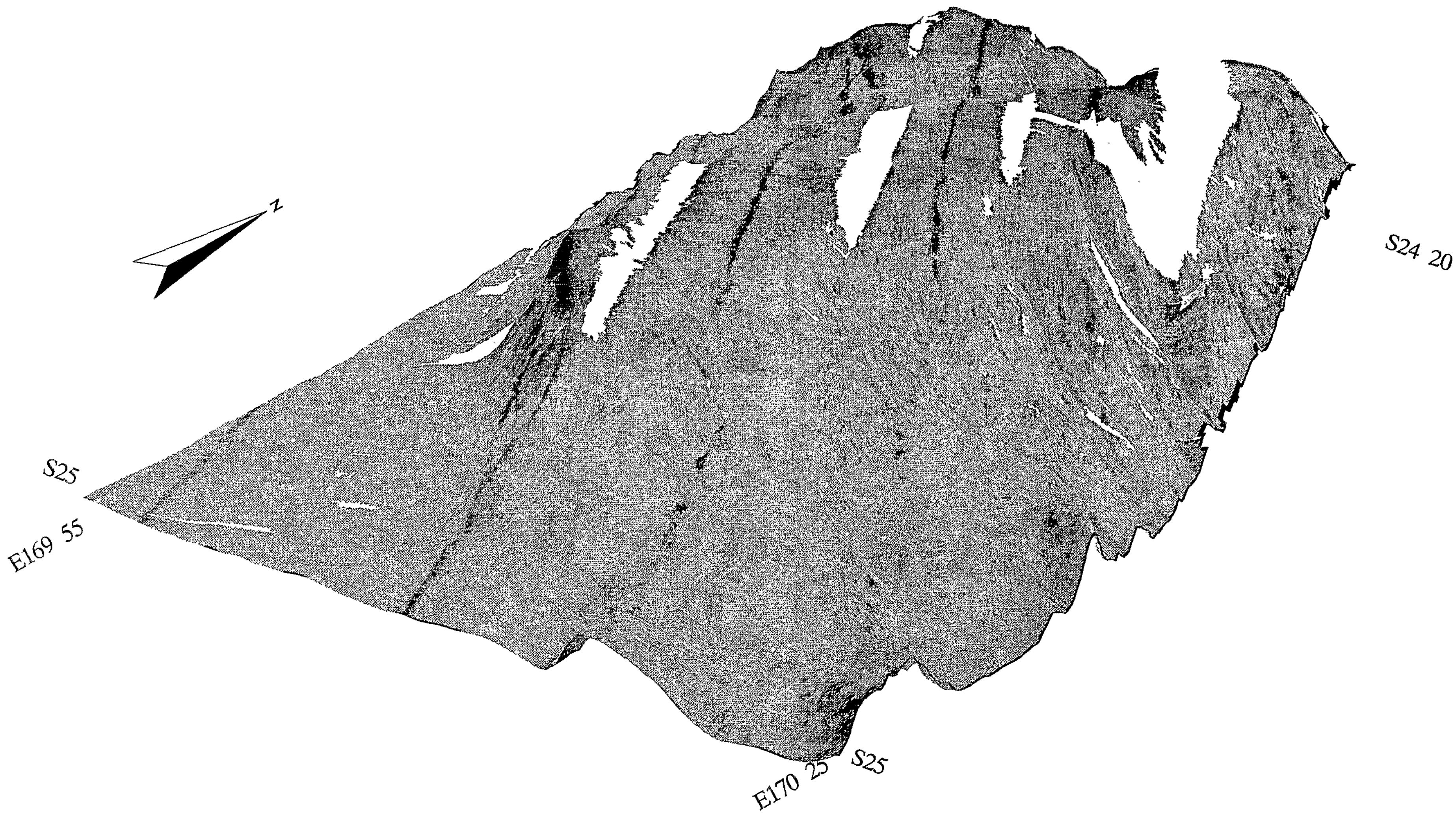

Fig. 7. Superposition of the imagery with the bathymetry for seamount K (white zones: lack of data; black straight marks: track of the vessel). Image provided by the SGVL (SMAI-Nouméa) with the VEGA software.

and of the nature of the bottom, the less the incertitude on the extrapolation. However, it remains that the extrapolated areas will have to be considered as first cut estimations to be taken with caution, given the incertitude remaining on the other environmental conditions, as well as on the spatial distribution and the behaviour of the species concerned.

In the south-east part of the EEZ of New Caledonia, the areas of the exploited zones on seamounts B, C, D, J and K and corresponding values of Bo are known for alfonsino. The 450 and 800 m isobaths, which delimit the habitat of this species, were taken from the bathymetric charts produced by the EM 12 during the cruise ZoNéCo 1. They delimit an area of 1,230 km^2. Knowing from Lehodey (1994) that the areas exploited by the alfonsino fishery on seamounts B, C, D, J and K totalled 273 km^2 and that the Bo for the five seamounts was 1,800–2,250 tons, the average Bo values by standardized area unit fall between 6.6 and 8.2 tonnes per km^2. The extrapolation of Bo values to the exploitable area comprised between the 450 and 800 m isobaths leads to a total Bo of alfonsino between 8,100 and 10,125 tonnes. Given the results obtained by Lehodey (1994), who estimated that the MSY ranges from 10 to 20% of Bo, the total alfonsino MSY for the south-east part of the EEZ of New Caledonia, would range from 810 to 2,024 tons a year. However, the presence of exploitable stocks of alfonsino over seamounts appears to be correlated to good environmental conditions, particularly to a favourable hydrological circulation (Hénin, 1994; Lehodey, 1994). Consequently, these estimates will only be valid if exploratory fishing in the unexploited areas proves successful.

A similar method is based on the use of the length of a reference isobath that is representative of the habitat of a given species instead of the surface of the habitat of this species as described above. This method has been applied to the deep snapper resources of several Pacific islands by different authors (Ralston and Polovina, 1982; Brouard and Grandperrin, 1985; Polovina, 1986; Polovina *et al.*, 1990; Langi *et al.*, 1992) using the 100 fathom or 200 m isobath as reference isobath.

Conclusion

The alfonsino bottom longline fishery developed for four years on the seamounts of the south-eastern portion of the EEZ of New Caledonia, despite the absence of reliable bathymetric information. Although the fishing masters made their own charts in order to set the gear properly, they did not spend much time looking for new fishing grounds. The accurate bathymetry achieved later with the EM 12 by the R.V. *L'Atalante* revealed the existence of new, potentially exploitable zones, much larger than those actually fished. It is therefore clear that good seabed mapping should precede exploratory fishing. More generally, in unknown zones, the first step before initiating any deep-bottom fishery should be a rough location of the main seafloor structures by processing sea-surface altimetric satellite data. After this rough preliminary seabed mapping is achieved, the zones which appear potentially fishable should then be accurately charted by the use of sophisticated swath mapping techniques. The exploratory fishing effort, focused on the most promising identified zones, will then provide enough data to give a very rough estimate of the size, and economic feasibility of a future fishery. Thus, in New Caledonia, the next deep exploratory fishing operations to be made in the 800–1,500 m depths range are planned in the zone that was charted with the EM 12 during the ZoNéCo1 cruise.

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Special Issue

Seafloor Mapping in the West, Southwest and South Pacific: Results and Applications

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