Fisheries thematic mapping - A prerequisite for intelligent management and development of fisheries [1]

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Abstract

The relevance of Fisheries Thematic Mapping in the general fisheries context is discussed and the current importance of resource mapping, particularly in the new Exclusived Economic Zones of developing countries, is indicated.

An historical perspective on development of fisheries science in long established fishing areas supports recognition of resource mapping as an important preliminary stage to fish stock assessment, particularly for coastal resources. Some methods of assessment that stem directly from such mapping exercises are referred to, as are the dangers of uncritical use of population models which assume that "dynamic pool" assumptions apply to geographically dispersed and contagious populations. A review of spatial considerations that affect various types of fisheries analysis is given.

Some criteria, and a rough classification of various types of applications of mapping in fisheries are proposed, which include their use in fisheries prospection, in support of research vessel surveys, statistical and information gathering systems; the preparation of fisheries resource management plans and the leasing of marine culture purposes; coastal planning and environmental impact studies; and in support of negotiations on maritime boundaries and fisheries access agreements.

The time scales for updating fisheries maps vary between different applications. In some cases the main consideration should be ease of updating rather than great accuracy — which is constrained by the limited position — finding capabilities of small fishing vessels. The need for promoting routine application of new technology such as micro-computers and remote sensing in mapping, as well as suitable software for rapid compilation and updating of various thematic maps, is stressed.

Key words : Thematic mapping — Stock assessment — Management — Development — Assemblages.

Résumé

La cartographie thématique des ressources : un préalable à l'aménagement et au développement des pêches

Le document discute la pertinence de la cartographie thématique dans le contexte général de l'halieutique et indique l'importance de la cartographie des ressources, en particulier dans les ZEE des pays en développement.

La perspective historique du développement de la science halieutique dans les zones de pêches traditionnelles confirme que la cartographie des ressources est une première et importante étape de l'évaluation des stocks, particulièrement dans la zone côtière. Certaines méthodes d'évaluation découlant directement de cette cartographie sont mentionnées, ainsi que les dangers d'une utilisation abusive de modèles supposant que les hypothèses d'homogénéité s'appliquent à des populations géographiquement grégaires et sous-dispersées. Le document passe en revue les diverses considérations spatiales qui affectent les divers types d'analyses effectuées sur les pêcheries.

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On y propose quelques critères et une classification grossière des divers types d'application de la cartographie aux pêches, y compris leur utilisation pour la pêche exploratoire, les prospections des navires de recherche, les systèmes de collecte des statistiques, la préparation des plans d'aménagement, l'allocation de l'espace maritime pour l'aquaculture, l'aménagement du littoral et les études d'impact, les négociations concernant les frontières maritimes et les accords de pêche.

La périodicité de la mise à jour des cartes varie selon les applications. Dans certains cas, le principal souci doit être la facilité de mise à jour plutôt qu'une grande précision dont la nécessité est souvent limitée par les capacités de positionnement des petits bateaux de pêche. Le document insiste, enfin, sur la nécessité de promouvoir l'application en routine de technologies telles que les microordinateurs et la télédétection, ainsi que l'élaboration de logiciels pour l'établissement et la mise à jour rapide des cartes thématiques.

MOTS-CLÉS : Cartographie — Évaluation des stocks — Aménagement — Développement — Peuplements.

1. INTRODUCTION

An appreciation of the spatial interrelationships between the renewable resources and the fishery (including coastal communities, harvesting units, shore plant and transhipment routes to market) is constrained by a knowledge of the local geographical configuration, an understanding of which is a necessary prerequisite to proper analysis of part or all of the fisheries system. This necessary precondition to detailed analysis of subcomponents of the system has rarely been explicitly recognized in most fisheries analyses however, and the preliminary stage of mapping key elements of knowledge already formally or informally available, which should ideally precede the design of information gathering and analysis systems, is often not recognized as such. In fact, few fisheries models in current use employ the sorts of spatial information that can be among the earliest types of data available on the exploited resource.

It is an essential requirement for scientific management of fisheries, as well as for their orderly development, that all the existing relevant information is made available and displayed in an accurate, concise and up-to-date form which is easy to read and to interpret by all concerned. Mapping the fishery and the resource should be among the priority tasks when planning for fisheries management and should not be postponed until "complete" information is available, since redundencies or blanks in the information base will more readily appear in the process of elaboration. The question of accuracy of spatial representation is probably less important, except for purposes of navigation, than of ease of update: a requirement that poses serious demands on new technology for entry and display of information in a cost-effective fashion. The existence of readily assimilated and regularly updated information, displayed in the form of a chart or map, is essential in the early stages of setting up new information gathering and analysing systems. This possibility is now being given priority by many developing countries, and FAO now gives particular emphasis to information gathering and display for a variety of purposes in the fisheries sector. Some perspectives on a number of current applications are given in this paper.

2. MAPPING, MONITORING AND MODELLING

This often-expressed idealization of the course of events in ecosystem investigation also applies to fisheries research, and represents in a very real way the sequence of operations that has taken place in the course of development of the renewable marine resources of the world's oceans. Starting with an overall description or "mapping" of the coastline, its bathymetry, currents and tidal configurations, the traditional navigation chart is soon extended by the fishermen themselves into a fishing chart which serves as a mnemonic in recording their personal experience with the distribution of the main commercial resources. Early in the history of a resource investigation, this information may then be integrated, following its collection in a properly planned fishermen survey, and can lead to a broad overview or "thematic fisheries map" of immediate use for fishery planning and development. Such a map can also display information obtained from biological investigations, including location of spawning and nursery areas, migration routes, fishing grounds and points of landing and of processing and transhipment of fish. Fisheries charts having the more practical purpose of aiding fishermen in locating resources in the absence of modern navigational aids, were prepared in the early part of the 20th Century for a number of areas in the Northern Hemisphere, and updates for a variety of purposes have been prepared more recently (*e.g.* HARE, 1977; SCARRATT, 1982; CHARBONNIER and GARCIA, 1985) and are now being prepared in a number of developing countries (*e.g.* GARCIA, 1982, Fig. 1). Alternatively, or in addition, as noted by Butler *et al.* (in preparation) and by McGUIRE (1979), a thematic map can be used to highlight the importance of certain parts of a marine

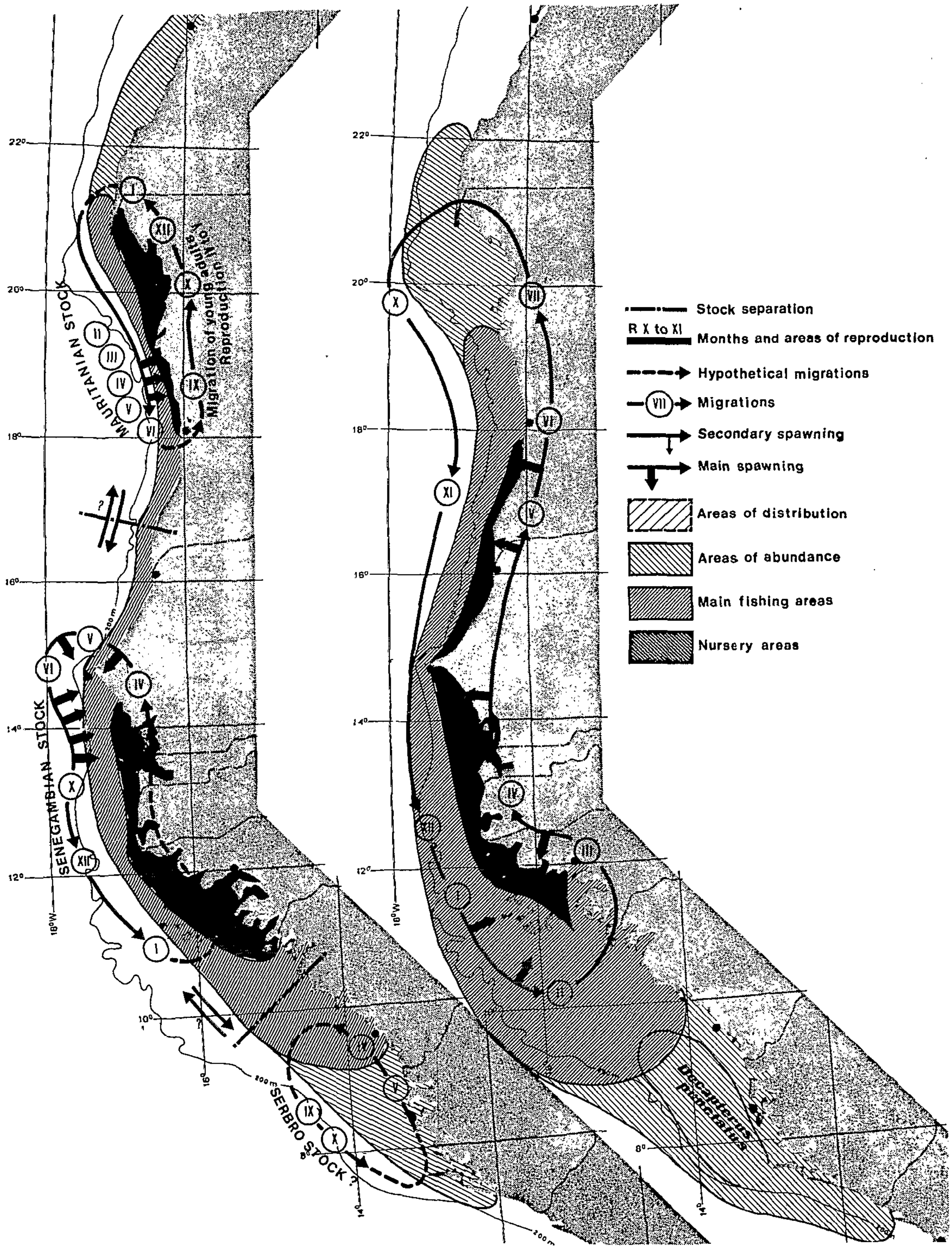

FIG. 1. — Distribution, migration and spawning of *Sardinella maderensis* (left) and *Decapterus rhonchus* in North West Africa. (Compiled by GARCIA, 1982, from various sources, including CHAMPAGNAT and DOMAIN, 1978, and BOELY and FRÉON, 1979)

Distribution, migration et ponte de Sardinella maderensis *(gauche) et* Decapterus rhonchus *(droite) en Afrique du Nord-Ouest. Compilé par* GARCIA *(1982) d'après diverses sources, y compris* CHAMPAGNAT *et* DOMAIN *(1978) et* BOELY *et* FRÉON *(1979)* area for other human activities such as dumping of industrial waste, recreation, coastal development and navigation, all of which impinge on the fisheries sector and all of which can be expressed on a thematic map which is of direct relevance to all users of the marine environment.

For the North Atlantic and in other areas where industrial fishing developed early on, it was, to a significant extent, the accumulation of fishery-related information in a spatial context by early exploratory fishing, that accelerated the development of fisheries science. There, a long tradition of descriptive work has preceded attempts to manage individual stocks: this latter activity only got fully underway well after the Second World War. The large body of information accumulated previously on North Atlantic ecosystems and their seasonal and areal distributions was no doubt essential to the feasibility of applying fishery management measures that controlled the level and the nature of removals. Thus, for the Northwest Atlantic Fishery Commission the boundaries of the unit areas subsequently used for fishery management were suggested by earlier work on the distribution and migrations of (especially) cod stocks on the different offshore banks, and led to a fisheries map of the area (Fig. 2), whose divisions reflect to the extent possible in a mixed fishery, meaningful stock units of relevance to management. Regional geographic boundaries of this kind developed by fisheries commissions and FAO, are now integrated into the global system of fisheries data collection which issues annually the FAO Year Book of Fisheries Statistics.

To a large extent, the preparation of a fisheries map occurs in two stages: mapping of the primary data (*e.g.* Fig. 3 top), which with supplementary information leads to a hypothesis on stock structure, movements etc. which as a second stage, may result in an interpretation of the primary data: (*e.g.* Fig. 3 bottom). There is a danger of course that such preliminary mapping of hypotheses can crystallize future perceptions of the resource, and this emphasises the importance of having the digitised data base readily available for later revisions.

There is reason to believe that the considerations described above for the North Atlantic apply also in other areas of the world's oceans (see FAO, 1985), although the important early descriptive work on the resources and their environment has not yet been carried out in many regions. FAO has been

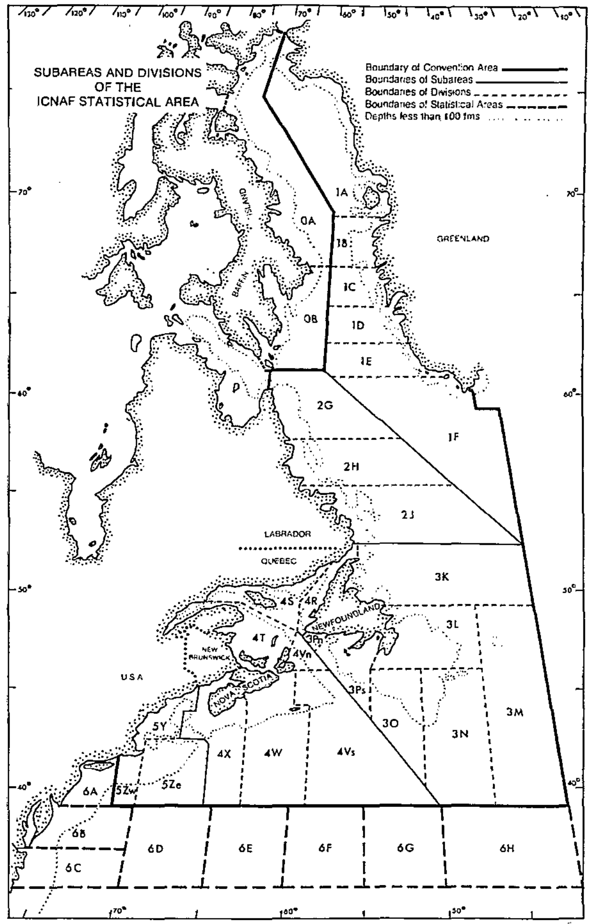

FIG. 2. — Statistical unit areas of ICNAF
Divisions statistiques de la CIPAN

focusing necessary effort first on the description and inventory of species available in each area through the publication of Species Identification Sheets, now developed for most of the world's major fishing areas. These include for each species a small scale distribution map, but a comprehensive knowledge of the biology, distribution and migration of many key species and their interractions is not yet available, although they may already support major fisheries. Thus, the important industrial fisheries that sprang into existence, in several cases as late as the 1970's, came as a result of technological transfer and through the operation of long-range fleets by industrialised

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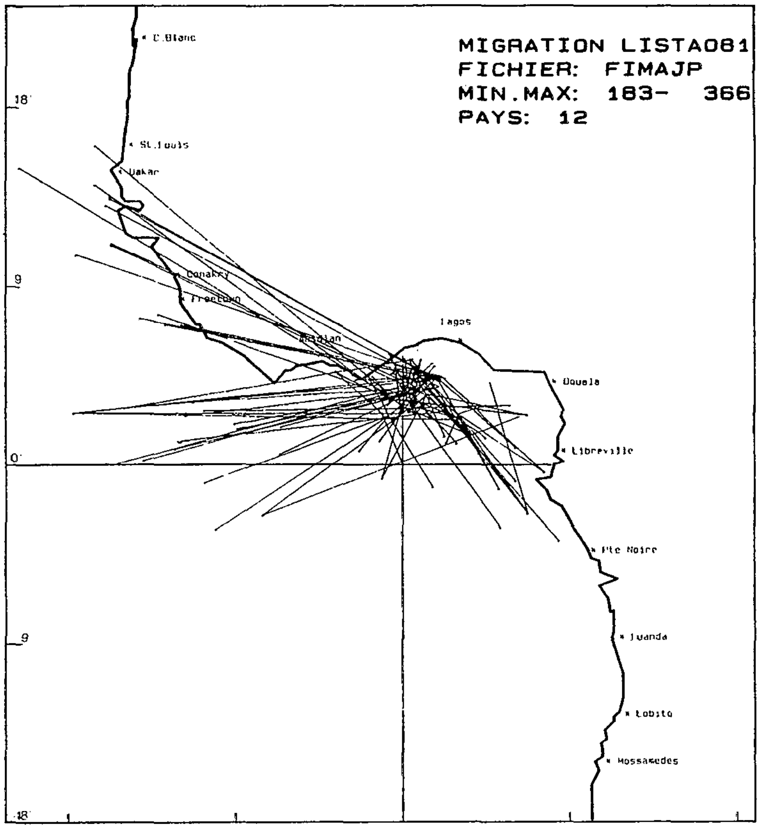
FIG. 3. — *Top.:* Apparent movements of skipjacks tagged in the center of the Gulf of Guinea. *Bottom:* Interpretation, from BARD (1984) (courtesy of « La Pêche Maritime »)

Haut : *Mouvements apparents des listaos marqués dans le centre du Golfe de Guinée.* Bas : *Interpretation selon* BARD *(1984) (avec l'aimable autorisation de « La Pêche Maritime »)*


MIGRATION LISTAO81
FICHIER: FIMAJP
MIN.MAX: 183- 366
PAYS: 12
18°
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C.Blanc
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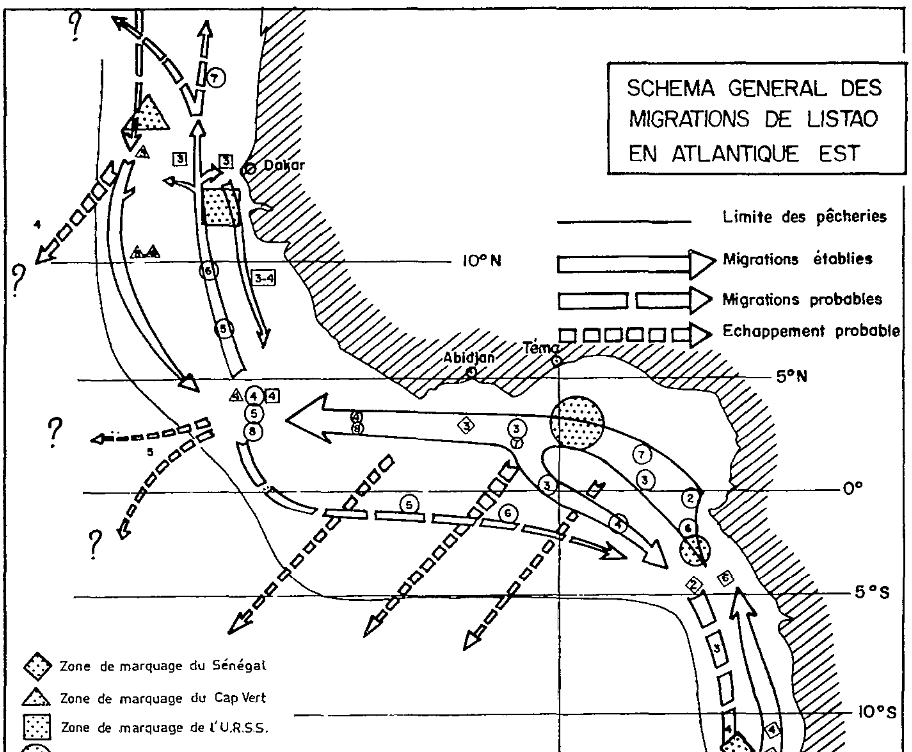
Lobito
Mossamedes


SCHEMA GENERAL DES MIGRATIONS DE LISTAO EN ATLANTIQUE EST
Limite des pêcheries
Migrations établies
Migrations probables
Echappement probable
Dakar
Abidjan
Téma
10° N
5°N
0°
5°S
10°S
Zone de marquage du Sénégal
Zone de marquage du Cap Vert
Zone de marquage de l'U.R.S.S.
Zone de marquage du Japon
Zone de marquage de la Côte d'Ivoire
Trimestre d'observation des listaos marqués par le Japon et la Côte d'Ivoire
Trimestre d'observation des listaos marqués par le Sénégal
Trimestre d'observation des listaos marqués par le Cap Vert
Trimestre d'observation des listaos marqués par l'U.R.S.S
Trimestre d'observation des listaos d'après les données des pêcheries
Les trimestres sont indiqués par leur rang sur deux années consécutives où les listaos, demeurent dans les pêcheries, mesurant de 40 à 60 cm.

nations. Usually the coastal states lacked a proper basis of information for their control and management, in the form of knowledge of stock distributions and their migrations, and estimate of the abundance and the distribution of key resources: key information sources that can best be developed in the form of a readily updatable fisheries chart.

3. MARINE RESOURCE MAPPING IN THE POST-EEZ ERA

As we have noted, despite the difficulties of adapting conventional models to a spatial context, many problems met in fisheries have a spatial dimension. For instance, the most heavily exploited resources tend to be those closest to the port, unless they are fished out, and the exploitation rate for resources having a similar unit value tends to decrease with distance from the port especially in artisanal fisheries Conflicts between competing sectors of the fishing industry often involve use of a common location as a fishing ground, and may require further development of fishing "boxes", or "windows", to constrain the use of a given area by, for example, certain types of set or fixed gear, or in areas and seasons of high vulnerability due to spawning. In certain areas of potential gear conflict, fixed gear may be required to be set in strings on a given compass heading to minimize conflicts with towed gear. Other spatial interactions can occur, such as in sequential (gauntlet) fisheries, where a series of fisheries occur at various points on the migration route of a species (Fig. 4), and elucidation of the possible migration routes for highly migratory species usually requires a mapping of the location (and the timing) of operation of exploiting fleets in order to reveal it clearly: (*e.g.* Hunte and Mahon, 1985). Noting that fishing locations recorded by fishermen in log books are often given in terms of the electronic navigational system they used in locating the fishing ground, a system of direct transposition of coordinates to latitude and longitude is necessary for mapping catch and effort data, and such systems have been developed for same areas. It is also necessary in this connection to choose appropriate algorithms for drawing contour lines through the raw data, and some experience in this area has been recorded, but needs to be formalized in readily available microcomputer software. Where a common electronic navigation system is in place, there may be something to be said for defining coordinates of closed areas in this fashion to avoid fishermens' misunderstanding

Excessive fishing effort exerted on demersal resources in most tropical areas leads to progressive accumulation of fishing intensity closer and closer inshore (Garcia, 1986) and to progressive encroachment, on the coastal zone usually reserved *de facto* or by legislation for artisanal fishermen. Other problems are even more directly the consequence of competition for the use of space; as in the case of conflicts between small-scale fishermen and mariculture, or between the extraction of building material and reef fisheries, or between coastal trawling and the installation of artificial reefs. As a matter of fact, in traditional fishery management, prior to the application of quotas and limited licensing mechanisms, allocation of space often served as a substitute for allocation of resources, and still plays an effective role in this regard, especially in traditional fisheries (see *e.g.* Christy, 1982; Smith and Panayotou, 1984).

Spatial characteristics of fisheries have always been important for local coastal fisheries but these fisheries have been given very little attention until recently. In this connection, the United Nations Convention for the Law of the Sea and the concept of the 200 miles Exclusive Economic Zones have abruptly brought back into centre stage the spatial dimension of formerly international fisheries, as a result of the need to resolve maritime boundaries and overlapping claims in the light of stock distributions and migratory resources. It is significant here that the first FAO Atlas of the living resources of the sea had been issued in 1971, just prior to the first session of the Third United Nations Conference on the Law of the Sea, as part of the FAO's technical contribution to the preparatory work of the conference. Following this milestone event, many developing and developed nations have taken the opportunity to greatly increase the benefits they receive from their resources by taking the first steps towards proper management and adequate development of resources within their Extended Economic Zones (EEZ's). This has inevitably increased the need for information on the distribution and movements both of resources and of foreign and domestic fleets within the 200 miles zone, on a priority basis.

The resolution of problems of access between domestic and foreign fleets continues to be a source of concern, and, perhaps less easily resolved, that between local artisanal and industrial fleets also needs to be solved on a national basis, and often geographic allocations of one kind or another are the answers arrived at. These kinds of decisions with their direct political implications on access to coastal waters always existed, but have come more directly within the area of responsibility of governments since declaration of EEZ's. Such conflicts for use of the available space not only include those between sectors of the fishery (small-scale and coastal trawl fisheries), but also between capture fisheries and aquaculture (in lagoons, estuaries or in the open sea). The traditional local rights to a part of the fishing

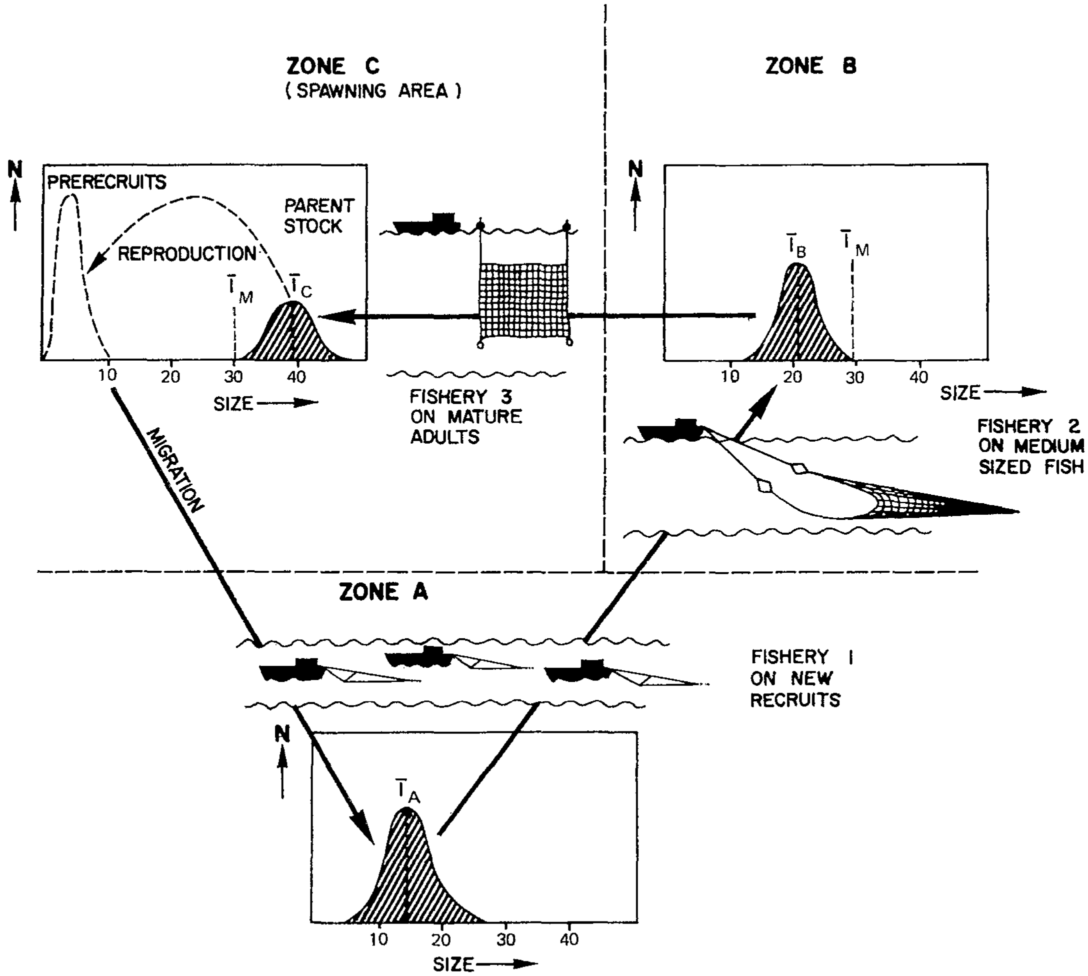


FIG. 4. — Illustration of a simple gaunlet model, in which a species spawned in Zone C, first reaches fishable size in Zone A, before passing at successively larger sizes through successive fisheries (and hence running an accumulating risk of capture in Zones B and C later in its life history. (l_A, l_B + l_C are mean sizes of capture, and l_M mean size at maturity). Pre-recruits in Zone C are too small for fishing. From CADDY, 1982

Illustration d'une pêcherie sequentielle simple, dans laquelle une espèce est pondue en Zone C, atteint une taille exploitable en Zone A avant de passer à des tailles de plus en plus grandes à travers des pêcheries successives, accumulant le risque d'être capturée en traversant les Zones B et C vers la fin de son cycle vital. (l_A, l_B et l_C sont les tailles moyennes de première capture, l_M est la taille moyenne de maturation). Les pré-recrues en Zone C sont trop petites pour être exploitées. (D'après CADDY, 1982)

ground were to some extent ignored in the wave of industrialisation that took place in the 1960's and 1970's, and the Territorial User Rights of Fishermen — TURF's — (CHRISTY, 1982, and SMITH and PANAYOTOU, 1984), are beginning to be reasserted in a number of areas. This emphasises the importance of coastal planning, and the requirement for displaying precise geographical information; particularly in countries where interacting mariculture and fisheries industries are highly structured and diversified. Examples of the extent to which coastal waters may need to be zoned between competing users, is provided by Japan (RUDDLE, in press), but is likely to be shortly approached in other countries in S.E. Asia where acute problems are arising. Rapid display and more importantly, the capability for constant updating of geographical information is now at the cutting edge of fisheries science, and can be realised at relatively little cost given recent developments in microcomputing and graphic display, once the necessary software is widely available. This is an essential development for any national or regional system dealing with integrated management and development of coastal areas. For artisanal fisheries, it will be very important to map as accurately as possible the various fishing grounds of the different villages, which often describe some sort of *de facto* traditional allocation of space. Once the range of action of the fishing crafts is known, it may also be possible to use this information displayed on a chart to identify overlaps in fishing areas, and hence potential areas of conflict, as well as regions for further fisheries development. Seasonal migrations of fishermen should also be described where these occur. It is obvious that these types of maps existed long ago for many countries, but their use seems to have been overlooked in the present era of numerical analysis and modelling.

In varying the scope of fisheries management from international high seas fisheries (a few of which still exist!), to fisheries in EEZ's, and then via coastal fisheries to integrated management of coastal lagoons, estuaries and littoral areas, we span most of the scales of the maps needed as an aid to fisheries analysis management and development.

4. SPATIAL CONSIDERATIONS IN FISHERIES

4.1. Spatial Components in Fisheries Models: the Dynamic Pool Approach and its Limitations

The main objective of fisheries management is usually considered to be that of maintaining the stock and insuring optimal return from a fisheries resource by the control of overfishing. In order to provide a theoretical basis for tackling these problems mathematical models were established (Beverton and Holt, 1956; Schaefer, 1954; Ricker, 1958) which have since structured most of fisheries research in support of management, from the collection of data, its analysis and interpretation, to the elaboration of management measures.

Fundamental to nearly all of these approaches is the concept of the "dynamic pool" which is a basic axiom of most current fisheries models, implying that all components within the model, whether predator and prey or fish stocks (and their human predatory equivalent, the fishing fleet) are perfectly intermixed, so that any unit interraction occurs between them with consequences determined by the mean abundance of stock, and the mean intensity of harvesting pressure that were in effect over that interval of time: *i.e.* spatial components such as diffusion, relocation, migration, etc. are removed from consideration. Although these latter complications were treated in a theoretical way in the seminal work of Beverton and Holt (1956), there have been few subsequent applications, probably because of the massive data storage and manipulation procedures that would be involved for mobile resources and fleets. The dynamic pool convention is not entirely unreasonable if we are dealing with mobile species of a single unit stock over the whole area of the population, and are considering the species at time intervals of one year. For a mobile fishing fleet equipped with modern fish-finding aids such as sonar, spotter planes or satellites for locating suitable fishing areas, this is equivalent to in effect, "exteriorizing" spatial relationships from consideration in the model and implicitly assuming them as constant. This is less than satisfactory also if the energetics of predators is the object of study (large pelagic predators use a major part of their energy budget in swimming and migration), if the economics of fishing are being studied, where fuel consumption is a distance-related function, in studies of fish marketing and trade, and in any case when the spatial distribution of fish and fishing are likely to be affected by the amount of fishing. In all these cases, the implicit assumptions of the dynamic pool assumptions are not met, requiring a more explicit mapping of spatial factors.

4.2. Introducing Spatial Considerations into Fisheries Models

To some extent, it is the question of spatial scale for display of relevant phenomena which determines the appropriate model to use (see Sharp and Csirke, 1983): thus on a very large scale (*e.g.* the whole North Atlantic), it may be reasonable to consider even stocks of mobile species, such as cod, as stationary (*e.g.* Clayden, 1972). It is less than reasonable, however, to apply the dynamic pool axiom to widely dispersed sedentary species such as molluscan shellfish, and models of such populations have been based on describing mortality and growth processes for small unit areas, and subsequently integrating outputs for the whole area of the stock (*e.g.* Caddy, 1975). At least in theory, these types of models can be applied to routine management tasks, such as in developing the optimal rotational harvesting regime for shellfish populations over an area of fishing grounds (Gales and Caddy, 1975). Similar models that introduce a spatial component into coastal fisheries development are undergoing development at this time in FAO, and will attempt to allow for migratory and diffusional components. Such models should have a generalised format that can be adapted in a flexible fashion to a given configuration of resources, fishing ports, fishing grounds and coastline, in order to explore different options for fisheries development at a local or regional level.

The first step in introducing spatial components into the model may be to identify key loci whose relative geographic position and the distance from port to fishing ground as well as the relative costs of moving between the grounds (each considered as a dynamic pool stock), are left indeterminate (see *e.g.* KOLBERG *et al.*, 1981). This approach was adopted for example by CLAYDEN (1972) in modelling the North Atlantic cod fishery. A similar approach which treats the question of spatial co-occurrence, but avoids specific definition of geographic location, is by the use of Venn diagrams (Fig. 5), which in the topological sense of the word, "map" the distribution of predators onto the distribution of prey.

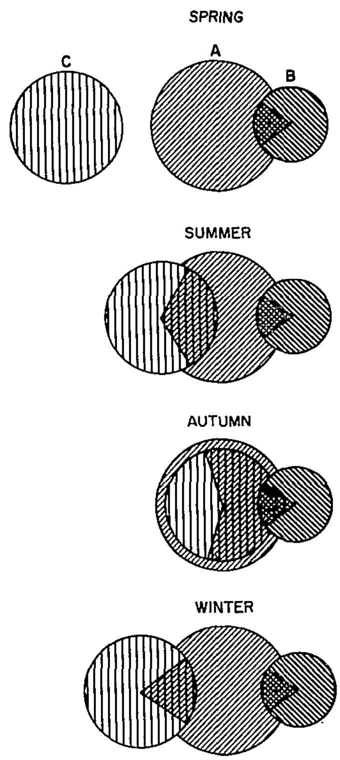


FIG. 5. — Degree of spatial coincidence between a prey species (A) and its resident (B) and migratory (C) predators, expressed as 4 seasonal Venn diagrams, in which the area and relative location of each circle represent geographical extent and the degree of spatial co-occurrence. The shaded segments of the predator circles represent the % stomach contents (diet) consisting of the prey

Degré de coïncidence saisonnière entre la distribution spatiale et une proie (A) et de ses prédateurs résidents (B) et migrateurs (C) exprimé par 4 diagrammes de Venn, dans lesquels la surface et la position relative de chaque cercle représentent l'extension géographique et le degré de co-occurrence dans une zone donnée. Les parties hachurées des cercles correspondant aux prédateurs représentent l'importance (en %) de la proie dans le contenu stomacal

The next step upwards in detail may then be to introduce an explicit spatial component in the form of a system of unit areas (*e.g.* on the basis of latitude and longitude), within each of which perfect mixing may be assumed. The appropriate size of such units in relation to the mean dimension of patches of organisms should ideally be considered, and some of the consequences of the generally contagious types of distributions characteristic of marine organisms are treated for example in PIELOU (1969). This type of non-random distribution needs to be considered particularly when planning fishery surveys, which is one of the main occasions where spatial considerations are taken explicitly into account (see *e.g.* DOUBLEDAY and RIVARD, 1981).

Using unit areas of latitude and longitude for mapping commercial fisheries data is a common practise, particularly when logbooks on commercial vessels or port interview data are used to reconstruct distribution patterns of vessels or species (catches), and to estimate the index of spatial concentration of fleet onto resource (ROTHSCHILD and ROBSON, 1972).

With current improvements in the state of the art in marine navigation, the problem of locating fishing stations with an accuracy of less than 0.5 nautical mile is solved, but for many developing countries the absence of electronic navigation aids on many vessels is a hinderance to the development of sophisticated schemes for spatial allocation of fishing rights as well as for too detailed zonation of coastal areas. At the moment the availability of cheap technological aides still places a limit on the effective precision of fisheries mapping. On the other hand, the cost of accurate position-finding equipment tied into satellite navigation networks continues to decline, and is likely to soon come into the acceptable price range for small-scale fishermen, as is already the case for simple and cheap depth sounders.

4.3. The Importance of Mapping Resources for Making Regional Estimates of Potential Yields

As noted earlier, in "developed" fisheries, such as those in the North Atlantic, resources may be assessed by analysis of removals as a function of fishing, assuming dynamic pool assumptions apply for a given "unit stock". This may be done either by deriving an empirical relationship between removals and total fishing effort (the so-called production model estimates) or by analysis of the age composition of the catch, and hence population mortality rates, for different levels of removals (*e.g.* by cohort analysis or by fisheries surveys: see later). In both cases, independent biomass estimates from surveys may be used to check the results of these calculations. Two approaches are gaining acceptance in areas where the necessary research input for the above approach is not available, as is the case in most developing countries.

The first approach combines mapping of resources and/or fishing areas, with making production estim-

TABLE I

Estimated maximum sustainable yield of tropical demersal marine fisheries (from MARTEN and POLOVINA, 1982)
(The estimation method and the bibliographic source are given in the original)

Estimations de prise maximale équilibrée dans les pêcheries marines démersales tropicales (d'après MARTEN *et* POLOVINA, *1982)*
(Les méthodes d'estimation et les sources bibliographiques sont données dans le document original)

Location	MSY ($t/km^2/yr$)	Depth (m)	Area (km^2)	Primary productivity ($gC/m^2/yr$)[a]
North Coast Gulf of Mexico	6.7	0-110	111,210	135
U.S. Atlantic Coast (N. Carolina—Florida)	5.5	0-110	125,000	135
Gulf of Thailand	3.9	0-50	179,000	365
Philippines	2.8	0-200	152,700	135
North Coast of Java	2.6	0-50	26,160	180
Sunda Shelf—South	2.3	0-50	267,900	75
South China Sea	2.0	0-200	500,000	45
West Coast of Florida	1.8	0-110	179,280	135
Sunda Shelf—NW Borneo	1.7	0-50	62,900	75
South Coast of Kalimantan (Borneo)	1.5	0-50	113,590	135
Sunda Shelf—NW Borneo	1.1	50-200	69,700	75
Gulf of Thailand	1.1	50-200	126,700	365
Sunda Shelf	0.8	50-200	398,500	135
U.S. Atlantic Coast (N. Carolina—Florida)	0.5	110-548	20,480	45
North Gulf of Mexico	0.5	110-548	44,070	45
West Coast of Florida	0.4	110-548	72,120	45

[a]Primary productivity estimated from a world map in FAO (1972).

ates of fleet size for each individual fishing area. Both of these operations may be carried out cost effectively by remote sensing: estimates of the extent of fishing areas can be built up on a chart from fishermen's interviews combined with exploratory fishing, and expressed on either a nautical chart or an expansion of a remote sensing image (which can give significant water penetration in clear water tropical areas: (*e.g.* LYZERGA, 1978; CADDY and PIAGGESI, 1983). The catches determined by statistical survey at the points of landing can then be expressed in terms of production by unit area (see Table I). Fishing intensity can also be estimated remotely, *e.g.* by aerial survey of landing points for fleet size or number of boats fishing (BAZIGOS, 1979), or by counting stationary fishing gear during overflights (*e.g.* PRINGLE and DUGGAN, 1983; CONAN *et al.*, 1985), or more commonly, by acoustic methods from surface craft (see JOHANNESSON and MITSON, 1983).

Recognizing that production per unit area in various areas of similar biological productivity is a function of fishing intensity, it is necessary to allow for the possibility of combining in a "Composite Model" individual estimates of production for each unit area/year in order to determine the optimal fishing intensity (MUNRO, 1977; CADDY and GARCIA, 1983). This has developed as an outgrowth of the production model approach (Fig. 6), which is useful when data series are too short, and changes of fishing intensity between biologically comparable locations in the same time period, show more contrast than between years on the same fishing ground. When dealing with specific regional problems of shared stocks management in areas with more highly dynamic stock distributions, detailed information on fish stock movements is essential, and a particular effort in compilation and experimentation is necessary, which may for example include tagging studies (*e.g.* JONES,

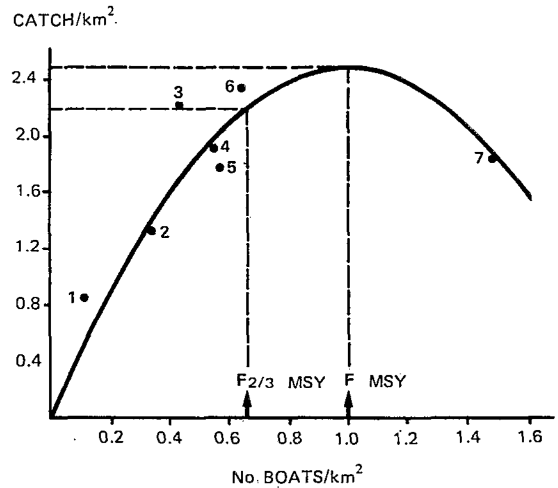


FIG. 6. — Relationship between mean annual catch/km^2/port and the number of boats per unit fishing area

Relation entre la capture moyenne annuelle/km^2/port et le nombre de bateaux par unité de surface des fonds de pêche

1976), which will help to elucidate overall stock migrations and boundaries (as in Fig. 3 top).

The second approach is derived from pioneering work by BARANOV (1918), namely combining mapping of resource areas with area swept estimates by towed gear, leading to the definition of an "elemental" fishing intensity which can be used in preliminary assessment studies (*e.g.* GARCIA and VAN ZALINGE, 1982).

5. TIME SCALES FOR DISPLAYING SPATIAL INFORMATION

5.1. Long Time Scale Mapping

The requirements for updating spatial information in fisheries vary significantly with application: for instance, in the application described above, there will be no need for frequent changes in statistical areas once established, and although species distributions and extents of unit stocks can vary in time, the base maps used for fisheries surveys will not usually need to be frequently updated. For migratory species distributions patterns of the stock may require to be displayed, often separately, on a seasonal basis (Fig. 7) but are then less liable to change. This also applies to those more precisely established baselines set up for leasing inshore areas and lagoons for aquaculture (*e.g.* MORSE, 1971), in coastal development, or in the location of closed areas, underwater parks, etc. Generally speaking, maps showing national maritime baselines and areas prohibited for certain types of fishing operations also do not require frequent updating, nor do those overprinted charts used in conjunction with navigational aids (*e.g.* Decca and Loran navigations systems).

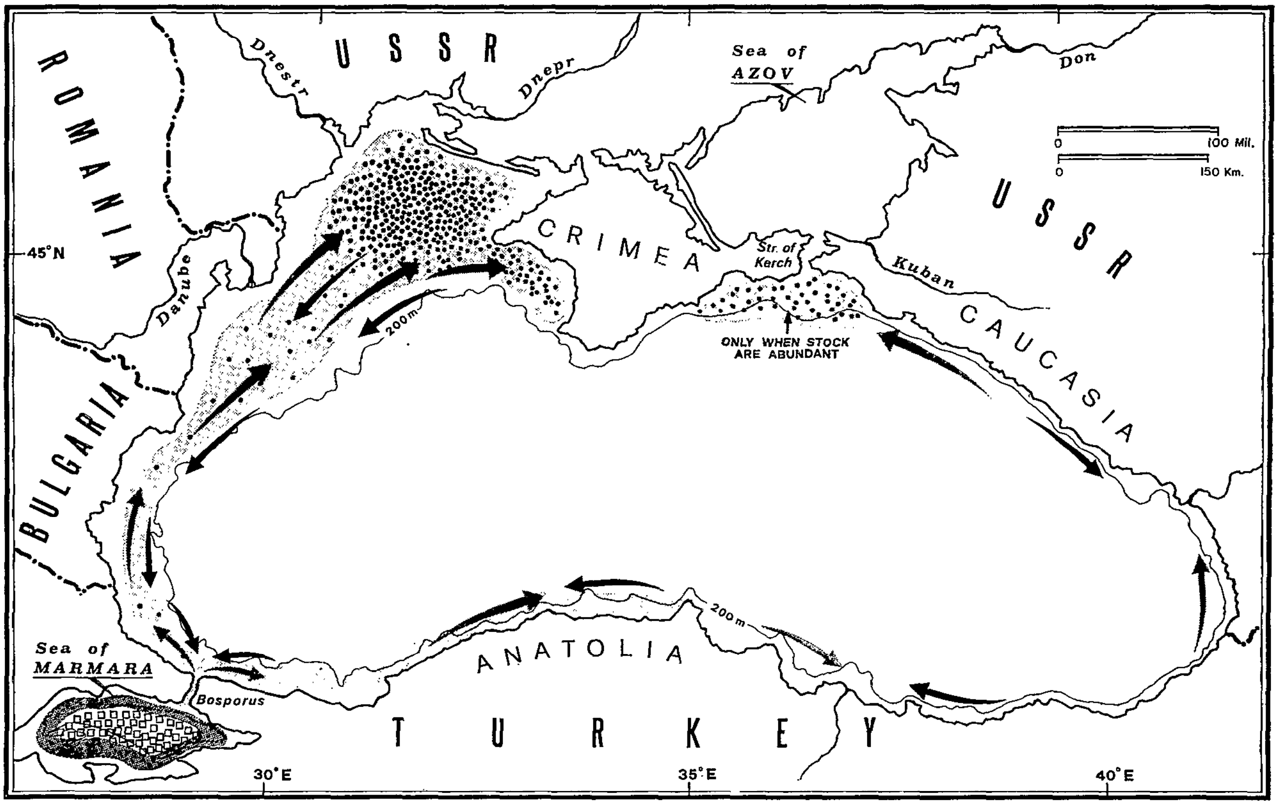


FIG. 7. — Distribution movements and spawning of the mackerel *Scomber scombrus* in the Black Sea. From IVANOV and BEVERTON (1985)

Changements de distribution et ponte du maquereau Scomber scombrus *dans la mer Noire. D'après* IVANOV *et* BEVERTON *(1985)*

5.2. Mapping Over Annual Time Scales

Several applications of mapping do require regular updating such as the annual display of catches and fishing effort by area, or in the case of leasing of for example shellfish or mariculture areas, the individual leases allocated, which may change hands on a fairly regular basis. Generally speaking, however, mapping spatial data for fisheries applications tends to fall into those mappings that do not require frequent updating as described above, and those tonched upon below.

5.3. Real Time or Close to Real Time Display of Spatial Information

The type of information relevant to fisheries that require to be regularly updated, is generally that which is required for fisheries operations or associated activities such as maritime surveillance. Included here are those transmissions of weather charts that are regularly picked up by larger fishing boats, and particularly for distant water tuna fleets, remote sensing imagery which permits identification of "fronts" between different water masses which have from experience proved to be areas of concentration of large pelagic fish (*e.g.* STRETTA and SLEPOUKHA, 1983). For demersal and small pelagic fish stocks, the analogous spatial fishing aids are those provided by various sonar devices which display fish schools in real time.

The spatial distribution of the domestic fleet and of foreign vessels licensed to fish in the EEZ, are also required on a close to real time basis by the coastguard and/or fisheries protection services (VAN HALVOORT, in press).

6. FISHERIES APPLICATIONS OF MAPPING TECHNIQUES

6.1. Mapping Local Environments and Production Systems

The requirements for mapping that come under this heading include the delimitation of centres of ecological productivity and key biological habitats (*e.g.* eel grass beds, mangroves, seaweed beds); the communication of information concerning closed areas, marine parks or reserves; the mapping of coastal lagoons and estuaries for aquaculture uses, oyster leasing, mapping artificial reefs and statutory areas for the use of fixed gear, wrecks and designated trawling areas; the charting of harbours, wharfs, processing and freezer plants, markets and transport facilities and routes; the modelling of spatial processes in harvesting, and calculating indices of concentration of fishing effort; the real-time mapping of oceanographic phenomena (upwellings, cells, fronts) and finally marine weather forecasting.

6.2. Designing Statistical Data Collection

It is essential to have a clear picture of the overall spatial distribution and routes between key sampling points in the fisheries sector, in order to properly plan a land-based statistical survey (CADDY and BAZIGOS, 1985). Such a picture (*e.g.* Fig. 8), might consist of a synoptic mapping of the main concentrations of fishermen (the communities), the fishing ports and beach landing points, as well as the markets, processing, freezing and transhipment points where quantities and characteristics of fishing products may be conveniently sampled, and repair yards, dealers in boats and gear, and sources of credit where economic information may be collected. Such a map may be conveniently cross-referenced to the filing system where information from the various sampling points is stored, and be the basis for scheduling of the activities (and travel budgets) of statistical officers. Such a document is the basis for proper statistical survey methodologies, for estimating catches, effort, species composition, etc. It will also help to identify the most economically important activities and their interrelationships.

6.3. Planning Scientific Resources Surveys

One major application of mapping to fisheries is in the design of appropriate sampling schemes for trawl surveys, necessitated by the non-random distributions of most fish resources. The theoretical considerations involved in stratified random sampling are described for instance by DOUBLEDAY and RIVARD (1981). The relevant operations here are usually the division of bathymetric strata into "cells", to each of which a preset probability of being sampled can be assigned (Fig. 9). Sedimentological maps displaying different bottom types can theoretically also be used for this purpose, and when used in conjunction with resource maps they can help in defining fishing grounds. For examples in the tropical area see, for instance GIRESSE, 1980 or DOMAIN, 1977. Other (systematic) approaches to population sampling than random sampling are also being looked at carefully by different fisheries workers (*e.g.* FOGARTY, 1985; CONAN *et al.*, 1985), such as those used for mineral resource mapping (*e.g.* DAVID, 1977).

The high level of development of acoustic techniques also provides an approach to mapping of pelagic resources which has been widely applied in developing countries. Some of the technical considerations involved, including mapping, are given in in JOHANNESSON and MITSON (1983), (see Fig. 9).

Underwater camera surveys and SCUBA direct observation techniques, are also now playing a key role in mapping locally contagious resources with a high degree of accuracy.

6.4. Preparing Inventories of Resources

The renewable resources are the basis for a fishery, and sometimes the object of property or user rights (CHRISTY, 1982). Their distribution is the main

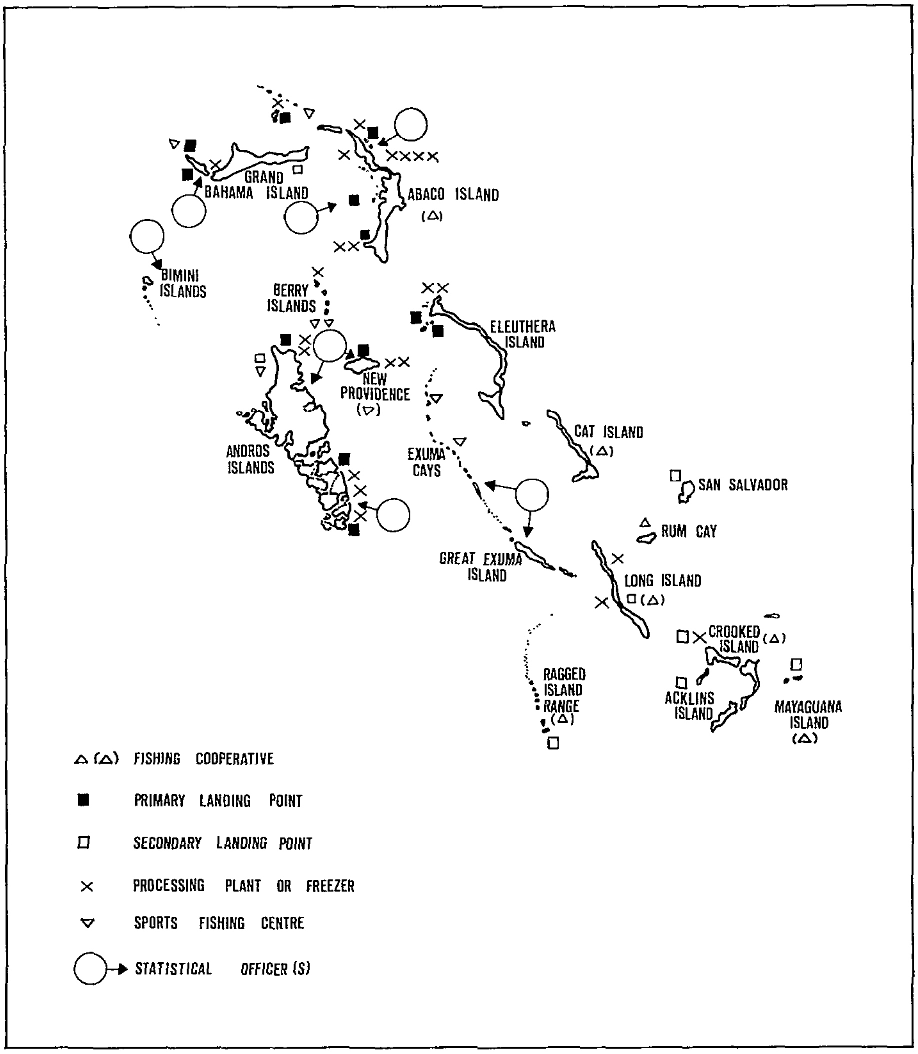


FIG. 8. — Example of a thematic map showing elements useful in constructing a statistical frame. (Modified from CADDY, 1982)

N.B. — Although based on the fisheries infrastructure of Bahamas, this is for demonstration purposes only, and is not intended to represent an up-to-date representation of the current situation.

Exemple de cartographie thématique montrant les éléments utiles pour l'établissement d'un cadre d'enquêtes statistiques. (Modifié de CADDY, *1982)*

N.B. — Bien que basé sur l'infrastructure des Bahamas, cette figure n'a qu'un but illustratif et ne prétend pas donner une représentation exacte de la situation présente

parameter driving the fishing strategy of fishermen. Knowledge of the state and distribution of resources is among the important factors which condition the success or failure of fisheries development. The requirements are a knowledge of the following: species distribution or, better still in the multi-species contexts, the distribution of fish assemblages, as in CHARBONNIER and GARCIA (1985); fish migrations, with information on their seasonal timing (Fig. 1 and 3 bottom); distribution and extent of nurseries and spawning areas; distribution of critical habitats such as mangroves; distribution of resource biomass or catch rates; distribution of national (small scale and industrial), and foreign fishing effort.

6.5. **Elaborating Management Plans**

Representation of various kinds of information on a single map or on overlays at the appropriate scale is certainly the most illustrative and simplest approach to combining spatial information in a

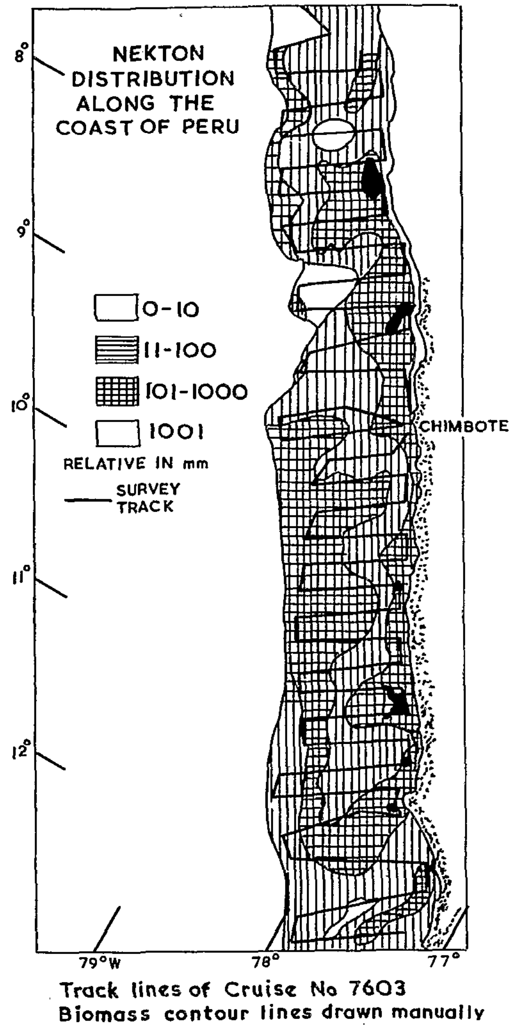
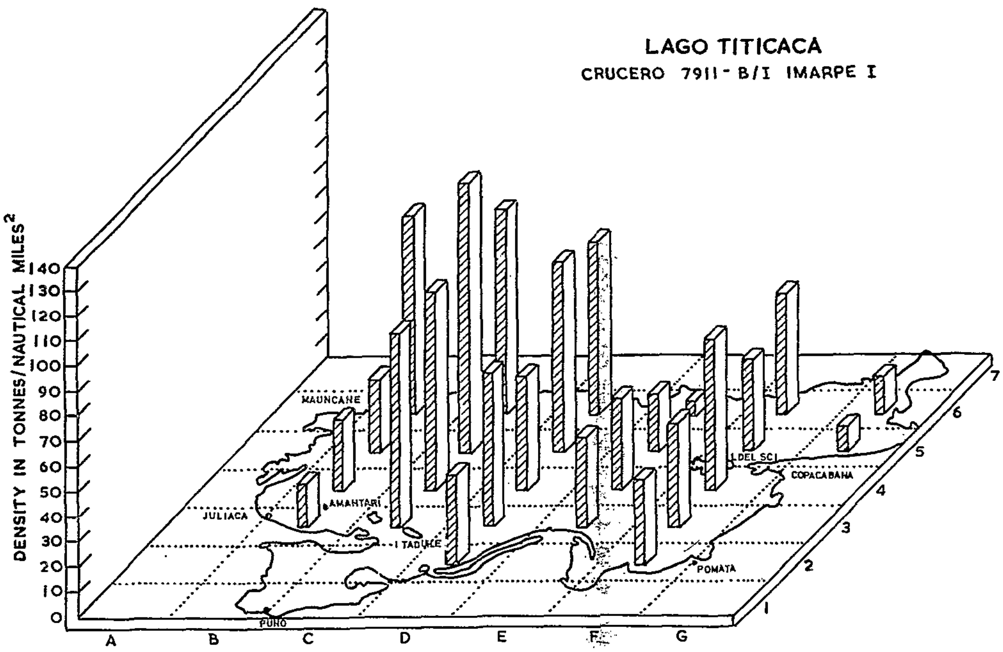


FIG. 9. — Mapping pelagic fishery resources by acoustic surveys (from JOHANESSON and MITSON, 1983)

Cartographie des ressources halieutiques pélagiques par les prospections acoustiques (d'après JOHANESSON and MITSON, 1983)



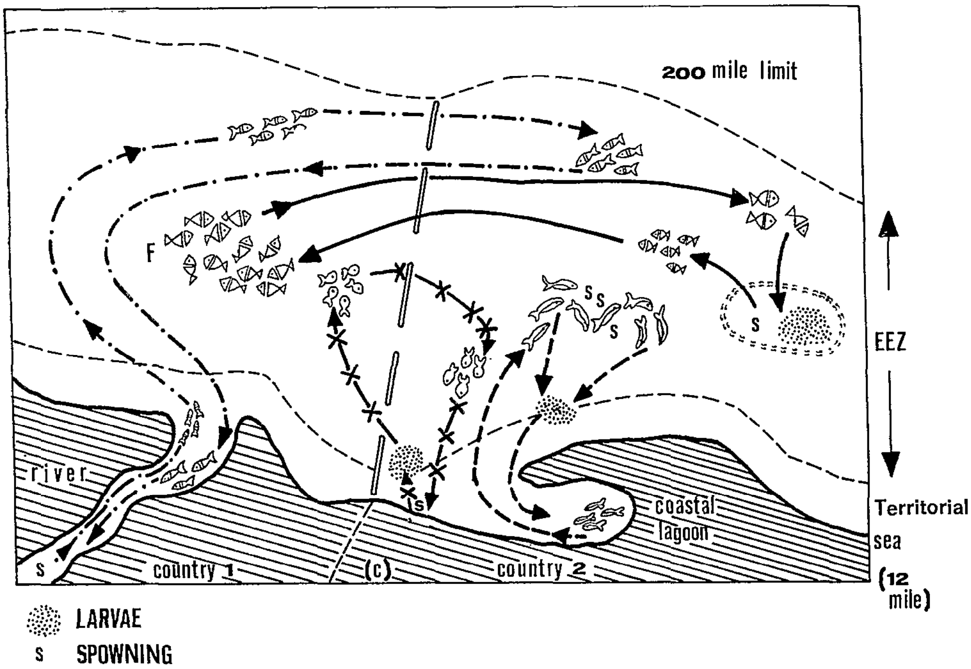


FIG. 10. — Diagrammatic representation of various types of migratory stocks moving between zones : S = spawning area ; F = feeding area

Représentation schématique de divers types de stocks migrateurs se déplaçant à travers deux zones: S = aire de ponte; F = aire d'alimentation

cross-disciplinary fashion. This can then easily be used as a basis for discussion, negotiation, training, and information transfer. Such a synoptic map can also be an invaluable basic document for investment planning, and for display of economic information in a spatial context (*e.g.* display of earnings of fishermen and enterprises, rates of unemployment, etc.). One of the areas where information of a variety of types needs to be combined in this way, is in preparation of management plans for fisheries (*e.g.* Caribbean Fishery Management Council, 1981; ARMSTRONG, 1983). This formal planning process is a commonly-adopted approach to management of fisheries and wildlife in areas of common access.

6.6. Mapping Fishing Effort Distribution and Fishing Grounds

Depicting and updating the actual quantitative distribution of various types of fishing effort, from log-book data or interviews of fishermen, and the way the different fisheries interact, on a map format, provides very valuable information on unoticed changes in distribution of fishing pressure in space, and on potential conflicts. Surreptitious changes of fishing distribution in space can occur, that impact the fishing pattern (and the fishing mortality by age group), or even the target species. These changes, which may not be evident on pooled data, result in changes in the catchability coefficients and in the relationship between fishing mortality and fishing effort, and between abundance and catch rates. In these circumstances they can invalidate the use of simple production models on long time series, and suggest that an area by area approach to effort compilation might be more appropriate. From a different point of view, in young developing countries, whose resources have been traditionally exploited by foreign fleets, mapping of fishing grounds and resources on the basis of national log-book schemes or from interviews with captain of foreign vessels is a good way of transferring knowledge important for their own national fishery development.

6.7. Mapping in Support of International Agreements

The advantage of having good documentation of present and past fishing effort and catches on a location-specific basis is clearly considerable when negotiating maritime boundaries, or in coordinated management or temporary access agreements: (see *e.g.* HARE, 1977). A proper classification of stocks in terms of their life history, migrations and key areas is also essential, and some of these considerations are touched on GULLAND (1981) and CADDY (1982) (see Fig. 10).

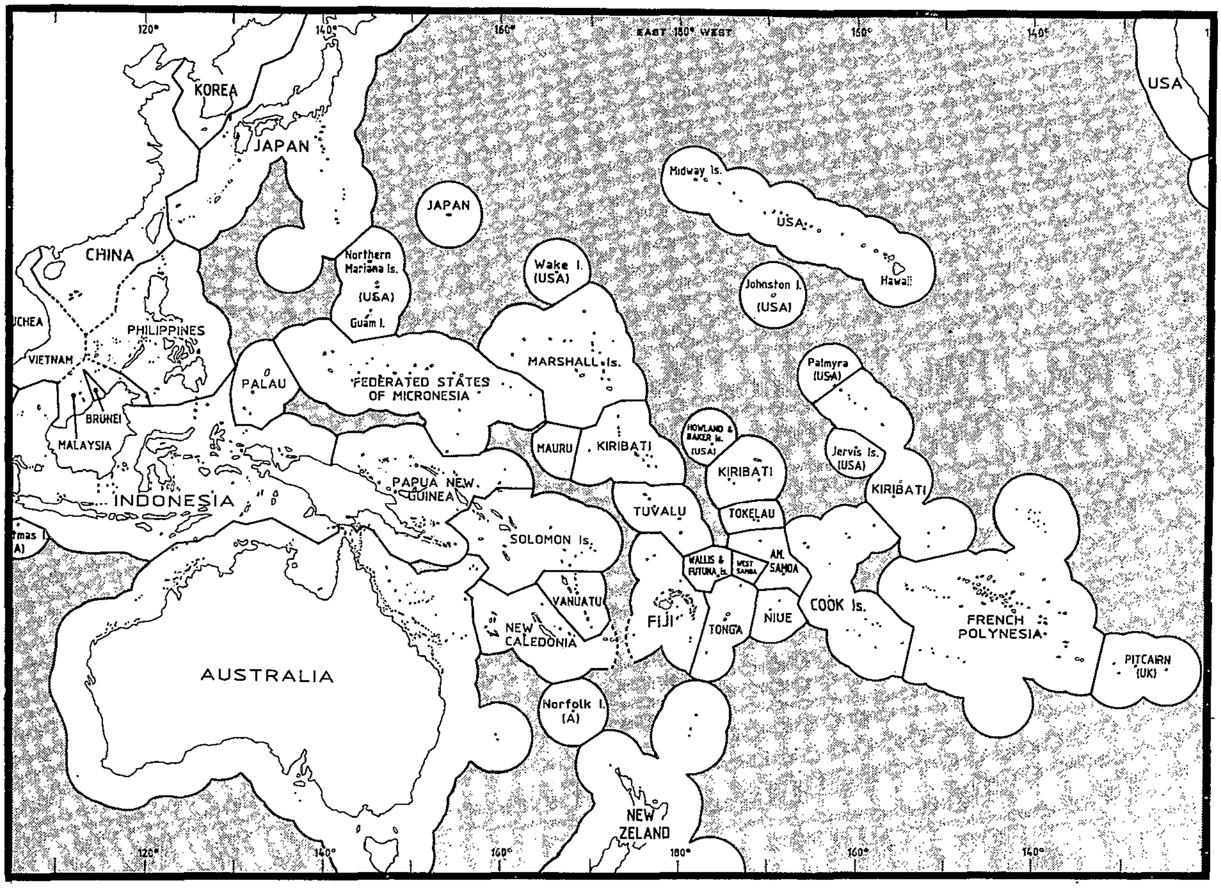


FIG. 11. — Illustration of the complexity of the national juridictions in the South Pacific (to be compared with Fig. 12)

N.B. — This map is presented purely for illustrative purposes and does not imply any expression of opinion by the authors regarding the location of the maritime or other boundaries of the states or territories concerned or the status of any claims.

Illustration de la complexité des juridictions nationales dans le Pacifique Sud (à comparer avec la figure 12)

N.B. — Cette carte est présentée dans un but purement illustratif et n'implique aucune opinion des auteurs concernant la position des frontières, maritimes ou autres, des états et territoires concernés ou le statut des revendication.

The proclamation of Extended Economic Zones (EEZ's) since the late 1970's has offered major potential benefits to coastal states, but has greatly complicated the map of the World's oceans (*e.g.* Figure 11), and brought the spatial scale of fisheries into high relief. A high proportion of world fish resources lie within EEZ's, but at the same time, a considerable proportion of these cross EEZ boundaries, either between adjacent countries or with contiguous high seas areas. The large number of potential boundary disputes that could thus be involved, as well as the complexity of fishery managements, especially for highly migratory species in the absence of regional agreements, is illustrated by comparing Figures 11 and 12.

6.8. **Remote Sensing and Mapping**

This technique for rapid and precise integration of large scale information, together with the rapidity of display of this and other types of graphics in electronic form, has revolutionised the whole concept of mapping, and made it a much more accessible discipline for experts in various disciplines. A number of recent reviews have touched upon the various applications of remote sensing imagery in fisheries, for example, GOWER (1982), KAPETSKY and CADDY (1985), and an overview introductory manual is now in preparation (BUTLER and JAYASINGH, in preparation). It is beyond the immediate scope of this paper to elaborate on the applications of this methodology, except to note that in clear coralline areas, such imagery has been used to point out shoreline changes when compared with navigational charts (which are often based on ship-based surveys in the 18th century: *e.g.* LYZERGA, 1978; DAVIS, 1982; CADDY and PIAGGESI, 1983). Some specific mapping applications in support of coastal fisheries are for example, in mapping coastal seaweeds (JENSEN and ESTES, 1980), surveying oyster resources (HARRIS,

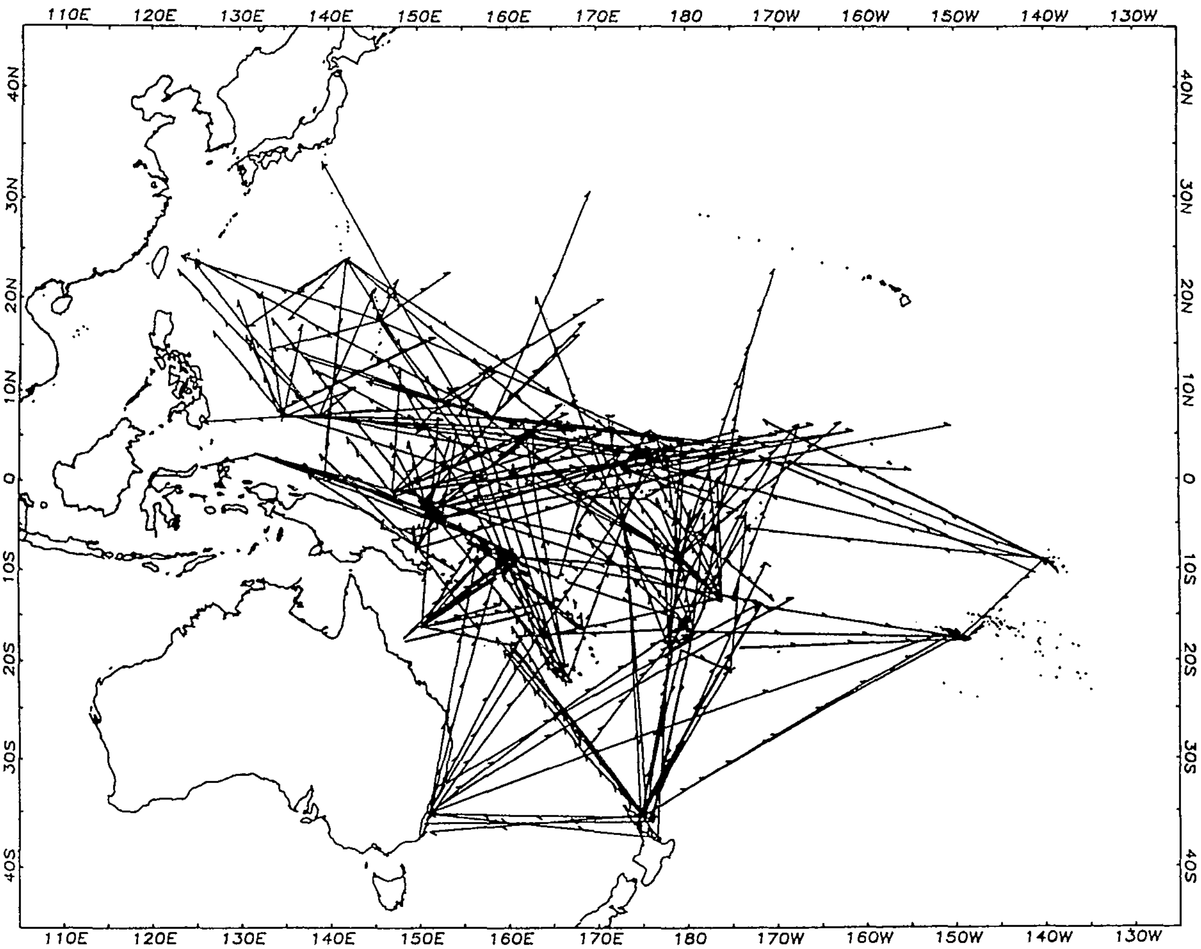


FIG. 12. — Apparent routes of tagged skipjack tunas in the South Pacific (from KEARNEY, 1983). Courtesy of the South Pacific Commission

Mouvements apparents des listaos marqués dans le Pacifique Sud (d'après KEARNEY, *1983). Avec l'autorisation gracieuse de la Commission du Pacifique Sud*

1980), in estimating shrimp production from shoreline length (FALLER, 1979) and interpreting species migrations and fishing fleet movements (DOMAIN, 1980). Some oceanic applications are in mapping upwelling areas and primary productivity (*e.g.* SZEKIELDA *et al.*, 1977), and in tuna prospection (*e.g.* STRETTA and SLEPHOUKHA, 1983).

7. FAO'S WORK IN SUPPORT OF RESOURCE EVALUATION AND MANAGEMENT

Having indicated the importance of spatial information and mapping in information processing and transfer to individuals in various specialities associated with fisheries, some practical examples of FAO's work in this field can be given. The preparation of maps can conveniently be classified at various scales of action:

7.1. **At World Level**

The Atlas of the Living Resources of the Seas (FAO 1981) summarizes the wealth of knowledge acquired (in particular through the acoustic survey of pelagic resources), on the distribution of resources world wide. It found immediate application since as it was first published shortly before the 3rd UNCLOS held in 1971, and because it contains general information at global level on the primary productivity, total catches and total potential yield of renewable marine resources, by statistical division, and by tonnage and value, with an indication of the state of exploitation of stocks. It also contains regional maps showing distribution and movements of fishery resources and potential yields, as well as maps describing in detail the movements particularly of important migratory stocks (whales, tunas, salmons, clupeids, cod, etc.). About 11 000 copies have been distributed up to now of what has become a very important reference document.

7.2. **At a Regional Level**

The Regional Atlases are particularly useful documents for regional fisheries bodies, such as CECAF, GFCM, etc. The Atlas of the Fisheries of the Western and Central Mediterranean (CHARBONNIER and GARCIA, 1985), for instance, was produced at the initiative of the General Fisheries Council of the Mediterranean (GFCM) in order to assist in regional efforts to promote better management and more rational development of fisheries in the Mediterranean. Fish migrations here are of limited extent, except for tunas and billfish, and the main fisheries problem encountered is overfishing, heavy mortality of undersized fish (discards), and the large fleet overcapacity existing in some areas. The bioeconomic data base is still rather poor because of the low level of development of national fishery research and management structures in some countries, and only rather empirical resource assessment methodologies are in general use. The Atlas was prepared with the collaboration of scientists from the region as a visual aid for the comparative intra-regional approach to fisheries analysis described earlier in this paper (paragraph "The importance of mapping resources for making regional estimates of potentials yields", *supra* 4.3).

The main types of information contained in the atlas are: the resources distribution and spawning areas by species groups in species assemblages (pelagic fish, demersal fish by communities, tunas); the main fishing areas and approximate levels of exploitation; annual catches by main categories; the current summed fishing power (total HP) by fishery sector; the fleet movements (when known and relevant) and essentially for tuna fishing; the agreed boundaries and limits of continental shelves.

Although there is still room for improvement and update, the document offers some interesting perspectives. From a simple comparison of the size of local and national fleets, their total catches, and the shelf area available between different parts of the Mediterranean having similar overall productivity, the Atlas clearly depicts drastic differences in potential yield and economic efficiency, and in a convincing fashion illustrates to managers the limitations of fishery development in their local areas and the likelihood of serious overcapacity in some of them. In fact the Composite Production Model referred to in 4.3 has been applied to the Mediterranean on the basis of this Atlas (GARCIA, 1984).

At the request of the Committee for the Eastern Central Atlantic Fisheries (CECAF) and as a following to the CECAF Consultation on Stock Management in the CECAF statistical divisions — Sahara and Cape Verde (Dakar, June 1979) a compilation of all the information available on movements of northern CECAF resources and their chronology was made (GARCIA, 1982). This work confirmed and emphasized the extensive movements of stocks in the area between the Sahara statistical division and Senegal, and the need for collaboration in management at regional level by Mauritania, Senegal, Gambia and Guinea-Bissau (see Fig. 1). It is on such type of information that the local fisheries bodies based their preliminary discussions on resource allocation between coastal countries of the northern CECAF area.

The compilation also revealed that the region between Guinea-Bissau and Sierra Leone is also a sub-regional unit where extensive stock mixing occurs and management coordination is needed. Similar efforts have been made by FAO in other regions of the world in parallel with the preparation of regional resource reviews, for instance in the Black Sea (IVANOV and BEVERTON, 1985, see Fig. 7) or in connection with specific working groups on shared stocks in South East Asia (CHULLASORN and MARTOSUBROTO, in preparation).

7.3. **At National and Local Level**

When dealing with problems of resource evaluation, management or development at national level, the precision of the information must increase even further and a much smaller scale have to be used. An extreme example here is in allocating areas of the order of 1 hectare or less in intertidal or subtidal areas for *e.g.* shellfish farming (*e.g.* MORSE, 1971), where lease boundaries may have to be accurate to within 5 metres. In order to achieve this, bench marks will have to be established that tie into the adjacent land grid. This in itself poses problems, both of a technical and legal nature, since marine charts are usually referred to Chart Datum or low water mark, which is rarely defined in land surveys, and property rights and beach access may be tied to high water mark or mid-tide level.

In fact at national level the problem of summarizing the already available information for managers is so crucial that we consider it the first task to be undertaken by a developing fisheries laboratory even before starting to implement statistical or biological data collection systems, and certainly before preparing any management plans. This is because the undertaking of an overall mapping of the fisheries involves identifying all potentially useful data sources and conflicts, shows some of the practical spatial characteristics of fisheries, and gives to the scientists and to the manager a framework within which to operate. In many developing countries this framework is presently not available, leading to a piecemeal approach to research, management and development. This is true even in some developed countries, and there is the risk that the conventional approach of a management plan elaborated species by species or stock by stock, will not lead to the overall understanding and optimization of the fishing industry that is obviously necessary.

8. DISCUSSION

It is often said, although often forgotten, that a fishery is a system, and we must of course recognize that building a realistic system model that takes into account all of the key biological, oceanographic,and commercial parameters into account within a spatio-temporal framework, is pushing the limits of modelling techniques. More critically for the marine resources, the number of unknowns are such that the realism of output of such models leads to a certain scepticism as to their potential practical application for management. This is even more so if a simple descriptive and quantitative representation of the fishery has not been elaborated first to delimit the system, identify its components and their interrelationships, depict the resource, and map its distribution and spatial structure.

Fisheries clearly operate in a multi-dimensional context, but over the last two decades, temporal considerations, particularly of a biological nature, have largely overweighed the spatial, social and economic ones. Biological parameters have been given overwhelming importance and time series have been very widely used. Economic and social dimensions are now slowly being recognized as equally critical for fishery management. The spatial structure of fisheries systems has also been largely forgotten, either because of the desire for extreme simplicity in the provision of scientific advice to fisheries administrators, or because spatial characteristics of fisheries are not as easily generalizable in a scientific forum. It is obvious that spatial characteristics are most critical on a local scale, and this probably explains why in most instances the local enforcement units have to deal with spatial problems, even though the National Fisheries Administrations or fisheries commissions do not always consider them.

During the last decade, the growing numbers of fishery biologists, and more specifically stock assessment scientists (we suspect this is also true for some economists), have tended to view fisheries models as systems of linear regressions with one dependent and one or more independent variables. This extreme abstraction of such a complex activity was probably essential for analysis of some of the key interrelationships involved, but elaboration of manage ment measures on the sole basis of catch-effort, cost-value relationships or yield per recruit analysis may lead to unrealistic and insufficiently documented decisions and therefore to lack of compliance by fishermen or conflict with these decisions. The present document attempts to synthesise some of the current trends in fisheries, which to us, are leading to a better appreciation of the spatial context of fisheries activities.

REFERENCES

ARMSTRONG (R. A.), 1983. — Marine environments of Puerto Rico and the Virgin Islands : automated mapping and inventory using LANDSAT data. Hato Rey, Puerto Rico. Caribbean Fishery Management Council Document.

BARANOV (T. I.), 1918. — On the question of the biological basis of fisheries. *Izv. Nauch. Issled. Ikktiol. Inst.*, 1 : 81-128.

BARD (F. X.), 1984. — Le Listao de l'Atlantique. 3. Résultats des campagnes de marquages effectuées de 1980 à 1982. *La Pêche Marit.*, 1275 : 319-324.

BAZIGOS (G. P.), 1979. — Phase II. Progress report, 3. Aerial frame survey along the southwest coast of India. UNDP/FAO Pelagic Fishery Investigation Project on the southwest coast of India. Rome, FAO, FIRM/IND/75/038, 104 p.

BEVERTON (R. J. H.) and HOLT (S. J.), 1956. — On the dynamics of exploited fish populations. *Fish. Invest. Minist. Agric. Fish. Food G. B. (2 Sea Fish.)*, 19, 533 p.

BOELY (T.) and FRÉON (P.), 1979. — Coastal pelagic resources. *In* Troadec, J.-P., and S. Garcia, The fish resources of the eastern central Atlantic. Part 1. The resources of the Gulf of Guinea from Angola to Mauritania. *FAO Fish. Tech. Pap.*, 186.1 : 13-76.

BUTLER (M. J. A.) and JAYASINGH (D.). — The application of remote sensing technology to marine fisheries : an introductory manual (tentative title). *FAO Fish. Tech. Pap.* (in preparation).

BUTLER (M. J. A.) *et al.* — Marine resource mapping : an introductory manual (tentative title). *FAO Fish. Tech. Pap.* (in preparation).

CADDY (J. F.), 1975. — Spatial model for an exploited shellfish population, and its application to the Georges Bank scallop population. *J. Fish. Res. Bd Can.*, 32 (8) : 1305-1328.

CADDY (J. F.), 1982. — Some considerations relevant to the definition of shared stocks and their allocation between adjacent economic zones. *FAO Fish. Circ.* (749), 40 p. Issued also in Spanish.

CADDY (J. F.) and GARCIA (S.), 1983. — Production modelling without long data series. *FAO Fish. Rep./FAO Rapp. Pêches/FAO Inf. Pesca*, 278 Suppl. : 309-313.

CADDY (J. F.) and PIAGGESI (D.), 1983. — Mapping of shelf areas for fisheries yield estimation. *FAO Fish. Rep./ FAO Rapp. Pêches/FAO Inf. Pesca*, 278 : 296-308.

CADDY (J. F.) and BAZIGOS (G. R.), 1985. — Practical guidelines for statistical monitoring of fisheries in manpower limited situations. *FAO Fish. Tech. Pap.*, 257, 86 p.

Caribbean Fishery Management Council, 1981. — Environment impact statement/fishery management plan and regulatory impact review for the spiny lobster fishery of Puerto Rico and the U.S. Virgin Islands. Hato Rey, Puerto Rico, Caribbean Fishery Management Council Document (July 1981), 43 p.

CHAMPAGNAT (C.) et DOMAIN (F.), 1978. — Migration des poissons démersaux le long des côtes ouest africaines de 10 à 24° de latitude nord. *Cah. ORSTOM, sér. Océanogr.*, 16 (3-4) : 239-262.

CHARBONNIER (D.) et/y/and GARCIA (S.) (Eds), 1985. — Atlas des pêcheries de la Méditerranée occidentale et centrale. Atlas de las pesquerias del Mediterraneo occidental y central. Atlas of the fisheries of the western and central Mediterranean. Rome, FAO, CGPM/GFCM et/y/and CEE/EEC, pag. var.

CHRISTY (F. T. Jr), 1982. — Territorial use rights in marine fisheries : definitions and conditions. *FAO Fish. Tech. Pap.*, 227, 10 p. Issued also in French and Spanish.

CHULLASORN (S.) and MARTOSUBROTO (P.). — Distribution and important biological features of marine fish resources in Southeast Asia. *FAO Fish. Tech. Pap.* (in preparation).

CLAYDEN (A. D.), 1972. — Simulation of the changes in abundance of the cod (*Gadus morhua* L.) and the distribution of fishing in the North Atlantic. *Fish. Invest. Minist. Agric. Fish. Food G.B. (2 Sea Fish)*, 27 (1), 58 p.

CONAN (G. Y.), MAGNARD (D. R.) and WADE (E.), 1985. — Estimates of lobster fishing effort by aerial surveys. Northwest Atlantic Fisheries Organization (NAFO), SCR Doc. 85/86, 20 p. (mimeo).

CSIRKE (J.) and SHARP (G. D.) (Eds), 1984. — Report of the Expert Consultation to examine changes in abundance and species composition of neritic fish resources. San José, Costa Rica, 18-19 April 1983. A preparatory meeting for the FAO World Conference on fisheries management and development. *FAO Fish Rep.*, 291 (1), 102 p. Issued also in French and Spanish.

DAVID (M.), 1977. — Geostatistical ore reserve estimation. New York, Elsevier Scientific Publishing Co., 364 p.

DAVIS (G. E.), 1982. — A century of natural change in coral distribution at the Dry Tortugas : a comparison of reef maps from 1881 and 1976. *Bull. Mar. Sci.*, 32 (2) : 608-623.

DOMAIN (F.), 1977. — Carte sédimentologique du plateau continental sénégambien. Extension à une partie du plateau continental de la Mauritanie et de la Guinée Bissau. ORSTOM. Notice explicative n° 68, 17 p., 3 cartes.

DOMAIN (F.), 1980. — Contribution à la connaissance de l'écologie des poissons démersaux du plateau continental sénégalo-mauritanien. Les ressources démersales dans le contexte général du Golfe du Guinée. Thesis for Doctorate in Sciences presented at the University P. et M. Curie, Paris VI and National Museum of Natural History, Paris, 342 p.

DOUBLEDAY (W. G.) and RIVARD (D.) (Eds), 1981. — Bottom trawl surveys. Relèves au chalut de fond. *Can. Spec. Publ. Fish. Aquat. Sci.*, 58, 273 p.

FADER (G. B.), KING (L. H.) and JOSENHANS (L. W.), 1982. — Surficial geology of the Laurentian Channel and the western Grand Banks of Newfoundland. *Mar. Sci. Pap./Geol. Surv. Can. Pap.*, 21, 37 p.

FALLER (K. H.), 1979. — Shoreline as a controlling factor in commercial shrimp production. *NASA Tech. Memo.*, 72-732, 27 p.

FAO, Fisheries Department, 1981. — Atlas of the living resources of the seas. Atlas des ressources biologiques des mers. Atlas de los recursos vivos del mar. *FAO Fish. Ser./Collect. FAO: Pêches/Colecc. FAO: Pesca*, 15, pag. var.

FAO, Marine Resources Service, 1985. — Review of the state of world fishery resources. *FAO Fish. Circ.*, 710, Rev. 4, 61 p. Issued also in French, Spanish, Chinese and Arabic.

FOGARTY (M.), 1985. — Statistical considerations in the design of trawl surveys. *FAO Fish. Circ.*, 786, 21 p.

GALES (L. E.) and CADDY (J. F.), 1975. — YRAREA : a program to demonstrate effects of exploitation on a contagiously distributed shellfish population. *Tech. Rep. Fish. Res. Bd Can.*, 582, 79 p.

GARCIA (S.), 1982. — Distribution, migration and spawning of the main fish resources in the Eastern Central Atlantic. *CECAF/ECAF Ser.*, (82/25), 9 p.

GARCIA (S.), 1984. — Un exemple d'utilisation des modèles de production composites en Méditerranée espagnole. *FAO Rapp.Pêches/FAO Fish.Rep.*, 305, 97-105.

GARCIA (S.), 1986. — Seasonal trawling bans can be very successful in heavily overfished areas : The « Cyprus Effect ». *Fishbyte*, 4 (1) : 7-12.

GARCIA (S.) and VAN ZALINGE (N. P.), 1982. — Shrimp fishing in Kuwait : methodology for a joint analysis of the artisanal and industrial fisheries. *In* Report of the workshop on assessment of the shrimp stocks of the West Coast of the Gulf between Iran and the Arabian Peninsula, Kuwait, October 1981. Rome, FAO/UNDP, FI : DP/RAB/80/015, 163 p.

GIRESSE (P.), 1980. — Carte sédimentologique du plateau continental du Congo. ORSTOM, Notice explicative n° 85, 24 p., 3 cartes.

GOWER (J. F. R.), 1982. — General overview of the nature and use of satellite remote sensing data for fisheries application. *NAFO Sci. Counc. Stud.*, 4 : 7-19.

GROSLEIN (M. D.) and LAUREC (A.), 1982. — Bottom trawl surveys : design, operation and analysis. *CECAF/ECAF Ser.*, 81/22, 25 p.

GULLAND (J. A.), 1981. — Some problems of the management of shared stocks. *FAO Fish. Tech. Pap.*, 206, 22 p. Issued also in French.

HARE (G. M.), 1977. — Atlas of the major Atlantic coast fish and invertebrate resources adjacent to the Canada-United States boundary areas. *Tech. Rep. Fish. Res. Bd Can.*, 681, 97 p.

HARRIS (C. D.), 1980. — Survey of the intertidal and subtidal oyster resources of the Georgia coast. Brunswick, Georgia, Department of Natural Resources, Coastal Resources Division, 44 p.

HOWARD (J. A.) and WELCOME (R. L.), 1977. — FAO and remote sensing applied to fisheries. *In* Aerial and spatial remote sensing and marine living resources. Present and future possibilities. Brest, France, March 14-17, 1977. Association Européenne Océanique (EUROCÉAN) Monaco, Centre National pour l'Exploitation des Océans (CNEXO), Brest, France, Centre Océanologique de Bretagne. Monaco, EUROCÉAN, pp. 27-37.

HUNTE (W.) and MAHON (R.), 1985. — A preliminary investigation of the migration of oceanic pelagic fish in the Western Central Atlantic. *FAO Fish. Rep./FAO Inf. Pesca/FAO Rapp. Pêches*, 327 Suppl. : 154-164.

IVANOV (L.) and BEVERTON (R. J. H.), 1985. — The fisheries resources of the Mediterranean. Part Two. Black Sea. *Etud. Rev. CGPM/Stud. Rev. GFCM*, 60, 135 p.

JENSEN (J. R.) and ESTES (J. E.), 1980. — Remote sensing techniques for kelp surveys. *Photogramm. Eng. Remote Sensing*, 46 (6) : 743-755.

JOHANNESSON (K. A.) and MITSON (R. B.), 1983. — Fisheries acoustics. A practical manual for aquatic biomass estimation. *FAO Fish. Tech. Pap.*, 240, 248 p.

JONES (R.), 1976. — The use of marking data in fish population analysis. *FAO Fish. Tech. Pap.*, 153, 42 p.

KAPETSKY (J. M.) and CADDY (J. F.), 1985. — Applications of remote sensing to fisheries and aquaculture. Paper presented at the Eleventh Session of the Advisory Committee on Marine Resources Research. Rome, 21-24 May 1985. Rome, FAO, ACMRR : 11/85/Inf. 12, 13 p. (mimeo).

KEARNEY (R. E.), 1983. — Assessment of the skipjack and baitfish resources in the central and western tropical Pacific Ocean : a summary of the skipjack survey and assessment programmes. South Pacific Commission, Noumea, New Caledonia.

KOLBERG (W.) *et al.*, 1981. — Introduction Chapter 2. The setting : Costa Rica, El Salvador and Guatemala. *In* Small-scale fisheries in Central America : acquiring information for decision-making, edited by J. G. Sutinen and R. B. Pollnac. Kingston, R.I., University of Rhode Island, International Center for Marine Resource Development, pp. 7-43.

LYZERGA (D. R.), 1978. — Passive remote sensing technique for mapping water depth and bottom features. *Appl. Optics*, 17 : 379-383.

MARTEN (G. G.) and POLOVINA (J. J.), 1982. — A comparative study of fish yields from various tropical ecosystems. *ICLARM Conf. Proc.*, 9 : 255-89.

MCGUIRE (B. E.), 1979. — Environmental atlas of the southern Gulf of St. Lawrence. Ottawa, Department of Environment Canada, Marine Environment Branch, Environmental Protection Service, Atlantic Region.

MORSE (N. H.), 1971. — An economic study of the oyster industry of the Maritime Provinces. *Bull. Fish. Res. Bd Can.*, 175, 81 p.

MUNRO (J. L.), 1977. — Actual and potential productions from the coralline shelves of the Caribbean. *FAO Fish. Rep.*, 200 : 300-321.

PIELOU (E. C.), 1969. — An introduction to mathematical ecology. New York, Wiley Interscience, 286 p.

PRINGLE (J. D.) and DUGGAN (R. E.), 1983. — A remote sensing technique for quantifying fishing effort. *Can. Tech. Rep. Fish. Aquat. Sci.*, 1217, 16 p.

RICKER (W. E.), 1958. — Handbook of computations for biological statistics of fish populations. *Bull. Fish. Res. Bd Can.*, 119, 300 p.

ROTHSCHILD (B. J.) and ROBSON (D. S.), 1972. — The use of concentration indices in fisheries. *Fish. Bull./NOAA/NMFS*, 70 : 511-514.

RUDDLE (K.). — Administration and conflict management in Japanese coastal fisheries. *FAO Fish. Tech. Pap.* (in preparation).

SAVILLE (A.) (Ed.), 1977. — Survey methods of appraising fishery resources. *FAO Fish. Tech. Pap.*, 171, 76 p. Issued also in French and Spanish.

SCARRATT (D. J.) (Ed.), 1982. — Canadian Atlantic offshore fishery atlas. *Can. Spec. Publ. Fish. Aquat. Sci.*, 47, 101 p. Issued also in French.

SCHAEFER (M. B.), 1954. — Some aspects of the dynamics of populations important to the management of the commercial marine fisheries. *Bull. I ATTC*, 1 (2) : 25-56.

SHARP (G. D.) and CSIRKE (J.) (Eds), 1983. — Proceedings of the Expert Consultation to examine changes in abundance and species of neritic fish resources. San José, Costa Rica, 18-29 April 1983. Actas de la Consulta de Expertos para examinar los cambios en abundancia y composición por especies de recursos de peces neriticos. San José, Costa Rica, 18-29 abril 1983. A preparatory meeting for the FAO World Conference on fisheries management and development. Una reunión preparatoria para la Conferencia Mundial de la FAO sobre ordenación y desarrollos pesqueros. *FAO Fish. Rep./FAO Inf. Pesca*, 291 (2), 253 p.

SHARP (G. D.) and CSIRKE (J.) (Eds), 1983a. — Proceedings of the Expert Consultation to examine changes in abundance and species of neritic fish resources. San José, Costa Rica, 18-29 April 1983. Actas de la Consulta de Expertos para examinar los cambios en abundancia y composición por especies de recursos de peces neriticos. San José, Costa Rica, 18-29 abril 1983. A preparatory meeting for the FAO World Conference on fisheries management and development. Una reunión preparatoria para la Conferencia Mundial de la FAO sobre ordenación y desarrollos pesqueros. *FAO Fish. Rep./FAO Inf. Pesca*, 291 (3) : 557-1224.

SMITH (I. R.) and PANAYOTOU (T.), 1984. — Territorial use rights and economic efficiency : the case of the Philippines fishing concessions. *FAO Fish. Tech. Pap.*, 245, 17 p. Issued also in French and Spanish.

South Pacific Commission, 1984. — An assessment of the skipjack and baitfish resources of Papua New Guinea. *Final Ctry Rep. Skipjack Surv. Assess. Programme S. Pac. Comm.*, 12, 91 p.

STRETTA (J. M.) et SLEPOUKHA (M.), 1983. — Les satellites, l'ordinateur et l'aide à la pêche thonière. *La Pêche Marit.*, 1258 : 38-40.

SUTINEN (J. G.) and POLLNAC (R. B.) (Eds), 1981. — Small-scale fisheries in Central America : acquiring information for decision making. Kingston, R.I., University of Rhode Island, International Center for Marine Resource Development, 602 p.

SZEKIELDA (K. H.), SUSZKOWSKI (D. J.) and TABOR (P. S.), 1977. — Skylab investigation of the upwelling off the northwest coast of Africa. *J. Cons. CIEM*, 37 (3) : 205-13.

VAN HALVOORT (G.). — Observer programs operations manual. *FAO Fish. Tech. Pap.* (in preparation).