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Pierre Labrosse, Jocelyne Ferraris, Yves Letourneur. Assessing the sustainability of subsistence fisheries in the Pacific: the use of data on fish consumption. *Ocean and Coastal Management*, 2006, 49, pp.203-221. 10.1016/j.ocecoaman.2006.02.006 . hal-00094524

HAL Id: hal-00094524

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Submitted on 7 Oct 2022

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Assessing the sustainability of subsistence fisheries in the Pacific: The use of data on fish consumption

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Coastal fisheries in Pacific island countries are characterised by a strong predominance of catches for subsistence purposes which involves mainly finfish and is difficult to quantify. In 1997–1998, a consumer survey conducted in the Northern Province of New Caledonia (Southwest Pacific Ocean) made it possible to indirectly estimate subsistence fishing production. Catch from subsistence fishing did not result in a significant change of the exploitation potential. The catch composition of subsistence fishing differed significantly from commercial fishing, with a higher proportion of species less vulnerable to exploitation. Interpretation of the consumer typology highlighted the importance of factors such as ethnic group and geographical location in explaining eating habits and therefore, indirectly, fishing behaviours. These results suggest that this fish consumption survey could assist in the design of subsistence fisheries monitoring programmes.

1. Introduction

For a very large proportion of the population of Pacific island countries, seafood products account for most of their protein intake. This population consumes more seafood

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products per capita than any other area in the world, except the islands in the Indian Ocean [1]. This is particularly true for the smallest islands (i.e. Micronesia and Polynesia) which do not have enough land area to develop significant agricultural activities. In terms of monetary value, coastal fishing, particularly reef and lagoon fishing, is not comparable to high seas industrial fishing [2]. Reef and lagoon fisheries are characterised by a wide variety of exploitation types and an important role of subsistence fishing. Catch of the latter is clearly higher than for commercial fishing, the percentage being roughly estimated at about 80% of the volume of total catch of reef and lagoon fisheries [1]; value lies much more in the importance it has for islanders themselves, particularly for rural and tribal communities. For some authors, reef fishing pressure for the South Pacific is linked to population growth and in the Pacific islands, with a direct relation between the number of inhabitants and fishing pressure on resources [3,4]. This pressure has increased significantly [1]. It has also been directly affected by the introduction of high performance gear and motorised boats, the emergence of new markets and constraints linked to the switchover from a subsistence economy to a market one [5]. For these reasons, over fishing and habitat degradation are on the increase in coastal and reef and environments. These disturbances affect both the resource characteristics and its uses [4,6–8]. In the long run, they may threaten the food security of island communities and affect their sources of income at the risk of deepening their economic dependence [2,9].

In spite of its importance, subsistence fishing is poorly documented from the point of view of fisheries assessment. Often underestimated, its impact is almost unknown [10] mainly because this activity is difficult to assess directly, i.e. by monitoring fishing effort and landing surveys. This situation leads to a general lack of reef fisheries statistics which makes difficult the implementation of fisheries management plans [11]. Obtaining new data which would make it possible to deal with this activity and determine its evolution remains a major concern for Pacific island managers and decision-makers [12]. Consumption is one known mean of indirectly assessing subsistence fishing [13–16]. Fish consumption has been proposed to indirectly assess subsistence fishing in tropical island setting and may be considered as an indicator of this activity [17]. Indeed, exchanges of fish between islands are negligible for most of isolated islands. In such cases, the equation “production = consumption” is almost verified. Consequently, surveying the consumption could assist in monitor the trends of reef fisheries including the most important part represented by subsistence fishing. This approach might also be integrated in the fishery ecology based management context by comparing captures with resources assessed during ecological surveys [18]. Nevertheless, most of the results of consumption surveys implemented up to now have been reported in technical reports. In particular, they have been little exploited to understand the structuring factors of subsistence fishing. In addition, this information may be useful for reef fisheries management purposes, which is particularly important in the context of transition from a subsistence economy to a market economy in Pacific islands countries.

New Caledonia has not escaped from the difficulties related to estimating subsistence fishing [19,20]. An initial approach based on landing surveys [21] estimated production at 2700 t for the whole of New Caledonia in the end of 1970s. A second study implemented in the same years and based on both production per vessel and fish consumption estimated production between 4410 and 5430 t [22], i.e. nearly twice the previous assessment. More recently [17] finfish production was assessed in Ouvea Atoll only (Fig. 1), with an estimate of 220 t/year. A resource assessment survey of demersal lagoon finfish was undertaken on a

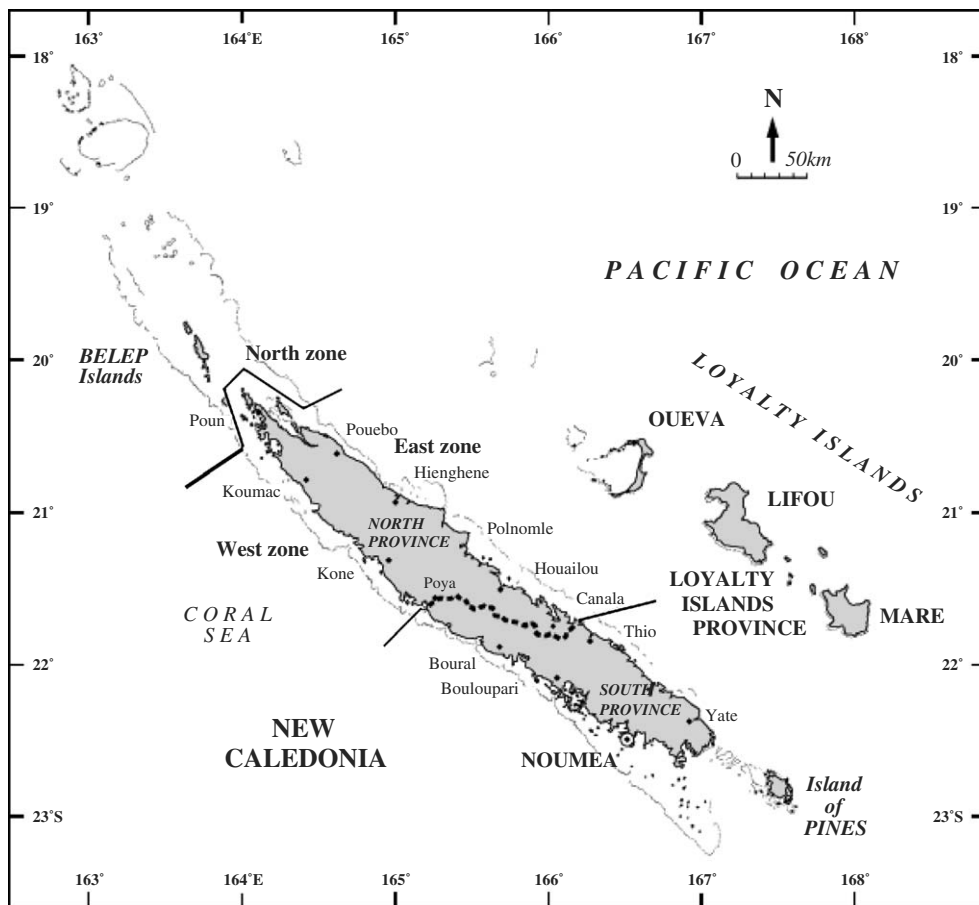


Fig. 1. Location of New Caledonia in the Southwestern Pacific Ocean and studied areas in the Northern Province.

large spatial scale in the Northern Province of New Caledonia between 1995 and 1998, covering more than 10 000 km² of lagoon area [23,24]. To compare standing stocks with fishing pressure, commercial catches were estimated using fishermen tally sheets and a quantitative assessment of subsistence fishing was undertaken using data and results from household consumption budgets in 1991 [25] and the latest population census in 1996 [26]. This last estimate was based on the assumption that for fresh fish, local consumption equals local fisheries production [16,27]. Yearly subsistence fishing was roughly estimated at about 1350 t of fish, i.e. 92% of all reef and lagoon fish catches. However, this approach did not allow the qualitative estimate of catch necessary for the management of a multi-species resource. In addition, in the Northern Province of New Caledonia, the expected development of nickel mining activities and especially the building of a large factory will likely speed up the transition from a subsistence economy to a merchant economy in this area in a near future. In term of monitoring, it represents an interesting case to assess the impact of this change on reef fisheries. This situation justified a target survey on fish consumption on a sample population in the Northern Province. This work was

implemented in 1998 and its purpose was (i) to quantify and identify the main fish species, or groups of species, consumed and, therefore, harvested, (ii) then to explain these results by socio-economic and geographic criteria linked to consumers. The aim of this analysis of this fish consumption structure is to give some preliminary assessment of the impact of subsistence fishing on reef and lagoon fish resources and to evaluate the usefulness of household consumption budgets in order to monitor fishing activities and fishing pressure.

2. Materials and methods

2.1. Study zone

New Caledonia is located in the South-Western Pacific Ocean (Fig. 1). The main island (New Caledonia proper) is surrounded by a barrier reef which borders one of the largest lagoons and coral ecosystems in the world. Administratively, it is divided into three provinces (Northern, Southern and Loyalty Islands). This research work was conducted throughout the Northern Province between October 1997 and March 1998 (Fig. 1). The population structure of the Northern Province of New Caledonia is characterised by a large majority of Melanesian (79%) followed by Europeans (17%) and other ethnic groups (4%) [26]. Almost the entire population lives along the coast.

2.2. Sampling strategy

Due to time and cost restrictions, an empirical sampling method was used, i.e. random walk quota sampling. The information available from the last census of New Caledonia's population was taken into account in setting quotas [26]. Consequently, a total of five criteria were thought to have an influence on individual behaviour with regards to fish consumption and were selected in order to formulate the sample design (Table 1): gender, age, ethnic group (Melanesian, European, other), urban area stratum (rural or tribal) and geographic location (northern, eastern or western zone) (Fig. 1). Previous analysis of a seafood consumption survey in Noumea [28] and of the last household consumption survey performed in 1991 in New Caledonia [25] indicated significant differences in consumption patterns between urban, rural and tribal stratum, and between ethnic groups. Geographic location was selected for two main reasons: the differences of geographical characteristics (coastline topography, reefs and lagoons morphology, population structure) and differences in the structure of finfish assemblages [23,24].

Given the similarity existing with the quota method, the sample size was calculated using the formula of calculation of the minimum sampling size for a stratified random sampling. The Kish correction (i.e. by multiplying the margin of error value by 1.4) was applied in order to take into account sampling biases [29]. Using this formula, a sample of 646 people was surveyed. This sample size gives a 5.4% error of estimate for a confidence level of 95% on the basis of consumption's variable. The quotas (i.e. the number of persons to be interviewed for each selected criteria) were calculated from the demographic data available for the entire population of the Northern Province (41 413 inhabitants). However, for practical reasons, only residents over the age of 7 were interviewed (size of statistical population = 35 471 inhabitants). Each individual accounted for a sampling unit.

Table 1
Population and sample size for the various criteria selected for analysis, $N = 646$ people for each criteria

Criteria	Size of population	Size of sample	%
<i>Gender</i>			
Male	21742	342	52.5
Female	19671	304	47.5
<i>Age</i>			
0–19 years old	14702	288	44.9
20–59 years old	23895	314	48.3
60 years and over	2816	44	6.8
<i>Ethnic group</i>			
European	7868	110	16.9
Melanesian	32261	504	77.9
Other ethnic groups	2153	32	5.2
<i>Stratum</i>			
Rural	13942	217	34
Tribal	27471	429	66
<i>Zone</i>			
Northern	923	14	2.2
Western	15401	238	37.2
Eastern	25089	394	60.6

Source: [26].

2.3. Questionnaire

The survey was run during the austral summer, between October 1997 and March 1998. The surveyors (Pierre Labrosse, Yves Letourneur, and three persons of the Fisheries Service of the Northern Province: two Melanesians and one European) walked randomly in the selected areas and interviewed people following the quotas allocated in the sampling plan for other criteria. They used a 13 question form divided into three parts (see Appendix A). The first part covered both quality and quantity of fish consumption during the last three meals, as well as the origin of the fish (calling on “short-term memory” of the survey participants). The purpose of these questions was to quantify consumption in order to estimate the Northern Province’s overall reef fisheries production at the time of the survey and, more specifically, catches for subsistence purposes. The second part dealt with yearly average amount consumed per meal, meal frequency and the most widely consumed species in order to get an overall picture of fish consumption in the Northern Province. These two parts of the questionnaire included questions about the origin of the fish consumed (i.e. bought or caught) in order to distinguish real subsistence fishing and market-based fishing. Finally, the third part included information on quota criteria designed to explain consumption behaviour through socio-economic variables. People were interviewed in French. The possible answers to each question are presented in the Appendix A. These were either figures for quantitative variables (e.g. quantity consumed) or categories for qualitative variables (e.g. gender = female or male).

2.4. Data analysis

Total fish consumption estimates were calculated from quantitative data according to the sampling design. Qualitative data were processed in order to build a consumer typology using a multivariate statistical analysis divided in two steps (Fig. 2): (i) the analysis of the structure of the data set (relationships between variables and individuals) by factorial analysis and clustering methods and (ii) the identification of the socio-economic explanatory variables for each consumer category by contingency tables (χ^2 test). The

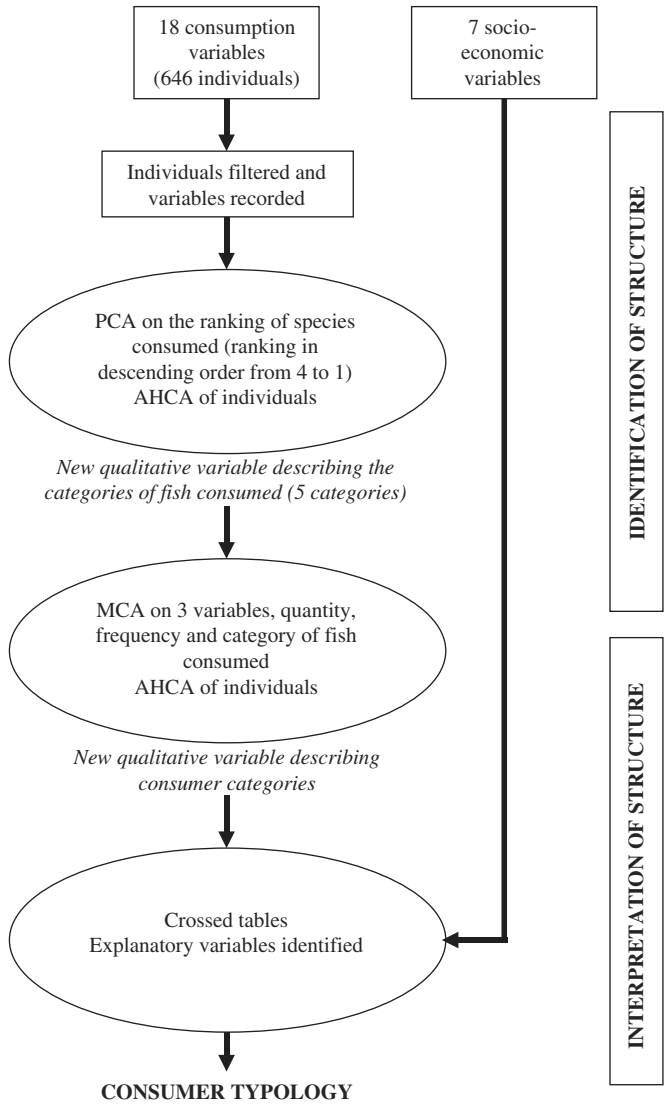


Fig. 2. Statistical framework of the analysis of the frequencies, quantities and species of fish consumed performed to determine consumer typology (principle component analysis, PCA; ascending hierarchical cluster analysis, AHCA; multiple correspondence analysis, MCA).

multivariable statistical processing is based on principal component analysis (PCA) applied on rank variables (consumed species), multiple correspondence analysis (MCA) adapted to the multivariable contingency table analysis [30] and ascending hierarchical cluster analysis by the Ward method (AHCA). The classification of individuals (consumers) was carried out after the factorial analyses (PCA or MCA), on the basis of the individual coordinates projected on the factorial axes [30]. Only consumption variables were used in the factorial analyses and classification. Explanatory variables were projected onto the structures given by the previous analyses (factorial axes or categories) in order to interpret and explain the results of the consumer typology.

The statistical analysis framework was based on a synthesis of the information coming from the data set by constructing new variables which summarise consumption behaviours and explaining the final consumer typology through socio-economic variables. Data analysis comprised four main stages (Fig. 2). First, a data filter was applied in order to differentiate fish consumers from non-consumers and to keep only people who met all the consumption variables. Second, a PCA was run on the table of consumed species ranked in descending order of preference (Rank 4 = preferred species → Rank 0 = species not mentioned) by keeping the difference in scale between species (PCA on variance-covariance matrix); from AHCA applied on individual coordinates of the factorial axes, consumers were characterised by a single new qualitative variable corresponding to the combinations of the most frequently consumed species. Third, consumers were classified on the basis of three consumption variables, i.e. type of species (previous stage), frequency and quantity of fish consumed using both MCA and AHCA. MCA was applied to the three consumption variables after pooling the classes to balance the numbers in each variable. “Eat fish at every meal” and “Once a day” were combined into “1–2 meals a day”. In the same way, the average quantities “300–400 g” and “> 400 g” were combined into “> 300 g”. Finally, the classification results were interpreted through socio-economic variables to give a consumer typology (χ^2 test).

3. Results

Of the 646 people who participated in the survey, only 7 said that they never ate fish (i.e. 1.3% of the sample). Analysis of the relation between whether or not people ate fish and available socio-economic variables (quota criteria) did not uncover any significant correlation (χ^2 test), which indicates that this phenomenon is not linked to gender, age, ethnic group or geographic location and can be explained by simple food preferences.

3.1. Mean annual per capita consumption

On the basis of both the average quantity consumed when fish was included in the menus of the last three meals (233 g/meal ± 16 g) and the average weekly frequency of meals including fish (4.8 meals/week ± 0.7), mean annual per capita fish consumption was estimated at 28.0 (± 2.0) kg. Subsistence quantities (non-monetary consumption) amounted to 25.7 (± 2.1) kg/inhabitant/year, i.e. about 92% of the total, with the other 8% corresponding to purchased fish (monetary consumption). Subsistence fish came from two different sources, i.e. fishing by a member of the respondent’s household (83%) and gifts (17%). Applied to the whole population of the Northern Province, it represents about 1064 t/year.

3.2. Consumption distribution by species group

In all, 41 species or groups of species were mentioned during the survey. The first ten categories of fish accounted for more than 75% of all fish consumed during the last three meals (Table 2). Mullet headed the list with more than 18% of the mentions, followed by rabbit and surgeon-fish and sprangled emperor. Spanish mackerel was fourth with slightly more than 8%.

Examination of how often the fish most frequently eaten over the year were mentioned corroborated these results overall (Table 2). Apart from two exceptions (Scaridae and *Naso* spp.), the most frequently mentioned categories were the same with, in descending order: mullet, rabbit and surgeon-fish, sprangled emperor. These three categories alone accounted for about 40% of all mentions.

3.3. Consumption structure

Using the PCA axes for consumed species to classify individuals made it possible to identify five classes corresponding to a combination of species (Table 3) which explained 35% of the data set variability. The principal sources of variability between consumers and the relationships between the three consumption variables were analysed on the MCA factorial axes, as shown on the first plan (Fig. 3). The first axis is linked to a frequency and quantity gradient (positive section = unfrequent consumption and in low quantities; negative section = 2–3 times/week and in large quantities). This gradient is associated with a type of consumption in which the freshwater species group with the category “tilapia” is opposed to the “emperor/bream” and “rabbit fish and surgeon fish” categories (Table 3).

Table 2

Quantities (as percentages) of the main fish groups or species eaten during the last three meals (CONSUM: question 4 of the questionnaire) and how often (as percentages), on average, mention was made of the most frequently consumed fish groups or species (QUOTED: question 8 of the questionnaire)

Fish species, or group of species		CONSUM	QUOTED
Taxa	Local name		
Mugilidae	Mullets	18.6	16.8
Siganidae and Acanthuridae other than the genus <i>Naso</i>	Rabbit fish-surgeon fish	11.6	14.6
<i>Lethrinus nebulosus</i>	Sprangled emperor	10.4	9.9
<i>Scomberomorus commersonii</i>	Spanish mackerel	8.3	5.2
	“Mixed” ^a	5.5	NM ^b
Scaridae	Parrot fish	5.1	6.6
Lethrinidae other than <i>Lethrinus nebulosus</i>	Breams	4.9	4.1
<i>Thunnus</i> spp.	Tuna	3.7	1.4
<i>Plectropomus</i> spp.	Coral trout	3.7	2.0
<i>Naso</i> spp.	Unicorn fish	3.3	8.2
<i>Oreochromis niloticus</i>	Tilapia	1.3	4.8
Serranidae other than the genus <i>Plectropomus</i>	Groupers	0.2	3.9

^a“Mixed” correspond to an undetermined and unquantified mixture of various species but often involving parrot-fish, rabbit-fish, surgeon-fish and/or mullets.

^bNM = not mentioned.

Table 3

List of the three qualitative variables used in the multivariate correspondence analysis

Variables	Number of people	%
<i>Frequency of consumption</i>		
Very often (1–2 times/day)	71	11
Often (2–3 times/week)	289	45
Fairly often (1 time/week)	183	29
Rarely (1 time/month)	85	13
Missing	11	2
<i>Quantity consumed</i>		
Very small quantity (< 100 g)	152	24
Small quantity (100–200 g)	219	34
Average quantity (200–300 g)	154	24
Large quantity (> 300 g)	112	17
Missing	2	1
<i>Species consumed</i>		
Spanish mackerel—Parrot fish	184	29
Emperor—Brems	114	18
Tilapia	76	12
Mullet	112	17
Rabbit fish and surgeon fish	153	24
Missing	0	0

The last one corresponds to the main consumed species characteristics of the five classes obtained after the principal component analysis of the ranking species by preference order (on 639 people, i.e. 646–7).

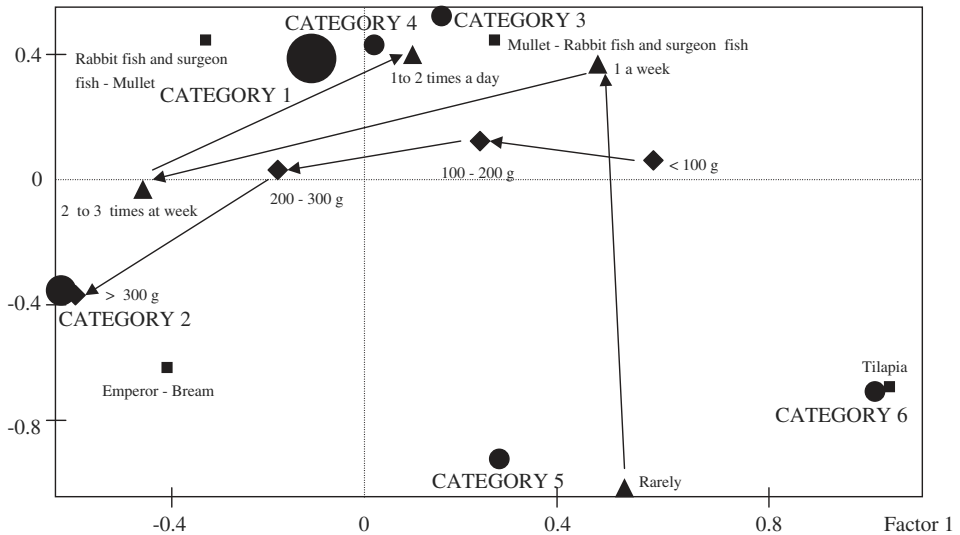


Fig. 3. Factorial map (axis I/II) of the multiple correspondence analyses applied to variables of consumption: fish consumption categories are given in term of species (square), quantity (diamond) and frequency (triangle). The six consumer categories centres of gravity obtained by hierarchical cluster analysis are projected as supplementary elements; the size of the circles is proportional to the number of elements in each category.

All the MCA axes were kept for the final classification. This made it possible to create six categories of consumers (Fig. 4). The first dichotomy of the dendrogram opposes occasional consumers (22% of the population who ate fish) to frequent consumers (78%). Table 4 and Fig. 5 illustrate the characteristics obtained for each category of consumer depending on the control values used in the study.

Categories 1, 3 and 4 involved mostly Melanesians people living in tribal areas. Category 1 was represented by rabbit and surgeon-fish consumers who ate between 100 and 300 g of fish per meal, 1–3 times a week. They were fairly young (54% of this category was under 20). People of category 3 ate fish 1 time per week in average, mainly mullet. Consumers of the category 4 comprised mainly males who ate fish very often (once or twice a day) without any preference for a specific species. 11% of whom came from the northern area. Some 52% of this category was under the age of 15.

Category 2 comprised mainly European people living in the rural areas of the west coast (coastal villages) who mainly ate spangled emperor, bream and coral trout. About 69% of them were between 20 and 60 years old and they ate fish 2 to 3 times a week, at a rate of more than 300 g per meal.

Categories 5 and 6 were composed of individuals who ate fish on an occasional basis (once or twice a month). Consumers of category 5 were mainly Europeans living in rural areas (villages). On the other hand, half of the consumers of the category 6 were Melanesians living on the West Coast and in tribal areas in the mountains. Their fish consumption is mainly represented by freshwater fish, mostly tilapia.

Categories 1 and 2 accounted for more than half the people who said they ate fish. It should also be noted that all those individuals who said they ate fish once or twice a month were included in either Category 5 or 6.

An age and household size effect linked to the axis I of the MCA can be noted along with a geographic effect (Fig. 3). The northern zone differentiated itself from the eastern and western zones. The mountain chain region was clearly different from the coastal area with less variance in the observed behaviour. These trends indicated that a correlation

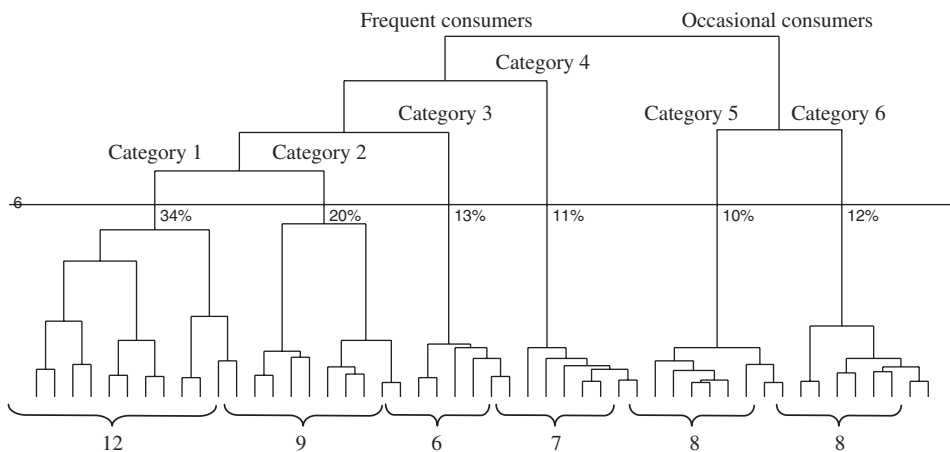


Fig. 4. Results of the hierarchical cluster analysis of individuals using their coordinates on all multiple correspondence analysis axes. The number of branch for each category is given by the lowest row of numbers.

Table 4

Main characteristics of the consumer typology obtained from the multivariate correspondence analysis (% of individuals of the consumer category with one characteristic of qualitative variables)

Categories	Species	Frequency	Quantities	Number
1	Rabbit fish and surgeon fish-Mullet (49.5%) Spanish mackerel Parrot fish (50.5%)	1 time/week (49.9%) 2–3 times/week (58.2%)	200–300 g (32.3%) 100–200 (42.7%)	220
2	Emperor-Breams (67.5%)	2–3 times/week (73.8%)	> 300 g (49.2%) 300–400 g (27.8%)	126
3	Mullet (100%)	1 time/week (44%)	—	84
4	All species except tilapia	1–2 times/day (100%)	—	67
5	All species except tilapia	1–2 times/month (96.9%)	—	66
6	Tilapia	1–2 times/month (27.6%)	—	76
χ^2 , DDL, probability	1405.53, DDL = 20, $P < 0.001$	1108.64, DDL = 15, $P < 0.001$	152.59, DDL = 20, $P < 0.001$	

$N = 639$ people.

— corresponds to a value of zero and indicates that the category shows no significant differences in values for that variable's modalities. The value of χ^2 is a function of the deviation from the initial hypothesis of independence between the two qualitative variables (typology in six categories and active variables) and the associated probability indicates whether or not that correlation is significant ($P < 0.01$).

existed between eating behaviours and socio-economic variables, which was tested statistically once classification were completed (Fig. 5).

4. Discussion

Although this survey was conducted in 1998, its output is still meaningful as the mining factory of the Northern Province in New Caledonia has not yet been built and as there has been no important social or economical changes during these 8 last years [31]. Moreover, fish communities show little variations from year to year in their abundance and structure [32]. Therefore, it may be assumed that little significant changes occurred which may have some effects on the validity of these results.

4.1. Annual per capita fish consumption

The estimated annual per capita fish consumption for this study (i.e. 28.0 ± 2.0 kg) was about the same as that obtained from a previous household consumer budgets and therefore confirms that figure [16] (Table 5). The same was true for its distribution in terms of monetary consumption (purchases) and non-monetary consumption (subsistence) (Fig. 6). The annual consumption value fits into the range proposed by Veillon (Table 5)

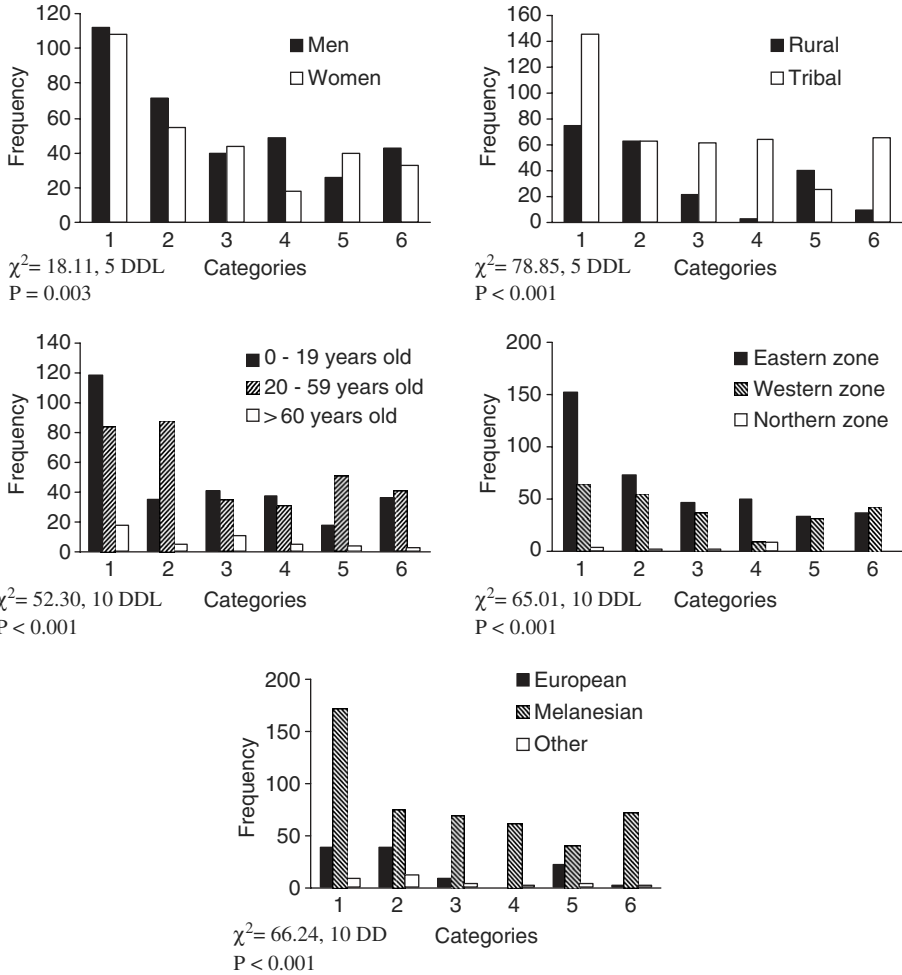


Fig. 5. Histogram of distribution of the six consumer categories according to control variables. The value of χ^2 is a function of the deviation from the initial assumption of independence between the two qualitative variables (typology in 6 categories and control variables) and associated probability indicates whether or not this correlation is significant ($P < 0.01$).

but it is lower than the value given proposed by Loubens for New Caledonia (Table 5). This difference may mainly be explained by (i) the hypothesis chosen by Loubens, i.e. that the consumption level of Melanesians is the same as that of Tahitians, i.e. 50 kg/inhabitant/year [22] was most likely incorrect and (ii) a greater fish abundance which might be linked to the lower number of inhabitants in New Caledonia when the survey was performed.

With regards to the Pacific islands, annual per capita fish consumption can be compared to those reported for other island countries in Melanesia (Table 5). It is close to the mean annual per capita value estimated for the entire Pacific region, i.e. 23 kg, but differs significantly from some obtained in several islands with value ranking from 4.8 to 40 kg/inhabitant/year [1]. Several causes may explain these differences. There are many different types of behaviour which are probably linked to the islands' characteristics and natural

Table 5

Mean annual consumption seafood product per inhabitant in some island countries of Melanesia (in kg/inhabitant/year)

Country	Consumption	Source
New Caledonia (Northern Province)	28 ^a	Present study
New Caledonia (Northern Province)	30.3 ^a	[16]
New Caledonia (Loyalty Is.)	39.4 ^a	[16]
New Caledonia (Europeans)	35	[22]
New Caledonia (Melanesians)	50	[22]
New Caledonia	27–37	[33]
New Caledonia	23	[16]
Vanuatu	22.8–23.7	[34]
Vanuatu	27	[35]
Fiji	40	[36]
Fiji	30	[6]
Fiji (Viti Levu)	32.5–41.2	[38]
Fiji	41.8	[35]
Papua New Guinea (West Sepik Prov.)	18.4	[37]
Papua New Guinea	16.9	[35]
Solomon Islands	44.8	[35]

^aFinfish only.

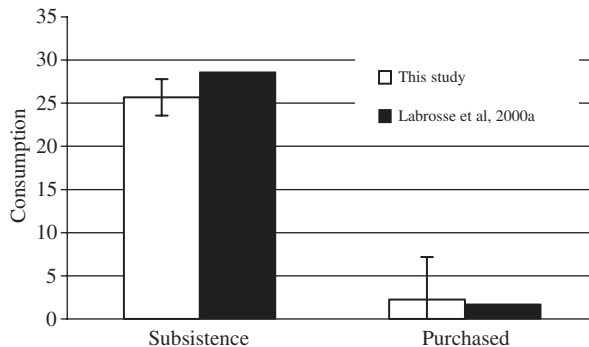


Fig. 6. Comparison of the fish consumption estimate for this study and the estimate made from household budgets (source: [25]) (in kg/inhabitant/year).

resources as well as to market influences. The sampling strategies and the occasionally local nature of some studies are limited to a few villages and may not necessarily lead to a good representation for the island system as a whole. Ethnic, economical and cultural components, particularly the issue of access to land and marine resources, which is linked to geographical characteristics and types of traditional exploitation [39], are rarely taken into consideration [10]. Although fish do account for the major part of subsistence catches [1], the values recorded on other Pacific islands cover all seafood products consumed, and therefore include in particular invertebrates. Finally, it is important to notice that quantitative approaches to fish consumption and subsistence fishing are very poorly documented and it is often difficult to make comparisons mainly because of the different methods and sampling designs applied.

4.2. Species targeted by subsistence fishing

Despite this study was conducted only during the austral summer, it may be however broadly assumed that fish consumption does not significantly vary between seasons, mainly due to the fact that temporal variations in fish abundance are relatively low in New Caledonia [40]. One exception could be the Spanish mackerel, which tends to be more abundant during the reproductive season (October–December). Until now, no quantitative data on the distribution of fish categories consumed was available. Commercial and subsistence fisheries were significantly different in the importance of the seven main categories of fish caught. These categories accounted for over 80% for commercial fisheries [27] and for less than 60% for subsistence fisheries. The relative percentages of the three most frequently targeted species, or groups of species, by subsistence fisheries (mulletts, spangled emperor, and rabbit-fish) were lower than those for commercial ones (Table 6). In contrast, parrot-fish accounted for a greater share of commercial fisheries. Similar differences were also observed for less frequent groups of fish. This may be explained by several reasons. The quantities consumed, and therefore produced by subsistence fishing are spread out over a wider number of species or groups of species than commercial fishing catches. In addition, commercial fisheries target species according to their market value. They follow the demand on the Nouméa market, the main destination for seafood products, where eating habits differ [28]. Home consumption based on subsistence fishing depends heavily on fishing capacity in terms of material resources, i.e. both gear and vessels. Limitations in this area often lead fishermen to remain close to shore leading to the catch of a majority of inshore species, in particular rabbit-, surgeon-fish and mullets. This type of assessment is relevant if the assumption “finfish production = finfish consumption” [16,17] is validated. With the exception of commercial fishing activities, it implies that catch is consumed on the spot, which is only partially true. In fact, some catch is sold outside the legal market system and so does not enter “consumption”. However, this catch probably accounts for only a very small part of the overall catches and therefore has a very limited impact on the observed differences.

Table 6

Catch distribution (as percentages) of the main species or groups of species caught by commercial (mean from 1993 to 1995, Source: Northern Province Fisheries Service, unpublished data) and subsistence fisheries (according to consumption) in New Caledonia’s Northern Province

Species or group of species		Commercial fishing	Subsistence fishing
Taxon	Common name		
Mugilidae	Mulets	26	18.6
<i>Lethrinus nebulosus</i>	Spangled emperor	25.9	10.4
Siganidae and Acanthuridae other than <i>Naso</i> spp.	Rabbit fish and surgeon fish	2	11.6
Scaridae	Parrot fish	12	5.1
<i>Naso</i> spp.	Unicorn fish	7.2	3.3
Lethrinidae (other than <i>L. nebulosus</i>)	Bream	5.7	4.9
Serranidae	Cod	5	3.4
Total		84	57.3

From the consumed species, some indications can be broadly deduced about the most important fishing gears and fishing grounds. Mullet, rabbit and surgeon-fish are species mainly encountered along the shore and caught with nets. Other species are caught on all types of reefs (coastal fringing reefs, reefs around lagoonal islets, and barrier reefs) using mainly hand-line and spear-guns. Therefore, most of the fishing pressure is probably to be located close to the shore.

Among those species targeted for home consumption, it should be noted that the percentage of fresh water fish was 3.4%, distributed as follows: tilapia (1.3%), carps (*Kuhlia* spp. 1.2%), river mullet (*Cestraeus plicatilis* 0.6%) and eels (*Anguilla* spp. 0.3%).

4.3. Consumption structure: impact on fishing pressure and potential yields

On the basis of non-monetary consumption and given the number of inhabitants recorded in the 1996 census [26] subsistence harvest was estimated at 1064 t/year. This value is within the same range as what was previously reported using household consumption budgets (1184 t) [16] but rises again the question of the relevance of the official reef fisheries statistics in New Caledonia, as will in a large number of Pacific island countries. Subsistence fishing catch was clearly higher than commercial catch, which has been estimated at about 140 mt/year [14,16]. Total catch (reef and lagoon fish) combining subsistence and commercial sources, was estimated at about 1204 mt in 1996, i.e. less than 1% of total stock (estimated at 138 300 t), and about 10% of the potential yields [23,24].

The analysis of home consumption gave detailed information on the nature of subsistence fishing catch. More than a third of the most frequently targeted fish species, or groups of species, (in particular, mullet, rabbit and surgeon-fish) are characterised by rapid growth rates, short life spans, small to medium sizes and high fertility (demographic strategies close to the “r” type) [41]. These species usually belong to low trophic levels. This quantitative aspect is significant in terms of management because this species are less vulnerable to exploitation than fish like spangled emperors, groupers or breams the main targets of commercial fishermen and/or consumption by New Caledonians of European origin. The latter species belong to high trophic levels and many have a long life span and reproduce later in life than species targeted by subsistence fishing.

Labrosse et al. [16] estimated the potential yields for the Northern Province at 12 600 t based on a biomass model [42]. By carrying out the same calculations with the subsistence catch from our study, this potential increased by 50 t, which may be considered as negligible in comparison to total catch. Similar conclusions were obtained for the potential yields of the main fish species or families, which did not vary by more than 1%. This is explained by the very low volume of the catch. However, it should be emphasised that the higher the fishing pressure, the greater the impact of subsistence fishing on exploitation potential. In this context of multispecies fishery, even if the catch is well under the potential yield, some species might be overexploited due to their specific life history characteristics (that make them more vulnerable). Socio-economic changes (increasing of mining and industrial exploitation, and possibly of European population, employment, etc.) may also lead many fishermen to switch from subsistence to commercial fishing. These species are often those that fetch a highest market prices and the preferred targets of commercial fishermen (e.g. spangled emperors, breams and groupers).

The consumer typology showed a strong relation between the characteristics of fish consumption and certain demographic parameters. In particular, it confirmed the influence

of ethnic composition on the consumption patterns, as already reported in the greater Nouméa area [28]. Geographic distribution and age were also significant factors. This can be explained by differences in eating habits, purchasing power and access to resources. Melanesians eat fish more often than Europeans. For the latter, the preference for groupers, emperors and breams confirmed a trend already observed [28]. Melanesians seem to prefer rabbit fish, surgeon fish and mullets, which probably corresponds to eating habits, but also to the fact that these fish can be easily caught from the shore, without using a motorised vessel. Freshwater fish consumption was mainly associated with tribes living in the mountains for which reef and lagoon resources are difficult to access (limited means of transportation). In addition, finding a source of ocean fish is problematic for them, due to absence of fish trade between the coast and the mountain and to the gradual disappearance of bartering. This situation could also explain their low level of fish consumption.

5. Conclusion

Through the case of the Northern Province of New Caledonia, this study showed that the analysis of fish consumption surveys can yield useful quantitative and qualitative information on subsistence reef and lagoon fisheries (e.g. the most frequently caught species, the amount of catch and types of consumers) with regards to their impact on reef and lagoon fish resources and management issues. This approach allowed indirect estimates of subsistence fishing production (1064 t/year). This fishery alone accounted for 88% of the total volume of the catch, estimated at 1204 t in 1996. It also revealed that the catch composition of subsistence fishing differed significantly from commercial fishing. In particular, subsistence fishing was more diversified and caught less vulnerable species. The low catch level of subsistence fishing had little influence on the potential yield as it represented a small proportion of the available stock. For that reason, fish populations of interest for consumption and/or marketing seem generally not endangered in the Northern Province. The consumer typology suggests that combinations of control variables should be used to stratify future samplings in order to assess fish consumption as an indicator of fishing level [43], and consequently as an estimator of reef and lagoon fish production. It could also be of interest for predictions as these results in combination with information about the population's demographic structure may allow to assess the future variations of fishing pressure over time given that the shift towards a monetary economy is taken into consideration. Finally, although fish exchanges with other islands are negligible for most of isolated islands and that "production equals consumption" is nearly validated, the efficiency of this method depends however closely on the possibility of getting a reliable and accurate estimate of the balance between fish importations and exportations.

Acknowledgements

This work was funded by the Northern Province of New Caledonia. We are grateful to the fisheries officers of the Fisheries Department of the Northern Province, to Michel Kulbicki (IRD) and to Sheryl Mellor (SPC translator) for their valuable assistance, and to the anonymous referees for their constructive comments on the manuscript.

Appendix A. Presentation of the questionnaire with possible responses for each variable

No	Question	Variable name	Possible responses
1	Do you eat fish?	Consumption	Yes No
2	Did you eat fish at one or more of your last three meals?	Meals	Yes No
3	If yes, how often?	Number of meals	1 time 2 times 3 times
4	Which fish and what quantities of fish did you eat of your last three meals?	Fish Quantity	Fish 1 Fish 2 Fish 3 Quantity 1 Quantity 2 Quantity 3
5	How did you get this fish? . bought . caught . given	Origin meal 1 Origin meal 2 Origin meal 3	Bought 1 Caught 1 Given 1 Don't know 1 Bought 2 Caught 2 Given 2 Don't know 2 Bought 3 Caught 3 Given 3 Don't know 3
6	On average, how often do you eat fish?	Mean frequency	FRQ RE FRQ J FRQ S FRQ 2 3 S FRQ M Don't know
7	On average, what quantity of fish do you eat at each meal?	Mean quantity	<100 g 100 à 200 g 200 à 300 g 300 à 400 g 400 à 500 g Don't know
8	Which fish do you eat the most often?	Fish consumed	Fish 1 Fish 2 Fish 3 Fish 4
9	Interviewee is...	Gender	Man Woman
10	What is your age?	Age	Age
11	What is your ethnic groups?	Ethnic group	European Melanesiann Other
12	Which village or tribe do you live in?	Location	Location
13	How many people live in your house?	Household	1 person 2 persons 3 persons 4 persons 5 persons 6 à 9 persons > 9 persons

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