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ESTIMATING DEMERSAL LAGOONAL FISH STOCK IN OUVEA, AN ATOLL OF NEW CALEDONIA

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ABSTRACT

Ouvea, the largest atoll (900 km²) in the Territory of New Caledonia was surveyed for its demersal fish resources. Two methods were used, handline fishing and underwater visual census. Handline fishing was conducted at 129 stations which were evenly spaced over a 1 nautical mile grid. Visual census counts were performed on 46 of the shallowest fishing stations. The species composition, CPUE (in numbers and weight) and size frequencies were recorded at each station. The visual census counts yielded species composition, density, biomass and size distribution. The data were analysed to determine whether the results of the two methods were correlated. The only significant correlation was between CPUE in weight and biomass. This relationship was improved by stratifying the data by depth. This enabled the estimation of total demersal fish standing stock, but the confidence limits for individual species were very wide. The visual census counts gave an average biomass estimate of 56.2 g/m² of which 29.9 g/m² are commercial species. The CPUE was on average 6.9 kg / man-hr. The total demersal standing stock is estimated to be 8,080 t, with 95 per cent confidence limits of 4,470 t and 14,760 t. The major commercial species belonged essentially to three families, Lethrinidae (Emperors), Lutjanidae (Snappers) and Serranidae (Groupers), of which the major species were *Lethrinus nebulosus*, *Lethrinus atkinsoni*, *Lethrinus rubrioperculatus*, *Lutjanus gibbus* and *Epinephelus maculatus*. These results will be used to formulate management strategies for the development of a commercial fishery.

INTRODUCTION

Ouvéa is the largest atoll in New Caledonia. It has long had a reputation of being an exceptionally rich fishing ground, however, no study had ever been made on the fish stock of its lagoon. ORSTOM was asked by the Department of Primary Industries of the Loyalty Islands to undertake an assessment of the fishing potential of this island (Kulbicki et al., 1994a).

Ouvéa (figure 1) is approximatively triangular in shape, and covers 900 km². This atoll has numerous passes. Depth increases regularly from the eastern part towards the west. Most of the land (main island) lies to the east, a number of reefs, the size of which declines westwards, limits the southern and northern part of the atoll.

Two major biotopes can be defined, reef and lagoon bottom. The border between these two biotopes is usually well defined, but at times, essentially near the main island, there are a number of isolated patch reefs dispersed on the lagoon bottom near the major reef. It was not possible to sample both the lagoon bottom and the reef with the same methods. Indeed, reefs are easy to survey by visual census, but fishing there requires special skills and replication of fishing experiments is difficult. Lagoon bottom is easy to fish without special skills and replication is easy, but visual censuses are limited to only part of the lagoon because of depth. The present article intends to give the results on the assessment of the lagoonal bottom fish stock. The assessment of these fish stocks was made in conjunction with an overall ecological survey during which the geomorphology, physical oceanography, sedimentology, primary production (planktonic and benthic), benthic communities were analysed (Kulbicki et al. 1993, 1994 b).

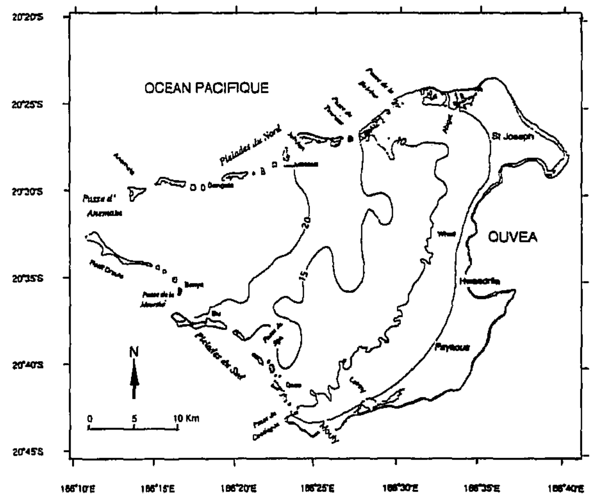


Figure 1: Ouvéa atoll

MATERIAL AND METHODS

Two types of stations were studied, fishing and visual census stations. The former were spaced on a 1 n.mile grid (figure 2). The latter were performed on stations spaced every 2 n.m. and in water depths not exceeding 25 m.

Each fishing station was visited by a dinghy with two fishermen. Each fisherman had a handline (figure 3). Fishing started 1/2 hour before official sunset and ended 1 1/2 hour after sunset. The mooring of the dinghy was changed every half hour, the distance between each mooring being approximatively 200 m. All fish caught were retained for further biological analysis. The weight, number of fish and species composition of the catch were recorded for each station.

On the visual census stations, a 100 m transect line was set at random from the surface. Then, two divers, one on each side of the line recorded all the fish they could see on their side of the line. For each sighting, the fish species, the number of fish, the size and the perpendicular distance of the fish to the transect were recorded. Fish size was noted according to the following classes, fish less than 10 cm in 1 cm classes, fish 10 to 30 cm in 2 cm classes, fish 30 to 50 cm in 5 cm classes, fish above 50 cm in 10 cm classes. The distance of the fish to the transect was noted in 1 m classes up to 5 m and in 2 m classes beyond that distance. All visual censuses were performed on fishing stations, however, fishing and censusing did not necessarely take place the same day. The fishing zone and the area censused could be distant by as much as 500 m.

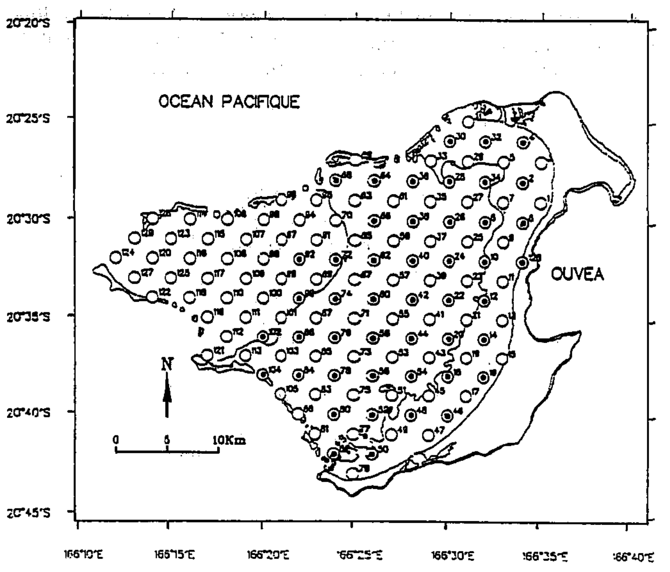


Figure 2: fishing (O) and visual census (●) stations

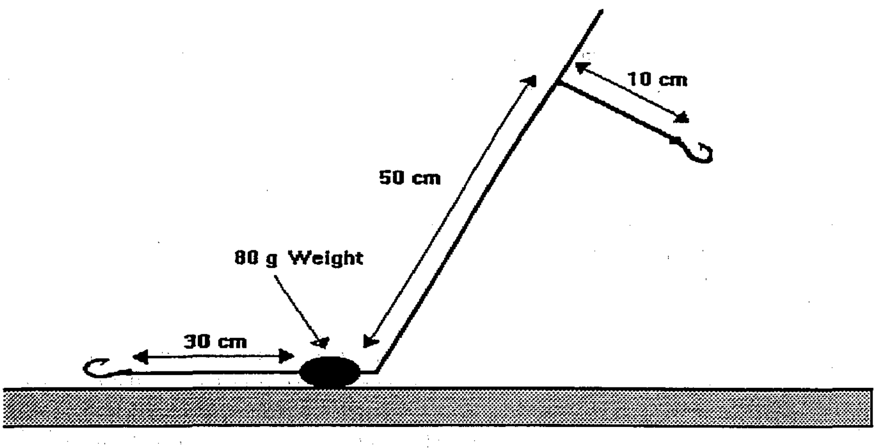


Figure 3: handline set used for the experimental survey.

Densities and biomasses were calculated from visual censuses according to the methods described by Burnham et al. (1980). For visual censuses fish weight were estimated from length-weight relationships (Kulbicki et al., 1994a).

RESULTS

FISHING

A total of 128 stations were sampled by fishing. The total catch was 3551 kg and 4012 fish. This yields an average of 27.7 kg and 31 fish per station. 57 species were captured (table 1), of which 23 were found on at least 5 % of the stations. Most species (44) have a commercial value, this high percentage being due to the absence of ciguaterra on Ouvéa. Indeed, 9 of the species caught are known to be ciguatoxic in other parts of New Caledonia. Most species belong to 3 families, Serranidae (10 species), Lutjanidae (10 species) and Lethrinidae (13 species). These three families also represent most of the catch in number and in weight, Lethrinidae being the most abundant (69% of the fish number, 56% of the fish weight). Lutjanidae represent 25% of the numbers and 16 % of the weight, Serranidae represent 12 % of the numbers and 13 % of the weight.

The CPUE in numbers for all species are indicated on figure 4. The lowest yields were in nearshore areas and the maximum in an area 10 km from the main island. The CPUE in weight (figure 5) and the average fish size (figure 6) indicate a marked increase with depth (Figure 1). The number of species caught per station follows the same trend (figure 7).

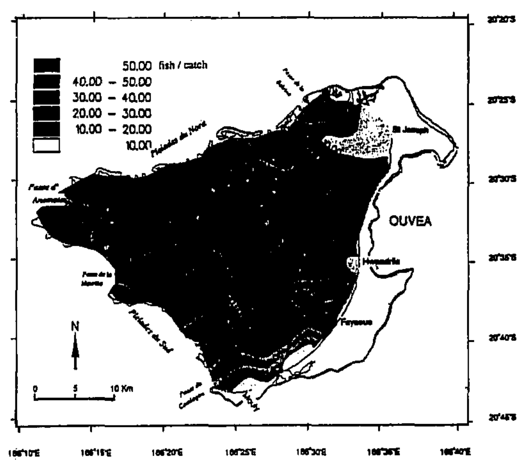


Figure 4: CPUE in numbers

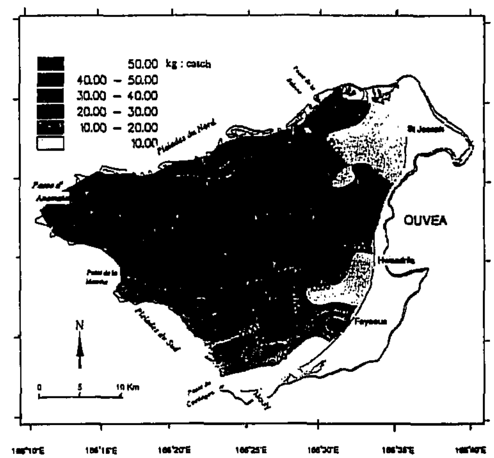


Figure 5: CPUE in weight

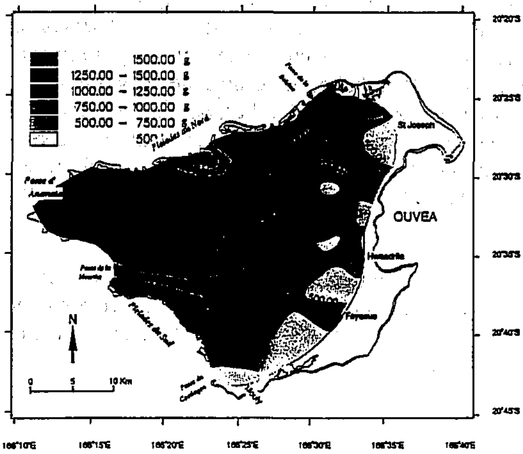


Figure 6: spatial distribution of average weight

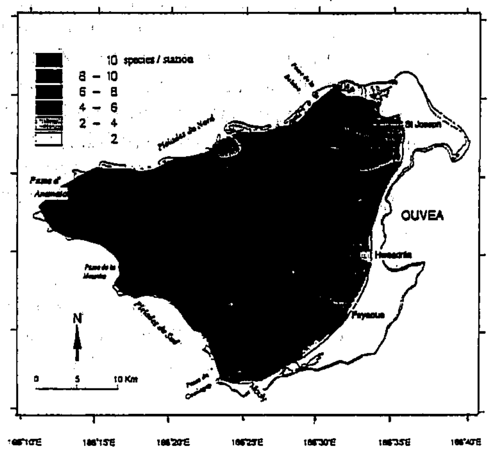


Figure 7: diversity of the catch

Table 1: catch per species at Ouvéa. Weights are in kg, non commercial species are noted by ** and ciguatoxic species elsewhere in New Caledonia are noted by +. Stations: number of stations where the species was caught.

Species	Number	Total weight	Average weight	Stations
CARCHARHINIDAE				
***Carcharhinus albimarginatus*	2	6.0	3.00	2
***Carcharhinus amblyrhynchos*	9	48.5	5.40	7
***Triaenodon obesus*	5	11.5	2.31	5
GINGLYMOSTOMATIDAE				
***Nebrius ferrugineus*	1	3.5	3.55	1
DASYATIDAE				
***Dasyatis kuhlii*	3	2.70	0.90	3
HOLOCENTRIDAE				
Sargocentron spiniferum	2	0.80	0.40	2
SERRANIDAE				
Cephalopholis miniata	2	0.80	0.41	1
Cephalopholis sonnerati	10	8.8	0.88	7
Epinephelus cyanopodus	57	169.6	2.97	40
Epinephelus fasciatus	12	2.93	0.24	8
Epinephelus macrospilos	12	2.33	0.19	9
Epinephelus maculatus	374	260.7	0.70	84
Epinephelus merra	4	0.23	0.06	4
Epinephelus polyphekadion	2	2.50	1.25	2
Epinephelus rivulatus	1	0.64	0.64	1

Species	Number	Total weight	Average weight	Stations
Variola louti	2	2.01	1.00	2
Total Serranidae	476	450	0.94	
ECHENEIDAE				
***Echeneis naucrates*	5	4.75	0.95	4
CARANGIDAE				
Carangoides chrysophrys	1	1.64	1.64	1
Carangoides fulvoguttatus	1	0.52	0.52	1
Caranx sexfasciatus	2	7.0	3.50	1
Decapterus russelli	1	0.30	0.300	1
LUTJANIDAE				
Aprion virescens	**36**	**114.2**	**3.17**	**19**
+*Lutjanus bohar*	**87**	**236.8**	**2.72**	**40**
+*Lutjanus fulviflamma*	15	6.17	0.41	9
+*Lutjanus gibbus*	**330**	**145.1**	**0.44**	**65**
Lutjanus kasmira	51	6.34	0.12	22
Lutjanus lutjanus	1	0.08	0.08	1
Lutjanus quinquelineatus	**341**	**34.9**	**0.10**	**78**
+*Lutjanus rivulatus*	2	17.9	8.95	2
Lutjanus russelli	5	2.06	0.41	2
Lutjanus vittus	31	19.3	0.62	18
Total Lutjanidae	899	582	0.65	
HAEMULIDAE				
Diagramma pictum	**58**	**122.2**	**2.11**	**36**
LETHRINIDAE				
Gymnocranius euanus	23	30.2	1.31	11
Gymnocranius grandocculis	1	4.05	4.05	1
Gymnocranius species	29	35.3	1.22	19
Lethrinus atkinsoni	**645**	**384.1**	**0.60**	**88**
Lethrinus genivittatus	6	0.47	0.08	5
Lethrinus nebulosus	**1394**	**1438**	**1.03**	**103**
Lethrinus obsoletus	1	0.15	0.15	1
+*Lethrinus olivaceus*	**41**	**167.2**	**4.08**	**23**
Lethrinus rubrioperculatus	**293**	**138.7**	**0.47**	**70**
Lethrinus species	1	0.12	0.12	1
Lethrinus variegatus	6	0.36	0.06	4
Lethrnius xanthochilus	23	37.7	1.64	19
Total Lethrinidae	2465	2238	0.91	
SPHYRAENIDAE				
+*Sphyraena barracuda*	5	1.06	0.21	2
+*Sphyraena forsteri*	50	25.2	0.50	31
+*Sphyraena putnamie*	3	6.55	2.18	2
LABRIDAE				
Bodianus perditio	1	3.0	3.0	1
BALISTIDAE				
***Balistoides viridescens*	2	7.42	3.71	2
***Pseudobalistes fuscus*	9	19.7	2.19	8
***Sufflamen fraenatus*	5	2.28	0.46	4
TETRAODONTIDAE				
***Arothron hispidus*	2	1.80	0.90	2
***Lagocephalus sceleratus*	2	1.10	0.55	1
TOTAL	**4012**	**3551**	**0.88**	

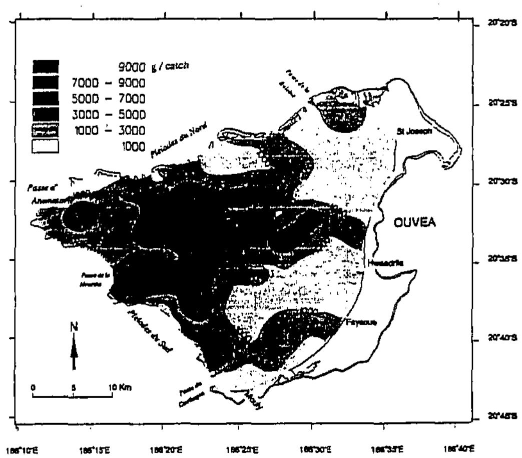
There are important differences between species in the spatial distribution of the catch.

a) **Serranidae** (groupers) : The catch of this family is dominated by two species, *Epinephelus maculatus* and *E. cyanopodus* (together they represent 90 % in numbers and 96 % in weight of the groupers caught). The distribution of these fish (figures 8 and 9) clearly shows a concentration in the deeper part of the lagoon. There is a correlation between fish size and depth, large fish being also caught near the passes.

b) **Lutjanidae** (snappers) : The catch of this family is dominated by four species. *Aprion virescens*, *Lutjanus bohar* and *L.gibbus* dominate the catch in weight, the fourth species, *L.quinquelineatus*, being only important in the catch in numbers. These fish have very different biological characteristics and this is reflected in the distribution of their catch. *Aprion virescens* is a very active hunter and will travel great distances. It is seldom found in great numbers, except during the reproductive season. The distribution of the catch of this species is very patchy. There is no correlation between the size or the number of fish caught with depth or the proximity of reefs. *L.bohar*, is usually found in small numbers around isolated patch reefs. The catch distribution of this species (figure 10) indicates that this species tends to be restricted to the deeper parts of the lagoon. Most small fish (which were scarce in the catch) were caught in waters less than 10 m deep. *L.gibbus* is typically a reef associated species and is often associated in reef passes. This is well illustrated by the distribution of its catch (figure 11). *L.quinquelineatus*, a small schooling species, is one of the few species which was caught preferentially nearshore (figure 12). The smallest of these fish were often caught in deeper waters, however, visual censuses on the barrier reef indicate that most of the smaller fish are found in shallow waters.

c) **Lethrinidae** (emperors) : Three species dominate this family, *Lethrinus nebulosus*, *L.atkinsoni* and *L.rubrioperculatus*. *L.nebulosus* is the major species caught by handline. It made alone 35 % of the catch in numbers and 40% in weight. This species is found mainly on sandy bottoms, seldom on reefs. This is reflected by the distribution of the catch, most fish being caught in the center of the lagoon (figure 13). There is a good correlation between fish size and depth, the smaller individuals being caught nearshore and the largest in the central part of the lagoon in depths of 20 to 35 m. *L.atkinsoni* has some affinities with *Lutjanus gibbus* in its distribution. Indeed, these fish are usually associated with reefs and tend to concentrate near passes. This is again reflected in the distribution of the catch (figure 14). The larger fish are usually caught in the deeper part of the lagoon and near passes. *L.rubrioperculatus* is usually found in small patches, seldom in schools, except the juveniles. During daytime it tends to shelter in areas with rubble at the base of reefs. The catch indicates (figure 15) that this species is mainly found near passes. The young prefer shallow waters. The other Lethrinidae caught (*Gymnocranius spp.*, *L.olivaceus*, *L.xanthocheilus*) prefer deep waters, the *Gymnocranius* being found on sand near passes, *L.olivaceus* and *L.xanthocheilus* being reef associated, but the former has a tendency to travel large distances.

The only other fish of some importance in the catch are *Diagrama pictum* (sweetlip) and *Sphyranea forsteri* (barracuda). It is rather unusual to catch *D.pictum* on handlines in New Caledonia, whereas this species is frequently caught in Queensland, thus indicating that behavior may change with locality. *Sphyraenea forsteri* was much more abundant than indicated by the catch composition, this species tending to cut the lines.



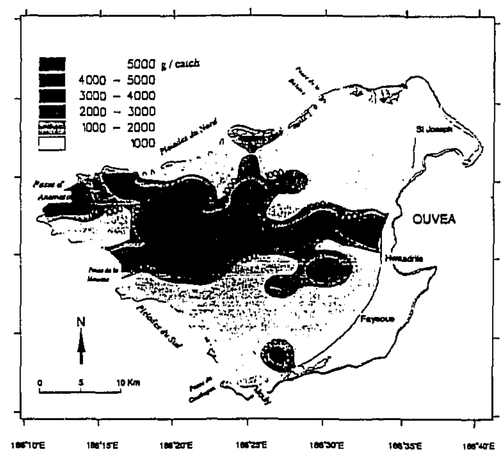
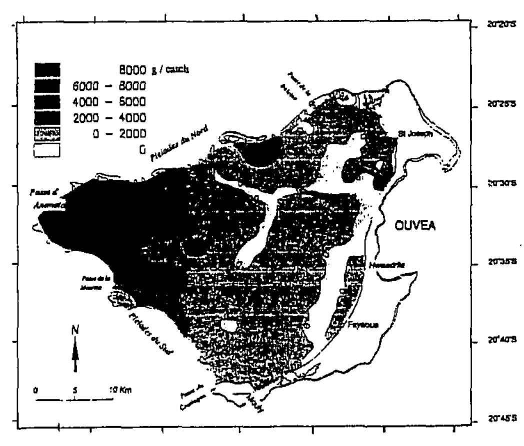


Figure 8: CPUE in weight of *E.maculatus*

Figure 9: CPUE in weight of *Epinephelus cyanopodus*



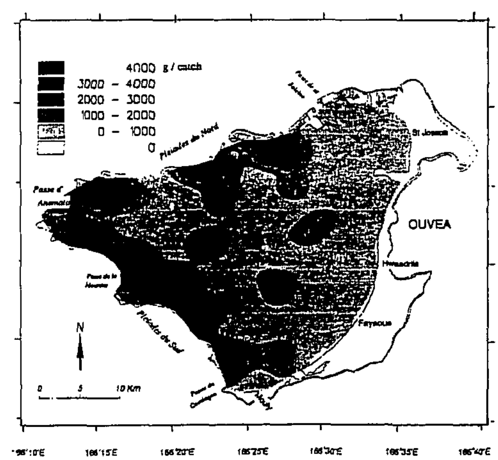


Figure 10: CPUE in weight of *Lutjanus bohar*

Figure 11: CPUE in weight of *L.gibbus*

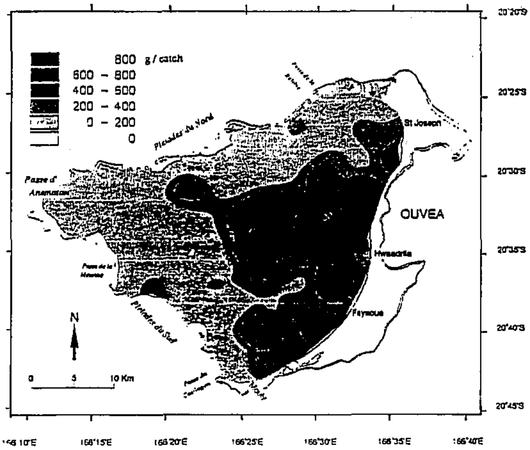


Figure 12: CPUE in weight of *L.quinquelineatus*

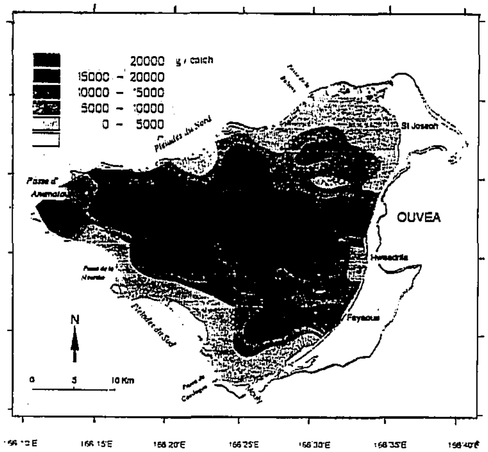


Figure 13: CPUE in weight of *Lethrinus nebulosus*

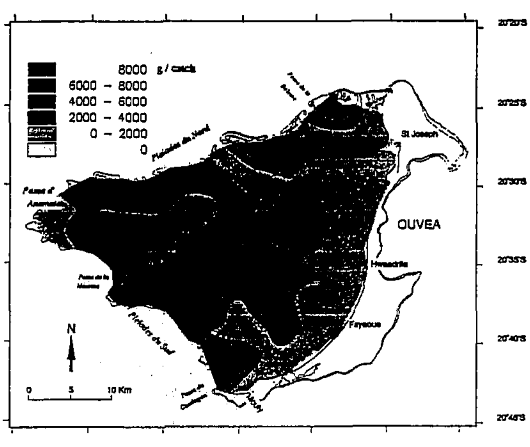


Figure 14: CPUE in weight of *L.atkinsoni*

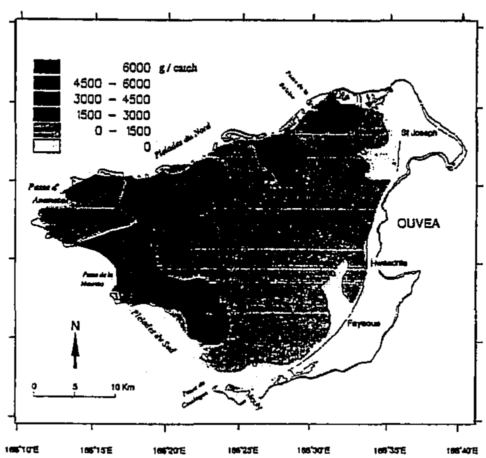


Figure 15: CPUE in weight of *L.rubrioperculatus*

VISUAL CENSUSES

A total of 220 species distributed among 38 families were observed underwater on the lagoon bottom. The densities and biomasses of the major species and families are presented in table 2. On average fish are small species (average weight 28 g). Most of the density is made of these small species, the commercial species making only 3.3 % of this density. Conversely, commercial species form 66% of the biomass. Most of the commercially important species are catchable by handline (80% of the biomass and 58% of the density of commercial species). It should be noted that a number of species considered as commercially important in New Caledonia may have little or no value elsewhere (i.e. Scaridae or Acanthuridae have little value in Australia), while, some species which are not eaten in New Caledonia may be important elsewhere (i.e. the Caesionidae have no value in Ouvéa, whereas they are popular for in the Philippines or Indonesia).

Table 2: density, biomasses, frequency and average size for fish from the major families observed during the visual censuses. Nb species: number of species in a family; Nb stations: number of stations where a species was observed; NB /occurence: average number of fish seen per observation. Average size in cm. Average weight in g. Density in fish / m². Biomass in g/m².

Species	Nb species	Nb Stations	Nb / Occurence	Average size	Average weight	Density	Biomass
SERRANIDAE							
Epinephileninae	12	41			430	0.0142	6.170
Cephalopholis miniata		9	1.80	32	570	0.0005	0.143
Epinephelus cyanopodus		17	1.56	55	3350	0.0016	2.715
Epinephelus maculatus		29	1.59	33	585	0.0060	1.747
Epinephelus merra		12	1.09	13	40	0.0021	0.042
Anthiinae	4	39				0.3933	0.924
Pseudanthias hypselosoma		23	51	6.5	5	0.3877	0.921
total Serranidae	16	39			18	0.4019	7.091
APOGONIDAE							
total Apogonidae	13	33	44	6.5	4.5	0.6535	0.3796
LUTJANIDAE							
Aprion virescens		20	1.48	58	3030	0.0029	4.371
Lutjanus kasmira		7	19	13	45	0.0039	0.089
total Lutjanidae	7	26	3.6		540	0.0087	4.706
CAESIONIDAE							
total Caesionidae	5	26	193	12	25	0.7906	11.58
HAEMULIDAE							
Diagramma pictum		7	3.3	47	1525	0.0029	2.243
total Haemulidae	5	9	2.9	45	1710	0.0034	2.875
LETHRINIDAE							
Lethrinus nebulosus		5	29	35	790	0.0063	2.472
total Lethrinidae	9	16	15	37	910	0.0118	4.905
MULLIDAE							
Parupeneus barberinoides		8	1.7	10	23	0.0032	0.0378
Parupeneus trifasciatus		26	7.2	10.5	26	0.0293	0.3829
toral Mullidae	11	38	6.1	13	35	0.0506	1.001
CHAETODONTIDAE							
Chaetodon auriga		11	1.6	12	57	0.0023	0.0667
Heniochus acuminatus		17	1.8	16	175	0.0012	0.1052
total Chaetodontidae	12	34	1.5	12	48	0.0114	0.2504

Species	Nb species	Nb Stations	Nb / Occurence	Average size	Average weight	Density	Biomass
POMACENTRIDAE							
Chromis spp.	9	10	23	5.5	5	0.0554	0.1459
Dascylus spp.	4	46	8.8	5.1	4.5	0.1663	0.4047
Pomacentrus spp.	7	46	6.7	6.2	6	0.1532	0.4310
total Pomacentridae	25	47	8.1	5.7	5.5	0.3812	1.0004
LABRIDAE							
Cheilinus bimaculatus		16	1.5	7.5	8	0.0058	0.0223
Halichoeres trimaculatus		23	1.5	9	11	0.0040	0.0214
Thalassoma spp	5	38	2.4	10	13	0.0196	0.1218
total Labridae	23	39	2.0		180	0.0400	1.388
SCARIDAE							
Scarus ghobban		15	1.9	38	1660	0.0016	1.2898
total Scaridae	13	27	3.1	27	615	0.0135	2.5654
ACANTHURIDAE							
Acanthurus spp.	10	24	2.8	27	760	0.0108	3.2600
Naso spp.	4	15	2.7	30	1080	0.0031	1.4765
total Acanthuridae	15	24	2.7	29	820	0.0144	4.7385
BALISTIDAE							
Pseudobalistes fuscus		13	1.0	38	1800	0.0006	0.5097
Sufflamen chrysopterus		20	1.2	15	95	0.0078	0.3719
total Balistidae	7	25	1.5	18	285	0.0091	1.1072
TOTALall species	220	47			28	2.012	56.17
TOTAL commercial species		47			550	0.0670	37.26
% total all species						3.3	66.3
TOTAL line species		44			770	0.0389	29.91
% total all species						1.9	53.2

The species richness is on average of 26 species /station. This parameter increases with depth and near passes (figure 16). This spatial distribution has many analogies with the distribution of the number of species in the catch (figure 7). The density of fish seen also increases with depth (figure 17), however there is a maximum found off Hwaadrila. This is due to small planktivorous species, essentially Caesionidae and Anthiinae. This concentration is further offshore than the concentration observed in the CPUE in numbers (figure 4). The distribution of the biomass increases also with depth (figure 18). Passes increase biomasses, whereas they had a weaker effect on the distribution of the CPUE in weight (figure 5). The distribution of average weight (figure 19) indicates that fish are larger offshore, with an exception in the SE part of the lagoon.

A comparison of the commercial species seen during the visual censuses and caught during the experimental fishing indicates many differences.

a) **Serranidae:** Twelve species of groupers were observed on the transects. Of these, *E.maculatus* and *E.cyanopodus* were the most common, all the other species, except *E.merra*, a small widespread species, were observed occasionally. Groupers were never seen in large densities, the highest value being 480 fish /ha and the average 142 fish /ha. The highest concentrations are mainly near the barrier reef. Groupers are large fish, this results in relatively high biomass values (6.2 g /m^2 on average, 11% of all the biomass and 20.6% of handline fish). Most of the smaller fish are seen near the coast, whereas the large fish are usually in more than 10 m of waters. Groupers are usually neutral toward divers, neither curious or scared, but their cryptic colors do not make them always easy to detect. It is however likely that the estimates from visual censuses are accurate for this family, especially for the two major species.

b) **Lutjanidae:** Only 7 species of snappers were seen underwater. *Aprion virescens*, the species with the highest commercial value in this family, was observed on 20 stations, mainly in the middle and south of the lagoon. A large concentration of these fish, probably spawning, was also found in the northern part of the lagoon. This species travels large distances and is very curious towards divers. It would therefore be possible that its density estimate from diving is overevaluated. The other major species observed is *L.quinquelineatus*. This fish is found in large schools near isolated rocky formations. It is found mainly nearshore, as the catch has also indicated. The only other Lutjanidae found in some numbers was *L.gibbus*, of which a large school was found near a pass. Most of the snappers caught were fished in waters deeper than those surveyed by visual census, especially *L.bohar* and *L.gibbus*. Lutjanidae are usually easily detected under water. Most of them are conspicuous (except *A.virescens*), they often school and are not scared by divers. Therefore visual census estimates are likely to be accurate, except for *A.virescens*.

c) **Lethrinidae:** Emperors were seldom seen during the dives on the lagoon bottom. These fish are difficult to see on sandy bottom, especially if the water is not very clear. However, when observed, they were not particularly shy. The two major species censused during the dives were *L.nebulosus* and *L.olivaceus*. The former species was usually seen in small schools of up to 20 fish, with the exception of one large school. There is no special trend in the distribution of this species according to the dives. *L.olivaceus* was always seen solitary or in groups of less than 3 fish, most of the observations being made in the center of the lagoon. Lethrinidae make only 8.7 % of the total biomass and 16.4% of the biomass of handline catchable species, whereas these fish made 63% of the catch.

d) **others:** Among the other species caught by handlines and observed underwater only *Diagramma pictum* was censused in any number. This species was seen in the same areas than where it was caught. This fish is very conspicuous underwater, forming small schools around isolated rocky formations.

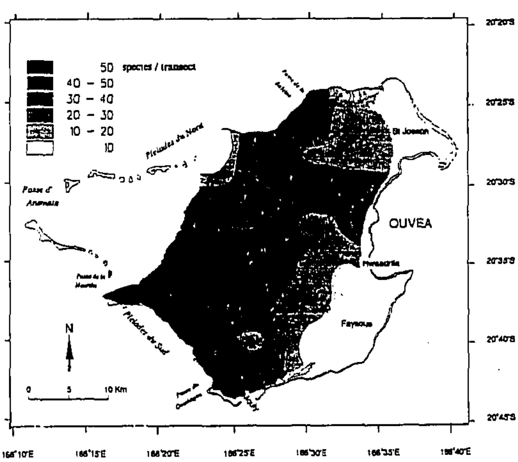


Figure 16: distribution of species richness from transects

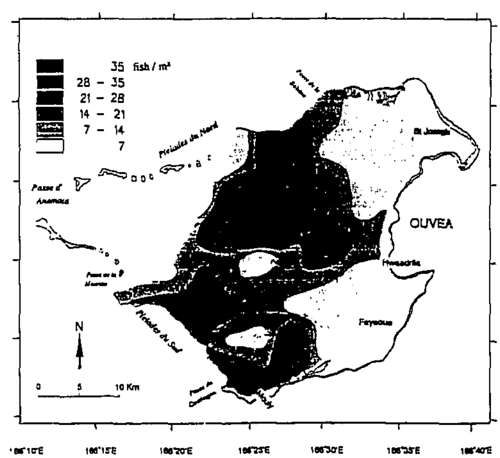


Figure 17: distribution of density from transects

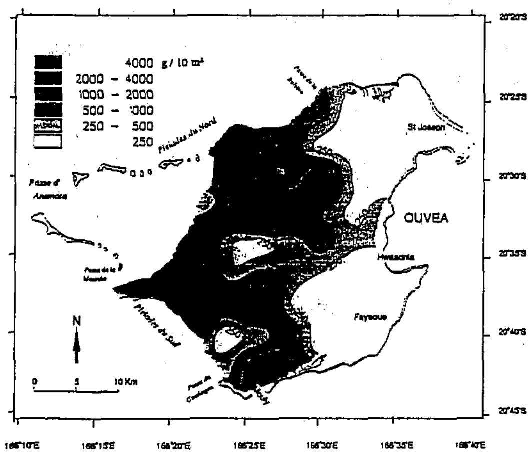


Figure 18: distribution of biomass from transects

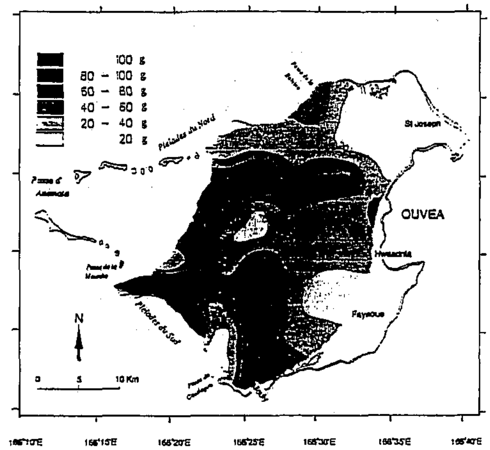


Figure 19: distribution of average weight from transects

CORRELATION BETWEEN FISHING AND VISUAL CENSUSES

All the visual censuses on the lagoon bottom took place on a fishing station. It is possible to estimate biomasses and densities from visual censues but not directly from experimental handline fishing. In order to make density and biomass estimates of fish in areas where visual censuses could not take place, it is necessary to correlate biomass and density estimates from visual censuses to the CPUE in number and weight.

a) **comparison of sizes** : The size estimates of the fish seen underwater and the measured size of the fish caught by handline are usually remarkably close when numbers are sufficient (table 3). There are a few exceptions. *L.bohar* was larger in the catch than estimated from the censuses. This is due to the concentration of the larger *L.bohar* in deeper waters where dives were not performed. *Diagramma pictum* is seldom caught under 40 cm, whereas many small fish (30 to 40 cm) are seen underwater. On the opposite, large sharks were seen underwater, but were not caught on our light tackle.

b) **correlations between densities and biomasses from visual censuses with CPUE** : There are several ways to compare these two sets of data. If all fish are considered (table 4), the only significant correlation is on a log scale between biomass and CPUE in weight. The correlations are slightly improved if one looks only at the commercial species in the visual censuses (table 5). However, with the exception of the Lutjanidae, the correlations at the family level are very poor.

Table 3 : Average weight of fish caught by handline and estimated weights (g) from visual censuses.
N: number of fish sampled. VS: visual census

Species	N -VS	Weight VS	N fishing	Weight VS
Nebrius ferrugineus	1	26400	1	3550
Triaenodon obesus	1	18000	1	1500
Dasyatis kuhlii	9	1565	2	645
Sargocentron spiniferum	10	430	1	500
Cephalopholis sonnerati	18	700	2	890
Epinephelus cyanopodus	53	3350	15	3040
Epinephelus fasciatus	13	150	4	260
Epinephelus macrospilos	9	90	4	160
Epinephelus maculatus	161	585	151	646
Epinephelus merra	25	40	1	80
Variola louti	9	1290	1	1150
Carangoides fulvoguttatus	161	3900	1	520
Decapterus russellii	6	100	1	300
Aprion virescens	92	3030	10	3227
Lutjanus bohar	9	380	16	2095
Lutjanus gibbus	1	575	120	385
Lutjanus kasmira	194	45	12	105
Lutjanus quinquelineatus	9	70	142	101
Lutjanus vittus	14	605	14	591
Diagramma pictum	60	1530	21	2120
Gymnocranius spp.	33	1210	10	1196
Lethrinus olivaceus	5	4200	5	3600
Lethrinus atkinsoni	1	1350	297	539
Lethrinus nebulosus	317	790	425	915
Lethrinus rubrioperculatus	4	290	80	487
Bodianus perditio	10	2890	1	3000
Pseudobalistes fuscus	18	1790	3	2116
Sufflamen fraenatus	9	700	1	740
Arothron hispidus	4	1450	2	900

Table 4: Correlation coefficient between catch statistics and visual transect results. 43 stations are taken into account, 3 stations being at more than 2 standard deviations from the mean were not considered. ln: logarithm base e
* : $\alpha < 0.05$ ** : $\alpha < 0.01$

	Number of species	Density	Biomass	Average weight	ln Density	ln Biomass
Species/catch	0.25					
Fish/catch		0.14				
Weight/catch			0.16			
Average weight				0.33*		
ln number fish			0.27		0.27	
ln weight			0.29			0.49**

Table 5: Correlation coefficient between catch statistics and visual transect results for handline species.
Only stations where observations were made are taken into account (number between brachets). ln : logarithm base e
* : $\alpha < 0.05$ ** : $\alpha < 0.01$

	Number of species	Density	Biomass	Average weight	ln density	ln biomass
species/catch total (46)	0.38**					
Serranidae(39)	0.08					
Lethrinidae (16)	0.30*					
Lutjanidae (45)	0.53**					
number /catch total (46)		0.12			0.19	
Serranidae (39)		-0.02			-0.08	
Lethrinidae (16)		-0.39			-0.34	
Lutjanidae (45)		0.38**			0.33*	
Weight/catch total (46)			0.12			0.39**
Serranidae (39)			0.04			0.18
Lethrinidae (16)			-0.35			-0.26
Lutjanidae (45)			0.58**			0.50**
Average weight (46)				0.37*		
Serranidae (39)				0.15		
Lethrinidae (16)				0.56*		
Lutjanidae (45)				0.53**		
ln number total (46)		0.15			0.21	
Serranidae (39)		0.02			-0.08	
Lethrinidae (16)		-0.49			-0.42	
Lutjanidae (45)		0.35*			0.31*	
ln weight total (46)			0.15			0.49**
Serranidae (39)			0.06			0.16
Lethrinidae (16)			-0.40			-0.27
Lutjanidae (45)			0.58**			0.50**

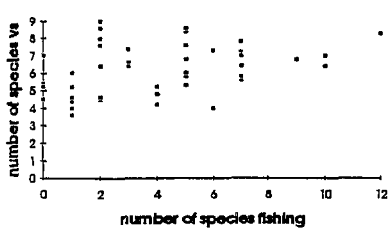


Figure 20 : correlation between the number of species seen underwater and the number of species caught during the experimental fishing.

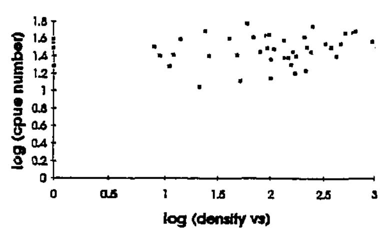


Figure 21: correlation (log scale) between the density of fish seen underwater and the number of fish caught

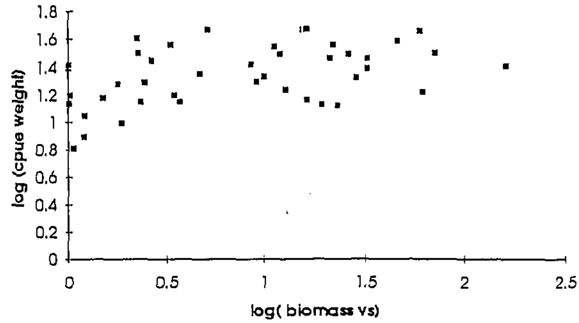


Figure 22: correlation (on a log scale) of the biomass of fish seen with the weight of the fish caught; $r = 0.70$ $\alpha = 0.0015$

Figures 20 to 22 show that there is a high dispersion in the correlations between visual censuses and fishing. There are a number of reasons for this. First, the visual censuses and the fishing did not necessarily take place the same day. Second, the visual census and the fishing were not always on the exact same place, distances between the two surveys varying up to 500 m. Knowing the high spatial variation of the substrate (Kulbicki et al., 1994b) and therefore of the fish populations, it is not surprising that the correlations are low. Schooling is another important factor. Many fish school during the day and disperse at night. Consequently, if these fish are detected on the transects during the day, chances are that only a small proportion will be caught during the night. By contrast, some fish disperse during the day and school at night. If a schools starts to bite, then chances are that large numbers of these fish will be caught, much higher than what visual censuses would predict.

In order to improve the quality of the correlation between visual censuses and fishing, an attempt was made to group the stations into zones. A first grouping of the stations into zones of a 6 mile radius (3 x 3 fishing stations) did not improve significantly the correlations. A second attempt was made by grouping the stations according to the depth gradient. This grouping had no influence on the level of significance (α) of the relationships between visual censuses and fishing for species number or densities. The correlation between biomasses and cpue in weight improved significantly (figures 23 a,b).

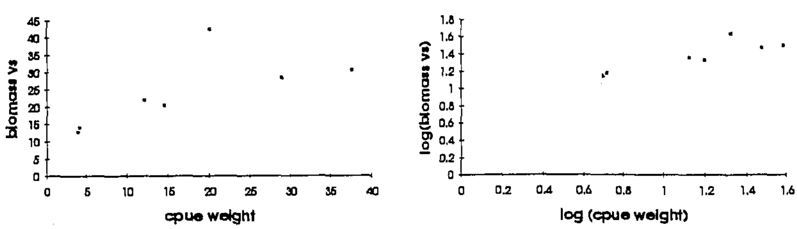


Figure 23: correlation between biomass estimates from visual censuses and the cpue in weight. The stations are grouped into depth zones.

a) normal scale $r = 0.68$ $\alpha = 0.05$ b) log scale $r = 0.86$ $\alpha = 0.002$

STOCK ESTIMATES

a) all fish

a1) *estimate from visual censuses alone*: if one considers that visual censuses give a good estimate of biomass for the entire lagoon, it is possible to calculate the stock S of line fish as

S = A x b where A = surface of the lagoon and b = biomass per unit of area

A = 844 km^2 and b = 29.91 t / km^2 therefore S = 25 244 tonnes

The confidence interval at the 95% level on b is [7.3 t /km^2; 56.9 t/km^2]
therefore the confidence interval for S is [6 668 t; 48 023 t]

This first estimate does not take into account the spatial variations of b. Unfortunately, we do not have estimates of b for the stations beyond 25 m of depth. The only way to estimate b for those stations is to use the correlation between cpue in weight and biomass.

a2) *estimate from the combination of visual censuses and experimental fishing*: two relationships were calculated between biomass estimates b and cpue in weight. The first one considers all the visual census stations

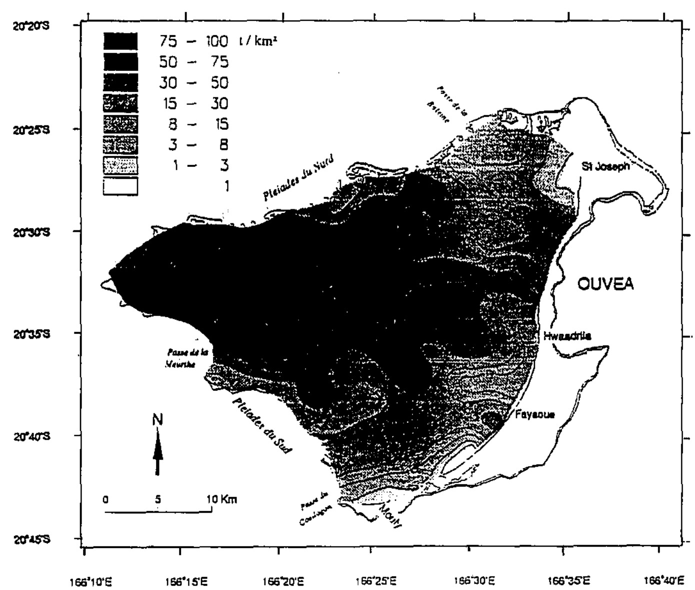


Figure 24: spatial distribution of the biomass from estimates based on equation (1)

(1) ln (biomass) = 5.538 (± 0.49) + 1.819 (± 0.155) ln (cpue weight) r = 0.486 N = 46

(biomass are in g /ha and cpue in weight are in kg; the numbers between brackets are the confidence intervals at the 95% level for the slope and intercept estimates). From this relationship it is possible to estimate the biomass (b_i) for each fishing station i. Knowing the area (a_i) covered by each fishing station it is then possible to estimate S:

$$(2) \qquad S = \sum_{i=1}^{129} a_i \times b_i$$

with a confidence interval based on the Bonferoni method (Neter and Wasserman (1974),

the estimated value is then S = 11 950 tonnes, the confidence interval at 95 % of S is [1 265t; 35 200t]. The spatial distribution of S is given on figure 24.

This is a very wide interval. It can be reduced by using the results of figure 22 b. The equation of the relationship between biomass and cpue is :

$$(3) \qquad \log(\text{biomass}) = 0.455\ (\pm 0.132) \log(\text{cpue wieght}) + 0.857\ (\pm 0.158) \qquad r = 0.86 \qquad N = 7$$

(biomass in g /m^2 and cpue in kg /station ; the numbers between brackets are the confidence intervals at the 95 % level for the slope and intercept estimates). From this relationship it is possible to estimate bi and use equation (2) to get a value for the total stock S

S = 8080 tonnes with a confidence interval at 95 % [4 470t; 14 760t]. The spatial distribution of S varies only little from the map given on figure 24.

b) per species

There are two ways of estimating the stock per species. Either, one considers that the visual censuses give an accurate image of the fish community and then one may use the contribution of each species to the biomass to estimate the stock of each species. Or, one considers that fishing gives the best image of the fish community and then the contribution of each species to the catch is used to evaluate its stock.

The total stock estimate used for the evaluation of the stock per species is the one given by equation (3). The estimates per species are given in table 6.

One notices that each method gives widely different results. There are only three species (*E.cyanopodus*, *E.maculatus* and *Gymnocranius* spp.) for which the results of the two methods agree. These three species are fish which tend to stay motionless during daytime and which do not form large schools. The other fish present two trends. Some are well detected but not caught in the same proportions, it is essentially the case of conspicuous fishes which form schools (*L.bohar*, other Lutjanidae, *Diagramma pictum*) or which swim actively and are curious towards the divers (*A.virescens*, Carangidae). Others are caught in proportions which are much higher than what the visual censuses predict. These are essentially large Lethrinidae and *L.gibbus*. We have no explanation for this low detection rate or high fishing vulnerability. These fish, when seen underwater, are usually in small to average schools (5 to 200 fish), they are not particularly shy but can be difficult to discriminate from their surroundings. A number of observations on the behaviour of these fish toward fishing (Kulbicki et al. 1994a) suggest that they stay in the deeper parts of the lagoon or in the passes during daytime and that they travel some distances between day and night. These fish tend also to get into "biting frenzies", during which a large number of fish of a same species are caught in a limited amount of time. It is therefore likely that for these large Lethrinidae and *L.gibbus*, the actual stock is intermediate between the values given by visual censuses and by fishing.

Table 6 : stock estimates (tonnes) for the major commercial species (line fishing) in the atoll of Ouvéa. VS: visual census. L95 indicates the lower confidence interval and H95 the upper confidence interval at the 95% level. For a given method, if the mean value is not included in the confidence interval of the other method it is printed in bold.

Species	VS mean	VS L95	VS H95	Fishing mean	Fishing L95	Fishing H95
Epinephelus cyanopodus	564	312	1030	341	189	623
Epinephelus maculatus	422	234	772	525	290	959
Other Serranidae	***679***	376	1241	80	44	146
Carangidae	***1034***	572	1888	19	10.5	35
Aprion virescens	***1187***	657	2169	229	127	420
Lutjanus bohar	***997***	541	1786	476	263	871
Lutjanus gibbus	74	41	135	***292***	161	533
Other Lutjanidae	***759***	420	1387	173	96	316
Diagramma pictum	***596***	330	1088	246	136	450
Gymnocranius spp.	117	65	214	140	77	256
Lethrinus atkinsoni	392	217	715	***773***	427	1413
Lethinus nebulosus	548	303	1000	***2896***	1602	5290
Lethrinus olivaceus	166	92	303	***337***	186	615
Lethrinus rubrioperculatus	7.7	4.3	14	***279***	154	510
Other Lethrinidae	***417***	230	761	82	45	149
Sphyraenidae	13	7.2	24	***66***	37	121
Bodianus perditio	***125***	69	229	6	3.3	11

DISCUSSION

The major problem when assessing a fish stock is to use the most adequate method. In the present case, the presence of large rock formations on the bottom prevented the use of nets (trawling, gillnets, tramels). Kulbicki (1988) had successfully used longlines to evaluate commercial line fish stocks in the SW lagoon of New Caledonia. The same method gave mediocre results in Ouvea for some unknown reason (Kulbicki et al., 1994a) and had to be abandonned in favor of line fishing. However, line fishing alone gives only a relative index of abundance and therefore has a limited use for a stock assessment. The visual censuses by enabling a correlation between the cpue and the visual estimates of biomass greatly enhance the power of the fishing results. However, visual censuses and line fishing both have biases. Some species are caught but not seen and others are seen but not caught. Kulbicki (1988) encountered the same problem when correlating bottom longline catches with visual censuses. There is unfortunately no way to eliminate these biases and this limits the power of the method. At best, one can take compromised values between visual census and fishing results, but this carries much subjectivity. On the other hand, to our knowledge, there are no better method available at the moment in this type of environment (no tag - recapture possible, almost no commercial fishing, too many species for camera or accoustic surveys).

The correlations between visual censuses and fishing could have been greatly improved if the two experiments had been carried out on each station the same day and on the exact same location. Kulbicki (1988), using longlines and visual censuses, performed both methods simutaneously, which resulted in a much better correlation ($r = 0.864$ $N = 45$ $\alpha < 0.0001$). However, some species, such as the large mobile Lethrinidae gave the same problems than in Ouvéa, large catches but low detection. In the case of the SW lagoon (Kulbicki, 1988), the stock estimates based on visual censuses alone could hardly account for the commercial catch of these species in the same area. Therefore, visual censuses greatly underestimate these species, but it is not yet possible to know by how much.

The equations given to calculate biomasses from cpue should not be applied without much caution to other regions. Indeed, even if one used the very same method to fish, there are differences in the behaviour of a same species from one region to another. These equations are also based on a given ratio between observed and fished species. This ratio is more than likely to change from one place to another. However, for a very gross estimate one could use equation (3) if fishing conditions are identical and the propotions of Lethrinidae, Lutjanidae and Serranidae in the catch are close to those observed in Ouvéa.

Table 7: yields for line fishing on tropical reefs. All yields are expressed as kg/hour/fisherman

Place	Yield	References
Ouvéa	6.9	present study
New Caledonia SW lagoon	10.0	Loubens (1978)
New Caledonia SW lagoon	2.6	Kulbicki et al. (1987)
Chuuk (ex. Truck)	2.3	Diplock et Dalzell, 1991
Guam - Lagon	0.9	Hosmer, 1980
	1.5	Molina, 1982
Nauru	5.8	Dalzell, unpubl.
Norfolk	13.6	Grant, 1981
Palau - reef	5.1	Anon., 1990a, 1991b
PNG - Lagon exploited area	1.2	Wright et Richards, 1985
PNG - Lagon virgin area	3.9	Wright et Richards, 1985
PNG - Port Moresby	2.5	Lock, 1986
Samoa - Lagoon	0.9	Wass, 1982
Yap	1.7	Anon., 1987
Australia NW	15.6	Stehouwer, 1981
Carribbean - 10-20m	1.7	Munro, 1983
20 - 30m	1.6	
30 - 40m	2.6	
40 - 60m	1.1	
Kenya	4.7 à 7.5	FAO, 1981
Maldives	2.4	Anderson et al., 1991
Seychelles	4.4	de Moussac, 1987

The catch rates in Ouvéa are high compared to many other places in the Indo-Pacific (table 7). In this type of comparison, one should however be cautious because experimental conditions play a very important role in the results. At Ouvéa fishing spots were taken at random, which should decrease the yields compared to studies where places were chosen according to their fishing potential. On the other hand, in Ouvéa, fishing time was chosen to maximize yields (sunset is usually the best fishing time in that lagoon). The increase of yields with depth in Ouvéa is comparable to the findings of Kulbicki et al. (1987) in the SW lagoon of New Caledonia, but Munroe et al. (1983) did not find such a correlation in the Carribeans. The increase of fish size with depth is particularly noticeable in Ouvéa, but was also noted in the SW lagoon by Kulbicki et al. (1987).

The dominance of Lethrinidae, Lutjanidae and Serranidae in the catch is a common trait to all the line fishing in shallow waters of the tropical Pacific (see reference of table 7). A comparison with the nearby SW lagoon of New Caledonia (table 8), indicates that all the major species caught in Ouvéa (*L.nebulosus, L.atkinsoni, L.rubrioperculatus, E.maculatus, E.cyanopodus, D.pictum*) are also the most common species for line fishing in the SW lagoon. Conversily, some common species of the SW lagoon are rare or absent in the catch at Ouvéa (*E.aerolatus, E.rivulatus, L.adetii, L.miniatus, Bodianus perditio*).

Only few species show the opposite trend, being frequently caught in Ouvéa but not in the SW lagoon (*L.bohar,L.gibbus, L.quinquelineatus, L.olivaceus, S.forsteri*). For some of these species the differences come from the effective scarcity of the fish either in the SW lagoon or in Ouvéa. For instance, *E.aerolatus, E.rivulatus, L.adetii* and *L.miniatus* were seldom, if at all, seen on the transect in Ouvéa. For other species (*L.bohar, L.quinquelineatus, S.forsteri* in the SW lagoon, *B.perditio* in Ouvéa) it could be differences in behaviour which explain the differences between the two regions, because these fish are present in both lagoons.

A comparison of average weights with the SW lagoon indicates that most common species (*E.maculatus, A.virescens, L.bohar, D.pictum, L.atkinsoni, L.nebulosus*) have a larger weight in the SW lagoon (table 8). Only *E.cyanopodus, L.vittus* and *G.euanus* have larger average size in Ouvéa. These variations may be genetic (Ouvéa is fairly isolated from the mainland) or ecological. For *L.nebulosus* it was demonstrated that other important biological traits were also different, thus sexual maturity is reached at 800 g in Ouvéa and 2700 g in the SW lagoon (Egretaud, 1992).

There are very few other works using visual censuses for demersal fishes (the litterature is abundant for reef fishes). The only comparable data sets that we know of are from the SW lagoon of New Caledonia (Kulbicki et al., 1994a) and from the Chesterfield islands (Kulbicki et al., 1990). Species richness is the highest in the SW lagoon (330 species), followed by Ouvéa (220 species) and the Chesterfield islands (143 species). This trend is in part due to a larger sampling effort in the SW lagoon, but it is likely that there is a correlation between species richness and isolation from the New Caledonian mainland. Some families are little if at all represented in Ouvéa (Leiognathidae, Nemipteridae, Synodontidae). These families are characteristic of soft bottoms with fine sediment. The number of species per transect is similar in Ouvéa (26 species/transect) and the SW lagoon (22 species /transect). Ouvéa has the highest densities of fish, the numbers being twice as high as in the SW lagoon (0.92 fish /m^2) and six times as high as in the Chesterfield islands (0.30 fish / m^2). Biomasses are comparable in all three regions (57.6 g /m^2 in the SW lagoon; 41.5 g /m^2 in the Chesterfield islands), as a consequence average weights are the highest in the Chesterfield islands and the lowest in Ouvéa.

In Ouvéa, there are less "important" species (fish forming more than 2% of the biomass) than in the SW lagoon. As already indicated by the line fishing results the average size of these important species is usually less in Ouvéa than in the SW lagoon excepted for *E.cyanopodus, A.virescens, D.pictum* and also the large herbivorous species (Scaridae and Acanthuridae). The results of the visual censuses confirm also the findings of the line fishing, many important species in the SW lagoon are rare or absent from Ouvéa (*L.genivittatus, Caesio cuning, Choerodon graphicus, Acanthurus mata...*)

Table 8: main species caught by handline (Loubens, 1978; Kulbicki et al., 1987) and by bottom longline (Kulbicki et al., 1987) in the SW lagoon of New Caledonia

	Longlines (Kulbicki, 1988)		Handline (Loubens, 1978)		Handline (Kulbicki et al., 1987)	
Species	Number	Average weight	Number	Average weight	Number	Average weight
Carcharhinus amblyrhynchos	7	3460				
Carcharhinus melapterus	5	2140				
Dasyatis kuhlii	2	2050				
Saurida undosquamis	84	150				
Cephalopholis miniatus	13	910	4	925	4	820
Cephalopholis sonnerati	38	1000	18	1000	10	880
Epinephelus aerolatus	72	495	142	425	11	510
Epinephelus fasciatus	29	270	129	190	12	220
Epinephelus cyanopodus	31	2780	60	2630	4	2100
Epinephelus maculatus	145	1070	304	1010	48	1060
Epinephelus rivulatus	85	430	80	500	34	400
Plectropomus leopardus	24	2360	19	3490	2	1220
Variola louti	15	2780	84	1270	7	1300
Lutjanus adetii	39	860	299	765	18	410
Lutjanus bohar	15	3270	9	2830		
Lutjanus vitta	20	400	126	270	5	340
Symphorus nematophorus	13	7940	7	6850		
Aprion virescens	14	6420	19	4090		
Lethrinus miniatus	24	1300	337	2000	22	1110
Lathrinus atkinsoni	83	810	60	675	1	1450
Lethrinus nebulosus	256	2350	980	1435	1	1140
Lethrinus rubrioperculatus	96	630	716	430	38	500
Gymnocranius grandocculis	39	2380	18	1910	30	840
Gymnocranius euanus	117	1150	365	1130	112	1070
Gymnocranius species	28	1330	27	860		
Nemipterus peroni	70	220	21	150		
Diagrama pictum	66	3100	28	2370		
Echeneis naucrates	110	950				
Bodianus perditio	208	1910	220	960	41	1430
Pseudobalistes fuscus	14	2740	13	2090		
Abalistes stellatus	19	1840	10	1290		
Sufflamen fraenatus			162	500	57	480
Gastrophysus sceleratus	22	2860				

BIBLIOGRAPHY

Anderson R., Waheed Z., Rasheed M., Arif A. 1991 Reef fish resources survey in the Maldives Phase II- *Technical report BOBP/ MDV/88/007*: 29 p. + annexes

Anon. 1987 A survey of village fishermen: 1987. *Marine Resources Management Division Yap State Department of Resources & Development*: 66 p.

Anon. 1990 Annual report -1990 *Division of marine Resources, Ministry of Resources & Development, Palau*, 40p.

Anon. 1991 Annual report -1991 *Division of marine Resources, Ministry of Resources & Development, Palau*, 66 p.

Burnham K., Anderson D.R., Laake J.L., 1980 Estimation of density from line transect sampling of biological populations *Wildlife Monographs* 72: 202p.

de Moussac G. 1987 Seychelles artisanal fisheries statistics for 1985. *Seychelles Fishing Authority Technical Report* 4:32 p.

Diplock J.H., Dalzell P. 1991 Summary of the results from the NFCF-OFCF survey of the deep slope fishery resources of the outer banks and sea mounts in the Federated States of Micronesia. September 1989 to February 1991. *South Pacific Commission Inshore Fisheries Research Project* : 22p.

Egretaud C. 1992 Etude de la biologie générale et plus particulièrement du régime alimentaire de *Lethrinus nebulosus* du lagon d'Ouvéa. *D.A.A de l'E.N.S.A de Rennes Halieutique*: 102p.
F.A.O. 1981 Offshore trawling survey - line fishing during the survey period 1979-1981 *FAO Project KEN/74/D23* : 21 p.

Grant C. 1981 High catch rates in Norfolk Island dropline fishery. *Australian Fisheries* 1981 (3): 10-13
Hosmer J.A. 1980 Inshore creel census. Guam oct. 79 to sept. 80. *Guam Department of Agriculture Aquatic and Wildlife resources Annual report* 1980: 13-30

Kulbicki M., 1988 Correlation between catch data from bottom longlines and fish censuses in the SW Lagoon of New Caledonia - *Proc. Sixth Intern. Coral Reef Symp. Townsville Australia August 1988* 2: 305-312

Kulbicki M., Garrigue C., Bargibant G., Menou J.L., Mou Tham G. 1993 Répartition du mégabenthos dans le lagon d'Ouvéa. *in* Evaluation des ressources en poissons du lagon d'Ouvéa: 1ère partie: l'environnement biologique: le macrobenthos, le mégabenthos et le plancton - *Rapport Conventions Sciences de la Mer ORSTOM Nouméa* 8: 37 - 98

Kulbicki M., Bargibant G., Menou J.L., Mou Tham G., Thollot P., Wantiez L., Williams J.T. 1994a Evaluation des ressources en poissons du lagon d'Ouvéa - 3ème partie: les poissons. *ORSTOM Nouméa Biologie marine Rapport de Convention* 11: 448p

Kulbicki M., Dupon S., Dupouy C., Bargibant G., Hamel P., Menou J.L., Mou Tham G., Tirard P. 1994b Caractéristiques physiques du lagon d'Ouvéa *in* Evaluation des ressources en poisson du lagon d'Ouvéa: 2ième partie: L'environnement physique, la biosédimentologie, les caractéristiques physiques - *Rapport Convention Sciences de la Mer ORSTOM Nouméa* 10: 48 -149

Kulbicki M., Mou Tham G., Bargibant G., Menou J.L., Tirard P. 1987 Résultats préliminaires des pêches expérimentales à la palangre dans le lagon SW de Nlle Calédonie - *Rapports Scientifiques et techniques Sciences de la Mer Biologie Marine ORSTOM Nouméa* 49: 104 p.

Kulbicki M., Doherty P., Randall J.E., Bargibant G., Menou J.L., Mou Tham G., Tirard P. 1990 La campagne Corail 1 du N.O CORIOLIS aux iles Chesterfield (du 15 aout au 4 septembre 1988): données préliminaires sur les peuplements ichthyologiques - *Rapports Scientifiques et Techniques Sciences de la Mer Biologie Marine ORSTOM Nouméa* 57: 88 p.

Lock J.M. 1986 Fish yields of the Port Moresby barrier and fringeing reefs. *Technical report 86/2. Department of Primary Industry- Papua New Guinea* 17 p.

Loubens G. 1978 La pêche dans le lagon neo calédonien - *Sciences de la Mer Rapports Scientifiques et Techniques ORSTOM Nouméa* 1: 52p.

Molina M. 1982 Inshore creel census oct 1 1981 to sept 30 1982 *Guam Department of Agriculture Aquatic and Wildlife ressources Annual report* 1982: 29-72

Munro J.L. 1983 Caribbean Coral Reef Resources *ICLARM Studies and Review* 7: 276p.
Stehouwer P.J. 1981 Report on a dropline fishing operation. *Northern Territory Department of Primary Production Fishery Report* 6: 28p.

Neter J., Wasserman W. 1974 *Applied Linear Statistical Models* Richard D.Irwin Inc. Homewwod Ill. USA 842 p.

Wass R.C. 1982 The shoreline fishery of American Samoa: past and present. in Ecological aspects of coastal zone management. *Proc.of a seminar on marine and coastal processes in the Pacific; Motupore island Papua New Guinea July 1980 - UNESCO-ROSTEA; Jakarta*: 51-83

Wright A. et Richards A.H. 1985 A multispecies fishery associated with coral reefs in the Tigak Islands, Papua New Guinea *Asian Mar. Biol.* 2: 69-84