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# Fish stock assessment of the northern New Caledonian lagoons: 3 – Fishing pressure, potential yields and impact on management options

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**Abstract —** The potential yields of demersal reefal and lagoonal finfish, which are valuable for trade or consumption in the Northern Province of New Caledonia, are unknown. Fishing pressure was estimated from tally-sheets of professional fishermen to assess trade fishing and a household consumption survey to assess subsistence fishing. Total yield was estimated to be 1 326 tonnes in 1995, 94 % of which correspond to subsistence fishing. Most of the catches were taken from the east and west coasts; in the north zone (Bélep Archipelago) catches were very low. From this fishing pressure and the total stock values, the maximum sustainable yield (MSY) was estimated to be 12 600 t, which was about 10 % of the total stocks assessed in the Northern Province (138 300 t). This MSY was dominated by five families, namely Lethrinidae, Acanthuridae, Scaridae, Serranidae and Lutjanidae. The results suggest that fishing effort in the Northern Province of New Caledonia could increase without endangering the stock. However, on a smaller geographical scale, some locations (Koné and Népoui on the west coast), reef habitats (near-reef areas) or species groups (fish caught by line) were already being intensively fished. Fishing techniques should be diversified so that part of the fishing effort be redirected toward the least heavily exploited groups of species and biotopes. 

**Lagoon fisheries / fishery resources / current yields / maximum sustainable yields / subsistence fishing / New Caledonia / Pacific Ocean**

**Résumé — Estimation des stocks de poissons des lagons de Nouvelle-Calédonie : 3 – Pression de pêche, rendements potentiels et impact sur les options d'aménagement.** Cette étude évalue le potentiel d'exploitation des poissons démersaux récifo-lagonaires d'intérêt commercial dans les lagons de la Province Nord de la Nouvelle-Calédonie. La pression de pêche est estimée d'après les relevés des pêcheurs professionnels et le budget de consommation des ménages. Les captures totales ont été estimées à 1 326 tonnes en 1995, dont 94 % sont représentés par la pêche de poissons consommés sur place. Les captures sont effectuées sur les côtes ouest et est, et sont très faibles dans le lagon nord (Bélep). Compte tenu de cette pression de pêche d'une part, et des stocks d'autre part, la prise maximale soutenue annuelle a été estimée à 12 600 t, soit environ 10 % du stock total (138 300 t). Elle est principalement constituée par des espèces de cinq familles : les Lethrinidés, Acanthuridés, Scaridés, Serranidés et Lutjanidés. Comparés à la pression de pêche sur l'ensemble des lagons, les stocks semblent loin d'être menacés dans leur ensemble. Il serait donc possible d'augmenter sensiblement l'effort de pêche. Cependant, à une échelle géographique plus fine, certains secteurs communaux (Koné et Népoui sur la côte ouest), certains biotopes récifaux (les abords récifaux), ou certains groupes d'espèces (poissons de ligne) semblent supporter déjà une activité conséquente. Des recommandations sont formulées, notamment la mise en place d'un suivi de la ressource des espèces cibles et la réorientation de l'effort de pêche en direction d'autres groupes d'espèces et d'autres biotopes grâce à une diversification des techniques de captures. 

**Pêcheries lagonaires / captures / prises maximales soutenues / pêche de subsistance / Nouvelle-Calédonie / océan Pacifique**

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## 1. INTRODUCTION

For almost the entire population of Pacific island countries, finfish and other seafood account for most of the protein intake. For centuries, the sea has provided adequate protein ration, but in recent decades, fishing pressure has increased substantially, leading to heavy exploitation of coastal areas and particularly coral reefs and lagoons [18, 20, 23]. Population increases, the introduction of very efficient fishing equipment, economic development constraints and the emergence of new markets are some of the reasons behind this increase in fishing pressure [18, 21]. Overfishing, habitat degradation and illegal fishing activities (e.g. dynamite and sodium cyanide fishing) [21, 32, 35] have already been reported. Such disturbances are likely to modify both resource characteristics and their use. In the longer term, they may threaten food security and increase the economic dependency of Pacific island countries. As such, it is necessary to define and implement measures to manage sustainably coastal resources.

In recent years, the administration of the Northern Province of New Caledonia sought to implement rational and sustainable management strategies for lagoon and reef fish resources. In addition, the representatives of the Province need to be able to answer various questions raised by fishermen. These questions mainly concern the acceptable exploitation levels for different species or fishing areas, fisheries development and the use of new techniques. To provide a scientific basis for answering these questions, an assessment of commercial lagoon fish resources was implemented by IRD (ex-Orstom) from February 1995 to March 1997.

The study of fish communities in the lagoon of New Caledonia's Northern Province has shown that stocks in the north zone are unfished, while the fish communities of the west and east zones show characteristics consistent with exploitation [25, 27, 30]. Thus, accurate knowledge of the level of pressure being applied to those resources is needed to confirm the existence of exploited stocks, to assess the quantities that can be taken without endangering the future productivity, and to address the need to plan for sustainable fisheries. In the Pacific islands, in contrast with industrialized nations, the assessment of the fishing pressure level cannot be limited to a study of the commercial fishing sector and must take into account subsistence fishing. The latter is estimated at about 80 % of the fishing pressure for most Pacific islands [12]. In New Caledonia, commercial lagoon fisheries remain poorly developed and to a great extent an artisanal activity. There is still too few data on the impact of subsistence fishing on fish populations. Though a few estimates have been made [34], it was recently suggested that 2 000 tonnes a year were caught throughout New Caledonia [38], but this is most probably an underestimate.

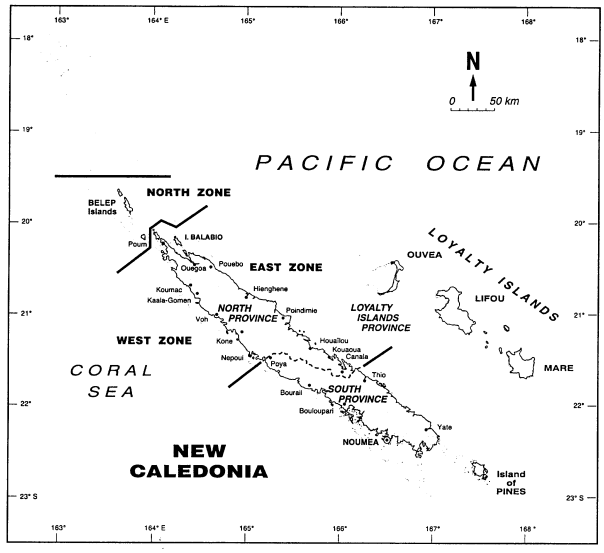


**Figure 1.** Location of New Caledonia, Northern Province, zones and sectors of study.

## 2. MATERIALS AND METHODS

### 2.1. Study areas

New Caledonia is located in the south-western Pacific Ocean (*figure 1*). The main island is surrounded by a coral barrier reef, delineating one of the most extensive lagoon and coral reef ecosystems in the world. The present work was carried out in the lagoons of the Northern Province. For practical reasons, these areas were divided into three zones: the north, the west and the east zones (*figure 1*). Each zone was subdivided into geographical sectors: one in the north zone, six in the west zone and nine in the east zone.

### 2.2. Fishing pressure

Two complementary methods were used to estimate the fishing pressure in each zone (*figure 1*) and the geographical sectors sampled [27].

The first method estimates commercial fishing pressure by monitoring the activities of professional fishers. The tally-sheets of the fishermen operating under an official licence were our only source of information, although we are cautious with this information.

The second method is based on fish consumption, and this is used to provide an indirect estimate of the subsistence fishing pressure. We worked on the assumption that in New Caledonia, and for fresh fish, consumption equals production [26, 34]. Fresh fish imports and exports represent a fairly low tonnage and nearly balance each other (*figure 2*). The net result is small enough to be considered nil, and we can safely equate local consumption with local production.

To estimate consumption, we used data from a household survey of family budgets performed in 1991

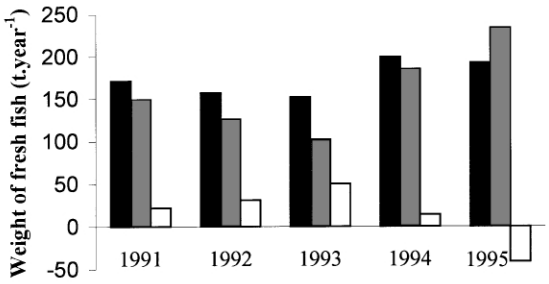


**Figure 2.** Import and export of fresh fish to or from New Caledonia, 1991–1995. Imports are in black, exports in grey, and net imports (negative values) or exports (positive values) in white.

by the Territorial Institute of Statistics (ITSEE) [16]. These allowed us to calculate the annual consumption of fresh fish. This included fish purchased on the open market (monetary consumption) and fish caught by the family itself, or obtained by other non-commercial means such as exchanges or gifts (non-monetary consumption). Families were asked to tell the investigators how much fresh fish they bought, and how much they caught themselves or were given by friends or relatives. The overall quantities were converted to a monetary value based on the average price of fish at the Nouméa fish-market (5.5 US$·kg$^{-1}$). The value of fish was used to estimate the mean quantities of fresh fish purchased or consumed per person in 1991.

We apply our calculated annual per capita consumption of fresh fish in 1991–1996 because both purchasing power and the price of fresh fish in New Caledonia have been relatively stable over the 1991–1996 period (*figure 3*). Retail price indices and salary variations over this period are similar (ITSEE). We also consider that consumption habits have not changed substantially during the same period, and all fishing is local.

The quantities of fish caught for private consumption allowed us to estimate the subsistence fishing production, and thus the level of pressure applied on the resource by subsistence fishing. This pressure level is mainly linked to demography. Therefore, if we take the figure for average annual consumption per capita,

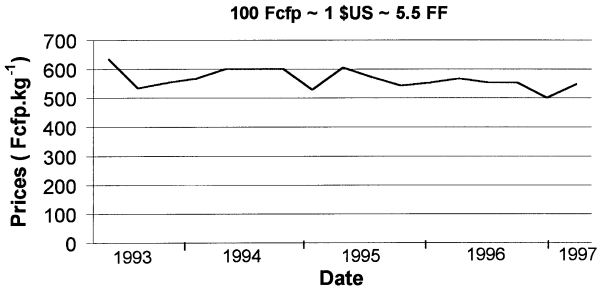


**Figure 3.** Retail lagoon fresh fish prices in the Nouméa market, 1993–1997.

and multiply it by the population figures for 1996 [1], we can have an idea of the pressure imposed by subsistence fishing on available resources, zone by zone, and sector by sector. Finally, the overall pressure on the fish resource is the sum of the contributions of professional and subsistence fishing.

### 2.3. Potential yields

Potential yields were calculated using maximum sustainable yield (MSY) estimators. Although MSYs may not be sufficient, even in the case of multispecies fisheries [28], from the data available in this study (standing stocks), MSYs represent the best tools to provide first rough estimates of the potential yields, and mainly to establish comparison between areas and then what could be done in terms of management actions and policies. MSYs were calculated from the total standing stock for the whole community and for the main species [25, 30] . On this basis, two surplus production models were applied. In Bélep area (north zone) where stocks can be considered as virgin, Gulland's formula was used [15]:

$$\mathrm{MSY} = 0.2\ \mathrm{M} \times B_{\mathrm{v}}$$

where $M$ is natural mortality and $B_{\mathrm{v}}$ is virgin stock biomass.

This assumes that MSY depends on the virgin stock biomass, a high $M$ corresponds to a high production, and $F$ (fishing mortality) = $M$ under optimum exploitation. The factor '0.5' suggested by Gulland was replaced by '0.2'. Indeed, the initial formula generally overestimates MSY by a factor of two to three. Natural mortality values were found in the literature [24]. When there was more than one value for the same species, the lower one gave generally a more conservative value. For some species, no values could be found in the literature, values for the nearest related species were then used.

For the west and east zones, we used the model proposed by Garcia et al. [14] which takes into account the yields, and has the same foundation as the Gulland's estimator:

$$\mathrm{MSY} = \frac{B \times M^2}{2M - \left(\frac{Y_i}{B}\right)}$$

where $Y_i$ is the yield of species $i$, $M$ is the natural mortality, and $B$ the average annual biomass.

Yields for each species were estimated considering total yields and percentage of each main category of fish caught by professional fishermen [34]:

$$Y_i = Y \times p_i$$

where $Y_i$ is the yield of species $i$, $Y$ is the total yield in the area considered and $p_i$ is the percentage of catch of species $i$.

**Table I.** Professional and subsistence fishing production (in tonnes) in the three zones studied.

| | North | West | East | Total |
|---|---|---|---|---|
| Professional fishing | 2 | 105 | 35 | 142 |
| Subsistence fishing | 26 | 438 | 720 | 1 184 |
| Total | 28 | 543 | 755 | 1 326 |

## 3. RESULTS

### 3.1. Fishing pressure

Based on tally-sheets of professional fishermen, total catches by commercial fishers were estimated at 142 tonnes in 1995. The largest part of this catch was taken from the west zone (*table I*).

In the Northern Province, this consumption was found to be 30.3 kg per capita, with 94 % represented by subsistence fishing (*figure 4*). It was significantly higher than in the Southern Province where the mean annual consumption was 18.3 kg of fresh fish per capita. The difference is even more pronounced in the Islands Province, where the overall annual consumption was of 39.4 kg per capita, almost entirely from local non-commercial fishing (*figure 4*). The proportion of bought fish was almost negligible.

Subsistence consumption was 1 184 tonnes during 1996 in the Northern Province. More than 60 % of subsistence fishing took place in the east zone (*table I*).

From the results of professional and subsistence fishing, the yield in the Northern Province is estimated at 1 326 tonnes in 1995 with 57 % for the east zone, 41 % for the west zone and 2 % for the north zone (*table I*).

The total size of fish stocks estimated on coral reefs was estimated at 65 000 tonnes and that on near-reef and soft-bottom areas was 57 600 tonnes [25, 30]. The

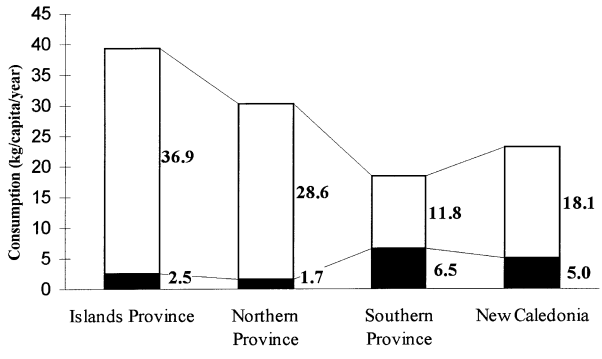


**Figure 4.** Average consumption per capita of fresh fish by province and type in 1991. Non-monetary consumption or subsistence productions are in white, monetary consumption or purchases in black.

**Table II.** Mean total yield, collective maximum sustainable yield (MSY), total stock and ratios total yield/total stock, total yield/collective (MSY) for studied zones and coastal sectors.

| Zone | Sector | Total yield ($t \cdot km^{-2}$) | MSY ($t \cdot km^{-2}$) | Total stock ($t \cdot km^{-2}$) | Total yield/MSY (%) | Total yield/total stock (%) |
|---|---|---|---|---|---|---|
| North | Bélép | 0.01 | 1.40 | 23.68 | 0.7 | 0.04 |
| West | Poum | 0.06 | 2.86 | 16.18 | 2.1 | 0.35 |
| | Koumac | 0.16 | 3.72 | 22.48 | 4.3 | 0.72 |
| | K.Gomen | 0.21 | 3.40 | 19.80 | 6.1 | 1.08 |
| | Voh | 0.42 | 4.00 | 35.95 | 10.5 | 1.17 |
| | Koné | 2.78 | 2.77 | 28.04 | 100 | 9.91 |
| | Népoui | 0.92 | 3.31 | 37.24 | 27.7 | 2.48 |
| | Mean | 0.29 | 2.77 | 22.01 | 0.10 | 0.30 |
| East | Balabio | 0.06 | 1.48 | 13.51 | 4.0 | 0.44 |
| | Ouegoa | 0.43 | 1.63 | 14.31 | 26.3 | 2.98 |
| | Pouébo | 0.36 | 1.79 | 15.37 | 20.1 | 2.31 |
| | Hienghène | 0.44 | 2.44 | 21.83 | 18.0 | 2.03 |
| | Touho | 0.18 | 1.52 | 13.74 | 11.8 | 1.33 |
| | Poindimié | 0.40 | 1.24 | 9.95 | 32.2 | 4.07 |
| | Houailou | 0.30 | 1.52 | 13.34 | 19.7 | 2.25 |
| | Kouaoua | 0.15 | 1.62 | 13.58 | 9.3 | 1.09 |
| | Canala | 0.34 | 1.29 | 10.69 | 26.4 | 3.21 |
| | Mean | 0.28 | 1.52 | 13.18 | 0.18 | 1.10 |

ratio of total catch to total stock is 0.04 % in the north zone, which is negligible (*table II*), 0.3 and 1.1 % on the west and east zones, respectively. Within the coastal subdivisions, the variations were more pronounced: in the southern part of the west zone, particularly in the vicinity of Koné, the ratio of catch to total stock reached 10 and 46 % of the stock of line-caught species (*table II*).

### 3.2. Potential yields

Potential yield was estimated as 12 600 tonnes, approximately 10 % of the total stock. A total of 5 300 tonnes were associated with coral reefs, 1 300 tonnes with near-reef areas and 6 000 tonnes with lagoon bottom; 3 900 tonnes were estimated in the north zone, 4 500 tonnes in the west zone and 4 200 tonnes in the east zone. More than two thirds of this MSY were composed of five families: Lethrinidae, Acanthuridae, Scaridae, Serranidae and Lutjanidae (*figure 5*).

As for total stocks, the MSY represented for each of these families about 10 % of the estimated stock [25, 30]. These families can be divided in two groups. The 'line-fish', Serranidae, Lutjanidae and Lethrinidae, found mainly on lagoon bottom and near-reef areas, represented about 50 % of the total MSY (*figure 5*). Herbivorous fish (Acanthuridae, Scaridae and Siganidae) constituted 25 % of the total MYS (*figure 5*), and are almost exclusively found on coral reefs where they represent 75 % of the fish resource of interest.

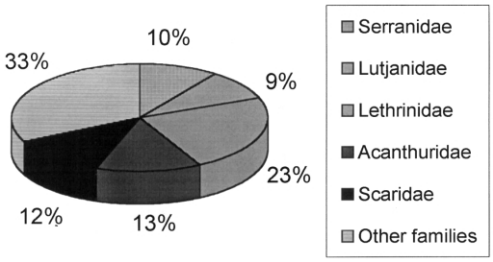


**Figure 5.** Distribution of maximum sustainable yield by family.

### 3.3. Links between fishing pressure, potential yields and total stocks

The total yield (1 326 tonnes) was 10 % of the total MSY and about 1 % of the total stock. Taken as a whole, this catch was well within sustainable yield values. However, it appears that in some sectors catches were close to the sustainable maximum, and may even have exceeded it (*table II*). This was the case for the southern part of the west coast, between Koné and Népoui.

We also tried to identify those biotopes that were subjected to the highest fishing pressure, by analysing the correlation between catch and stock figures measured for the different geographical sectors and biotopes studied. Two significant correlations were found (*figure 6*): between catches and total stocks of line-fish species for all biotopes, and between catches and total stocks of fish of near-reef areas for all species.

## 4. DISCUSSION

### 4.1. Current yields

Compared with yields from some Indo-Pacific locations (*table III*), those in the Northern Province of New Caledonia are very low. However, yields reported in *table III* represent the whole catch of fish, including other organisms such as invertebrates. However, finfish represent the major part of these yields [12]. The low yield in the Northern Province may be mainly explained by the density of the human population which is one of the lowest in the South Pacific (4.2 inhabitants·km$^{-2}$) [1] in comparison to the large fishable reefal and lagoonal areas (about 13 000 km$^2$), and, on the other hand, by social factors. Links between stocks and current yields suggest that fishing activities are very likely more oriented toward line-fish species, which fits well with what we know about local fishing practices. Moreover fishing activity concentrates on near-reef areas, which corresponds to local fishing habits, the lagoon bottom being harder to fish. Moreover, the structure of the fleet does not afford professional and non-professional fishermen to fish far from the place where they launch or anchor their boats.

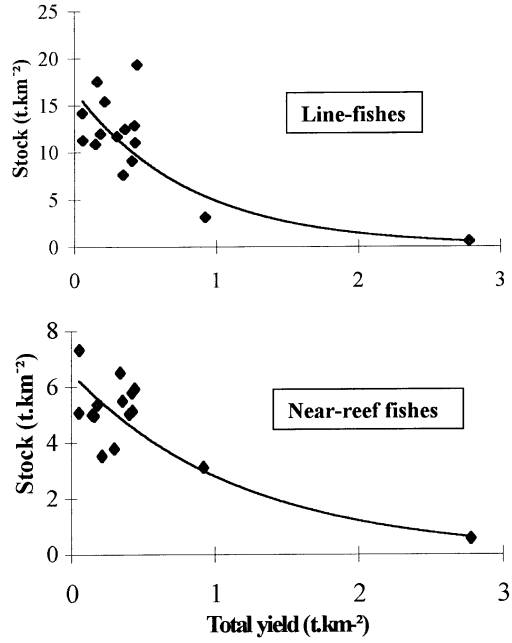


**Figure 6.** Significant correlations between stock and current yield estimated for the coastal sectors ($n$ = 15, $R$ = 0.94 for line-fish and $R$ = 0.93 for near-reef fish).

Our analysis may have underestimated the commercial fisher activity. Over the period 1993–1995, about ten fishermen declared more than 60 % of the production and can be considered as truly professional, meaning that fishing was their main activity (*figure 7*). The other so-called 'professional' fishermen only declare fishing as a part-time occupation, and submitted their tally-sheets on a very irregular basis. It is highly probable that they did not declare all their catch. A second explanation could be administrative. Indeed, above a certain production, fishermen have to pay their medical insurance which is otherwise free. Therefore, some of them probably tended to underestimate the yields on their tally-sheets in order to stay under this limit.

Consumption in the Northern Province and the importance of subsistence fishing may be partially explained by the population structure. There are differences in fish consumption among ethnic groups [17]. People of Melanesian origin represent the most important ethnic group of the Northern Province with 79 % of the population. They consume more fish than Europeans. This can explain that the mean consumption per capita is more important than in the Southern Province. Moreover, the economy of the Melanesian communities is based on a food crop system and a strong customary tradition [29]. This provides subsistence for people, and fishing activities are one of the two most important economic components with tuber and other crops. Their commercial fishing activities are poorly developed. Other estimates

**Table III.** Estimated yields from Pacific reef fisheries (adapted from Dalzell [8]).

| Location | Habitat type | Yield ($t \cdot km^{-2} \cdot year^{-1}$) | Reference |
|---|---|---|---|
| New Caledonia | | | |
| North lagoon | all coral reefs and lagoon | 0.01 | present study |
| North lagoon | all coral reefs and lagoon | 0.29 | present study |
| North lagoon | all coral reefs and lagoon | 0.28 | present study |
| Total Northern Province | all coral reefs and lagoon | 0.17 | present study |
| Papua New Guinea | all coral reefs | 0.21 | [10] |
| Kavieng | fringing and patch reefs | 0.42 | [40] |
| Port Moresby | fringing and patch reefs | 5.0 | [31] |
| Manus | coralline shelfs | 2.8 | [7] |
| American Samoa | fringing and patch reefs | 8.6–44 | [39] |
| Western Samoa | fringing and patch reefs | 11.4 | [41] |
| Tarawa (Kiribati) | fringing reef | 7.2 | [33] |
| Soloman Islands | fringing reef | 0.6 | [6] |
| Nauru | atoll reefs and lagoon | 4.5 | [9] |
| Niue | atoll reefs and lagoon | 9.3 | [11] |
| Philippines | | | |
| Apo | fringing reef | 11.4–24.9 | (3] |
| Sumilon | fringing reef | 14.0–36.9 | [2] |
| Panilacan | fringing reef | 10.7 | [36] |
| Hulao-hulao | fringing reef | 5.2 | [4] |
| Total | fringing reef | 5.9 | |
| Palau | barrier reef | 1.7–3.5 | [22] |
| Fiji | all coral reefs | 0.3–10.2 | [6] |
| Fiji | fringing and barrrier reefs | 5.1 | [19] |
| Ifaluk atoll | fringing reef | 1.9 | [37] |

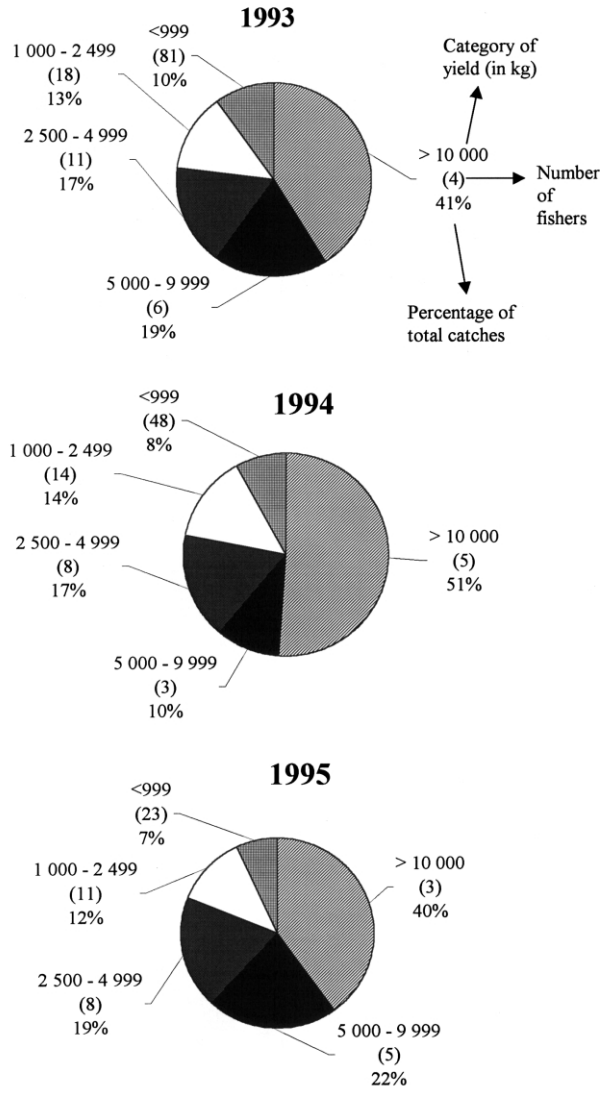


**Figure 7.** Classification of the professional fishermen. Each sector corresponds to the percentage of catches represented by each category of yield on the annual total catch.

given for large Melanesian islands show similar ranges of mean consumption per capita and per year to those in the Northern Province of New Caledonia. In Vanuatu, David [13] estimated fish consumption at 22.8–23.7 kg per capita in 1984. In Fiji, the consumption was around 30 kg per capita per year [5].

## 4.2. Potential yields

For commercial fish the MSY represented globally 10 % of the total stock, which was estimated to be 138 300 tonnes [25, 30]. However, this MSY is collective, and thus individual species can still be overfished even if the community as a whole is not. The calculated MSY are probably underestimated. Indeed, the current yields included all commercial species but not all biotopes. Maximum sustainable yield estimates did not take into account mangrove and estuarine fish species, for which we were not able to calculate stock figures, even though some fish such as mullets form an important part of the overall fishing activity. Therefore, the levels of exploitation in the sectors of Koné and Népoui are probably not so high, as mangrove fish are important there but were not taken into account in *table II*. Three explanations may be put forward. First, areas of these sectors are smaller than the others. Second, the lagoon bottom areas are limited compared to the reefs and near-reef areas. Moreover, the population is relatively more important than in other sectors.

Finally, another point is the percentages of each fish group caught by professional fishermen used for the yield per species and the MSY calculations. These

values are probably different from the proportions of catches for subsistence fishing. This could probably underestimate the catch and the MSY of some families such as Lethrinidae and Serranidae, which are mainly targeted by professional fishermen. A consumption survey of fresh fish should be realized to specify more clearly these percentages and then to refine the maximum sustainable yields per species.

## 5. CONCLUSION

This survey showed that, in the Northern Province of New Caledonia, the stocks of commercially valuable reefal and lagoonal fish were far from being endangered on a collective basis. The current yield is about 10 % of the MSY and 1 % of the total estimated stocks assessed [25, 30]. However, it also shows that fishing activity is beginning to affect the fish populations of the east and west zones, mainly the line-fish species and the near reef areas. Subsistence fishing represents the most important part of the yields. Thus, complementary surveys should help refine what the most important species targeted by subsistence fishing and the level of fishing pressure which could be applied on these, are.

Based on current trends of demographic growth, without taking into account immigration and economic development, we expect that the overall consumption of fresh fish will probably double over the next 15 years [27]. The catch of lagoon fish, particularly demersal fish, will therefore increase. In this context, this study can be considered as a starting point for a monitoring programme of fish communities and fishing activities. It shows that at present, consumption can be used as an indirect means to assess the subsistence fishing.

With these results, some management options could be implemented at mid- or long-term. For instance, fishing activities could be redirected away from the fish populations that are nearing the threshold of sustainability, and target other groups of species, such as the Scaridae and Acanthuridae. The possibility of fishing different grounds, for instance the lagoon floor, could also be investigated through a diversification of the fishing methods, such as the use of fish-traps or longlines.

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