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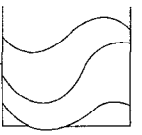

Benefits of swath mapping for the identification of marine habitats in the New Caledonia Economic Zone

Sabrina VAN DE BEUQUE[a]*, Jean-Marie AUZENDE[b,d], Yves LAFOY[c], René GRANDPERRIN[d]

[a] Université de Bretagne occidentale, 29200 Brest, France
[b] Ifremer, DRO/GM, BP 70, 29280 Plouzané, France
[c] Services des mines et de l'énergie, BP 465, Nouméa, Nouvelle-Calédonie
[d] IRD 98848 BP A5, Nouméa Cedex, Nouvelle-Calédonie

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Abstract – The ZoNéCo programme is devoted to the evaluation of the marine resources of the Economic Zone of New Caledonia. The results are essentially dependent on the quality of the seafloor mapping. From 1993 to 1996, four geological and geophysical surveys using the EM12 DUAL multibeam echosounder provided swath-mapping and acoustic imagery data of the seafloor of selected sites on the northern and southern parts of the Norfolk ridge, the Loyalty basin, around the Loyalty islands and in the westernmost part of the Economic Zone of New Caledonia. The accuracy of these documents shows the morphology of the seafloor in detail and allows rocky substratum to be differentiated from muddy bottom. It allows favorable emplacements of future exploratory fishing surveys to be determined. The benefits of swath mapping are illustrated by the Halipro 2 deep sea trawling cruise (1996) which used the swath mapping data of ZoNéCo 1 cruise (1993) on the southern prolongation of the New Caledonia mainland and Loyalty Islands. © 1999 Ifremer / CNRS / IRD / Éditions scientifique et médicales Elsevier SAS

SW Pacific / New Caledonia / swath-mapping / marine habitats / marine resources

Résumé – Cartographie des habitats marins dans la zone économique de Nouvelle Calédonie. Le programme ZoNéCo a pour objectif l'évaluation des ressources marines de la zone économique de Nouvelle-Calédonie. Les résultats du programme dépendent essentiellement de la qualité de la cartographie des fonds marins. De 1993 à 1996, au cours de quatre campagnes bathymétriques et géophysiques, une couverture bathymétrique et d'imagerie a été effectuée en utilisant le sondeur multifaisceaux EM 12 DUAL sur des sites choisis sur les segments Nord et Sud de la ride de Norfolk, dans le bassin des Loyauté, autour des îles Loyauté ainsi qu'à l'ouest de la zone économique de Nouvelle-Calédonie. La qualité des cartes obtenues permet de préciser la morphologie du fond mais aussi de différencier un substratum rocheux d'un substratum couvert par des sédiments et d'identifier les sites favorables à la réalisation de campagne de pêche exploratoire. Les bénéfices de la bathymétrie multifaisceaux sont illustrés, à partir des données de ZoNéCo 1 (1993), par la campagne de chalutage profond Halipro 2 (1996) sur la prolongation méridionale de la Grande Terre de Nouvelle-Calédonie et des îles Loyauté. © 1999 Ifremer / CNRS / IRD / Éditions scientifique et médicales Elsevier SAS

Sud-Ouest Pacifique / Nouvelle-Calédonie / cartographie multifaisceaux / habitats marins / ressources marines

* Correspondence and reprints: AGSO, GPO Box 378, Canberra, ACT, 2601, Australia.

1. INTRODUCTION

The aim of the ZoNéCo programme was to evaluate the marine resources of the New Caledonia Economic Zone. In 1991, a working group constituted of representatives of the French State, the New Caledonia Territory, the three New Caledonia Provinces and the research institutions based in New Caledonia (Ifremer, Orstom and UFP, *Université Française du Pacifique*) defined the bases of the ZoNéCo programme and the operations necessary to evaluate the marine resources.

The first step was to obtain accurate bathymetric data in order to define the morphology of the sites where marine living and non living resources were thought to be present. Therefore, it was decided to compile all the existing data concerning conventional bathymetry, geophysics, oceanography and fisheries. The documents and reports obtained [1, 12] allowed favorable sites providing good fishing grounds for deep-bottom and pelagic fisheries to be selected. The second step was to carry out swath-mapping cruises in order to obtain very precise bathymetry of these selected sites. From 1993 to 1996, geophysical and physical oceanography data were acquired during four cruises onboard the R.V. *L'Atalante*, which was equipped with the multibeam echosounder EM12 DUAL [2]. The bathymetric data obtained on these

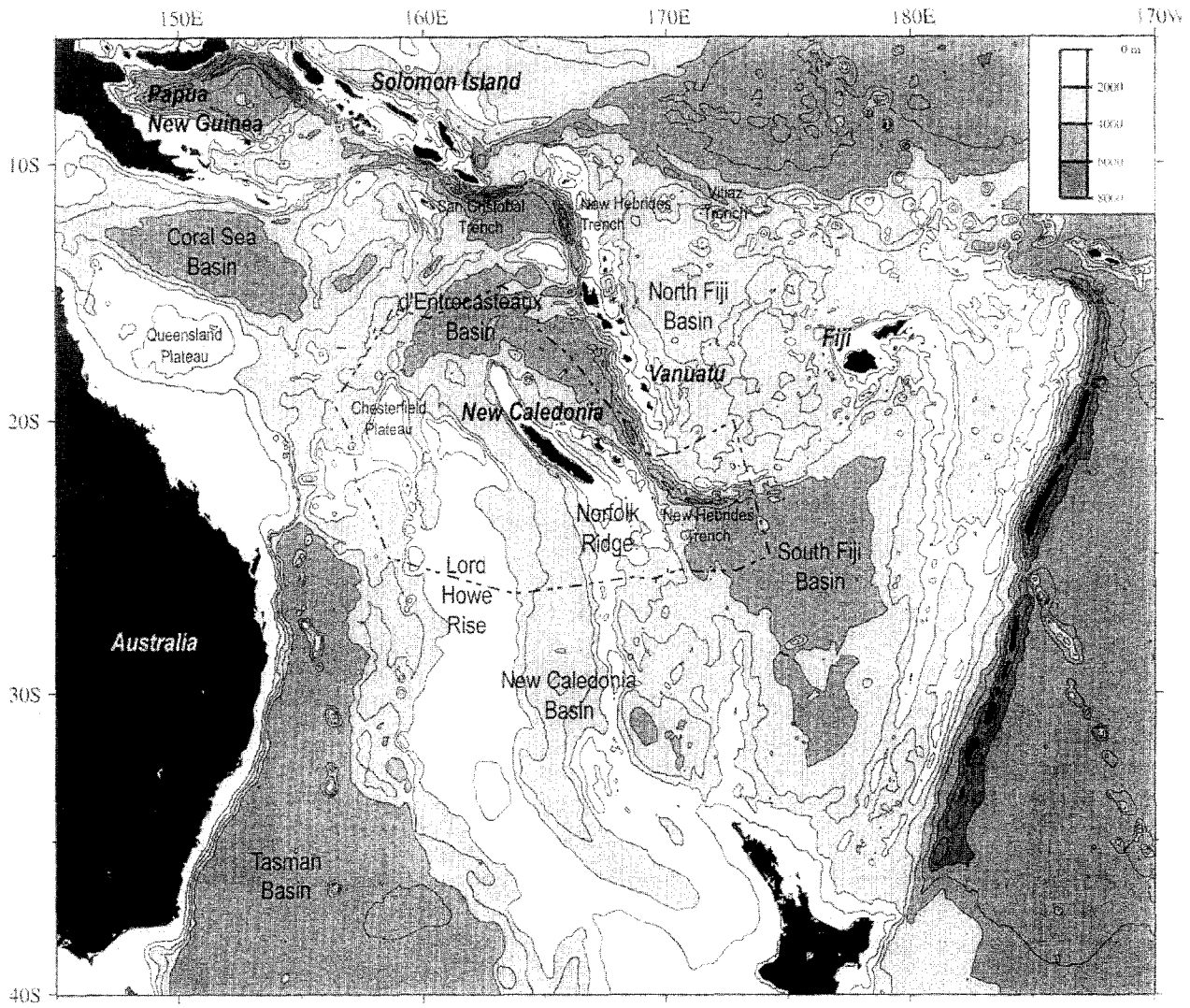

Figure 1. General framework of the South West Pacific Region. The dashed line indicates the boundary of the Economic Zone of New Caledonia.

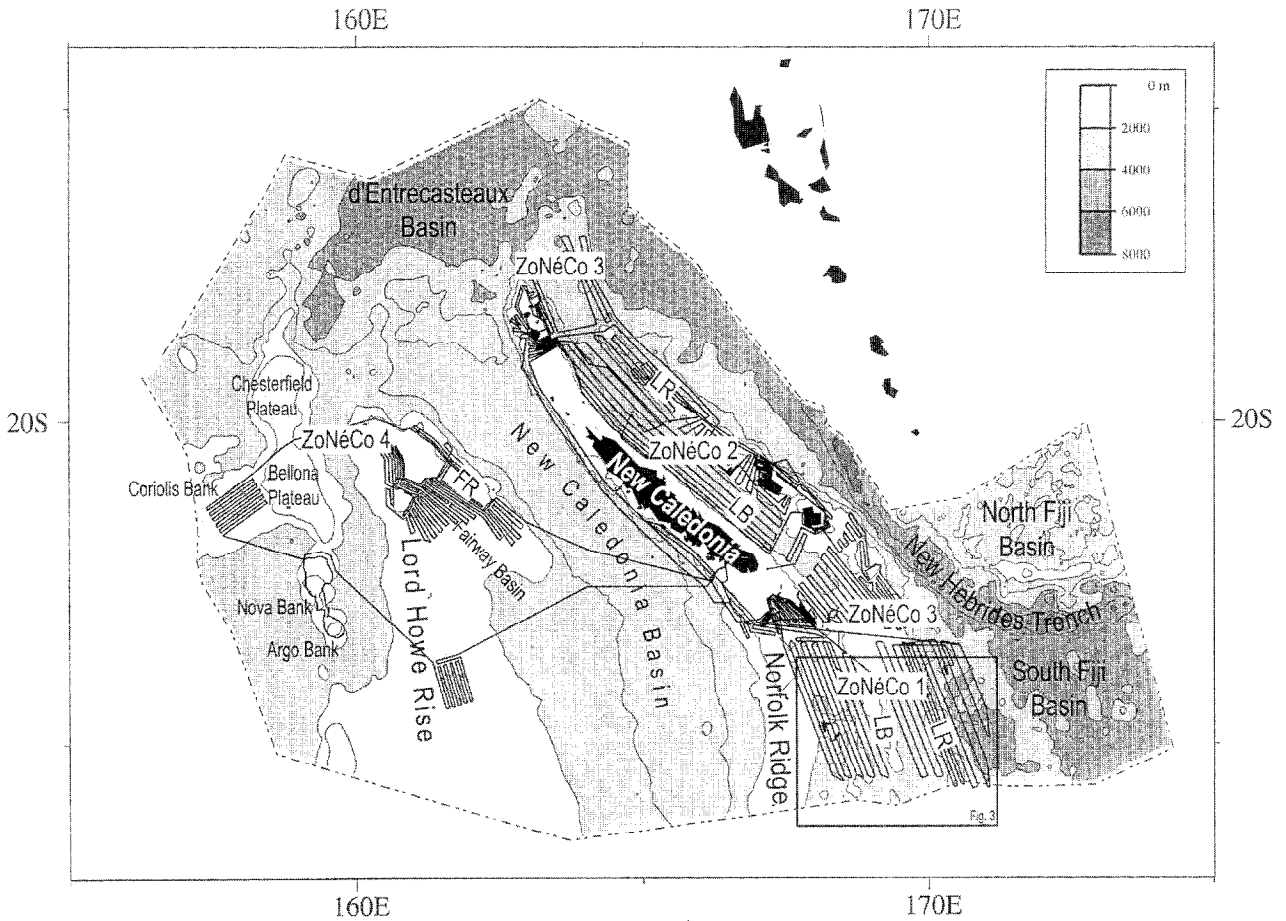

Figure 2. Presentation of the New Caledonia Economic Zone located between latitudes 15°–26° S and longitudes 156°–174° E. It lies at the eastern edge of the Australian plate and extends over an area of about 1.4 million km^2. Location map of the ZoNéCo 1 to 4 swath-mapping cruises; FR: Fairway Ridge; LB: Loyalty Basin; LR: Loyalty Ridge.

Table I. Quantitative information of surface vs depth (the surfaces indicated are in km^2).

Depth (m)	ZoNéCo 1	ZoNéCo 2	ZoNéCo 3	ZoNéCo 4
0 to – 500 *	577	566	2874	281
– 500 to – 800 **	1894	2855	3652	4409
– 800 to – 1500	11923	10714	11870	32204
– 1500 to – 2000	19129	12935	16003	6475
– 2000 to – 2500	22714	22414	7474	9032
– 2500 to – 3000	3756	10353	6575	2800
– 3000 to – 3500	3890	9907	8197	2741
– 3500 to – 4000	6379	3760	5679	5571
– 4000 to – 4500	8046	1	1958	0
– 4500 to – 5000	0	0	939	0
– 5000 to – 5500	0	0	266	0

* Deep red snappers (*Lutjanidae, Etelinae*) live within the depth range 300–500 m.
** Alfonsino (*Beryx splendens*) is found within this depth layer.

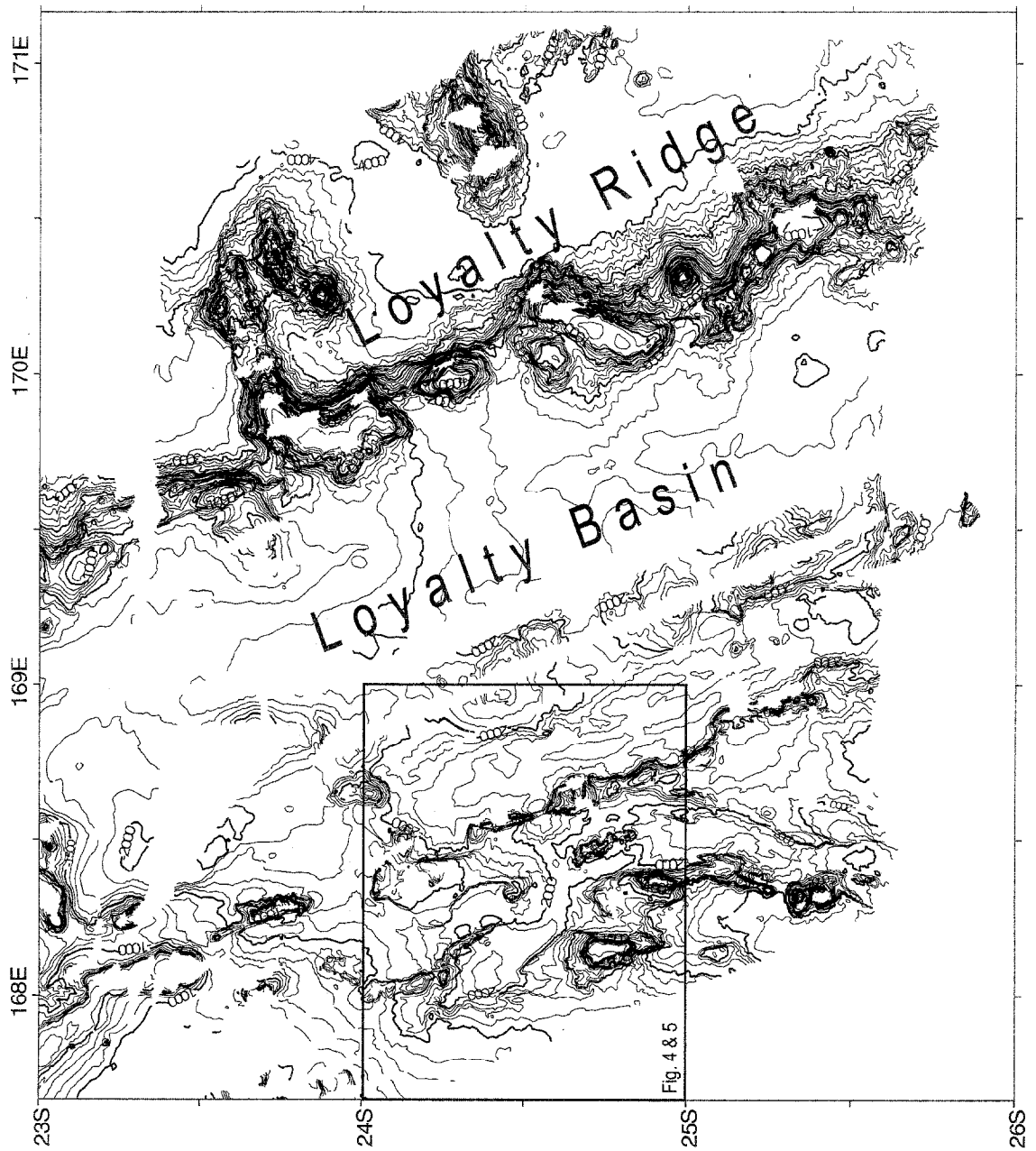

Figure 3. Detailed swath-mapping map of the Norfolk and Loyalty ridges resulting from ZoNéCo 1 survey. The isocountour is 100 m. The box indicates the location of *figures 4* and *5*.

surveys provide a basis for the preparation and compilation of deep-sea trawling surveys.

The South West Pacific area (*figure 1*) is the site of the convergence between the Australian and the Pacific plates. On a large scale the major indication of the convergence is the subduction of the Australian Plate, on which are located Papua New-Guinea, New Caledonia and New Zealand, beneath the Pacific plate which supports the Solomon Islands, Vanuatu and Fiji Islands. The boundary of the two plates is marked by a succession of trenches, from north to south: Manus or New Britain Trench, San Cristobal Trench and New Hebrides Trench.

The very early geodynamic evolution of the South West Pacific area can be roughly divided into two main phases.

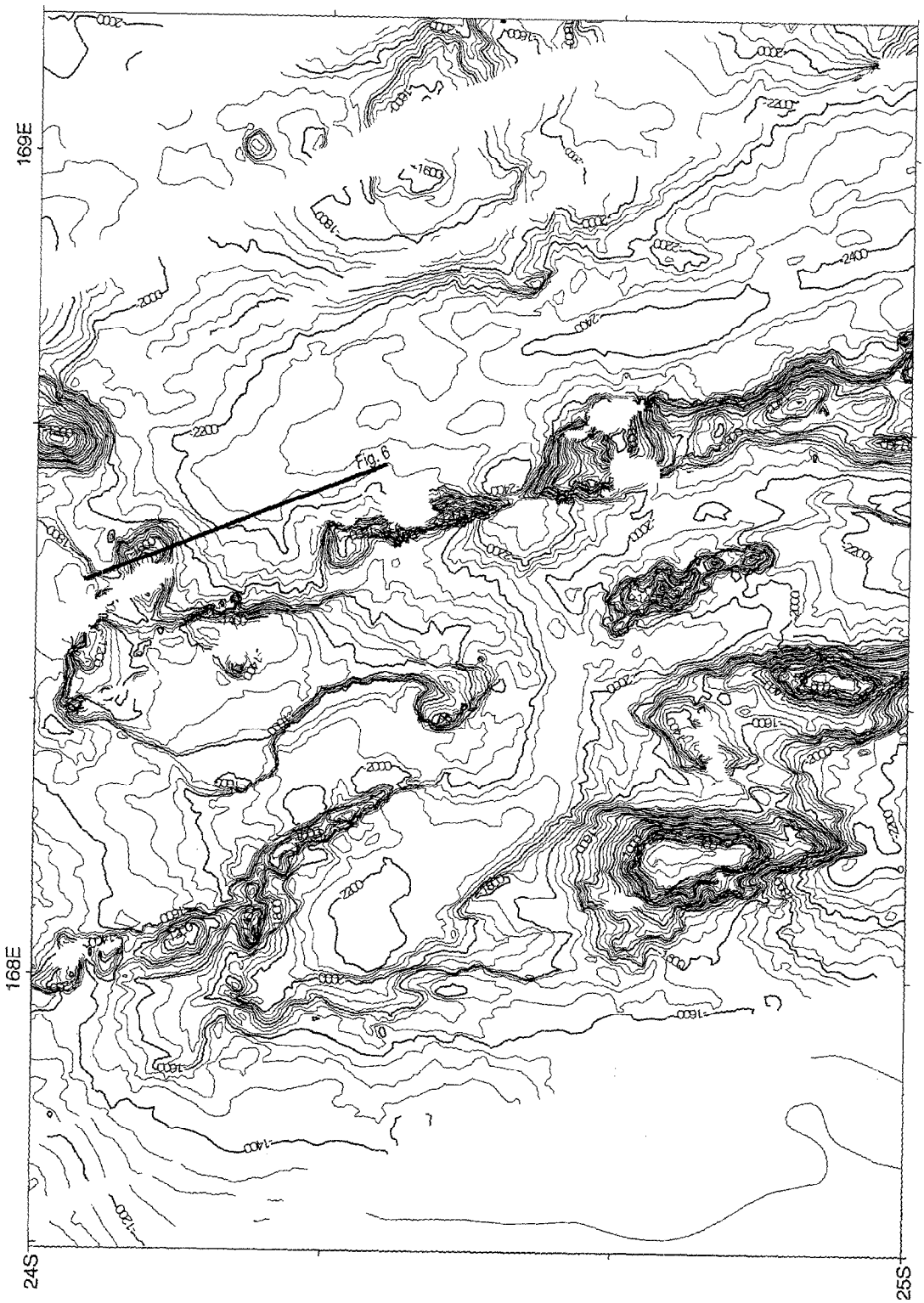

Figure 4. Enlargement of the swath-mapping map of the middle part of the Norfolk Ridge (see *figure 5* for location). The bold line shows the location of the mud-penetrator profile of *figure 8*.

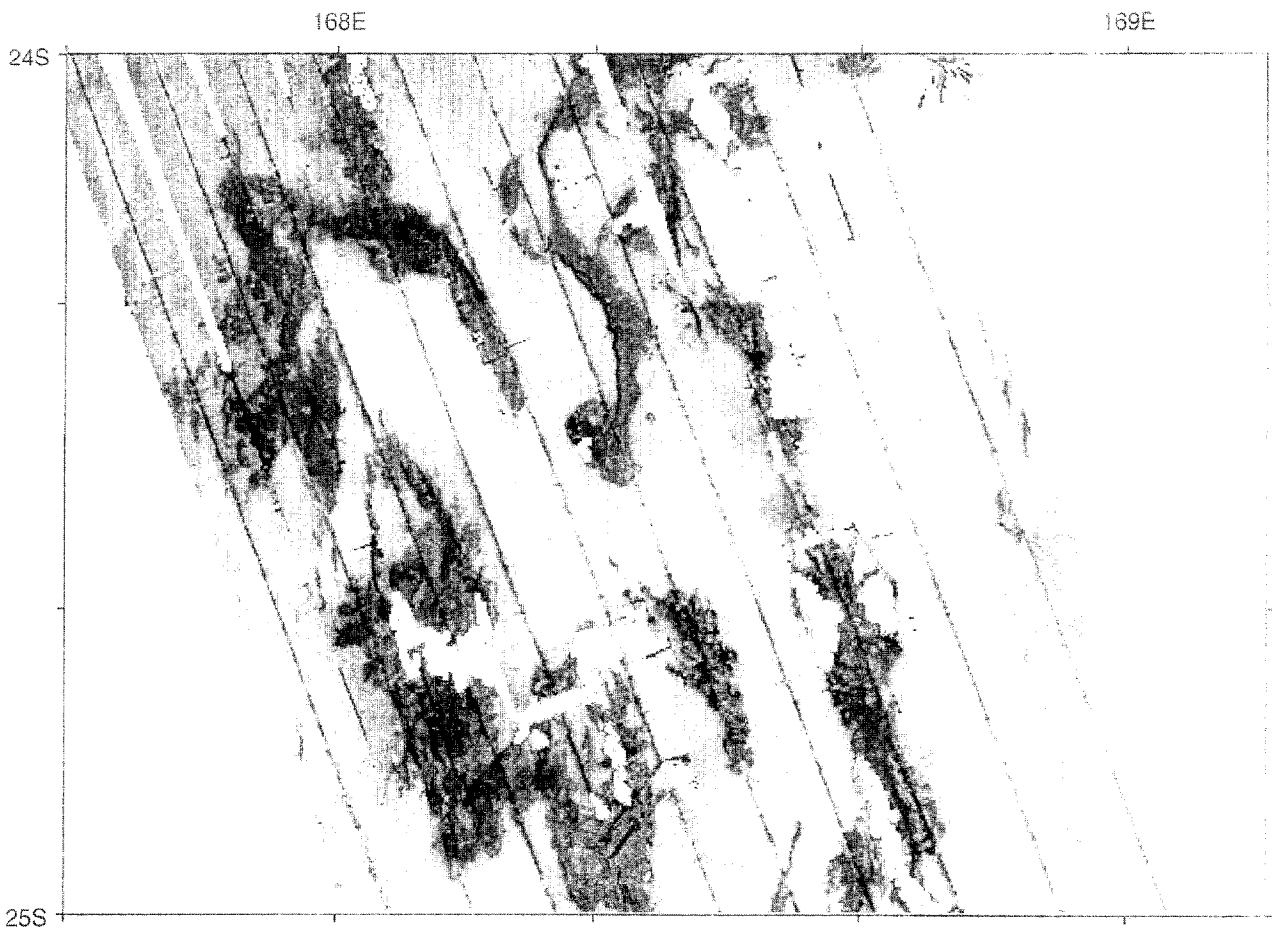

Figure 5. Imagery map of the same area as in *figure 6*. The bold line shows the location of the mud-penetrator profile of *figure 8*.

The first phase is characterized by the successive opening of the New Caledonia, Fairway and Tasman basins from 75 to 53 Ma (magnetic chron 33 to 24) [8, 11, 16]. The second phase is characterized by the northward motion of the Australian Plate, 45 Ma ago, followed by the Upper Eocene obduction of the New Caledonia ophiolites about 35 Ma ago [14].

The New Caledonia Economic Zone is mainly located on the Australian Plate, and shows a succession of ridges and basins resulting from the combination of extensive and compressive tectonic events affecting the area since the Cretaceous [4]. As shown in *figure 1*, a large surface of the ridges located between Australia and New Caledonia mainland is characterized by shallow depths ranging from a few hundred meters to 2 000 m.

The aim of this paper is to illustrate the results of the swath-mapping surveys and their benefits for the definition of Marine Habitats and consequently for the fishing exploratory cruises devoted to the evaluation of potential resources.

2. PREVIOUS SURVEYS

From 1979 to 1991, the 'ZOE Mapping Programme', a conventional mapping programme, was performed in the New Caledonia Economic Zone. The bathymetric map resulting [12] was, at that time, the most precise of the New Caledonia EZ. *Figure 2* shows, from west to east, a succession of basins and ridges. In the western part of the Economic Zone, the Chesterfield group, which supports the Chesterfield and Bellona Plateaus, Nova and Argo Banks, is marked by flat summits with depths ranging from 80 to 1 000 m. Eastwards, the Fairway Ridge - Lord Howe Rise system, culminates in its northern part at a depth of less than 200 m. The Norfolk Ridge, which

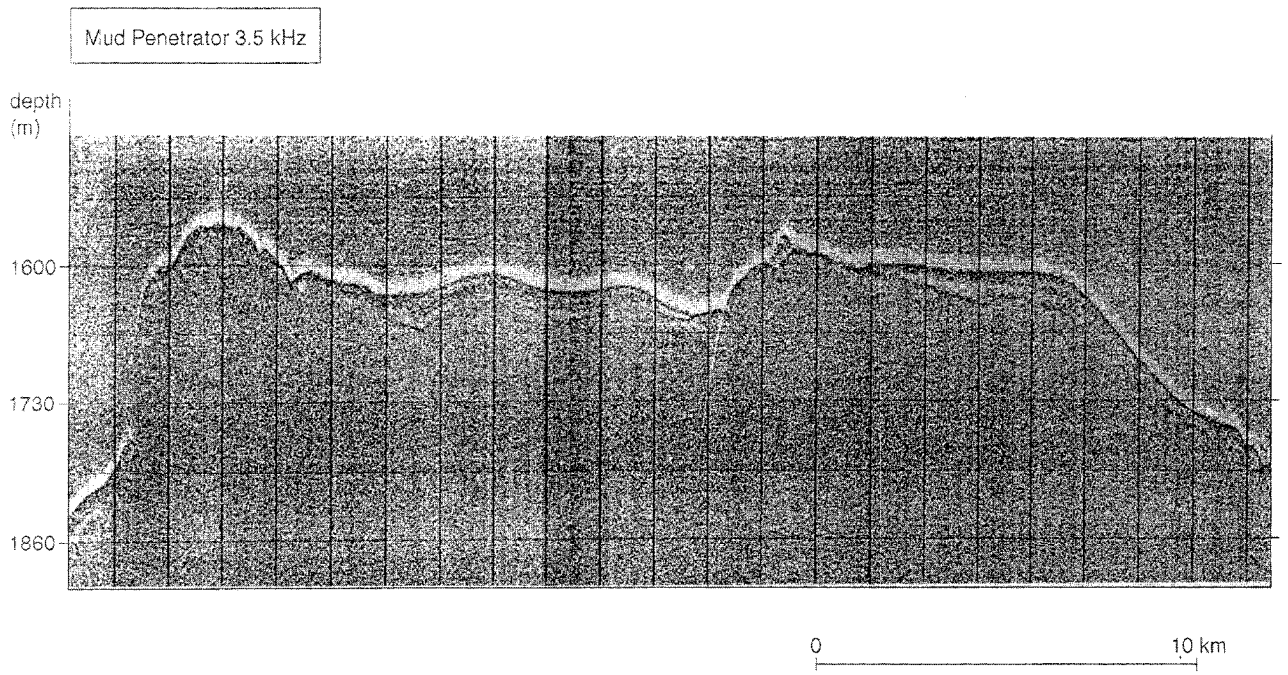

Figure 6. NNW–SSE-trending 3.5 kHz mud penetrator profile across the eastern side of the Norfolk Ridge.

supports New Caledonia, deepens to the south down to 2 000 m. The Loyalty Ridge is discontinuous and made up of a succession of tabular structures at a depth of 1 000 m.

The Norfolk and Loyalty Ridges were the most precisely surveyed structures prior to the ZoNéCo Programme. It is for this reason that the first exploratory fishing surveys and artisanal commercial exploitations were carried out on these two ridges. From 1991 to 1992 eleven scientific cruises were devoted to a research programme on alfonsino. Preliminary conventional seabed mapping, using EDO echosounders and GPS, was carried out in order to facilitate fishing operations.

3. THE ZONÉCO SWATH-MAPPING SURVEYS

The four ZoNéCo swath-mapping cruises carried out within the frame of the ZoNéCo programme between 1993 and 1996 (*figure 2*) used the Simrad EM 12 DUAL system installed onboard the R.V. *L'Atalante*. The EM12 DUAL is a multibeam echosounder providing both bathymetry and acoustic imagery of the seafloor. Its 162 beams allow a coverage of about seven times the water depth; i.e. a 15 km-wide coverage at 2 000 m depth and 20 km at 4 000 m [2, 3].

The objectives of the four ZoNéCo cruises were the mapping of respectively: the southern prolongation of New Caledonia and Loyalty Islands [15]; the northern prolongation of New Caledonia and the Loyalty Basin, between New Caledonia and the Loyalty Islands [9]; the junction of the southern part and northern part of New Caledonia and the Loyalty Basin, the countour of the Loyalty Islands [13]; the Fairway Ridge, the Northern part of the Lord Howe Rise, the Coriolis bank and around the Nova and Argo banks located in the western part of the EZ of New Caledonia [10].

The considerable amount of bathymetric data acquired during these four cruises represents about 20 % (259 448 km^2) of the total surface of the New Caledonia EZ ($1.4 \times 10^6 km^2$) (*figure 2*). The deepest limit for possible exploitation by industrial fisheries ranges between 0 and 2 000 m. The areas covered by swath mapping at depths of less than 2 000 m are situated: in the southern part of the New Caledonia EZ, mainly over the summit of the Norfolk Ridge, characterizing the successive tabular structures of Loyalty Ridge; in the northeastern part of the EZ, corresponding to the slope of the New Caledonia mainland and underlining the Loyalty Ridge which supports the Loyalty Islands; in the western part of the EZ, over the Fairway Ridge and the Lord Howe Rise where volcanic peaks culminating at about 500 m depth have been surveyed. On the Chester-

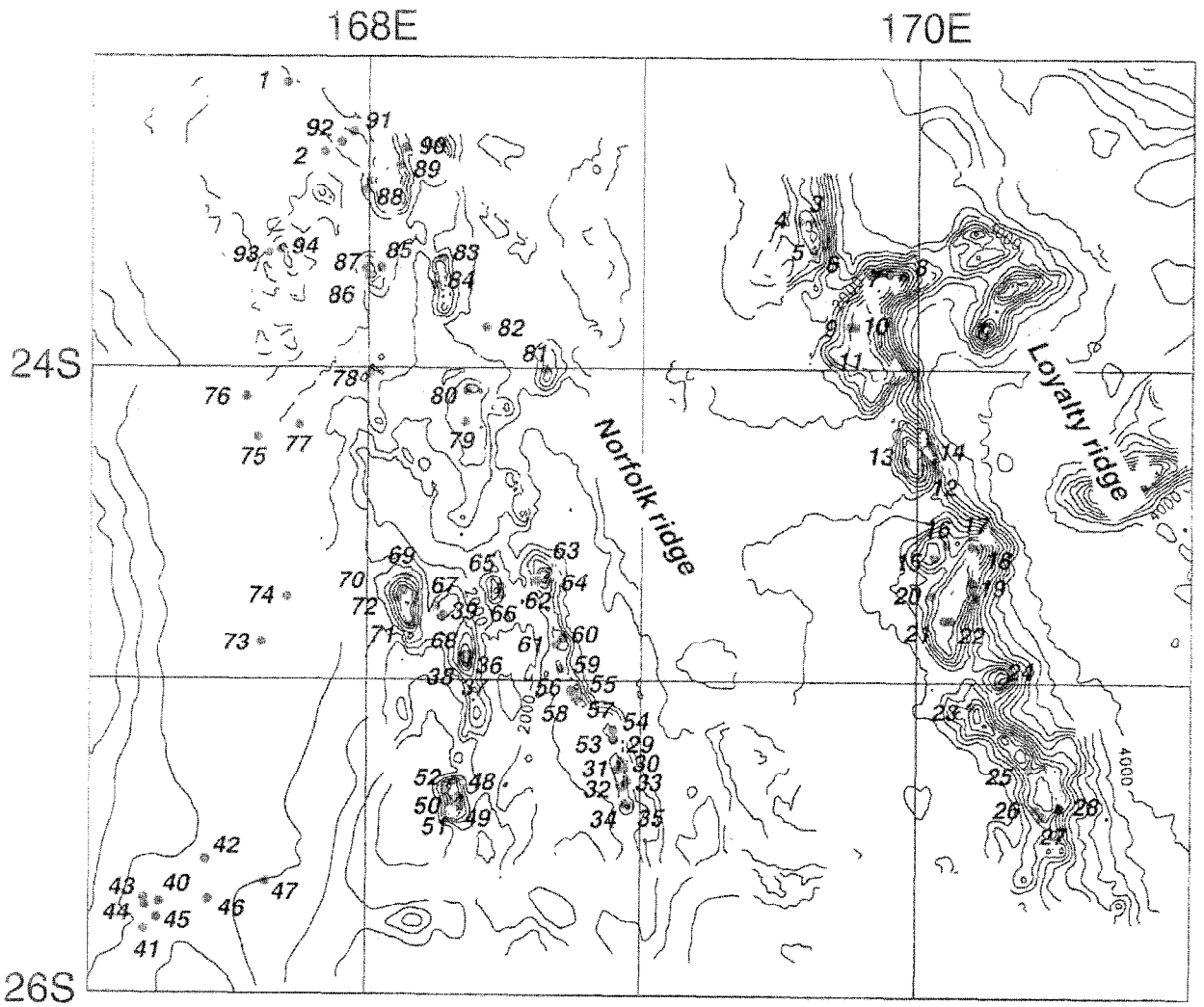

Figure 7. Location map of the trawling stations completed onboard TANGAROA on the Norfolk Ridge and on the southern prolongation of the Loyalty Ridge [7].

field volcanic line west of the Lord Howe Rise, the Coriolis Bank shows a smooth summit shallowing at less than 1 000 m deep. The Nova and Argo banks are also shallow structures culminating at less than 500 m deep.

All the bathymetric data acquired during the ZoNéCo cruises have been quantified and classified in surfaces vs depths in *Table I*.

4. APPLICATION OF SWATH MAPPING AND IMAGERY RESULTS: HALIPRO 2 CRUISE

In 1993, the ZoNéCo 1 cruise [5] surveyed the area between 23° S and 26° S and 167° 30' E and 171° E (*figure 3*) which is roughly characterized by two subparallel ridges. To the west, the Norfolk Ridge is underlined by the 2 000 m isobath which isolates 2 400-m-deep basins. The top of the Norfolk Ridge is marked by elongated seamounts of about 30 km long culminating at less than 600 m depth. These features are characterized by small-sized narrow summits, of about 5 km long and bounded by steep slopes (30 %). To the east, the Loyalty ridge, deeper than the Norfolk Ridge, is outlined by the 2 200 m isobath and is constituted by a succession of important tabular structures of about 90 km long culminating at less than 1 000 m depth. These structures are characterized by large, smooth summits about 50 km long and are bounded by slopes of about 20 %.

The enlargement shown in *figure 4* illustrates the complexity of the detailed topography of each of the seamounts. It shows that the flat tops of the seamounts are limited in size and that these structures present systematically eastern slopes steeper than the western flanks.

Figure 5 represents the imagery resulting from the processing of the swath-mapping data. It appears that high reflectivity areas are mainly superimposed on the steep flanks of the seamounts. This confirms that these flanks are probably void of sedimentary cover. However, in some places the tops of the seamounts are marked by high reflectivity indicating exposed basement.

In some places, a 3.5 kHz mud penetrator profile shows that the slope is still covered by sediments (*figure 6*). In these cases, the observed high reflectivity is also strongly linked with the steepness of the slope.

The morphology and the nature of the structures, observed on the swath-mapping and imagery maps, offer particularly interesting features as far as marine habitats are concerned. Before swath-mapping, the surface exploited by the fishery at a depths ranging from 500 to 800 m in the southern part of the EZ was about 280 km^2. The ZoNéCo 1 survey enlarged this surface up to 1230 km^2. Depths between 800 to 1 500 m account for about 15 000 km^2.

The interpretation of all these data (bathymetry, imagery, mud penetrator...) was a valuable guide for the definition of the strategy of the Halipro 2 exploratory deep-sea trawling cruise (*figure 7*) carried out in 1996, onboard the New Zealand R.V. *Tangaroa* chartered from NIWA (National Institute of Water and Atmospheric research). During Halipro 2, 106 hauls were made in the Norfolk–Loyalty ridges zone [7]. In total, 13 new seamounts located by the ZoNéCo 1 cruise have been explored. The habitats selected for this cruise were the summits of the seamounts of the Loyalty Ridge area and the summits and the flanks of the seamounts of the Norfolk Ridge area. The fish targets were the alfonsino (*Beryx splendens*) which occurs within the depth range 500–800 m and the orange roughy (*Hoplostethus atlanticus*). From 1988 to 1991, a commercial bottom longline fishery [6] was operating on the Norfolk and Loyalty ridges. It exploited the demersal species, especially alfonsino (*Beryx splendens*), over five seamounts between 500 and 800 m depth. The orange roughy, which had never been recorded previously within the Economic Zone of New Caledonia, is exploited further south in New Zealand where it is the target of a flourishing fishery between 800 and 1 500 m. Other species are associated with alfonsino: the blue nose (*Hyperoglyphe antartica*), the armourhead (*Pseudopentaceros richardsonis*) and *Pentaceros japonicus*. In terms of scientific results, 234 species of fish were caught, including many which were new to science. Halipro 2 cruise confirmed the existence of the alfonsino on the top of the seamounts between 500 and 600 m depth. Unfortunately, the expected orange roughy was not caught in the explored region, probably due to unfavourable hydrological conditions.

5. CONCLUSION

Swath-mapping survey constitutes the first necessary step for the identification and evaluation of the marine resources. It revealed the existence of new potentially exploitable zones much larger than those actually fished. In the New Caledonia EZ, the present-day swath-mapping coverage represents only 20 % of the total surface but the results already obtained are encouraging. In the southern part of New Caledonia, the ZoNéCo 1 swath mapping cruise and the Halipro 2 deep-sea trawling survey indicate an exploitable area five times the size of the conventional fishing coverage. The ZoNéCo programme will continue to carry out simultaneous swath-mapping cruises and exploratory fishing cruises to extend the area already covered particularly on the western part of the New Caledonia EZ.

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