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Présentée par

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Pour obtenir de grade de

DOCTEUR DE L'UNIVERSITE DE NOUVELLE-CALEDONIE

Évaluation de scénarios de gestion des ressources du lagon Sud-ouest de la Nouvelle-Calédonie : Intégration des connaissances et modélisation spatialement explicite

ANNEXES

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SOMMAIRE DES ANNEXES

ANNEXE 1

ARTICLE

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Considering multiple-species attributes to understand better the effects of successive changes in protection status on a coral reef fish assemblage

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The response of fish assemblages to changes in protection status is a major issue for both biodiversity conservation and fishery management. In New Caledonia, the Aboré reef marine reserve harbours more than 500 fish species, and has been subjected to changes in protection status since 1988. The present study investigates the impact of these changes on a wide subset of species (213), based on underwater visual counts collected before the opening and after the closure to fishing of this marine protected area (MPA). We analysed the spatial and temporal variability in fish assemblage attributable to protection status, explicitly considering habitat. To understand the successive responses of fish assemblage to fishing and protection, the assessment models included four criteria defining species groups that partition the fish assemblage: trophic regime, adult size, mobility, and interest for fishing. We could therefore identify the negative impact of opening the MPA to fishing on piscivores and highly mobile species. Surprisingly, target species were not affected more than non-target species. Model results were used to identify species groups that respond to fishing and protection. These results utilize fisheries-related criteria to provide new insight into the response of fish assemblages to protection from the perspective of MPA monitoring.

Keywords: assessment model, coral reef ecosystem, fish assemblage, fishing effect, MPA effect.

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Introduction

A key issue in tropical areas is the impact of the huge diversity found on tropical reefs on the effect of management measures. In particular, one can question the relative impact of such measures on the species composition of fish assemblages and their capacity for adaptation and their resilience, knowing that these highly diverse assemblages are subject to a number of anthropogenic and natural disturbances (Hughes, 1994; Connell, 1997; Nyström and Folke, 2001). In New Caledonia, recreational and subsistence fishing activities, mining and industrial activities, a growing population, and the development of tourism have all affected the reef systems negatively (Labrosse *et al.*, 2000).

Marine protected areas (MPAs) are acknowledged as a major tool for biodiversity conservation and fishery management (Agardy, 1994; Sumaila *et al.*, 2000), but they can also be seen as an instrument for an experimental approach aimed at improving our understanding of how communities respond to fishing. In this respect, MPAs are a tool for actively adaptive management in the sense of Walters and Hilborn (1976).

Many studies have focused particularly on marine reserves and assessed their effects on fish assemblages and on marine organisms (see reviews by Roberts and Polunin, 1991; Russ, 2002; Halpern, 2003; Pelletier *et al.*, 2005). In most papers, the impact of reserve or fishing experiments was assessed on a taxonomic basis (usually families; e.g. Alcala, 1988; Jennings *et al.*, 1996; McClanahan and Kaunda-Arara, 1996; Russ and Alcala, 1998) or for species having particular importance in the context of the study (e.g. García-Rubiés and Zabala, 1990; Letourneur, 1996; Edgar and Barrett, 1999; Johnson *et al.*, 1999). Classical methods have tested differences in density, biomass, and species richness between the reserve and a comparable zone. Few studies have evaluated reserve effects by grouping species other than at a taxonomic level; most have considered only a limited number of species or sometimes trophic groups (e.g. Russ and Alcala, 1996).

Assessment for a given species or species group does not provide a synoptic view of the impact of the reserve. Assessing the impact of a reserve at the fish-assemblage level is more preferable for providing scientific elements for an ecosystem approach to management (Botsford *et al.*, 1997; Jennings and Kaiser, 1998). This is particularly true in coral ecosystems, where diversity is particularly high (more than 600 observable species in New Caledonia according to Kulbicki *et al.*, 2007). The structure of the assemblage can be analysed based on the taxonomic, ecological, or economic grouping of species. This approach has been at the heart of several studies on the effects of MPAs on the reef fish assemblages of New Caledonia (Amand *et al.*, 2004; Ferraris *et al.*, 2005; Kulbicki *et al.*, 2007). Those first studies demonstrated the advantage of multi-species groups over single-species approaches in these highly diverse systems.

The objective of this study is to assess the effects of successive changes in protection status on the fish assemblage of the Aboré reef reserve. Located in the South Lagoon of New Caledonia, southwestern Pacific Ocean, this MPA had been in place for three years, when part of it was opened to fishing. Two years later, it was closed to fishing again. Fish assemblages were surveyed before and after the opening and the closure. We anticipated that changes in the fish assemblage would vary according to environmental factors and hypothesized that species attributes such as diet, species size, home range, or interest for fishing would be important factors in this variation. For instance, highly targeted species may be more affected by fishing than less-valued ones, and mobile species may be less affected than sedentary ones.

Material and methods

The Aboré reef reserve MPA has been studied by Amand *et al.* (2004), Ferraris *et al.* (2005), and Kulbicki *et al.* (2007), and the present study contributes distinct datasets and time-frames. Earlier studies used data from censuses where all fish species were recorded, resulting in more than 400 species observed, but it could only be performed by highly trained divers, and the number of replicates was necessarily low (69) because these censuses were time-consuming. Data used in the present study pertain to a restricted list of species (213), but correspond to a much larger number of transects (212) and could therefore be performed by less-trained divers.

Several factors that might explain the variations of observed fish counts independently of protection status were investigated. Then, the impacts of opening the area to fishing and the second closure of the area were tested using a range of biological responses, such as species richness, abundance, biomass, and mean individual size. The fish assemblage was partitioned, based on mobility, trophic regime, adult size, and interest for fishing, and each response was calculated according to the different partitions. By crossing variables and partitions of fish assemblage, the metrics per species group could be analysed, and the effects of changes in protection status at the fish-assemblage level were assessed simultaneously. We were able to demonstrate the benefits of our approach, by comparing these results with an overall approach considering responses averaged over all species. The partitioning provided insight into the effects of such changes on the fish assemblage.

Study area

The Nouméa lagoon, located in New Caledonia, southwestern Pacific Ocean (Figure 1), is a large lagoon seascape, including coral reefs, where several marine reserves (no-take zones) were established in the 1980s to protect the coral reef ecosystem from the impacts of fishing. The present study took place in the Aboré reef reserve, located on a barrier reef that is 25 km long and 20 km off Nouméa, and representing about 15 000 ha. The area was closed to fishing from 1988 to 1993; then two-thirds of the reef (area B) was reopened to fishing from August 1993 to July 1995 for a fishing experiment. The opening of the reserve immediately resulted in intense fishing pressure; in the first two weeks, 800 boats were observed, and the fish yield was 8.7 t, as estimated from a sampling of 57% of these boats (Sarramégna, 2000). These levels more or less corresponded to what had been observed previously over an entire year (Sarramégna, 2000). The whole reef has been closed to fishing since August 1995 (Figure 2; Table 1).

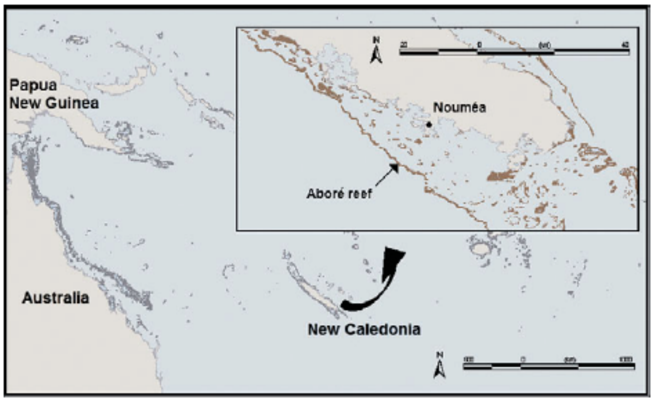

Figure 1. Geographic location of the study area (Aboré reef) in the southern lagoon of New Caledonia, southwestern Pacific.

Sampling protocol

The impact of allowing fishing in the reserve and the restoration effect after the final closure on fish assemblages were monitored from three surveys. In July 1993, a survey was performed using 60 transects in five locations spaced along the reef (Figure 2), just before resumption of fishing on two-thirds of the reef (area B; Figure 2), whereas one-third remained closed (area A). In July 1995, a second survey of 110 transects was conducted on both area A, closed to fishing, and area B, opened to fishing. Area B was closed again to fishing in September 1995, resulting in the complete closure of the Aboré reef for the second time. Six years later, in 2001, a third survey of 42 transects was conducted on the Aboré reef MPA (Table 1). The experimental design stratified the reef into two geomorphological zones: the inner reef flat and the inner reef slope (Figure 2). The reef flat is a very shallow area ranging from 0.7 to 1.5 m, whereas the inner reef slope is an intermediate zone between the reef flat and the sandy bottom lagoon, with inner spurs and grooves (Battistini *et al.*, 1975). For each of the three years surveyed, the five sampling locations, regularly spaced along the reef, were selected to ensure a good longitudinal coverage where both geomorphological zones were present (Figure 2). At each location for each geomorphological zone, at least two transects, 500 m apart, were sampled (see Table 2 for sampling design by year, area, and geomorphological zone).

Our study is based on the so-called commercial transects, during which 213 species corresponding to 32 families from a restricted list were counted, including all fished species plus a

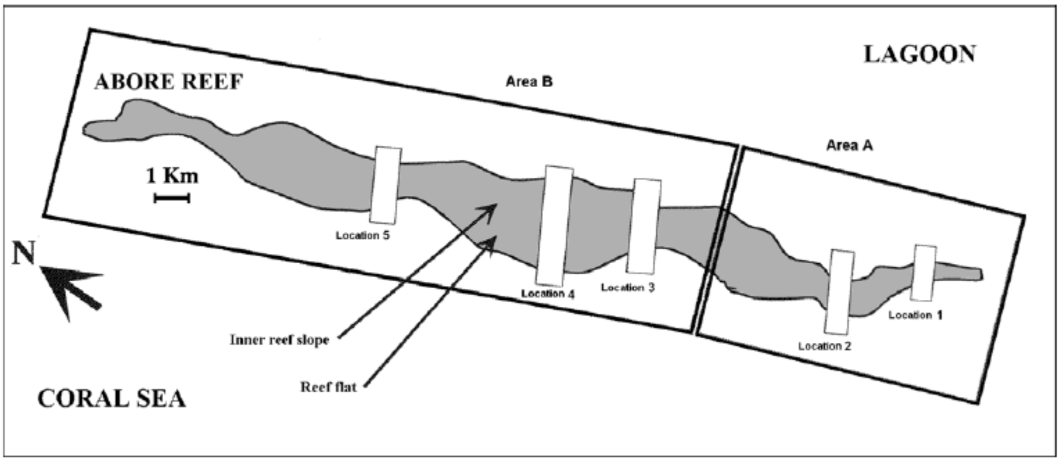

Figure 2. Sketch of the Aboré barrier reef displaying (i) area A that has been closed to fishing since 1990; (ii) area B that was opened to fishing between 1993 and 1995, and (iii) the sampling locations crossing the two sampled habitats: inner reef flat and inner reef slope.

number of species of scientific interest. Quantitative estimates of abundance of coral reef fish, using the distance-sampling method (Buckland *et al.*, 2001), were made using an underwater visual census (UVC; Kulbicki and Sarramégna, 1999). Transects of 50 m were marked by lines set on the bottom. A diver swam along the transect line and recorded fish from the species list mentioned above. For each observation, the diver recorded the species and size of the fish. Biomass of each fish was calculated through available length–weight relationships (Kulbicki *et al.*, 2005; Kulbicki, 2006).

Partitioning the fish assemblage

Choosing criteria for constructing species groups raised the question of how to define partitions of the fish assemblage that would be relevant to the impact of protection status. Four criteria were used: mobility, interest for fishing, trophic guild (feeding habits), and adult size. Following Grimaud and Kulbicki (1998), four mobility groups were defined: (i) territorial species with a very restricted range (usually $<10\ m^2$); (ii) sedentary species with a restricted range (ten to several hundred square metres); (iii) weakly mobile species, often distributed over the entire reef area (up to several thousand square metres); and (iv) highly mobile species, usually foraging over very large areas. Species groups corresponding to distinct interests for fishing were defined based on I. Jollit and colleagues (unpublished data): (i) highly targeted by spearfishing, (ii) moderately targeted by spearfishing, (iii) incidentally targeted by spearfishing, (iv) highly targeted by linefishing, (v) moderately targeted by linefishing, (vi) bycatch of linefishing, and (vii) not fished. The trophic groupings were based on diet composition following the results of Ferraris *et al.* (2005): (i) piscivores, (ii) macrocarnivores, (iii) microcarnivores, (iv) coral feeders, (v) herbivores, (vi) microalgae feeders and detritivores, and (vii) zooplankton feeders. Five size classes were defined based on adult sizes (Kulbicki, 2006): (i) 0–7, (ii) 8–15, (iii) 16–30, (iv) 31–50, and (v) >50 cm.

Table 1. Evolution of the protection status on the Aboré reef.

Time frame	Area A	Area B
1988 August	Closed to fishing	Closed to fishing
1993 July (first survey)	Closed	Closed
1993 September	Fishing closure maintained	Opened to fishing
1995 July (second survey)	Closed	Open
1995 September	Fishing closure maintained	Closed to fishing
2001 August (third survey)	Closed	Closed

Data analysis

We aimed at testing the impact on the whole fish assemblage of both the fishing effect after removal of reserve status and the definitive closure of the B area. Therefore, we assessed these effects at two levels: (i) overall variables per transect, namely species richness, abundance, and biomass summed over all species; and (ii) metrics computed per species group, namely species richness, abundance, biomass, and mean size per species group. Both the criteria to group the species and the variables define a set of metrics.

The methods used to assess the effects of changes in protection status upon the fish assemblage involved both exploratory and inferential techniques. Exploratory techniques relied on the use of non-metric, multidimensional scaling (MDS) to display graphically the similarities between transects measured by the Bray–Curtis coefficient. The representativeness of the plots was evaluated by the stress value (Clarke and Warwick, 2001). Using the PRIMER software, we could visualize the influence of a factor of interest (such as year or habitat) to explain differences among transects.

Inferential techniques include one-way analysis of similarities (ANOSIM), which rests on a permutation procedure to test whether or not a factor significantly explains differences between

Table 2. Sampling scheme, reporting the number of transects per geomorphological zone, area (A and B), and year.

Geomorphological zone	A			B		
	1993	1995	2001	1993	1995	2001
Reef flat	12	16	10	18	24	8
Inner slope	12	32	8	18	38	16
Subtotal	24	48	18	36	62	24

groups of transects (Clarke and Warwick, 2001). To perform this test (using the PRIMER software), similarities between transects were calculated using the Bray–Curtis coefficient. ANOSIM tests were based on 999 permutations of the transects between factor levels. In addition to ANOSIM, generalized linear models (GLMs; McCullagh and Nelder, 1989) were performed using R software (R Development Core Team, 2007), with suitable data distribution, depending on the variable modelled to test and assess the effects of both removal and closure of area B in 1995, while accounting for other factors that were relevant to explain the variability of the fish assemblage.

Because the UVCs were performed by several divers, we first explored potential diver effects on variations in visual counts, using MDS plots and ANOSIM applied to abundance, biomass, and mean size data. Significant diver effects were detected, so an observer term was included as a factor in subsequent analyses to allow consideration of the variability of counts caused by the diversity of divers.

In addition to the four factors considered for models of overall metrics (year, area, habitat, and diver), models of metrics per species group also included the species group factor, with levels depending on the species-grouping criterion, as described earlier, i.e. mobility (four levels), interest for fishing (seven levels), trophic regime (seven levels), and size class (five levels). These models included first-order interactions between factors (except for the diver factor), and additionally, second-order interactions between year, area, and species group, to assess possible species-group-specific effects of protection status. For overall metrics, one model was fitted for each variable, whereas for metrics per species group, one model was fitted for each combination of variable and species-grouping criterion.

All metrics per species group were modelled in two steps: a binomial model for presence–absence and a lognormal model based on non-zero values of corresponding metrics, following the procedure proposed by Stefánsson (1996). This method is suited for quantitative data with large proportions of zero values that make them unable to meet the assumptions of regular GLMs. Modelling non-zero values led to 16 model fits, crossing four metrics (abundance, biomass, mean size, and species richness per species group) with four grouping criteria. The goodness-of-fit of each model was assessed through adjusted R^2 and global Fisher's tests, and the conformity of model residuals to linear model assumptions was checked from standard residual plots and tests (Venables and Ripley, 1997). Once validated, models were selected to eliminate non-significant terms, based on the Akaike information criterion (Akaike, 1974). The significance of each effect was evaluated using the analysis of variance table based on the Type III sums of squares.

Regarding protection status, we were interested in both the fishing effect after removal of reserve status and the definitive closure of area B. The effects of these changes in protection status were assessed and tested through the interaction between the year and the area (A/B) factors (year × area) for overall metrics, and in addition through the interaction between the year, area, and species group factors (year × area × species group) for metrics per species group. When only the first-order interaction between area and year was significant, all species groups responded in the same way to changes of protection status. The magnitude and direction of the effect was quantified by computing adjusted means per area, year, and species group. Adjusted means correspond to predictions of the modelled metric, based on the significant effects of the model, thus leaving aside residual variations. In the analysis, adjusted means were computed for the year, area, and species group factors, while controlling for the diver effect. Multiple comparisons were performed using the Bonferroni correction for the following differences in adjusted means: (i) spatial difference between areas A and B in 1993, i.e. before the removal of reserve status; (ii) temporal variation in areas A and B between 1993, 1995, and 2001; (iii) spatial difference between areas A and B in 1995 and 2001. When the second-order interaction between area, year, and species group was significant, simultaneous confidence intervals were constructed per species group.

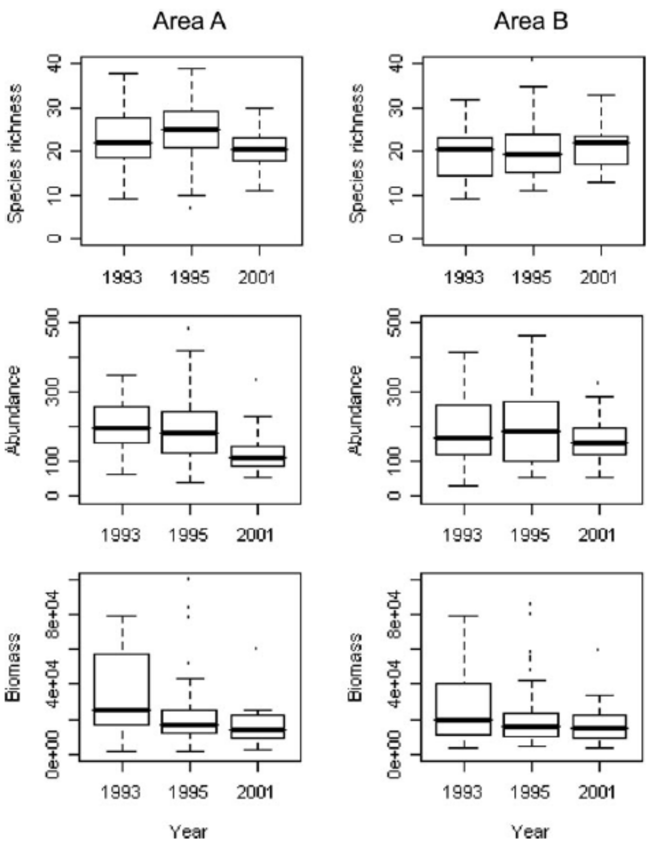

Figure 3. Boxplots of overall metrics per area (columns) and year (*x*-axis): species richness (top), abundance in number of fish per transect (middle), and biomass in grammes per transect (bottom). The horizontal bold line is the median, the lower and upper hinges correspond to the first and second quartiles, and the lower and upper whisker frame the third and fourth quartile. Points located outside the whiskers are outlying values.

Results

Assessment of changes in protection status on overall metrics per transects

Variations in species richness, abundance, and biomass per transect depended on the area (Figure 3; Table 3). Mean species richness increased between 1993 and 1995 in area A, then decreased in 2001, whereas in area B, it increased over the whole period. Overall abundance per transect consistently decreased in both areas over the same period, with a stronger decrease between 1993 and 1995 in area B and a stronger decrease between 1995 and 2001 in area A. Similarly, mean biomass decreased in both

Table 3. Means of overall variables by area and year.

Metric	A			B		
	1993	1995	2001	1993	1995	2001
Species richness	22.8 ± 7.5	24.2 ± 6.9	21.0 ± 4.4	19.2 ± 6.1	20.6 ± 6.55	21.2 ± 5.6
Abundance (number of fish transect^{-1})	200.8 ± 76.3	192.5 ± 96.5	132.6 ± 69.9	220.0 ± 107.4	195.1 ± 109.2	162.7 ± 64.6
Biomass (kg transect^{-1})	45.3 ± 48.8	23.6 ± 19.8	13.4 ± 12.6	26.6 ± 19.5	21.8 ± 17.0	15.2 ± 11.9

areas, with a much more important decline in area A between 1993 and 1995.

The observed trends were validated by significant models for overall metrics and for metrics per species group. In all models, residuals (not reported) conformed well to linear model assumptions, the global *F*-test was highly significant, although the variance explained by these models was quite low (Table 4). For these overall metrics, the diver effect was significant and well accounted for by the models (Table 4). There was no significant interaction between area and year, meaning that no effect of the 1993 fishing event or the 1995 closure could be detected from the species richness, abundance, or biomass data. In contrast, both abundance ($p = 0.0003$) and biomass ($p = 0.0027$) decreased over the years surveyed, as observed previously (Table 4). Species richness varied by area ($p = 0.0003$; Table 4), and both biomass and species richness were significantly lower in the inner reef flat zone ($p = 0.0003$ and $p < 0.0001$, respectively).

Changes in protection status and species attributes

The probability of occurrence of all adult size groups was lower in area A than in area B in 1993, whereas the difference was the other way around in 1995, revealing a significant effect of protection status ($p < 0.02$; Table 5). In all presence–absence models, the species group factor was highly significant ($p < 0.01$), illustrating differences in average occurrence between species groups, irrespective of how they were defined.

For non-zero values, model fits were generally much better than with overall metrics (Table 6). In particular, the R^2 values of models ranged from 0.34 to 0.77, with best fits for abundance and species richness. The increase in explanatory power was accomplished by retaining a much larger set of significant effects in the selected models, and in particular, the interactions between two or more factors. To rank factors according to their influence, we used the number of significant effects in the 16 models fitted (Table 7). Diver identity and species group effects were significant in all models, so explained more variance than spatial or temporal effects. First-order interactions involving the species-group factor were also highly significant, underscoring the differences in response between the groups to the effects of year, area, and habitat.

The change in protection status significantly affected mean size in the groups defined by fishing interest ($p < 0.01$). Protection status also significantly affected abundance in the different mobility grouping ($p < 0.01$) as well as biomass in the different trophic groupings ($0.05 < p < 0.01$). The adjusted means (Figures 4–6), based on year, area, and species group effects (see Material and methods section), illustrate the species group effects and the additive diver effect (Table 5).

Regarding the mobility criterion, between 1993 and 1995 (fishing period in area B), the abundance of sedentary species rose in area B and declined in area A, whereas the abundance of all other groups declined, particularly between 1995 and 2001 (Figure 4), but the only significant variation over time was the decline of highly mobile fish in area B between 1993 and 1995, which can be explained by the fishing impact. The abundance of this group remained stable after 1995, corroborating a relative protection effect.

Considering trophic groups (Figure 5), a decline in biomass between 1993 and 1995 was observed for all groups in both areas except zooplankton feeders. Yet, this decline was only significant for piscivores in area B in relation to the opening to fishing (note that 43% of piscivores were highly or moderately targeted by both spear- and linefishing). Macrocarnivores demonstrated a global decline of biomass in both areas, with biomass significantly lower in area B (fished) than in area A (no-take) in 1995. Between 1995 and 2001, all trophic groups tended to decline, except piscivores whose biomass increased slightly. Similar trends in abundance were also observed in area A. Zooplankton feeders displayed an inverse pattern in area B. Yet, almost half of the species in this group are highly or moderately targeted by spearfishing.

Finally, mean size in the different fishing interest groups demonstrated a variety of patterns over time in areas A and B

Table 4. Model results for overall metrics per transect: significant effects and adjusted R^2.

Metric	Model	R^2
Species richness	**Area + habitat + diver**	0.27
Abundance	**Year + diver**	0.21
Biomass	**Year + habitat + diver**	0.30

All effects are significant with $p < 0.01$, indicated by emboldened text.

Table 5. Models of presence–absence per species group, with goodness-of-fit statistics; bold, highly significant effects ($p < 0.01$); underlined, significant effects ($0.05 > p > 0.01$); italics, non-significant effects ($p > 0.05$).

Criterion	Effects retained	R^2
Mobility	**Year + diver + mobility**	0.92
Trophic	<u>Year</u> + **habitat** + **area** + **trophic**	0.49
Interest for fishing	*Habitat* + *area* + **fishing** + <u>diver</u> + **habitat:fishing** + <u>area:fishing</u>	0.53
Adult size	**Year** + **habitat** + *area* + **diver** + **adultsize** + **year:area** + **year:adultsize**	0.76

Table 6. Effects and goodness-of-fit (R^2) for models fit on non-zero values of metrics per species group; bold, highly significant effects ($p < 0.01$); underlined, significant effects ($0.05 > p > 0.01$); italics, non-significant effects ($p > 0.05$).

Criterion	Metric	Effects retained	R^2
Mobility	Abundance	Year + *habitat* + *area* + **diver** + **mobility** + **year:mobility** + **area:mobility** + **habitat:mobility** + **year:area:mobility**	0.58
	Biomass	*Year* + **habitat** + *area* + **diver** + **mobility** + **year:mobility** + **habitat:mobility** + **area:mobility**	0.48
	Mean size	**Year** + **habitat** + *area* + **diver** + **mobility** + year:mobility + **habitat:mobility**	0.34
	Species richness	*Year* + *habitat* + *area* + **diver** + **mobility** + area:mobility	0.56
Trophic	Abundance	**Year** + **habitat** + **area** + **diver** + **trophic** + *year:trophic* + **habitat:trophic** + **area:trophic**	0.77
	Biomass	**Year** + **habitat** + *area* + **diver** + **trophic** + **year:trophic** + **habitat:trophic** + **area:trophic** + year:area:trophic	0.60
	Mean size	**Year** + **habitat** + **diver** + **trophic** + **year:habitat** + **year:trophic**	0.44
	Species richness	*Year* + *habitat* + *area* + **diver** + **trophic** + **year:trophic** + **aire:trophic**	0.74
Interest for fishing	Abundance	**Year** + *habitat* + *area* + **diver** + **fishing** + **year:fishing** + **habitat:fishing** + **area:fishing**	0.67
	Biomass	**Year** + **habitat** + area + **diver** + **fishing** + **year:fishing** + **habitat:fishing** + **area:fishing**	0.54
	Mean size	**Year** + **habitat** + *area* + **diver** + **fishing** + year:area + **year:fishing** + **year:area:fishing**	0.45
	Species richness	**Year** + **habitat** + **area** + **diver** + **fishing** + **year:fishing** + **habitat:fishing** + **area:fishing**	0.60
Adult size	Abundance	**Year** + *habitat* + *area* + **diver** + **adultsize** + **year:adultsize** + **habitat:adultsize** + **area:adultsize**	0.77
	Biomass	**Year** + **habitat** + *area* + **diver** + **adultsize** + **year:adultsize** + **habitat:adultsize** + **area:adultsize**	0.51
	Mean size	**Year** + **habitat** + *area* + **diver** + **adultsize** + **year:adultsize** + **habitat:adultsize**	0.63
	Species richness	**Year** + *habitat* + *area* + **diver** + **adultsize** + **year:adultsize** + **habitat:adultsize** + **area:adultsize**	0.59

Table 7. Classification of model factors by number of highly significant ($p < 0.01$) and significant ($0.01 < p < 0.05$) occurrences in the 16 models of Table 6.

Factor	Number of highly significant occurrences	Number of significant occurrences
Diver	16**	–
Group	16**	–
Year:group	13**	1*
Year	12**	1*
Area:group	11**	1*
Habitat:group	11**	1*
Habitat	10**	–
Area	2**	1*
Year:area:group	2**	1*
Year:habitat	1**	–
Year:area	1*	–

** And * indicate a significant difference in adjusted mean at the $p = 0.01$ and $p = 0.05$ level in multiple comparisons, corrected using the Bonferroni method.

(Figure 6). Between 1993 and 1995, mean size decreased for most groups in both areas, except for species moderately targeted by linefishing, bycatch of linefishing, and for unfished species. As expected, unfished species were not affected by the opening to fishing, and species moderately targeted by linefishing and bycatch of linefishing declined in area B while remaining stable in area A between 1993 and 1995. After the final closure of area B between 1995 and 2001, the mean size of several groups declined further in both areas. The decline was mitigated in both areas for species highly targeted by linefishing, and in area B for bycatch and moderate targets of linefishing. For these two groups, the decline in mean size was larger in area A. The mean size of species caught by spearfishing declined but not significantly and over the 3 years in both areas.

Note that no species-group-specific protection status effect was found for the adult size criterion (Table 6).

Discussion

Spatio-temporal variations of the fish assemblage

First-order interaction of year, area, and habitat with species groupings demonstrated the complexity of variations in the measured abundance, species richness, and biomass of the fish assemblage. The factors that determined significant single effects in the models were the year, habitat, and diver factors. The significance level of the diver factor required the explicit inclusion of this factor in our models to control for observer variability. This aspect is often ignored or omitted in the literature.

Regarding temporal variations, a significant effect involving at least the year factor was found in 18 of the 23 fitted models in the whole study. Such variations corresponded to decreases over time of the studied metrics, a result that was also noted by Kulbicki *et al.* (2007), using a different approach. The causes of such temporal variations remain poorly understood and are obviously linked to factors that cannot be accounted for in such models. Undoubtedly, environmental fluctuations and events explain some of these variations and mask the effects of changes in protection status. For example, the large-scale oceanographic and climatic features such as *El Niño* Southern Oscillation (ENSO) events are known to influence water conditions greatly (temperatures, for example) and may seriously affect habitats and disrupt benthic populations and their reproductive success (Allison *et al.*, 2003). Cyclonic events are also likely in the studied area, and although no critical event took place during the period under study, consequences of such events may be observed on longer time-scales. Other events, such as the strong winds that prevailed during the 1995 survey, could also explain part of the variations under consideration. However, without sampling outside of the MPA and over a long temporal series, it is difficult to detect effects of long-term phenomena.

On the basis of inferential models, we could assess the effects of changes of protection status through the interaction between year and area factors for a range of metrics. Overall abundance, biomass, and species richness proved not to be sensitive to changes in protection status. Regarding metrics per species group, a few metrics, namely piscivore biomass, the abundance of highly mobile species, and the mean size of linefishing bycatch, displayed significant variations that were consistent with changes in protection status endured by the fish assemblage. Several other metrics demonstrated non-significant variations, which tended to be consistent with these changes, e.g. the biomass of herbivores, the mean size of species moderately targeted by linefishing, and species highly targeted by linefishing. Other variations could not be easily related to changes in protection status and, overall, there were few significant year × area interactions. Often, declining patterns observed in both areas A and B suggest a strong connection between these two adjoining areas. Such exchanges would inevitably reduce spatial differences in fish assemblage between areas A and B and therefore contribute to the lack of significant protection effects. The spillover of individuals from area A to area B would mitigate the decrease in area B and/or the regeneration in area A. Larval dispersion and larval settling depend on hydrodynamics that operate at scales larger than the MPA and may also contribute, but are poorly known in this area. Fish movements may be particularly important in such coral reef formations consisting of linear barriers and multiple islands and coral patches. This point is confirmed by Chateau and Wantiez (2009), who recently demonstrated that fish mobility in the Caledonian lagoon is more important than previously believed.

Habitat was a determining factor for explaining variations of the fish assemblage, even approximated at the scale of the geomorphological zone (a significant factor in 14 models of the 23 fitted). Geomorphological zones indeed correspond to distinct depth and coral type (Ferraris *et al.*, 2005). Therefore, environmental variations affecting coral cover and reef structure may ultimately be reflected in spatio-temporal variations of fish assemblages. Fine-scale changes in habitat structure may help to improve the explanatory power of the models (Ferraris *et al.*, 2005), but such data were not available for inclusion in our analysis. Ferraris *et al.* (2005) demonstrated that although accounting for fine-scale habitat data improved model fits, the degree of significance of the effects was only improved marginally. In addition, poaching may occur in the MPA, mitigating the effect of protection. Another hypothesis is that the general decline of fish populations in the whole southwestern lagoon is related to the increase in human population (occurring in the Nouméa region) and the evolution of fishing methods. Fish in the reserve migrate to zones outside of the MPA as these other areas become depopulated. The simultaneous decline in abundance of most of the groups, fished or not, argues against the direct impacts of fishing.

Partitioning the fish assemblage

One of our objectives was to utilize species attributes to understand better the consequences of changes in protection status on the fish assemblage. Partitioning the fish assemblage according to a range of criteria provided a variety of insights and is a step towards an ecosystem approach to MPA assessment. In fact, the models of overall metrics displayed few significant effects and none in relation to changes in protection status. In contrast, metrics per species groups revealed a larger number of significant effects, most of which included the species-group factor, which means that, for a given species-grouping criterion, the variation of the metric modelled differed across the species groups. Therefore, corresponding models explained a much larger fraction of variance (up to 77%), than models of overall metrics (<30%). Therefore, the inclusion of species attributes in the models improved the assessment. This method revealed that piscivores and highly mobile species were groups that react the most to opening to fishing (Figures 4 and 5).

However, some of our results are not intuitive. Hence, significant effects of changes in protection status were detected for very

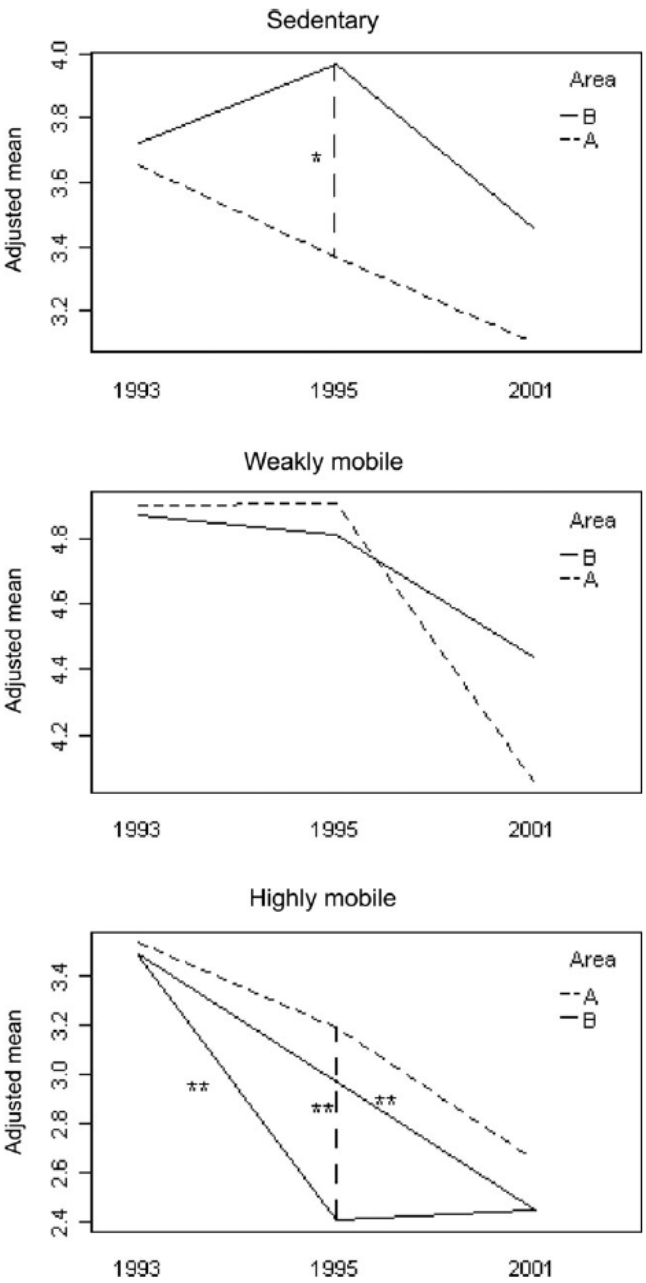

Figure 4. Adjusted means for the factors year, area, and species group factors in the model of log(abundance) per mobility group; ** and * indicate a significant difference in adjusted mean at the $p = 0.01$ and $p = 0.05$ levels in multiple comparisons, corrected using the Bonferroni method.

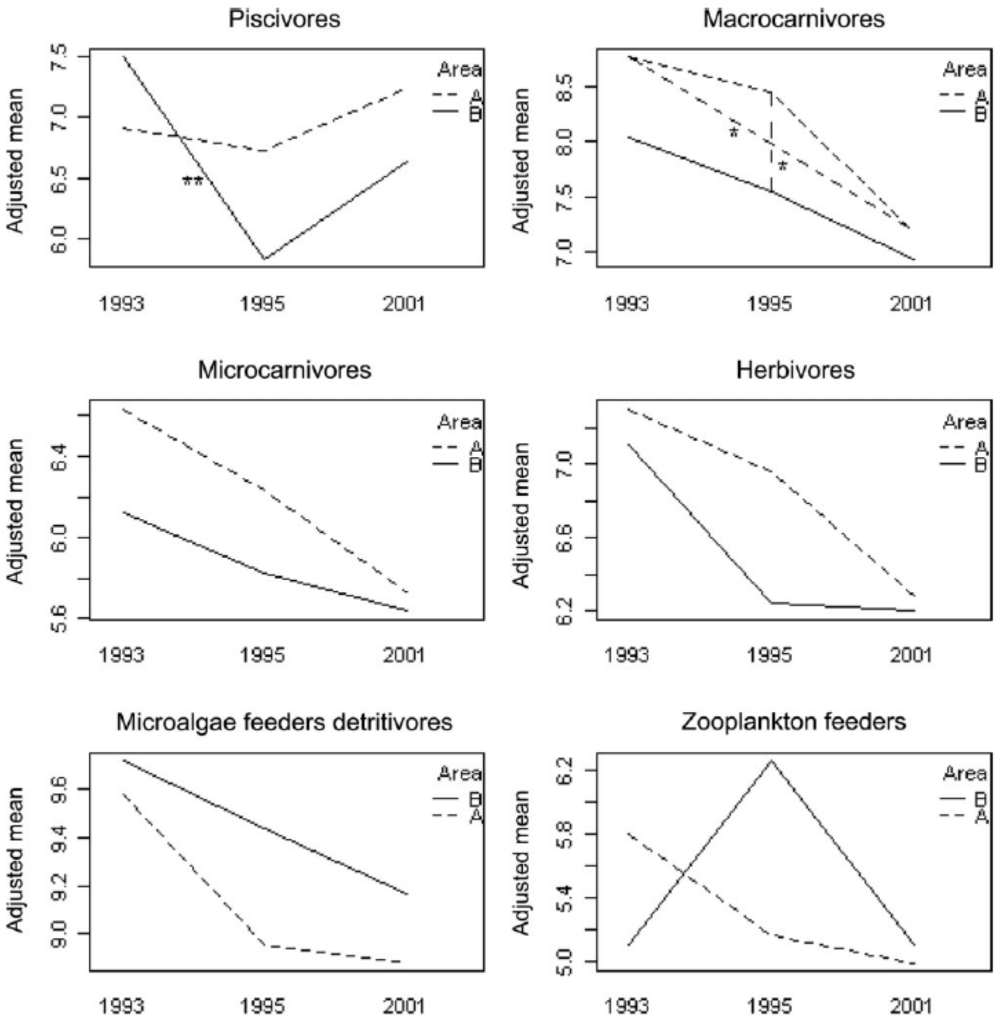

Figure 5. Adjusted means for the factors year, area, and species group in the model of log(biomass) per trophic group; ** and * indicate a significant difference in adjusted mean at the $p = 0.01$ and $p = 0.05$ level in multiple comparisons, corrected using the Bonferroni method. Coral feeder groups consisting of only one species did not allow statistical comparisons.

mobile species, which *a priori* can move easily between areas A and B. This kind of effect is generally not expected. It is important to note, therefore, that 58% of the species of the highly mobile group are also species targeted or highly targeted by spear- or linefishers. Yet, the abundance of these fishing groups was not significantly affected by changes in protection status. One could hypothesize that, after the opening, highly mobile species may have left area B for other reef areas with lower fishing pressure, including (but not exclusively) area A. Likewise, one could argue that partitioning species according to their interest for fishing gave few striking results; species strongly targeted by the main fishing gears demonstrated little sensitivity to the opening of fishing. Beyond considerations of area connectivity, fish mobility, and interest for fishing, these counter-intuitive results raise the question of defining species groups that are relevant to assessing the effects of changes in protection status. One could therefore consider defining groups based on the combination of two or more criteria.

Sampling considerations

Given the complexity of the dataset, models appropriate to test the effects of changes in protection status had to include a relatively large number of explanatory factors: year, area, habitat, and diver. Although the number of observations was overall large (212 transects), it may not have been sufficient to unravel the variability attributable to these four factors.

In other studies of the Aboré reef fish assemblage, Ferraris *et al.* (2005), Amand *et al.* (2004), and Kulbicki *et al.* (2007) used a different set of observations based on the census of all observed species for only two years, 1993 and 1995. The dataset included only ca. 70 transects vs. more than 200 (out of which 170 were for both 1993 and 1995) in the present study. A larger number of significant interactions involving year and area were found in these two studies, including intuitive results. Although the data had been collected by several divers, subsequent variability did not mask the effects.

Note that the works mentioned above only dealt with the 1993–1995 variation, a fishing effect that was probably more conspicuous than a restoration effect. Yet, in the present study, this fishing effect was not so obviously detected. This lack of significance raises the question of additional sources of variability, such as the diver effect (between-diver variability in our dataset and difference in divers between the other references and the present study). It may also be related to the issue of the species list retained for the visual counts. Note that the stratification of

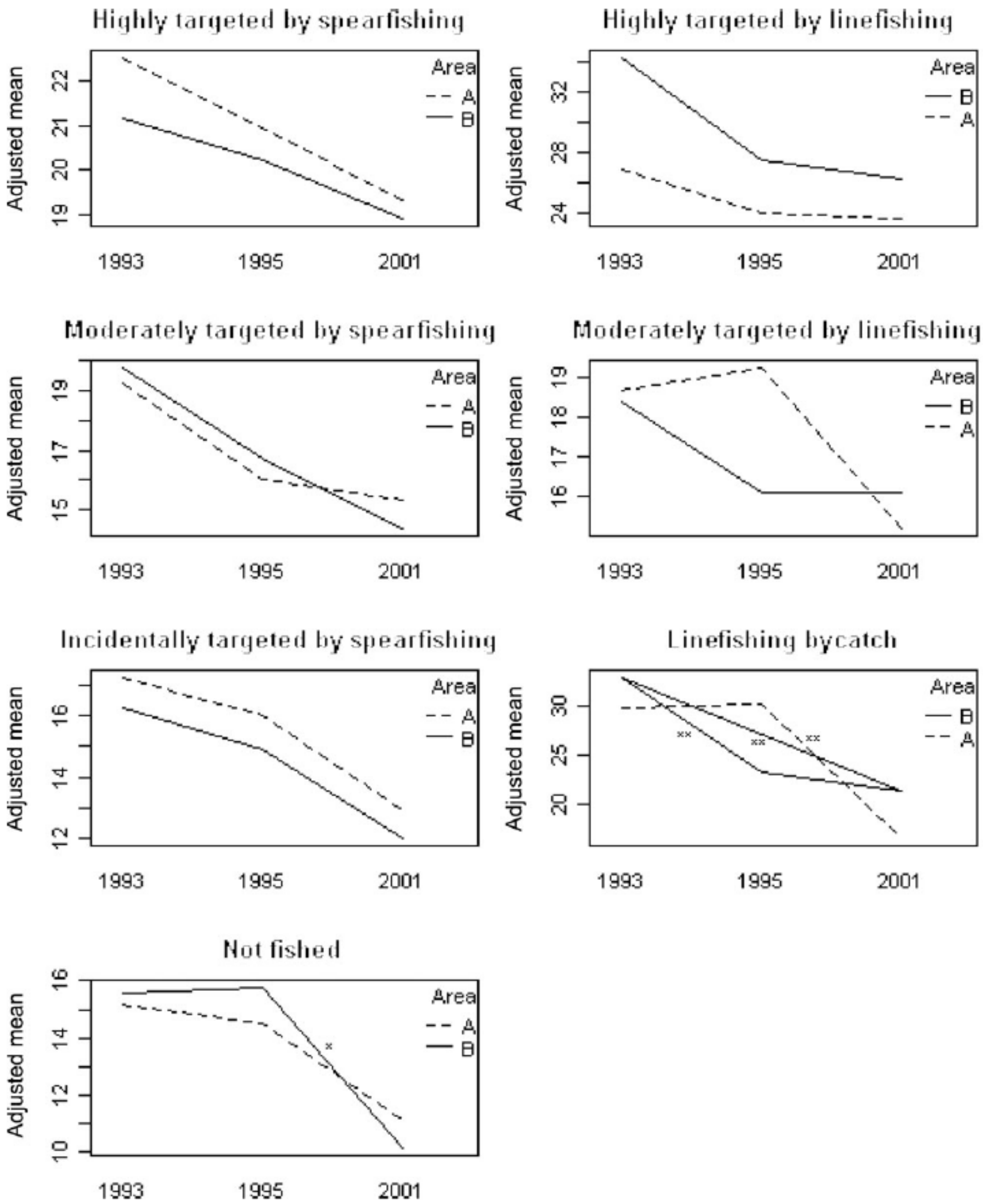

Figure 6. Adjusted means for the factors year, area, and species group factors in the model of mean size per fishing interest group; ** and * indicate a significant difference in adjusted mean at the $p = 0.01$ and $p = 0.05$ level in multiple comparisons, corrected using the Bonferroni method.

the sampling scheme and the geographical range of stations were the same in both datasets.

The present results lead us to conclude that, in this case, additional sources of variation prevented us from detecting the effects of changes in protection status (particularly the restoration effect), such as those mentioned above. When it comes to assessing restoration effects between 1995 and 2001, data are only available for 2001, with a smaller number of transects than the other two dates. Monitoring the restoration of the fish assemblage would require observations collected at several dates after the final closure.

Assessing the response of fish assemblages to changes in protection status is a major issue for fishery management. This work gives original insight into the issue of designing adequate protocols for monitoring MPA in terms of conservation of biodiversity and sustainable exploitation of resources. In this respect, considering species attributes was useful, and the partitioning criteria that are considered provided a variety of insights into the effects of such changes on the fish assemblage. Although based on the case of a coral reef ecosystem, our findings may be applied to other contexts.

Acknowledgements

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References

Agardy, M. T. 1994. Advances in marine conservation: the role of marine protected areas. Trends in Ecology and Evolution, 9: 267–270.

Akaike, H. 1974. A new look at statistical model identification. IEEE Transactions on Automatic Control, 19: 716–722.

Alcala, A. C. 1988. Effects of marine reserves on coral fish abundances and yields of Philippine coral reefs. Ambio, 17: 194–199.

Allison, G. W., Gaines, S. D., Lubchenko, J., and Possingham, H. P. 2003. Ensuring persistence of marine reserves: catastrophes require adopting an insurance factor. Ecological Applications, 13: S8–S24.

Amand, M., Pelletier, D., Ferraris, J., and Kulbicki, M. 2004. A step toward the definition of ecological indicators of the impact of fishing on the fish assemblage of the Aboré reef reserve (New Caledonia). Aquatic Living Resources, 17: 139–149.

Battistini, R., Bourrouilh, F., Chevalier, J. P., Coudray, J., Denizot, M., Faure, G., Fisher, J. C., *et al.* 1975. Eléments de terminologie récifale indopacifique. Téthys, 7: 1–111.

Botsford, L. W., Castilla, J. C., and Peterson, C. H. 1997. The management of fisheries and marine ecosystems. Science, 277: 509–515.

Buckland, S. T., Anderson, D. R., Burnham, K. P., Laake, J. L., Borchers, D. L., and Thomas, L. 2001. Introduction to Distance Sampling: Estimating Abundance of Biological Populations. Oxford University Press, Oxford, UK. 432 pp.

Chateau, O., and Wantiez, L. 2009. Movement patterns of four coral reef fish species in a fragmented habitat in New Caledonia: implications for the design of marine protected area networks. ICES Journal of Marine Science, 66: 50–55.

Clarke, K. R., and Warwick, R. M. 2001. Change in Marine Communities: an Approach to Statistical Analysis and Interpretation, 2nd edn. PRIMER-E, Plymouth, UK.

Connell, J. H. 1997. Disturbance and recovery of coral assemblages. Coral Reefs, 16: S101–S113.

Edgar, G. J., and Barrett, N. S. 1999. Effects of the declaration of marine reserves on Tasmanian reef fishes, invertebrates and plants. Journal of Experimental Marine Biology and Ecology, 142: 107–144.

Ferraris, J., Pelletier, D., Kulbicki, M., and Chauvet, C. 2005. Assessing the impact of removing reserve status on the Aboré Reef fish assemblage, New Caledonia. Marine Ecology Progress Series, 292: 271–286.

García-Rubiés, A., and Zabala, M. 1990. Effects of total fishing prohibition on the rocky fish assemblages of Medes Islands marine reserve. Scientia Marina, 54: 317–328.

Grimaud, J., and Kulbicki, M. 1998. Influence de la distance à l'océan sur les peuplements ichtyologiques des récifs frangeants de Nouvelle-Calédonie. Comptes Rendus de l'Académie des Sciences de Paris. Sciences de la Vie, 321: 923–931.

Halpern, B. 2003. The impact of marine reserves: do reserves work and does reserve size matter? Ecological Applications, 13: S117–S137.

Hughes, T. P. 1994. Catastrophes, phase shifts, and large-scale degradation of a Caribbean coral reef. Science, 265: 1547–1551.

Jennings, S., and Kaiser, M. J. 1998. The effects of fishing on marine ecosystems. Advances in Marine Biology, 34: 202–351.

Jennings, S., Marshall, S. S., and Polunin, N. V. C. 1996. Seychelles' protected areas: comparative structure and status of reef fish communities. Biological Conservation, 75: 201–209.

Johnson, D. R., Bohnsack, J. A., and Funicelli, N. A. 1999. The effectiveness of an existing no-take fish sanctuary within the Kennedy Space Center, Florida. North American Journal of Fisheries Management, 19: 436–453.

Kulbicki, M. 2006. Ecologie des poissons lagonaires de Nouvelle Calédonie. PhD thesis, University of Perpignan, Ecole Pratique des Hautes Etudes. 194 pp. + annexes.

Kulbicki, M., Guillemot, N., and Amand, M. 2005. A general approach to length–weight relationships for Pacific lagoon fishes. Cybium, 29: 235–252.

Kulbicki, M., and Sarramégna, S. 1999. Comparison of density estimates derived from strip transect and distance sampling for underwater visual census: a case study of Chaetodontiidae and Pomacanthidae. Aquatic Living Resources, 12: 315–325.

Kulbicki, M., Sarramégna, S., Letourneur, Y., Wantiez, L., Galzin, R., Mou-Tham, G., Chauvet, C., *et al.* 2007. Opening of an MPA to fishing: natural variations in the structure of a coral reef fish assemblage obscure changes due to fishing. Journal of Experimental Marine Biology and Ecology, 353: 145–163.

Labrosse, P., Fichez, R., Farman, R., and Adams, T. 2000. New Caledonia. *In* Seas at the Millennium: An Environmental Evaluation, pp. 723–736. Ed. by C. Sheppard. Elsevier Science, Amsterdam. 920 pp.

Letourneur, Y. 1996. Réponse des peuplements et populations de poissons aux réserves marines: le cas de l'île de Mayotte, Océan Indien occidental. Ecoscience, 3: 442–450.

McClanahan, T. R., and Kaunda-Arara, B. 1996. Fishery recovery in a coral-reef marine park and its effect on the adjacent fishery. Conservation Biology, 10: 1187–1199.

McCullagh, P., and Nelder, J. A. 1989. Generalized Linear Models, 2nd edn. Chapman and Hall/CRC, London. 511 pp.

Nyström, M., and Folke, C. 2001. Spatial resilience of coral reefs. Ecosystems, 4: 406–417.

Pelletier, D., Garcia-Charton, J. A., Ferraris, J., David, G., Thébaud, O., Letourneur, Y., Claudet, J., *et al.* 2005. Designing indicators for evaluating the impact of marine protected areas on coral reef ecosystems: a multidisciplinary standpoint. Aquatic Living Resources, 18: 15–33.

R Development Core Team. 2007. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria. http://www.R-project.org.

Roberts, C. M., and Polunin, N. V. C. 1991. Are marine reserves effective in management of reef fisheries? Reviews in Fish Biology and Fisheries, 1: 65–91.

Russ, G. R. 2002. Yet another review of marine reserves as reef fishery management tools. *In* Coral Reef Fishes, pp. 421–443. Ed. by P. F. Sale. Elsevier Science.

Russ, G. R., and Alcala, A. C. 1996. Marine reserves: rates and patterns of recovery and decline of large predatory fish. Ecological Applications, 6: 947–961.

Russ, G. R., and Alcala, A. C. 1998. Natural fishing experiments in marine reserves 1983–1993: roles of history and fishing intensity in family responses. Coral Reefs, 17: 399–416.

Sarramégna, S. 2000. Contributions à l'étude des réserves marines du lagon sud-ouest de Nouvelle-Calédonie: influence des différents statuts de protection sur la structure des peuplements ichtyologiques. PhD thesis, Université de Nouvelle-Calédonie, Nouméa, New Caledonia.

Stefánsson, G. 1996. Analysis of groundfish survey abundance data: combining the GLM and delta approaches. ICES Journal of Marine Science, 53: 577–588.

Sumaila, U. R., Guénette, S., Alder, J., and Chuenpagdee, R. 2000. Addressing ecosystem effects of fishing using marine protected areas. ICES Journal of Marine Science, 57: 752–760.

Venables, W. N., and Ripley, B. D. 1997. Modern Applied Statistics in Splus, 2nd edn. Springer, New York. 548 pp.

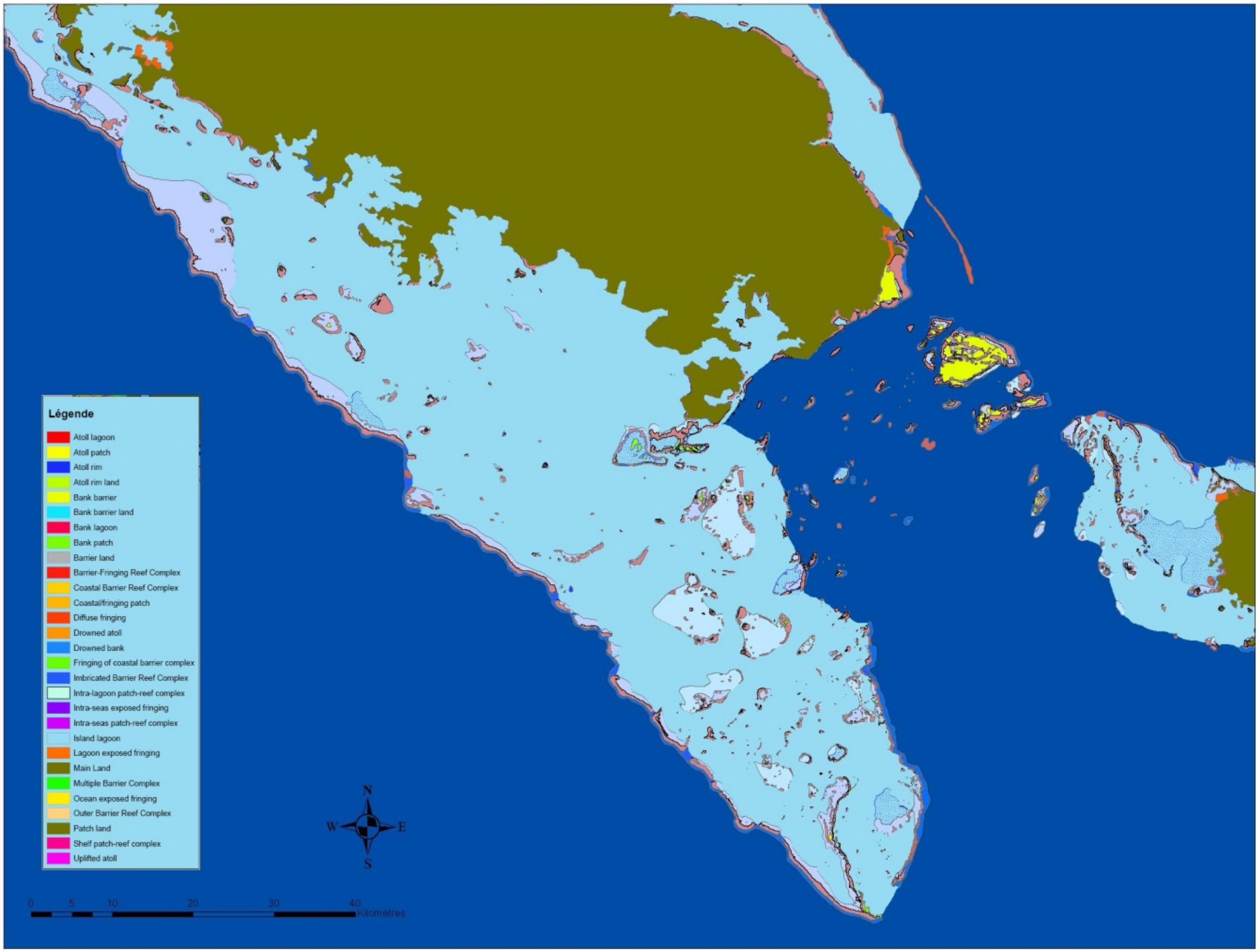
Walters, C. J., and Hilborn, R. 1976. Adaptive control of fishing systems. Journal of Fisheries Research Board of Canada, 33: 145–159.

doi:10.1093/icesjms/fsn204

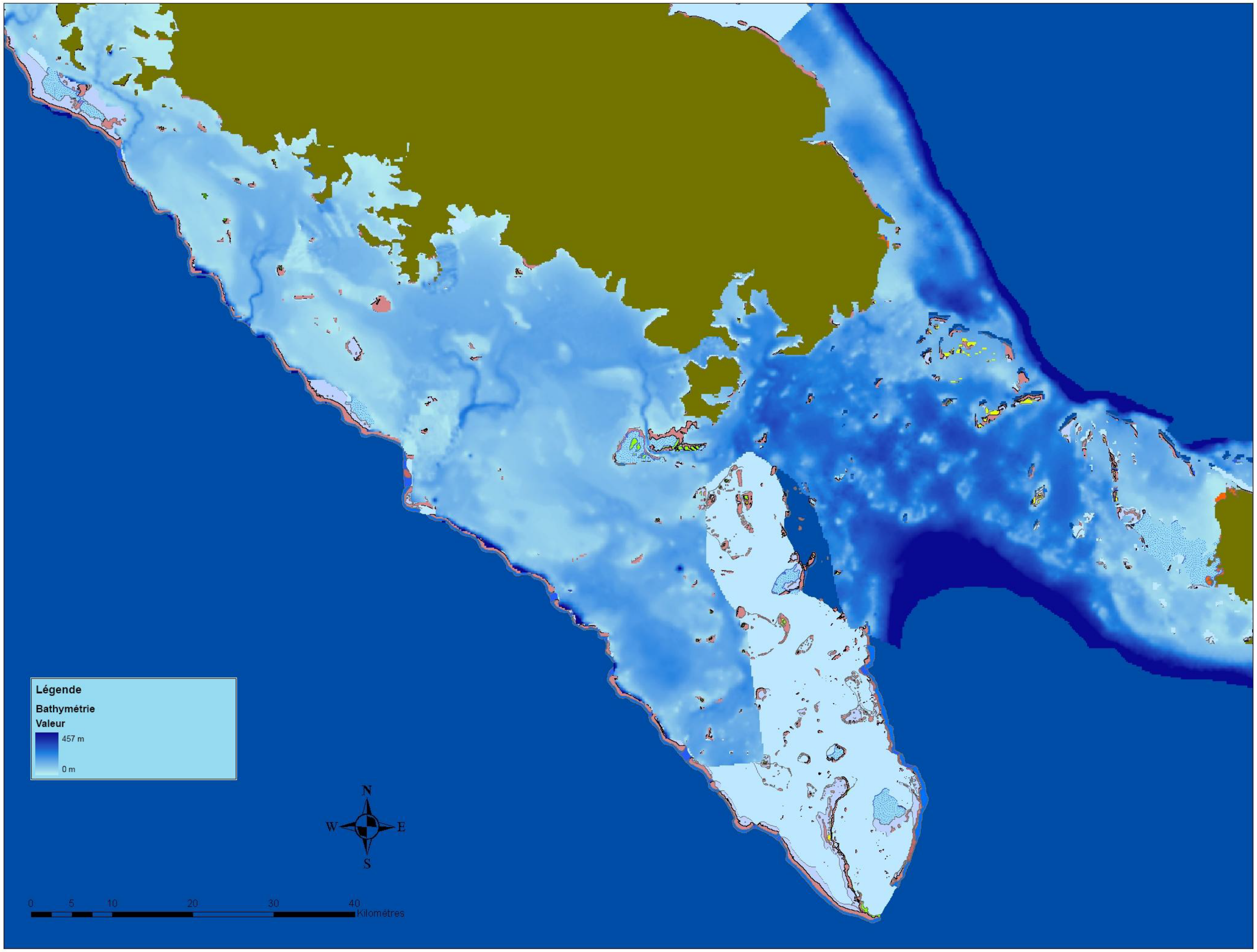
ANNEXE 2

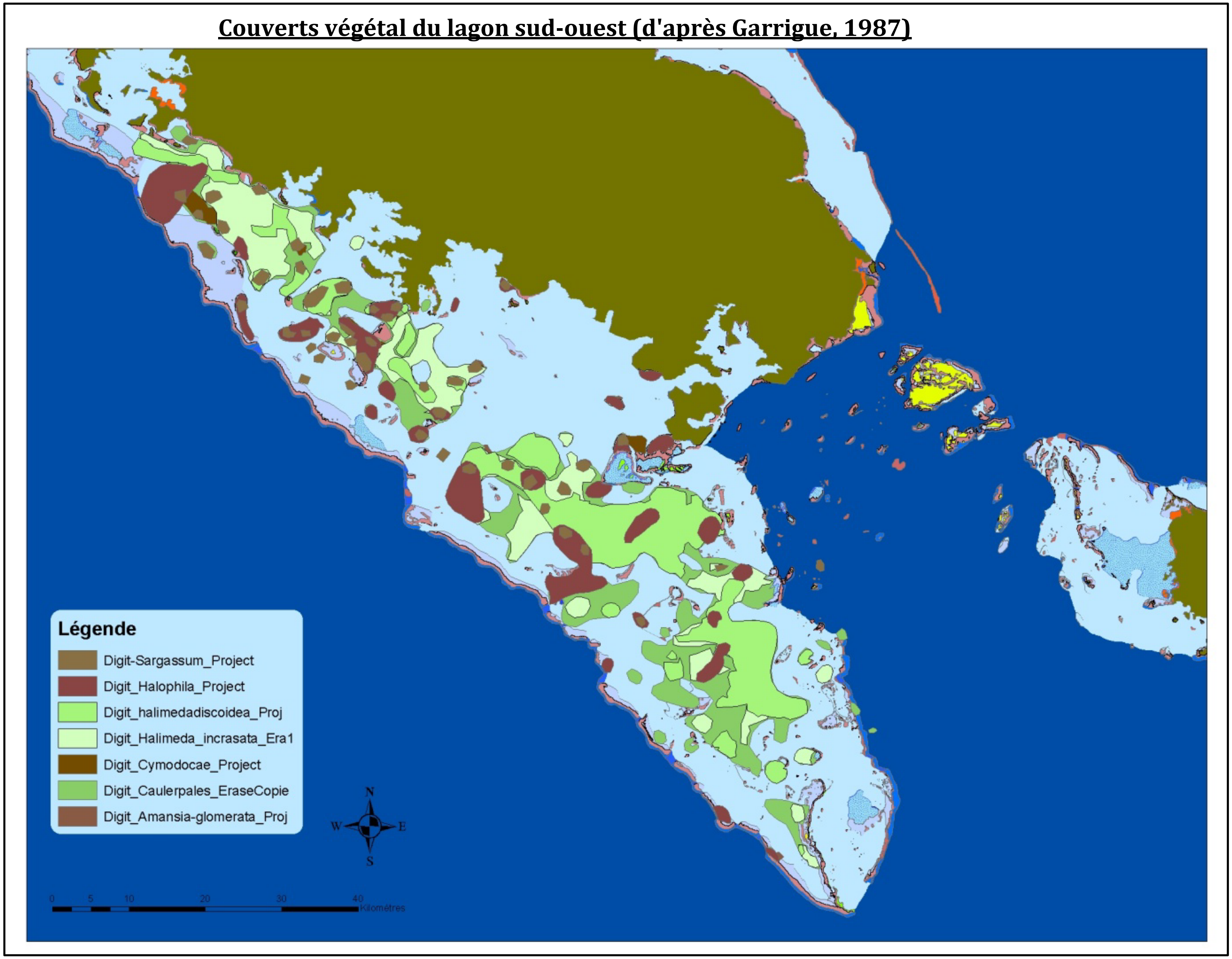
CARTOGRAPHIES DES CARACTERISTIQUES PHYSIQUES DU LAGON SUD-OUEST

Géomorphologie des récifs du lagon Sud-ouest (d'après Andréfouët & Torez-Pulliza, 2004)

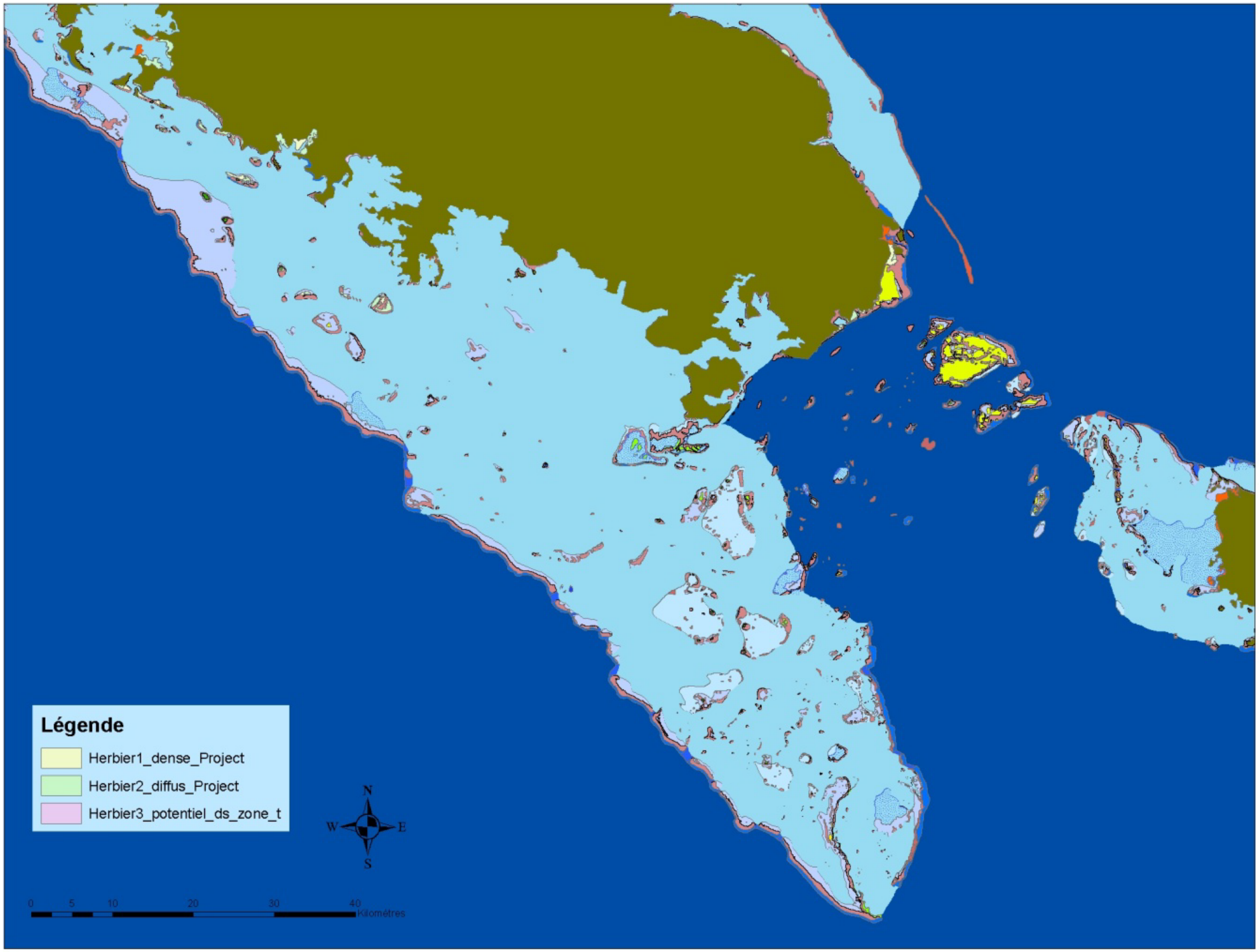


Bathymétrie du lagon Sud-ouest (source : DITT, 2009)

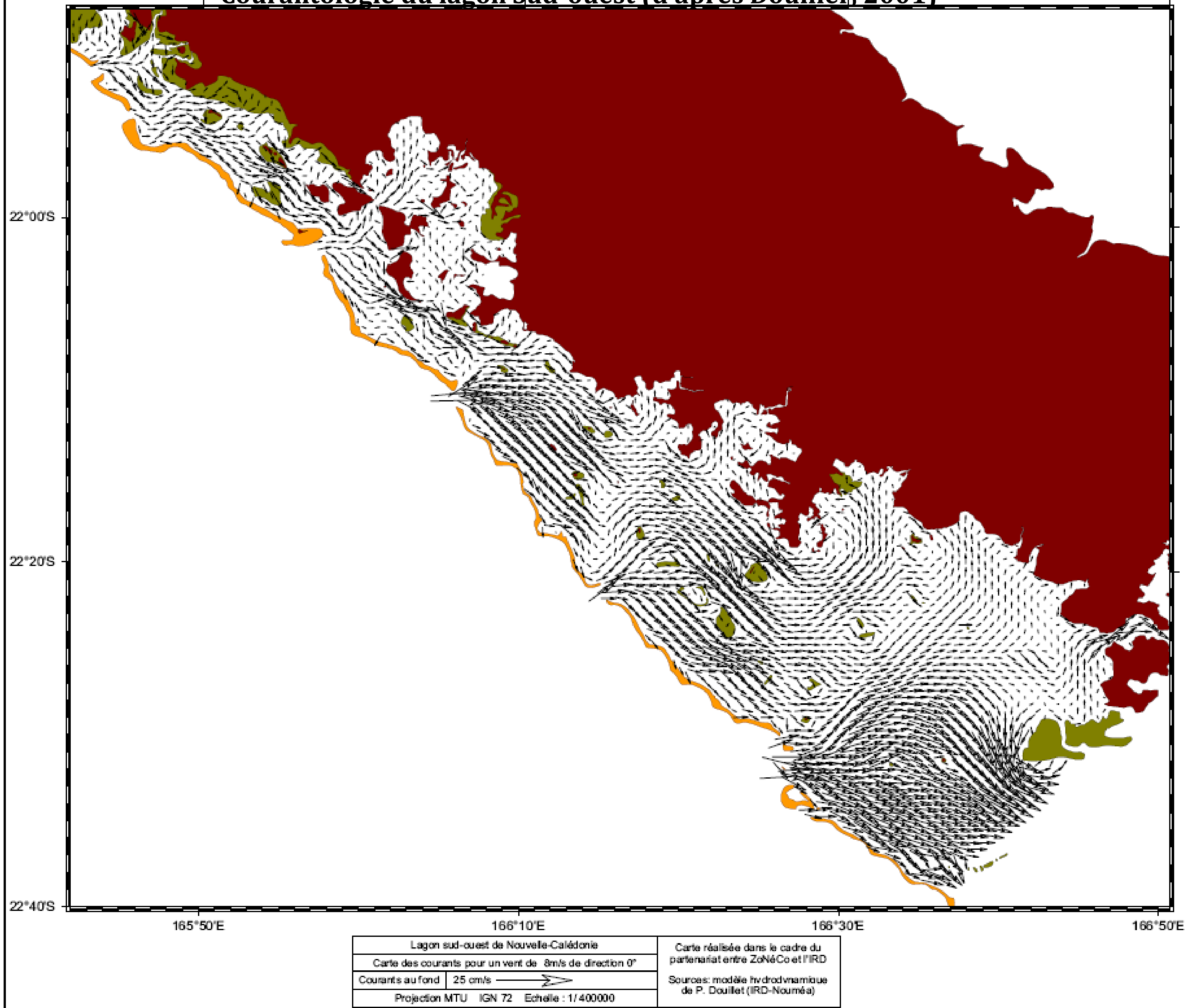



Couverts végétal du lagon sud-ouest (d'après Garrigue, 1987)
Légende
Digit-Sargassum_Project
Digit_Halophila_Project
Digit_halimedadiscoidea_Proj
Digit_Halimeda_incrasata_Era1
Digit_Cymodocae_Project
Digit_Caulerpales_EraseCopie
Digit_Amansia-glomerata_Proj
N
E
S
W
0
5
10
20
30
40
Kilomètres

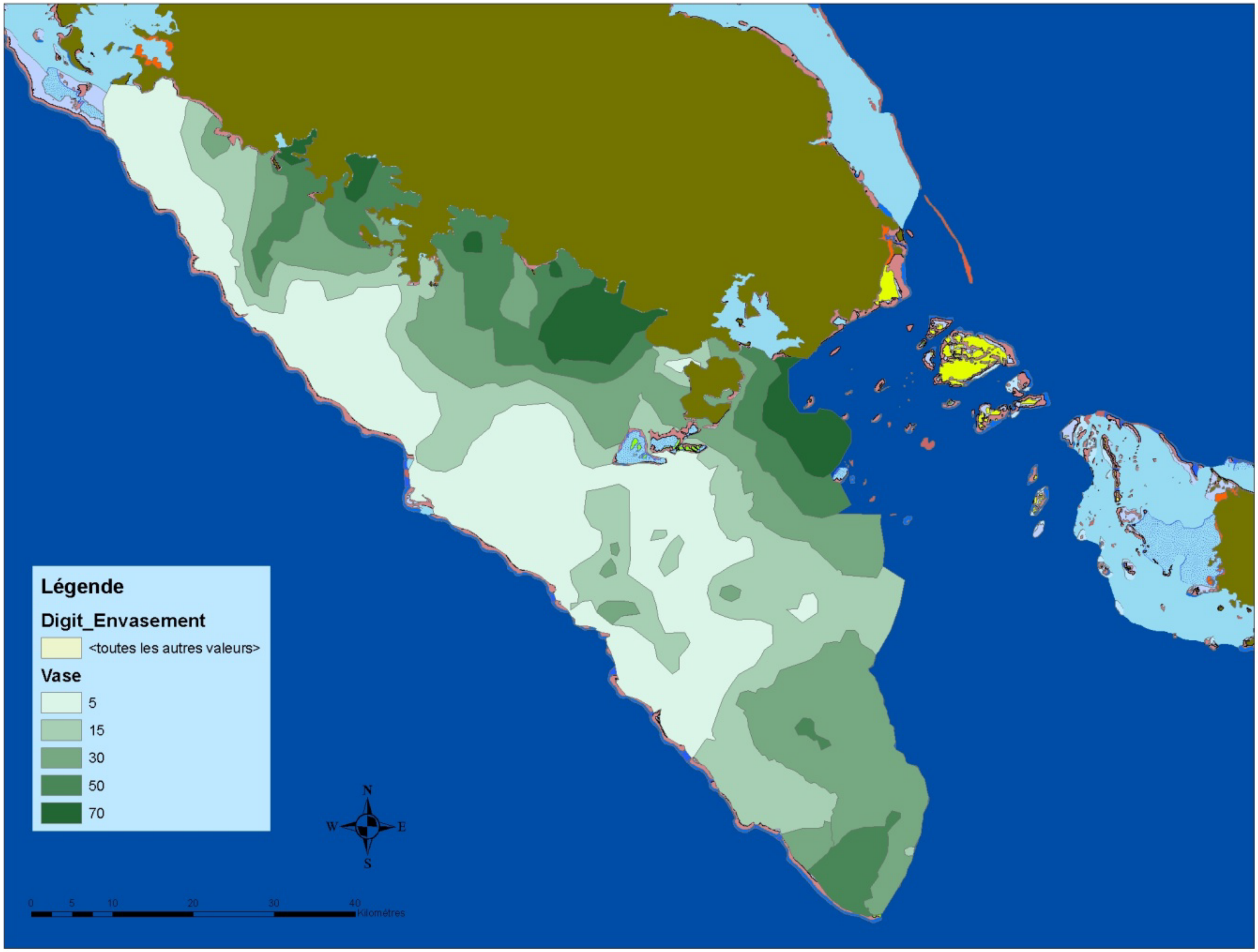
Inventaire des herbiers du lagon Sud-ouest (d'après Andréfouët *et al.*, 2010)



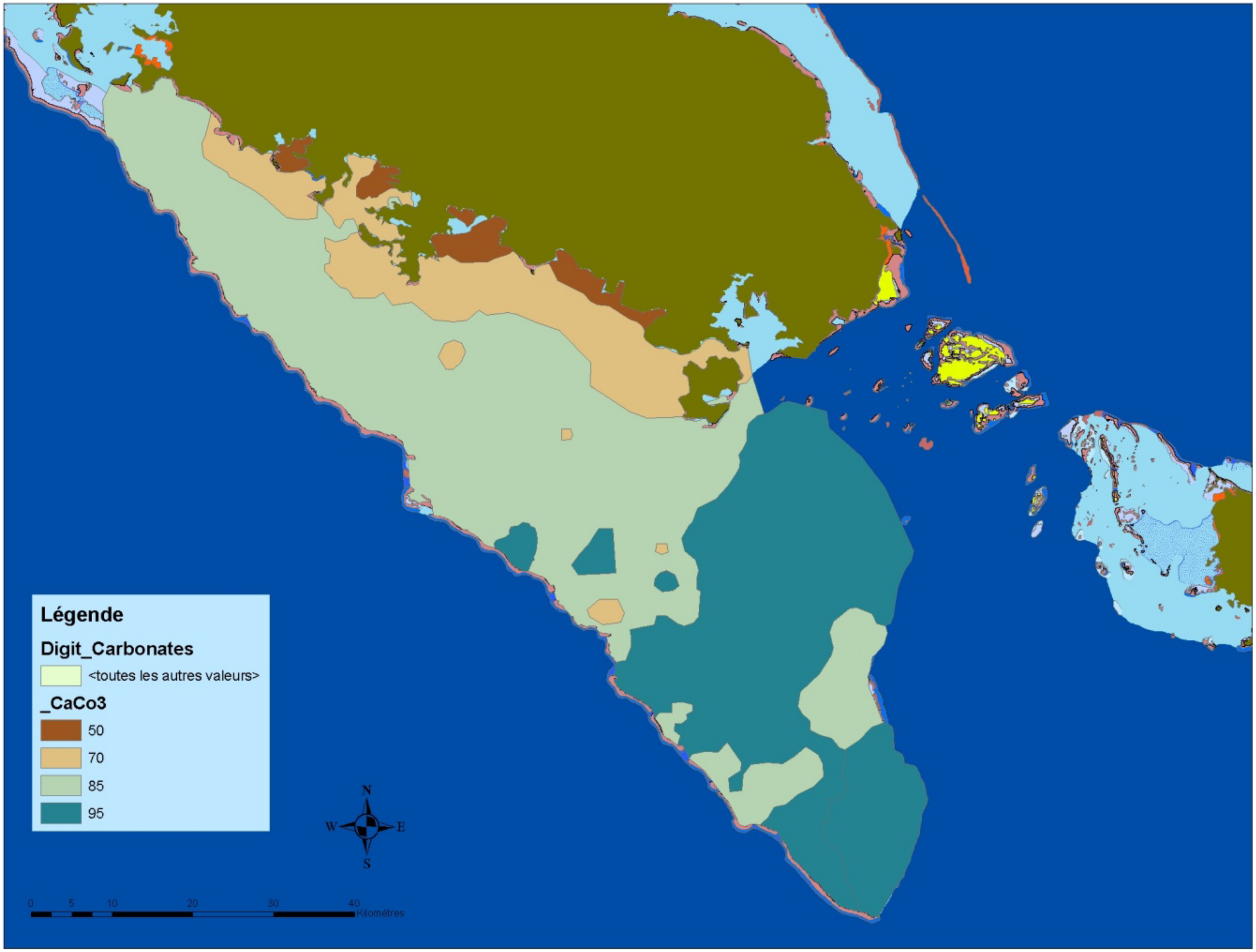
Courantologie du lagon Sud-ouest (d'après Douiller, 2001)

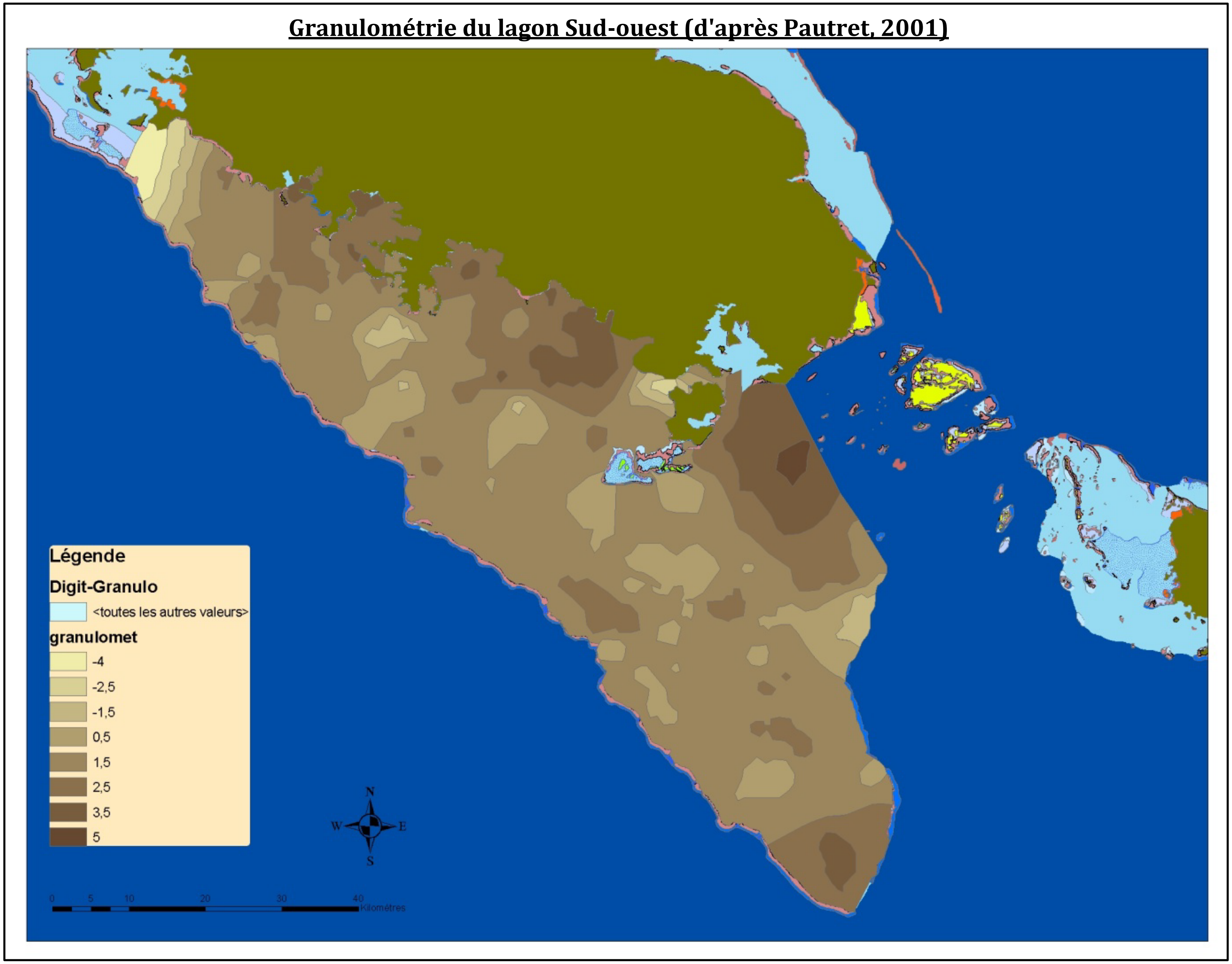


Envasement du lagon Sud-ouest (d'après Pautret, 2001)

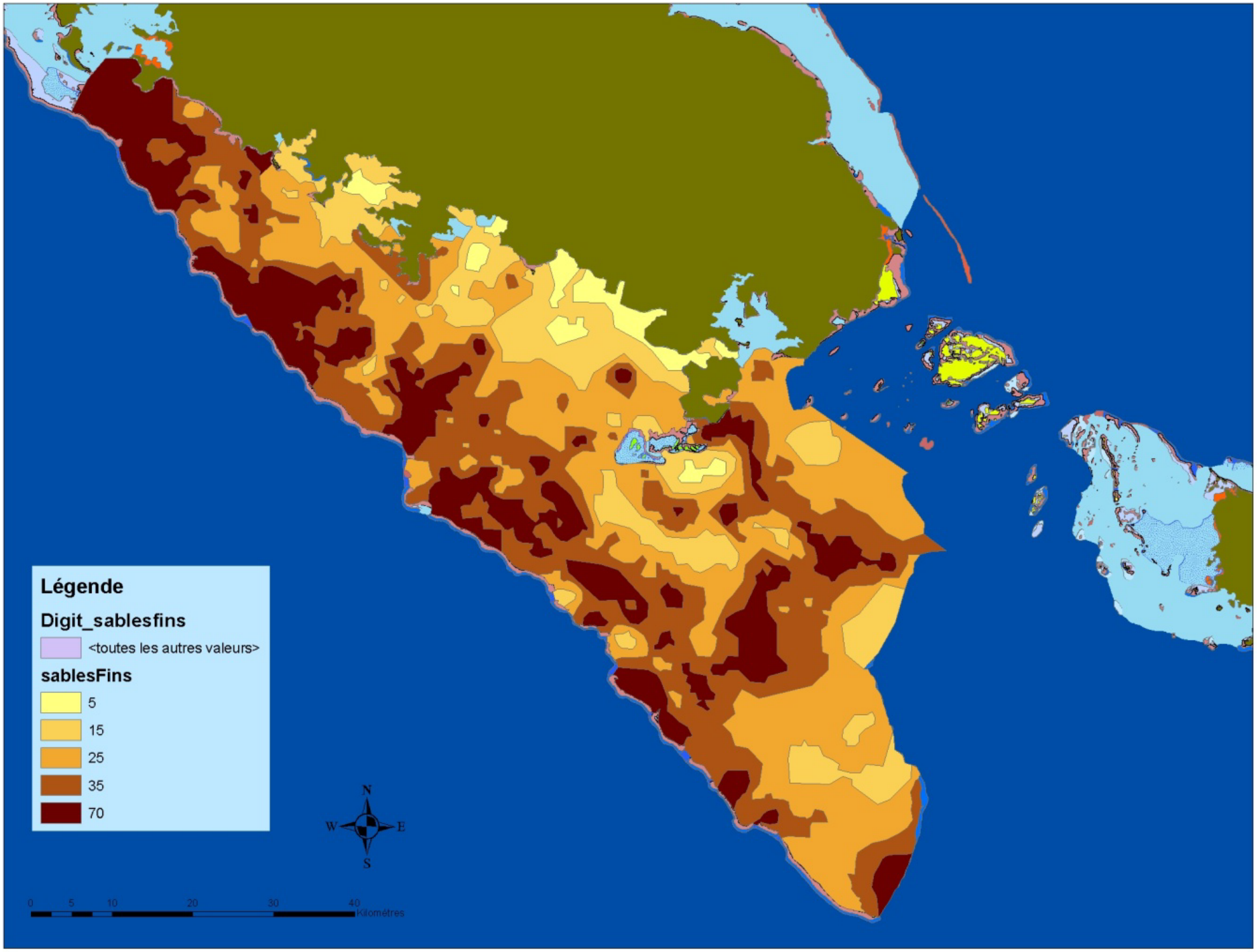


Apports terrigène dans le lagon Sud-ouest (d'après Pautret, 2001)




Granulométrie du lagon Sud-ouest (d'après Pautret, 2001)
Légende
Digit-Granulo
<toutes les autres valeurs>
granulomet
-4
-2,5
-1,5
0,5
1,5
2,5
3,5
5
N
W
E
S
0
5
10
20
30
40
Kilomètres

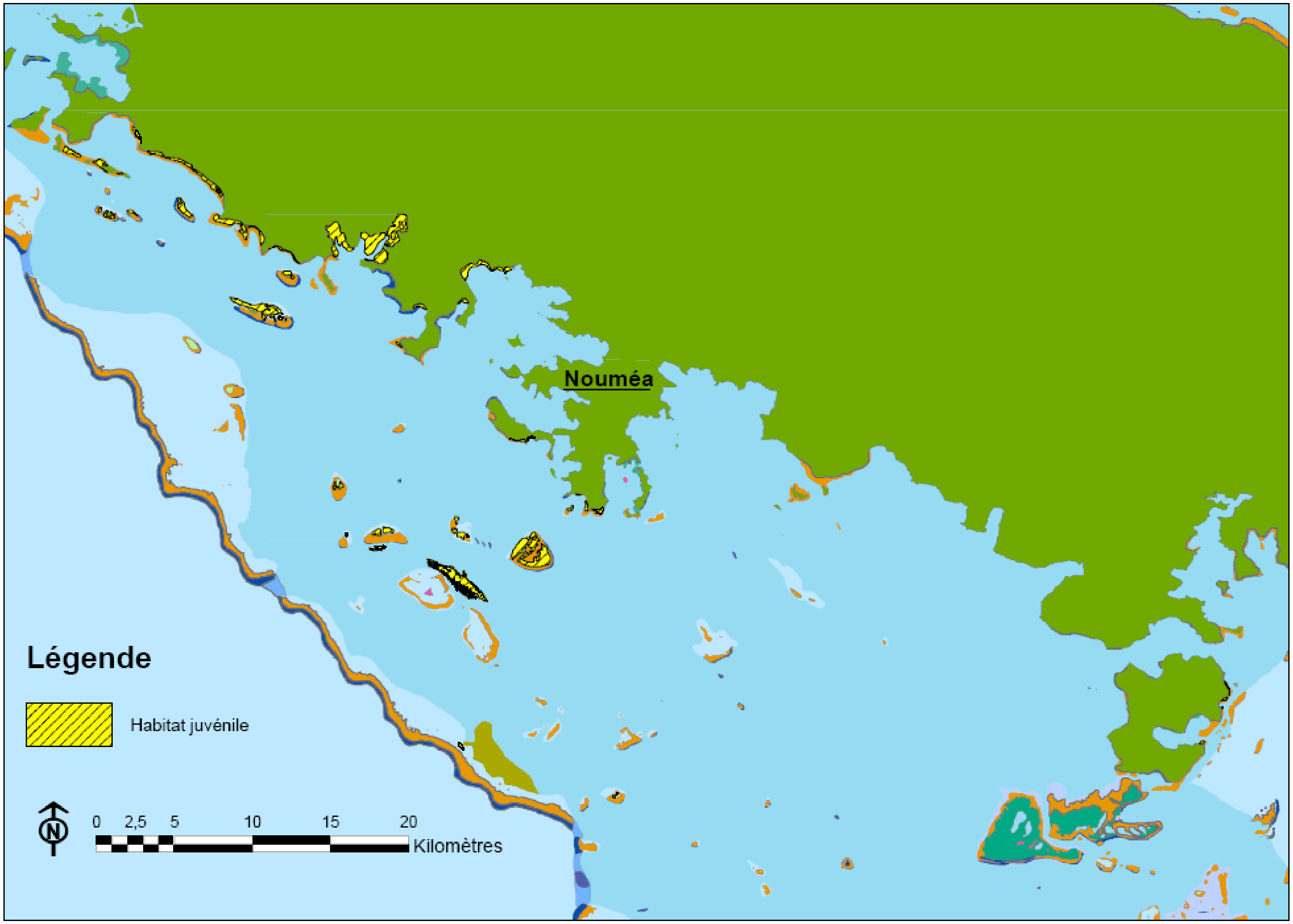
Sables fins dans le lagon Sud-ouest (d'après Pautret, 2001)



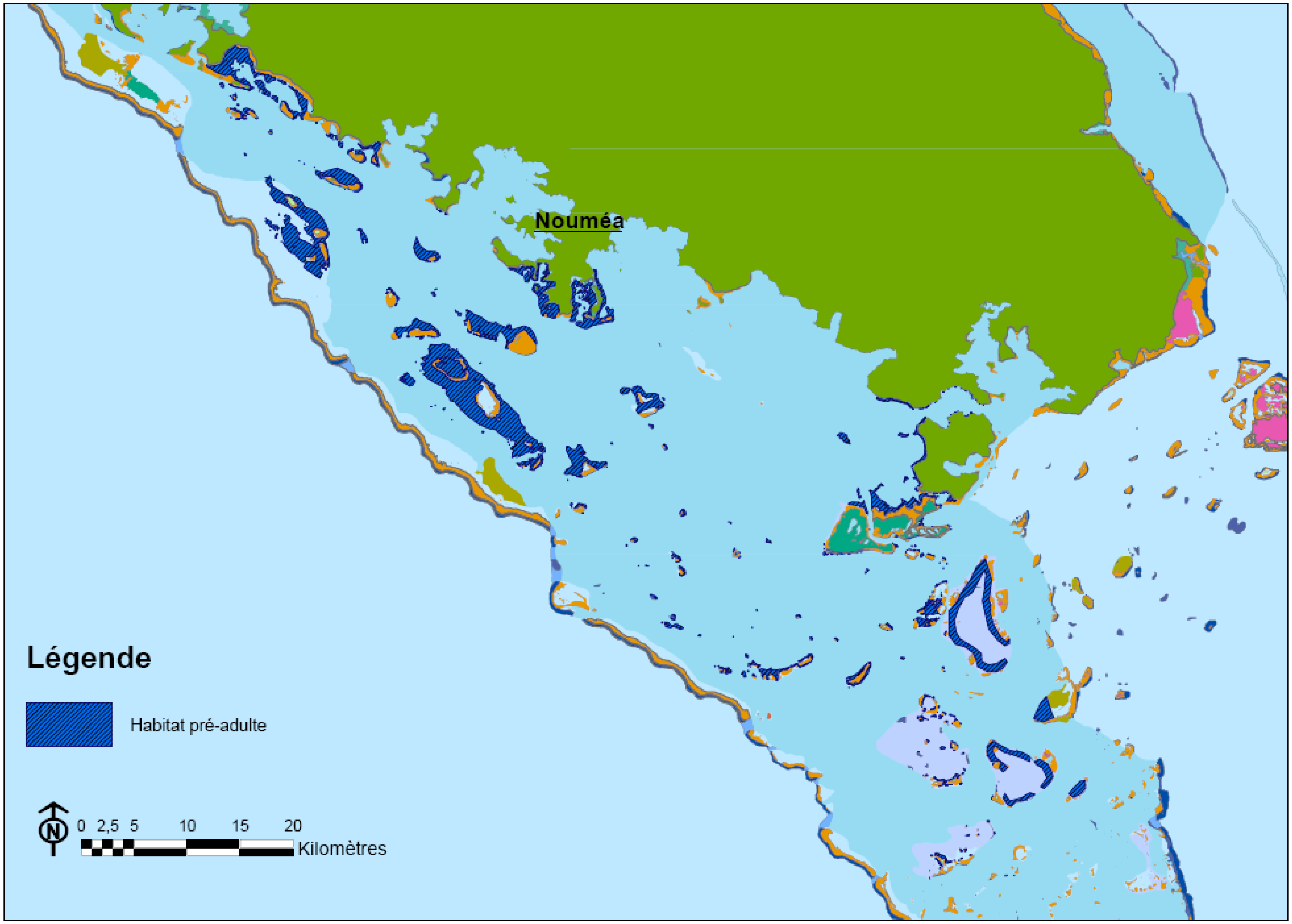
ANNEXE 3

CARTOGRAPHIES DES HABITATS DE VIE DE *LETHRINUS NEBULOSUS*, *PLECTROPOMUS LEOPARDUS* ET *NASO UNICORNIS*.

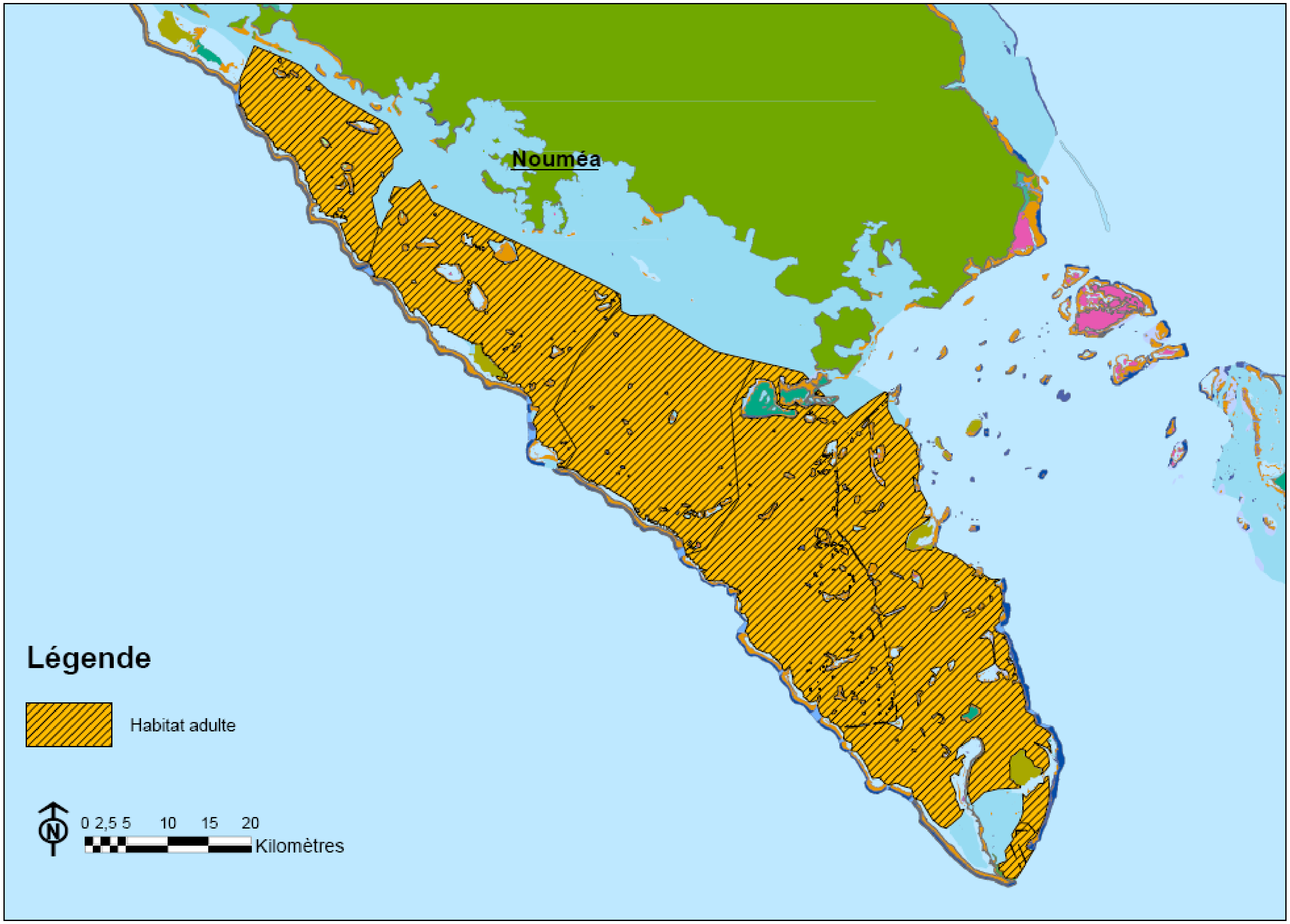
Habitat de *Lethrinus nebulosus*, stade juvénile.



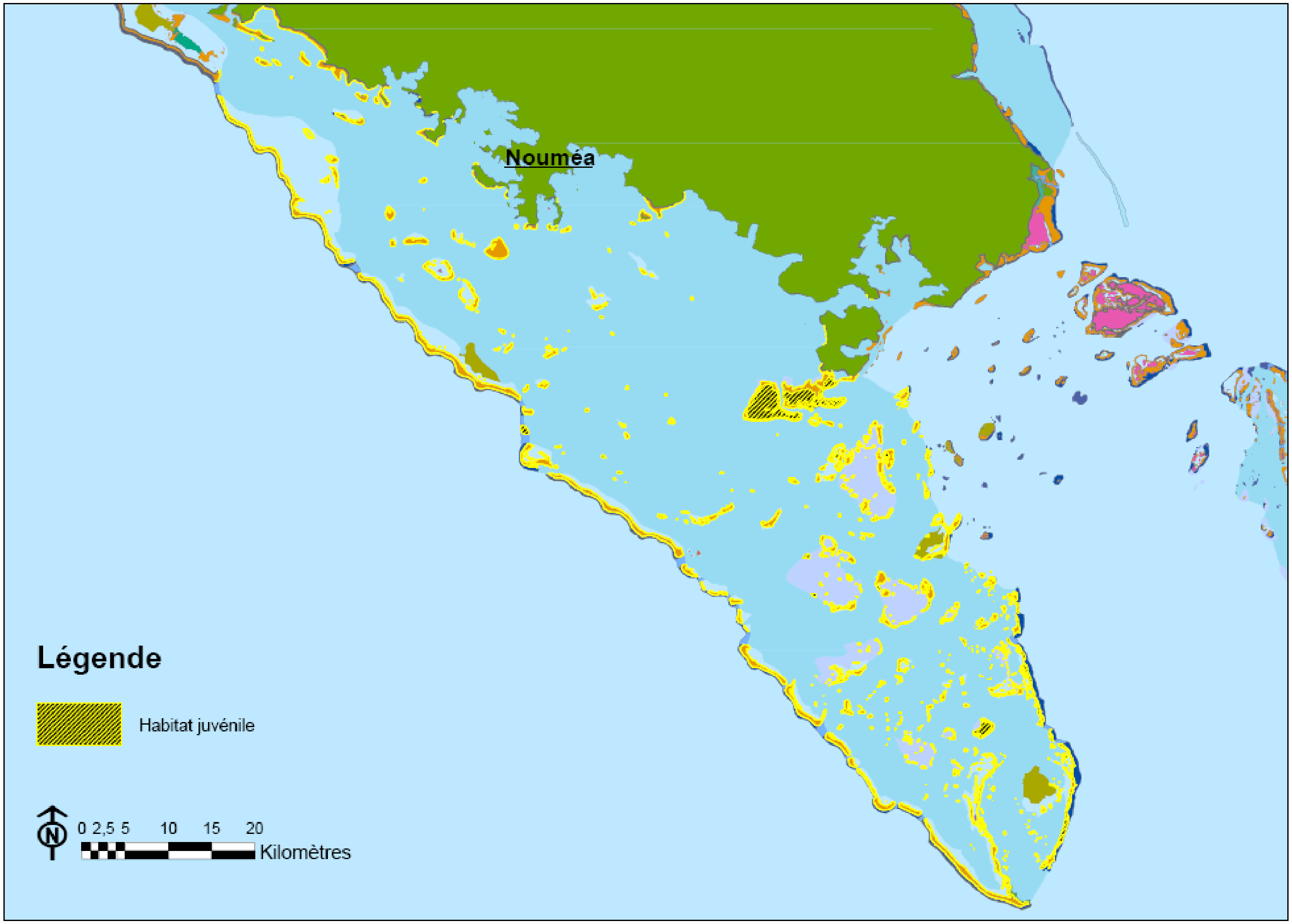
Habitat de *Lethrinus nebulosus*, stade pré-adulte.



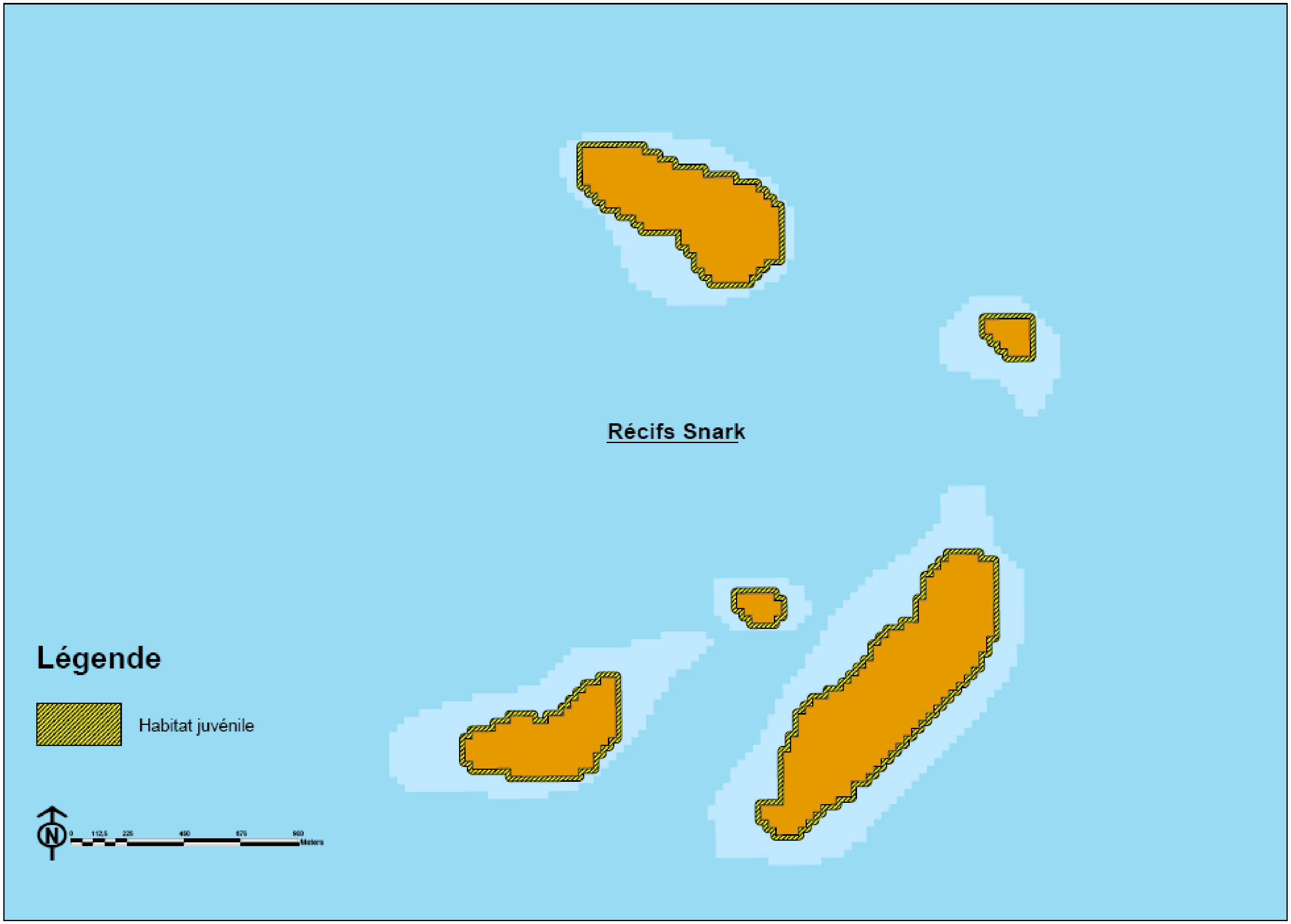
Habitat de *Lethrinus nebulosus*, stade adulte.



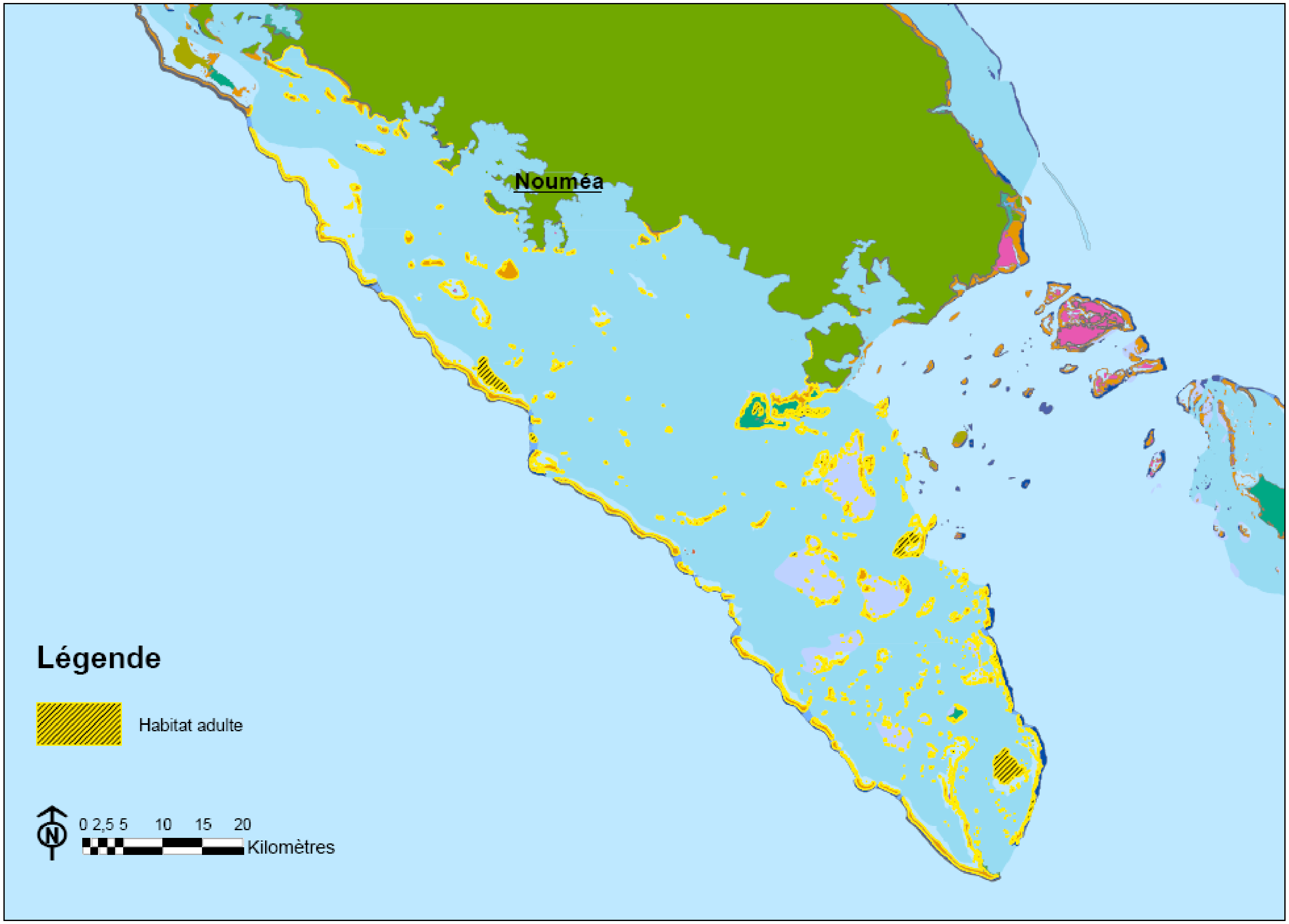
Habitat de *Plectropomus leopardus*, stade juvénile.



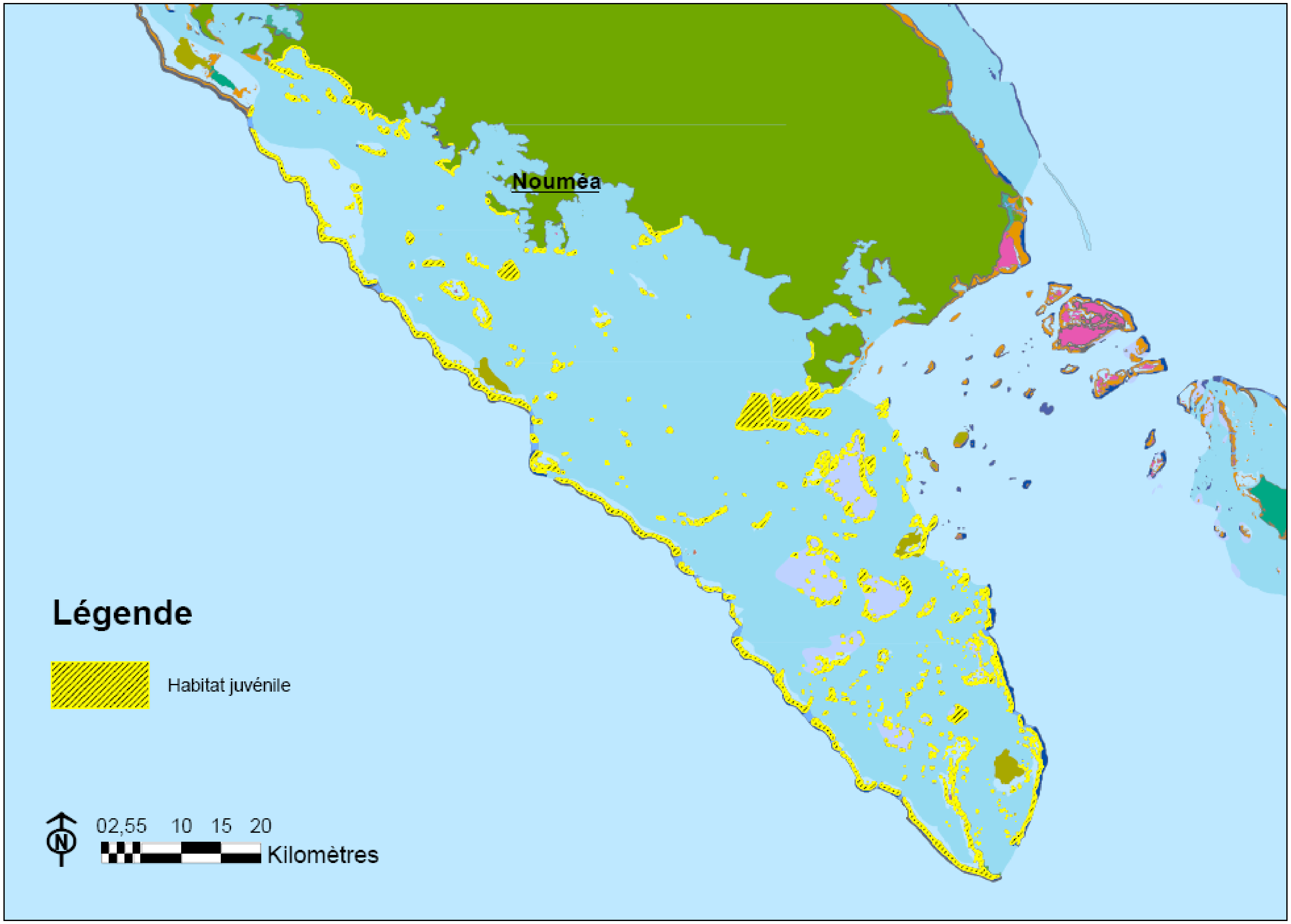
Habitat de *Plectropomus leopardus*, stade juvénile.



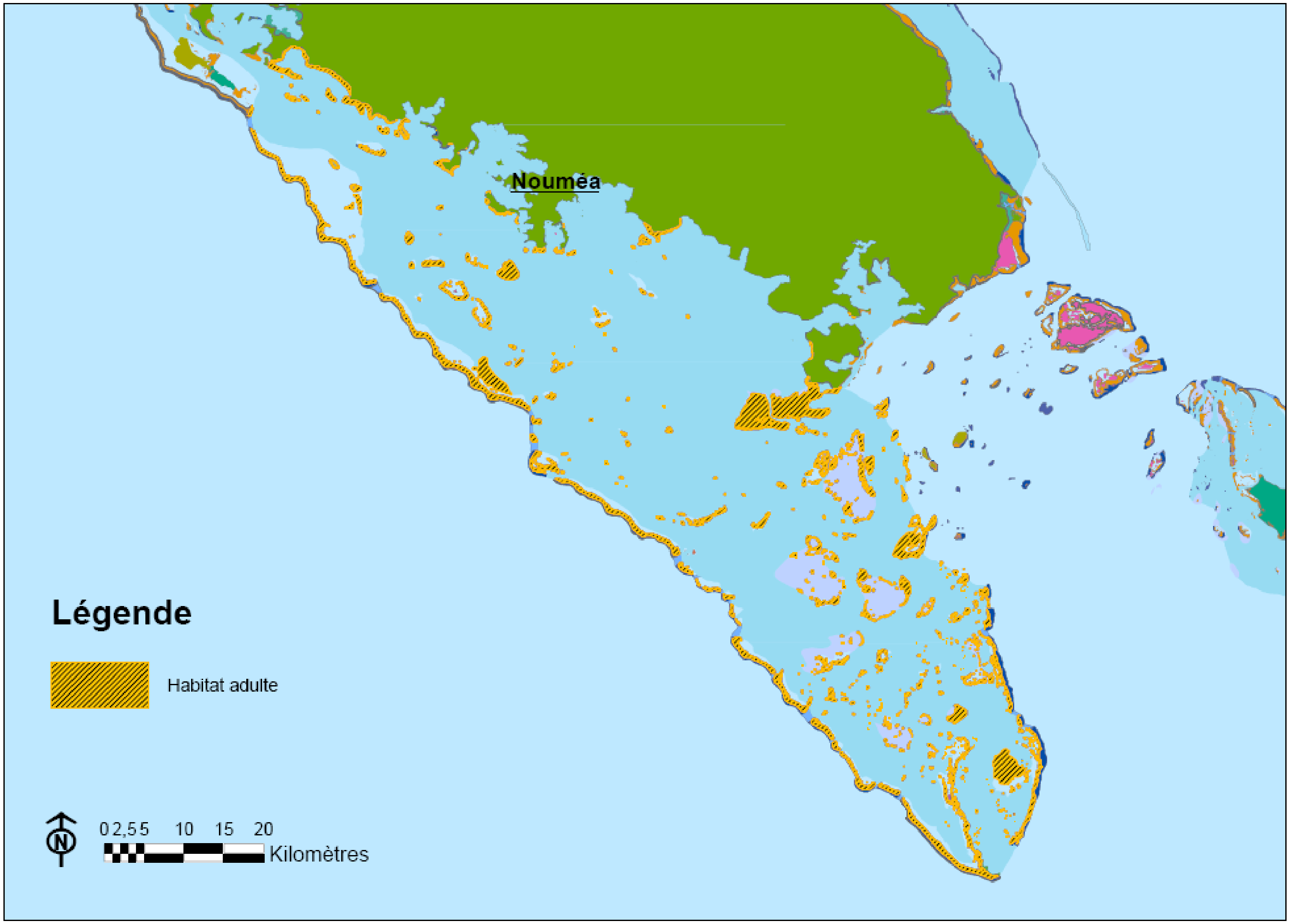
Habitat de *Plectropomus leopardus*, stade adulte.



Habitat de *Naso unicornis*, stade juvénile.



Habitat de *Naso unicornis*, stade adulte.



ANNEXE 4

TABLEAU RECAPITULATIF DES PARAMETRES DE LA DYNAMIQUE DE *LETHRINUS NEBULOSUS*, *PLECTROPOMUS LEOPARDUS* ET *NASO UNICORNIS*

(Certaines de ces valeurs sont susceptibles d'avoir été modifiées après calibration du modèle, voir Chapitre IV)

Paramètres de la dynamique de *Lethrinus nebulosus.*

	Valeur du paramètre	Référence(s) utilisée(s)	Autre(s) référence(s) sur le sujet	Autre(s) valeur(s) correspondante(s)
Structuration de la population	10 classes d'âge.	---	---	---
Classe d'âge +	oui	---	---	---
Maturité	A_{50} = 5 ans.	Compromis entre : Borsa *et al.* (2009) (entre 35 et 45 cm (LF), soit 4 ans), et Loubens (1980)(42 cm (LS) pour les males et 45 cm (LS) pour les femelles, soit entre 8 et 9 ans).	Ebisawa (2009).	4 ans pour les femelles.
Sexe ratio	1 : 1	Loubens (1990). Ebisawa (1990).	Borsa *et al.*, 2009.	Jusqu'à 70% de femelles à partir de 60 cm (LF).
Croissance	Equation de type Von Bertalanffy : $Lt = L\infty - a * e^{-kt}$ Avec L∞ = 543 ; a = 533.4 et K =0.212. (LS) en mm. Les tailles obtenues sont converties en longueurs à la fourche (LF) en cm, en utilisant la relation LS-LF : LF = 1.121 * LS + 8.4	Loubens (1980b).	Morales-Nin (1988). Baillon (1990). Borsa *et al.* (2009).	L∞ : 62 cm (otolithes) et 74 cm (retrocalcul) (LF). 227 cm (LF). 79 cm (mâles) et 82 cm (femelles) (LF).
Mortalité naturelle	Coefficient instantané de mortalité annuel. Pré-recrutement : M = 5 Classes d'âges 0 et 1 : M = 1.143 Classes d'âges 2, 3 et 4 : M = 0.848 Classes d'âges ≥ 5 : M = 0.48	Calculé à partir de l'équation de Pauly (1980).	Hoenig (1983) et Grancourt (2006). Taghavi (2010).	0.2 (pour les adultes). 0.56 (pour les adultes).
Relation taille-poids	$W = 0.0293 * LF^{2.875}$ (LF en cm).	Borsa *et al.* (2009).	Loubens (1980b). Kulbicki *et al.* (2005).	$W = 0.00005641*LS^{2.877}$ (LS en mm). $W = 0.0187*LF^{2.996}$ (LF en cm).
Saisons	Reproduction de juillet à octobre.	Loubens (1980a). Borsa *et al.* (2009).	Juncker (2010).	Reproduction toute l'année avec prédominance entre juillet et novembre.
Zones	<u>Zones de reproduction</u> : Fonds de lagon sableux parfois passes avec	Borsa *et al.* (2009). Juncker (2010).	---	---

	fonds érodés. <u>Zones de vie</u> : Juvéniles dans les algueraies et herbiers peu profonds. Adultes sur les fonds de lagon, se rapprochant de la barrière en grandissant.			
Fécondité (*Fe*)	Log(Fe) = Log(a) + b*Log(LF). Où a=1.58*10^{-3} et b=5.2 en aout et septembre, et a=3 et b=3.16 en juillet et octobre.	Ebisawa (1990).	---	---
Taux de reproduction (TR_c)	Classes 0 à 4 = 0 Classe 5 = 0.5 Classe 6 = 0.85 Classes 7 à 10 = 1	Calculés à partir des données de pêche à la palangre (Kulbicki et Mou Tham, 2006).	---	---
Distribution de la reproduction ($Prepro_t$)	juillet : 0.23 aout : 0.46 septembre : 0.24 octobre : 0.07	Calculés à partir des données de pêche à la palangre (Kulbicki et Mou Tham, 2006).	Loubens (1980a).	juillet : 0.13 aout : 0.35 septembre : 0.32 octobre : 0.2
Nombre de mois entre ponte et recrutement	1 mois.	---	---	---
Distribution du recrutement	1 mois, avec 100%.	---	---	---
Capturabilité	Valeurs fixées par calibration, voir Chapitre IV.	---	---	---
Mobilité	m_{esp} = 0.05	Wantiez (com. pers.). Kulbicki (com. pers.).	---	---

Paramètres de la dynamique de *Plectropomus leopardus.*

	Valeur du paramètre	Référence(s) utilisée(s)	Autre(s) référence(s) sur le sujet	Autre(s) valeur(s) correspondante(s)
Structuration de la population	16 classes d'âge.	---	---	---
Classe d'âge +	oui	---	---	---
Maturité	A_{25} = 3 ans A_{50} = 4 ans A_{100} = 5 ans	Ferreira (1995b).	Adams 2000.	A_{100} = 35 cm (LF).
Sexe ratio	Classe d'âge 0 à 10 : 100% de femelles. Classes d'âge 11 à 13 : 43% de femelles. Classe d'âge 15 : 0 % de femelles.	Loubens (1980a).	Ferreira (1995) et Adams (2000).	---
Croissance	Equation de type Von Bertalanffy : $Lt = L\infty - a * e^{-kt}$ Avec L∞ = 500 ; a = 425.1 et K =0.158 (LS) en mm. Les tailles obtenues sont converties en longueurs à la fourche (LF) en cm, en utilisant la relation LS-LF : LF = 1.145 * LS + 10.7	Loubens (1980b).	Ferreira (1994).	$L_t =$ $52.2\ (1 - e^{-0.354(t+0.766)})$ (LF) en cm.
Mortalité naturelle	Coefficient instantané de mortalité annuel. Pré-recrutement : M = 3.612 Classe d'âge 0 : M = 2.079 Classes d'âges 1, 2 et 3 : M = 0.320 Classes d'âges ≥ 4 : M = 0.1473	Leis & Carson-Ewart (1999). Masuma (1993). Armsworth (2002). Russ *et al.* (1998).	---	---
Relation taille-poids	P = 0.0118 * $LF^{3.06}$ avec LF en cm.	Loubens (1980b).	Loubens (1980b). Ferreira & Russ (1994).	P = 0.00002374 * $LS^{3.01}$ Avec LS en mm et LS = (LF(cm)*10 -10.7) / 1.145 P = 0.0079 * $LF^{3.157}$
Saisons	<u>2 saisons</u> : Reproduction : octobre à décembre. Non reproduction : janvier à septembre.	Juncker (2010).	Ferreira (1995). Loubens (1980a).	Reproduction entre août et décembre.
Zones	<u>Zones de reproduction</u> : Passes <u>Zones de vie</u> : Juvéniles : Crête et pente des platiers et	Juncker (2010).	Enquêtes frai ZoNéCo.	---

	constructions coralliennes peu profondes. Adultes : Crête et pente des platiers et constructions coralliennes profondes.			
Fécondité (*Fe*)	Fe = 0.0129*$L^{3.03}$ où L est en mm.	Sadovy (1996).	---	---
Taux de reproduction (*TR_c*)	Utilisé comme la combinaison du taux de reproduction et du sexe ratio. Classes d'âges 0 et 1 = 0 Classe d'âge 2 = 0.25 Classe d'âge 3 = 0.5 Classes d'âges 4 à 10 = 1 Classes d'âge 11 à 13 = 0.57 Classe d'âge 15 = 0	Loubens (1980a). Ferreira (1995b).	---	---
Distribution de la reproduction (*$Prepro_t$*)	octobre : 0.2 novembre : 0.3 décembre : 0.5	Loubens (1980a).	---	---
Nombre de mois entre ponte et recrutement	2 mois.	Masuma (1993).	---	---
Distribution du recrutement	1 mois avec 100%.	---	---	---
Capturabilité	Valeurs fixées par calibration, voir Chapitre IV.	---	---	---
Mobilité	m_{esp} = 0.005			

Paramètres de la dynamique de *Naso unicornis*.

	Valeur du paramètre	Référence(s) utilisée(s)	Autre(s) référence(s) sur le sujet	Autre(s) valeur(s) correspondante(s)
Structuration de la population	10 classes d'âge.	---	---	---
Classe d'âge +	oui	---	---	---
Maturité	A_{50} = 2 ans.	Rathacharen (1999).	--	---
Sexe ratio	1 : 1	Loubens (1980a).	---	---
Croissance	Equation de type von Bertalanffy : $Lt = L\infty(1 - e^{-kt})$ Avec L∞ = 69.015 et K = 0.1515 Cette équation est calculée sur la base de tailles en longueurs total (TL) en cm.	Compromis entre : Kitalon & Dalzell (1994). Rathacharen *et al.* (1999).	Kitalon & Dalzell (1994). Rathacharen *et al.* (1999).	Avec L∞ = 57 et K = 0.14 Avec L∞ = 81.03 et K = 0.163
Mortalité naturelle	Coefficient instantané de mortalité annuel. Pré-recrutement : M = 0.9416 Classe d'âge 0 : M = 4.605 Classes d'âges 1 : M = 1.127 Classes d'âges ≥ 5 : M = 0.387	Doherty *et al.* (2004). Calculé à partir de l'équation de Pauly (1980).	Kitalong & Dalzell (1994). Rathacharen *et al.* (1999). Wilson (2004).	Mortalité adultes = 0.413 Mortalité adultes = 0.4 Mortalité adultes = 0.27
Relation taille-poids	$P = 0.00002701 * LS^{2.951}$	Loubens (1980b).	Choat & Axe (1996). Rathacharen *et al.* (1999).	$P=0.00008495*LS^{2.843}$ $P = 0.0467*LT_{2.6701}$
Saisons	2 saisons : Reproduction : novembre à mars. Non reproduction : avril à septembre	Juncker (2010).	---	---
Zones	Zones de reproduction : Passes Zones de vie : Juvéniles : Platiers, tombant et constructions coralliennes peu profondes. Adultes : Platiers, tombant et constructions coralliennes profondes.	Juncker (2010). Wantiez (com. pers.).	---	---
Fécondité (*Fe*)	Log(Fe) = Log(a) + b*Log(LF). Où a=3 et b=3.16 en juillet et octobre.	En l'absence d'information c'est l'équation de *l. nebulosus* en juillet et octobre qui a été utilisés.	---	---
Taux de reproduction (*TR_c*)	Classes d'âges 0 et 1 = 0 Classe d'âge 2 = 0.5 Classes d'âge ≥ 3 = 1	Rathacharen (1999).	---	---
Distribution de la	novembre : 0.1		---	---

reproduction (*$Prepro_t$*)	décembre : 0.25 janvier : 0.30 février : 0.25 mars : 0.1			
Nombre de mois entre ponte et recrutement	2 mois.	Planes *et al.* (2002).	---	---
Distribution du recrutement	1 mois avec 100%.	---	---	---
Capturabilité	Valeurs fixées par calibration, voir Chapitre IV.	---	---	---
Mobilité	m_{esp} = 0.01	---	---	---

ANNEXE 5

FICHE DE DECLARATION DE CAPTURES DE PECHE PROFESSIONNELLE

FICHE DE CAMPAGNE

Période du : au :
jours de mer :
jours de pêche :

Heures moteur : *Départ:* *Arrivée:*
Zone de pêche :
Nbre d'équipage :

DEPENSES (charges)

FRAIS DE CAMPAGNE

	Qté	Prix
* Carburant	....	....
* Glace	....	....
* Vivres	....	....
* Petit matériel	....	....
* Frais commer,	....	....
* Frais OPT	....	....
* Appâts	....	....
* Autres	....	....
Total frais camp(1)		*F.CFP*

SALAIRES

* Patron	....	....
* Matelot 1	....	....
* Matelot 2	....	....
* Matelot 3	....	....
* Matelot 4	....	....
* Matelot 5	....	....
* Cotisations sociales employés:		
- Cafat et CRE	....	....
* Cotisation patron pêcheur:		
- RUAMM	....	....
Total salaires(2)	....	*F.CFP*

FRAIS D'ARMEMENT

Gros entretien

* Mat, pêche	....	....
* Ent, bateau	....	....
* Ent, moteur	....	....
Frais stockage	....	....
Frais excep	....	....
Total frais d'arm, (3)	....	*F.CFP*

TOTAL CHARGES = ,,,,,,,,,,,,,,,,,,,,,,,,,, ...
(1+2+3) **(A)**

Observations :

RECETTES (produits)

PRODUITS DES VENTES

* POISSONS	*Kg Entier*	*Gains*	*Kg Filets*	*Gains*
Becs de cane				
Bossus				
Carangues				
Dawas				
Gueules rouges				
Loches				
Mahi-mahi				
Maquereaux				
Mulets				
Perroquets				
Picots				
Tazards				
Thons				
Vivaneaux poulets				
Vivaneaux rouges				
Wiwas				
TOTAL				

*** AUTRES**	*KG*	*GAINS*
Bêches de mer		
Bénitiers		
Coquillages		
Crabes		
Huîtres (dz)		
Langoustes		
Poulpes		
Trocas		
TOTAL		

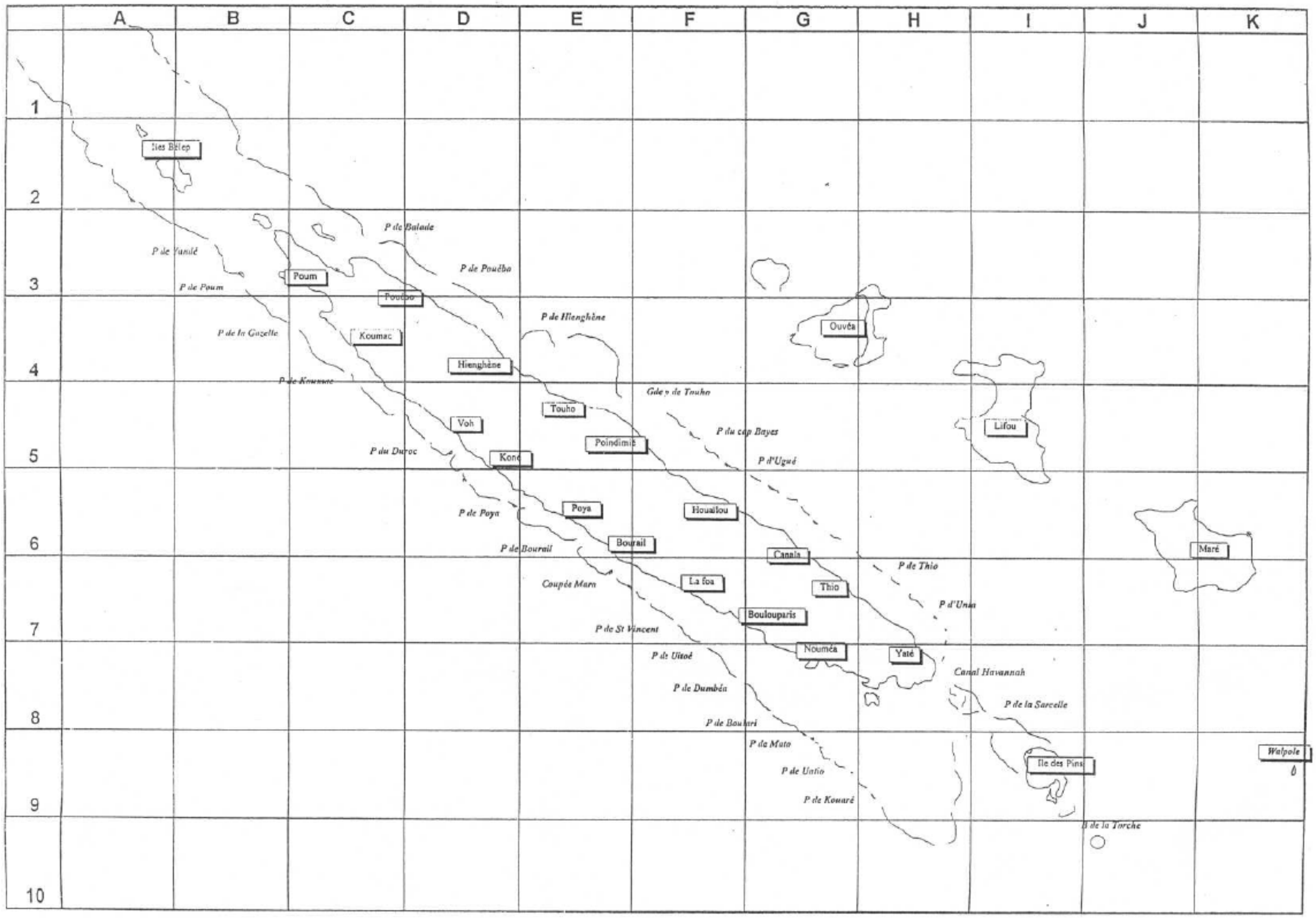
TOTAL PRODUITS =...
(B)

Produits non vendus (raisons) :

RESULTAT DE LA CAMPAGNE (B - A) = ... F.CFP
GAGNE
PERDU

ANNEXE 6

CARTE ET MAILLAGE POUR LA SPATIALISATION DES DECLARATIONS DE CAPTURES DE PECHE PROFESSIONNELLE


A
B
C
D
E
F
G
H
I
J
K
1
2
3
4
5
6
7
8
9
10
Iles Bélep
P de Balade
P de Pouébo
Poum
P de Poum
Koumac
P de la Gazelle
Hienghène
P de Hienghène
Ouvéa
Gde p de Touho
Touho
Voh
Koné
P du Duroc
Poindimié
P du cap Bayes
P d'Ugué
Lifou
Poya
P de Poya
Houaïlou
Bourail
P de Bourail
Canala
Maré
P de Thio
Coupée Mara
La foa
Thio
P d'Unia
Boulouparis
P de St Vincent
P de Uitoé
Nouméa
Yaté
Canal Havannah
P de Dumbéa
P de la Sarcelle
P de Boulari
P de Mato
P de Uatio
P de Kouaré
Ile des Pins
Walpole

ANNEXE 7

QUESTIONNAIRE DE PECHE PROFESSIONNELLE

Questionnaire Pêche Professionnelle site Nouvelle-Calédonie

Ce questionnaire est destiné aux pêcheurs professionnels en activité ou ayant été en activité. Le traitement des données recueillies restera confidentielle et anonyme et resteront dans le cadre du projet de recherche PAMPA.

Début :

1. date entretien :

2. site :

3. Nom de l'enquêteur :

4. Temps du questionnaire :

Partie 1 / DESCRIPTION DE VOTRE ACTIVITE DE PECHE

. Nom du bateau et immatriculation :

. Nom du pêcheur :

. Port d'attache :

. Année de naissance :

. En quelle année avez vous commencez à pêcher ? _______(ou a quel âge)

. Adresse :

. Etes vous : propriétaire du navire / copropriétaire / pas le propriétaire :

. Combien de navires possédez-vous :

. Raison d'entrée dans la profession :

. Diplôme de pêche :

. Avez-vous une autre profession que celle de marin-pêcheur ?

. « Numéro » du bateau :

13. Quelles sont les principales caractéristiques techniques de votre (vos) navire(s) ?

Bateau	Longueur (mètres)	Jauge (TJB)	Puissance du moteur	Année de construction	Année d'achat	Taille de l'équipage (patron inclus)
1						
2						
3						

14. Distance moyenne entre le port et vos lieux habituels de pêche (en miles nautiques) :

15. Depuis combien de temps pêchez-vous dans le lagon sud-ouest ? __________

17. Précisions sur vos activités de pêche

	Activité globale	**Description par engin**		
		Engin 1	**Engin 2**	**Engin 3**
Nom de l'engin				
Principales espèces ciblées				
Nom de l'espèce 1				
Nom de l'espèce 2				
Nom de l'espèce 3				
Nombre annuel de sorties				
Nombre total (sorties/an)				
% de sorties	%	%	%	%

IMPACT / INFLUENCE DES RESERVES SUR L'ACTIVITE DE LA PECHE

Comment avez vous perçu cette création ?

Quand vous avez commencé à pêcher dans le lagon sud-ouest ou lors de la création des réserves, comment avez-vous perçu ces réserves ?

☐ Très positif ☐ Plutôt positif ☐ Neutre ☐ Plutôt négatif ☐ Très négatif ☐ NSP

Quelle est votre opinion aujourd'hui ?

☐ Très positif ☐ Plutôt positif ☐ Neutre ☐ Plutôt négatif ☐ Très négatif ☐ NSP

Pêchiez-vous dans la zone de la réserve avant qu'elle ne soit créée ? Si oui, pourriez-vous nous dessiner les zones de pêche et nous indiquer le métier pratiqué ?

Qu'est-ce qui a changé dans votre activité depuis la création de la réserve ?

=> Question globale à poser une fois ; ce sera à nous d'en décortiquer les réponses

=> Concerne les zones de pêches ; Engins / Métier / Effort ; Captures :

Changement d'engins de pêche ☐ Oui ☐ Non

Changement de l'effort de pêche ☐ Oui ☐ Non

Changement du nombre de sorties ☐ Oui ☐ Non *(Pourquoi ?)*

Changement de zone de pêche ☐ Oui ☐ Non

Autres (précisez) :

Engins / Métier :

Engins / Métier	En augmentation	En diminution	Identique	NSP	Présence réserve ?	Période l'année

Pour quels engins ? La présence des réserves joue-t-elle sur votre décision ?

Engins	*Fréquence*	*Période de l'année*	*Distance réserve*	*Présence réserve ?*	*Commentaires*

Fréquence *:* ☐ <5% ☐ 5-25% ☐ 25-50% ☐ 50-75% ☐ 75-100%

Nb de sortie ☐ plus nombreuses ☐ moins nombreuses ☐ équivalentes ☐ NSP

Zones de pêche :

Distance à la réserve : ☐ qui diminue ☐ qui augmente ☐ équivalentes ☐ NSP

Distance à la côte : ☐ qui diminue ☐ qui augmente ☐ équivalentes ☐ NSP

Distance au port : ☐ qui diminue ☐ qui augmente ☐ équivalentes ☐ NSP

Captures :

Depuis que vous pêchez, avez-vous observé un changement dans vos captures ?

Nombre des prises ☐ plus nombreuses ☐ moins nombreuses ☐ équivalentes ☐ NSP

Taille des prises ☐ plus grandes ☐ moins grandes ☐ équivalentes ☐ NSP

Diversité des prises ☐ plus diversifiées ☐ moins diversifiées ☐ équivalentes ☐ NSP

Si baisse des ressources exploitées, quelles sont selon vous les raisons ?

☐ Effort de pêche trop important des professionnels

☐ Effort de pêche trop important des amateurs

☐ Chalutage illégal dans la bande côtière

☐ Braconnage

☐ Aménagements côtiers (Digues, plages...)

☐ Pollution marine ☐ / terrestre ☐

☐ Facteurs naturels (fluctuations cycliques des populations)

☐ Changement climatique global

☐ Politique de l'Etat

☐ Politique de l'Europe

☐ Autre (précisez) :

Et près des réserves ?

Nombre des prises	☐ plus nombreuses	☐ moins nombreuses	☐ équivalentes	☐ NSP
Taille des prises	☐ plus grandes	☐ moins grandes	☐ équivalentes	☐ NSP
Diversité des prises	☐ plus diversifiées	☐ moins diversifiées	☐ équivalentes	☐ NSP

Pour quelles espèces en particulier ?

Espèce	Evolution (P / N)	Impact (P / N)	Années	Raisons	Commentaires

***Evolution** : Augmentation forte (DF), Augmentation faible (DA), Stable (ST), Diminution faible (DA), Diminution forte (DA).*

***Impact** : Très positif (TP), Plutôt positif (PP), Neutre, (NE), Plutôt négatif (PN), Très négatif (TN), Ne se prononce pas (NSP).*

***Raisons** : Décisions politiques (DP), Chalutage illégal / braconnage (BR), Présence réserve (RE), Réchauffement des eaux / Changements climatiques (CC), Récifs artificiels (RA), Inexpliqué (IN), Autres (AU) à développer…*

IX. Quel est l'effet des réserves sur l'environnement (diversité, protection…) ?

☐ Très positif ☐ Plutôt positif ☐ Neutre ☐ Plutôt négatif ☐ Très négatif ☐ NSP

X. Globalement, quel est l'effet des réserves sur votre activité de pêche (professionnelle aux petits métiers) ?

☐ Très positif ☐ Plutôt positif ☐ Neutre ☐ Plutôt négatif ☐ Très négatif ☐ NSP

XI. Quel est l'effet des réserves sur l'économie locale (en termes d'emplois, tourisme…) ?

☐ Très positif ☐ Plutôt positif ☐ Neutre ☐ Plutôt négatif ☐ Très négatif ☐ NSP

Quelles sont vos relations avec les autres usagers ?

	Bonnes	Conflictuelles	Inexistantes
Les autres pêcheurs petits métiers côtiers			
Les pêcheurs récréatifs (du bord et embarqué)			
Les chasseurs sous-marins			
Les plaisanciers			
bateaux à touristes			
Les clubs de plongée			
Les plongeurs			
Les Jet ski			
Les surfers, windsurfers, kite-surfers…			
Les kayaks			
Les autres usagers (précisez)			

XII Pour vous, quelles sont les activités ayant le plus d'effet négatif sur votre activité ?

	Ressource	Espace	Commentaire
Les autres pêcheurs petits métiers côtiers			
Les pêcheurs récréatifs (du bord et embarqué)			
Les chasseurs sous-marins			
Les plaisanciers			
bateaux à touristes			
Les clubs de plongée			
Les plongeurs			
Les Jet ski			
Les surfers, windsurfers, kite-surfers…			
Les kayaks			
Les autres usagers (précisez)			

PERCEPTION DU FONCTIONNEMENT DES RESERVES

Quel est selon vous l'objectif des réserves dans le lagon sud-ouest ?

☐ Protéger et conserver les écosystèmes

☐ Favoriser l'activité de pêche professionnelle

☐ Favoriser l'activité de pêche récréative

☐ Favoriser le développement touristique (plongée et autres)

☐ Pas d'idée précise

Que pensez-vous des superficies des réserves ?

☐ Trop grandes ☐ Bonnes ☐ Pas assez grandes ☐ NSP

Pensez vous que le balisage des réserves est adapté ? :

☐ Oui ☐ Non ☐ NSP

Si non, quel est le problème :

Pensez vous que les réserves sont bien situées ?

☐ Oui ☐ Non ☐ NSP

Si non, ou faudrait-il les mettre :

XII. Avez-vous l'impression d'être suffisamment informé sur les réglementations en vigueur dans les réserves ?

Oui ☐ Non ☐

XIII. Si vous les connaissez, pensez-vous que ces réglementations sont bien adaptées ?

☐ Trop Strictes ☐ Bien adaptées ☐ Insuffisantes ☐ NSP

XIV. Pensez-vous que ces réglementations sont bien respectées ?

Oui ☐ Non ☐ NSP ☐

La surveillance en mer dans les réserves par la Province Sud est selon vous :

☐ Insuffisant ☐ Suffisant ☐ Trop important ☐ NSP

Le niveau de contrôle en mer par les autorités de l'Etat (Affaires Maritimes, Gendarmeries, Douanes) est selon vous :

☐ Insuffisant ☐ Suffisant ☐ Trop important ☐ NSP

Connaissez-vous les sanctions en cas de pêche dans les réserves ? :

☐ Oui ☐ Non ☐ NSP

Si oui, pensez vous que ces sanctions sont :

☐ Insuffisantes ☐ Suffisantes ☐ Trop élevées ☐ NSP

Vous est-il arrivé de pêcher dans les réserves ?

☐ Jamais ☐ Occasionnellement ☐ Fréquemment ☐ NSP

XV. Vous estimez-vous suffisamment associé au processus de décision dans le lagon sud-ouest ?

☐ Très bien ☐ Plutôt bien ☐ Pas très bien ☐ Non ☐ NSP

Avez-vous une attente en termes de partenariat ou d'aide vis-à-vis de la Province Sud?

(Ou alors Vers quelles actions souhaitez-vous que la Province Sud s'oriente ?)

☐ Oui ☐ Non ☐ NSP

Si oui, précisez :

☐ Plus d'informations scientifiques

☐ Plus d'informations techniques

☐ Plus de partenariats avec les pêcheurs (précisez quel type de partenariat?)

☐ Plus de contrôles ☐ vis à vis des plaisanciers ☐ vis à vis des chalutiers

☐ Autres (précisez) :

Etes-vous favorable à la création avec les autorités compétentes d'une « charte de pêche » (code de bonne conduite pour une pêche durable)

☐ Oui ☐ Non ☐ NSP

Si non, pourquoi ?

XVI. Quelle(s) solution(s) vous paraît la mieux adaptée pour soutenir la pêche côtière ? (2 max)

☐ Faire respecter la réglementation existante

☐ Agrandir les réserves existantes

☐ Créer une nouvelle réserve marine (précisez à quel endroit ?)

☐ Réempoissonnement de certaines zones (quelles espèces ?)

☐ Augmenter les tailles minimales de capture

☐ Fixer des quotas de pêche (ex. quantité maximale par espèce, par pêcheur, par jour, etc.)

☐ Fermer la pêche pendant la reproduction de certaines espèces (arrêt biologique)

☐ Diminuer les longueurs de filets

☐ Augmenter les mailles des filets

☐ Fixer des quotas pour la pêche récréative

☐ Créer un permis de pêche pour la pêche récréative

☐ Augmenter les subventions

☐ Vente locale

☐ Label de qualité

☐ Autres

XVII. Savez-vous qu'il existe des tailles minimales de capture pour certaines espèces ?

Oui ☐ Non ☐

Pensez-vous que la pêche a de l'avenir ??

☐ Oui ☐ Non ☐ NSP

Que faudrait-il faire pour soutenir (sauver) la profession :

(question ouverte) :

Avez-vous déjà entendu parler du classement du lagon calédonien au Patrimoine Mondial de l'UNESCO ?

☐ Oui ☐ Non ☐ NSP

Avez-vous connaissance des zones faisant partie du Patrimoine Mondial dans le lagon sud-ouest ?

☐ Oui ☐ Non ☐ NSP

Si oui par quel moyen ?

☐ par le syndicat des pêcheurs

☐ par la Province Sud

☐ par un élu

☐ par le bouche à oreille

☐ par la presse

☐ par la télévision

☐ par la radio

☐ par internet

☐ autre

Etes-vous favorable au classement des lagons calédoniens au Patrimoine Mondial de l'UNESCO ?

☐ Oui ☐ Non ☐ NSP

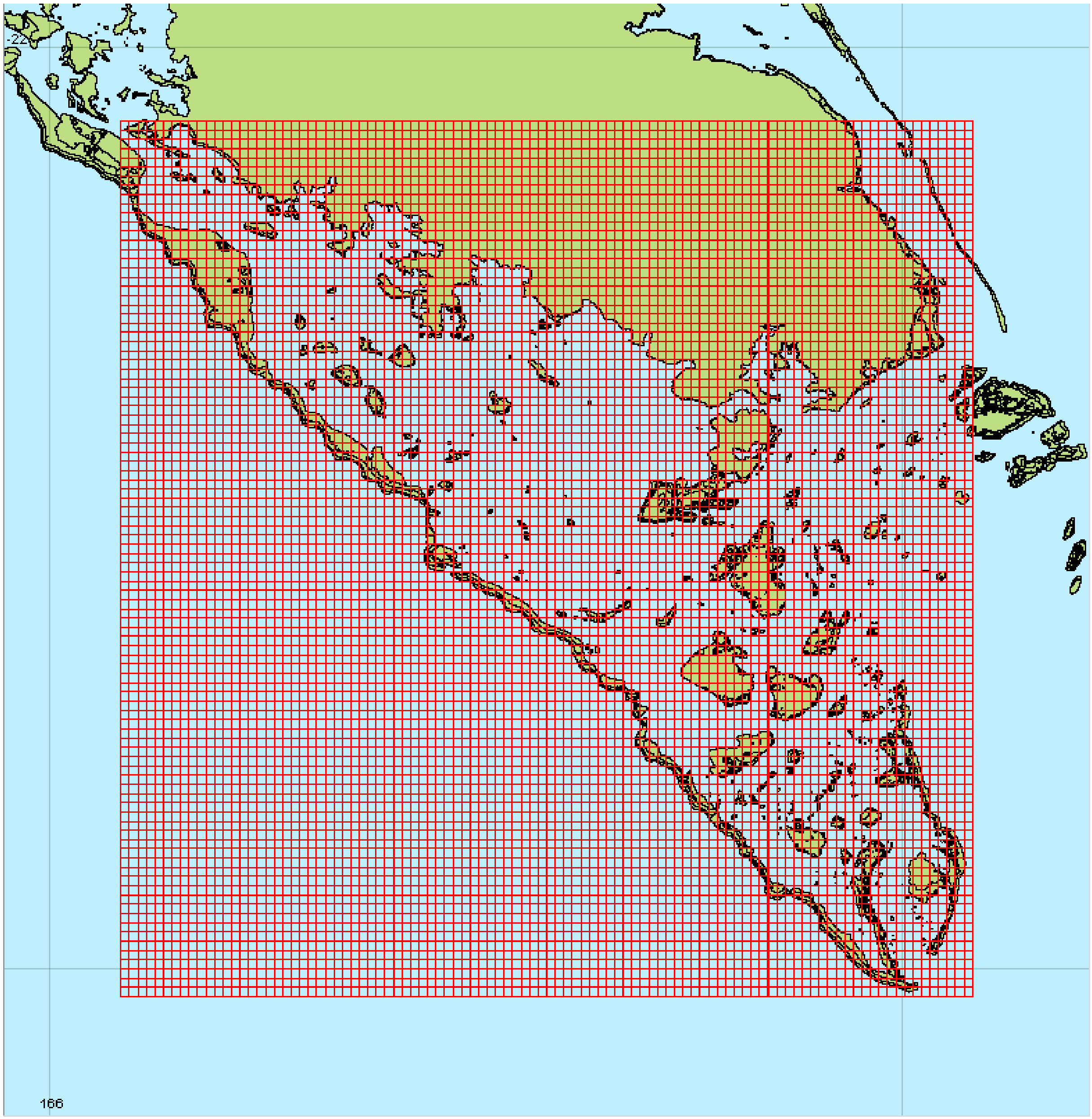
D'après vous, les informations suivantes sont vraies ou fausses ?	Vrai	Faux
Le Patrimoine Mondial impose une diminution de l'effort de pêche des professionnels	☐	☐
Dans un site classé au Patrimoine Mondial, toute activité de prélèvements (pêche, chasse) est interdite	☐	☐
Dans un site classé au Patrimoine Mondial, toute activité de loisir (plaisance, plongée, baignade) est réglementée	☐	☐

Un site classé au Patrimoine Mondial a pour objectif de conserver les habitats et les espèces représentatives de la biodiversité	☐	☐
Le Patrimoine Mondial impose une nouvelle réglementation sur les zones classées	☐	☐
Le Patrimoine Mondial s'est élaboré en concertation avec la population afin de définir des mesures de conservation des habitats et des espèces	☐	☐

Avez-vous des suggestions à faire, des remarques particulières sur le questionnaire ou la réglementation?

Merci de votre collaboration active !!

Carte de localisation des zones de pêche.



Calendrier d'activité

	Bec de cane	**Saumonée**	**Dawa**
Janvier			
Février			
Mars			
Avril			
Mai			
Juin			
Juillet			
Août			
Septembre			
Octobre			
Novembre			
Décembre			

ANNEXE 8

ECHELLES ET CODIFICATIONS DES INFORMATIONS CONTEXTUELLES RELEVEES LORS DES SORTIES EN MER.

Information contextuelle	Echelle et codification
Heure de départ et d'arrivée	hh : mm
Type de jour	js = jour de semaine jw = jour de week-end jw+vac = jour de week-end et de vacances pont = jour de pont vac = jour de vacances
Météo générale	Pluie Averses Couvert Eclaircies Soleil
Nébulosité	Echelle de 1 à 8 couramment utilisé en météorologie. 0/8= Ciel serein 1/8= Ciel peu nuageux à serein 2/8= Ciel peu nuageux variable 3/8= Ciel nuageux à peu nuageux 4/8= Ciel nuageux 5/8= Ciel nuageux à très nuageux abondante 6/8= Ciel très nuageux 7/8= Ciel très nuageux à couvert 8/8= Ciel couvert. Invisible ou brouillard
Direction du vent	N = Nord NNE = Nord Nord Est NE = Nord Est ENE = Est Nord Est E = Est ESE = Est Sud Est SE = Sud Est SSE = Sud Sud Est S = Sud SSW = Sud Sud Ouest SW = Sud Ouest WSW = Ouest Sud Ouest W = Ouest WNW =Ouest Nord Ouest NW = Nord Ouest NNW = Nord Nord Ouest
Force du vent	Echelle de Beaufort
Etat de la mer	1 = mer belle 2 = mer peu agitée 3 = mer agitée 4 = mer très agitée
Lune	NL = nouvelle lune LM = lune montante PL = pleine lune LD = lune montante

ANNEXE 9

FICHE DE RELEVE DE LA FREQUENTATION

Date : ………… ; type de jour : ……… ; météo : ………. ; nébulosité : ………… ; vent : ……… ; direction: ………. ; mer : ………. ;

Enquêteur : ………… Départ :…….. ; Arrivée :………….. ; Circuit :………

Heure	Ilot ou Lagon	Type et taille du bateau	Nom/ Immatri-culation du bateau	Nbre de personnes à bord	Mouillage	nature du fond	Si ancré et/ou Lagon : Position GPS	Activité	Commentaires	Q.n°

Codage des informations renseignées lors des relevés de fréquentation.

Information sur les navires	Echelle et codification
Type	M = moteur V = voilier
Taille	< 5 m = Inférieur à 5 mètres 5 - 7 m = de 5 et 7 mètres (non inclus) 7 – 10 m = de 7 et 10 mètres (non inclus) + 10 = 10 mètres et plus
Nom ou immatriculation	Généralement, nom pour les voiliers et immatriculation pour les navires à moteur
Position GPS	
Nombre de personnes à bord	
Type de mouillage	AC = ancré BC = beaché sur la plage CM =attaché à un corps-mort PT = accosté à un ponton DE = en dérive RO = faisant route
Nature du fond si ancré	H = herbier A = algueraie C = corail S = sable D = dalle
Activité (seules les activités concernant la pêche ont été reportées ici)	CH = chasse sous-marine PB = pêche du bord PE = pêche embarquée POC = plongeur corailleur aquariophile PP = pêche a pieds PRO = divers pêche professionnelle

ANNEXE 10

QUESTIONNAIRE DE PECHE PLAISANCIERE

N° ....

Enquêteur :

Etude de la pêche récréative dans les AMP

(Age minimum de l'enquêté **15 ans**)

PAMPA

A. Informations contextuelles

A.1 Date : ……../………/200…

A.2 Heure : …….h……..

A.3 Site : ……………………….

A.4 Etat de la mer : …………………..

A.5 Lune : …………………………………

A.6.1 Direction du vent : …………………

A.6.2 Force du vent : ……………………..

A.7 Nébulosité (/8 octats) : ………………

A.8 Point GPS : ……………………………..

B. Activité de pêche pratiquée aujourd'hui

B.1 Type de pêche

- ☐ Pêche du bord
- ☐ Pêche embarquée
- ☐ Chasse sous-marine
- ☐ Ramassage, récolte

B.2 D'où êtes vous parti pour cette sortie ?

☐ Port : ……………… ☐ Marina …………….. ☐ Rampe : …………….

B.3 Au cours de cette sortie en mer, combien y a-t-il de pêcheurs (à bord) ? ………..

B.4. Avez-vous pêché ailleurs que dans cette zone aujourd'hui ?

Si oui lesquels ? ……………………………………………………………………………..

B.5 Techniques de pêche du jour

B.5.1 Quels sont les engins que vous utilisez lors de cette sortie en mer ?

B.5.2 Combien de chaque utilisez-vous ?

- ☐ fusil sous-marin ………..
- ☐ traîne…………………
- ☐ palangre………….
- ☐ ligne à la main (palangrotte)……
- ☐ canne à pêche du bord …
- ☐ filet maillant ……………
- ☐ jig ………………
- ☐ casier……….
- ☐ ramassage à la main ………..
- ☐ senne de plage
- ☐ épervier

B.6 Combien de temps a duré (ou va durer) cette sortie ? ……….h……….

B.6.1 Début de la pêche : ……..h…….. **B.6.2** Fin de la pêche : ……..h………

B.6.3 Durée totale de la pêche : ……….h……….

B.7 Captures du jour : Quelles espèces avez-vous pêchées aujourd'hui ?

B.7.1 Méthode d'évaluation des captures

☐ estimation (à l'œil) ☐ mesure (balance ou mètre)

B.7.2 Quelles sont les espèces que vous avez pêchées aujourd'hui ?

Famille	Espèce	Nombre	Taille (ou poids si pesé)	Engin

C. Activité de pêche habituelle, sur l'année

C.1 Depuis combien d'années pratiquez-vous la pêche récréative ? ....

☐ - de 1 an ☐ 1 à 5ans ☐ 6 à 10 ans ☐ 11 à 20 ans ☐ 21 à 30 ans ☐ + de 30 ans

C.2 En général, quand pêchez-vous ?

C.2.1 Au cours de l'année ?

☐ Toute l'année
☐ Plutôt l'été
☐ Plutôt l'hiver

C.2.2 Au cours de la semaine ?

☐ En semaine
☐ Le week-end
☐ En vacances
☐ Indifférent

C.2.3 Au cours de la journée

☐ Matin
☐ Après-midi
☐ Soirée
☐ Nuit

☐ Indifférent

G.1 Planifiez-vous vos sorties de pêche en fonction :

☐ Des marées
☐ De la lune
☐ De la météo
☐ Indifférent

C.3 Quelles sont vos techniques habituelles de pêche ?

	Pêche embarquée	Pêche du bord	Pêche sous marine	Ramassage (pêche à pied)
C.3.1 Activités principales (oui/non)(max. 2)				
C.3.2 Engin principal (max. 2 par case)				

C.4 Nombre moyen de sorties par an

C.4.1 Nombre moyen de sorties (toutes zones, monde entier)

	Pêche embarquée	Pêche du bord	Pêche sous marine	Ramassage (pêche à pied)	**Total** (tout type de pêche confondu)
Nb moyen de sorties **/ an**					

C.4.2 Part de l'AMP : Approximativement, quelle proportion de vos sorties annuelles est réalisée dans les zones de pêche autorisées de l'AMP ou à proximité de l'AMP ?

- ☐ 0%
- ☐ 0-25%
- ☐ 25-50%
- ☐ 50-75%
- ☐ 75-100%

C.5 Quels sont les 3 facteurs qui influencent le plus votre choix d'un site de pêche ? Pouvez-vous les classer du plus important (1) au moins important (3)

- ☐ Abondance des poissons
- ☐ Espèces que vous recherchez
- ☐ Météo, marées…
- ☐ Accessibilité, proximité site de pêche
- ☐ Réglementation
- ☐ Beauté du site, paysage…
- ☐ Tranquillité (faible fréquentation)
- ☐ Présence des autres pêcheurs
- ☐ Autre :……………………………

C.6 Pour quelle raison principale pêchez-vous ? (deux réponses)

- ☐ Pour le plaisir de pêcher
- ☐ Pour manger le poisson que vous pêchez
- ☐ Pour manger du poisson (obligation)
- ☐ Pour vendre ou échanger du poisson

C.7 Captures annuelles (toutes zones, monde entier) :

C.7.1 Pouvez-vous nous indiquez les principales espèces que vous pêchez, dans l'année ?

Espèces principales pêchées (par ordre décroissant de poids)	
1.	4.
2.	5.
3.	

C.7.2 Approximativement, quel est le volume de vos captures, par an et par personne

- ☐ 0-25 kg
- ☐ 26-50 kg
- ☐ 51-100 kg
- ☐ 101-200 kg
- ☐ plus de 200 kg

G.2 Depuis que vous pêchez, avez-vous observé un changement dans vos captures ?

Nombre de prises	☐ plus nombreuses	☐ moins nombreuses	☐ équivalentes	☐ nsp
Taille des prises	☐ plus grosses	☐ moins grosses	☐ équivalentes	☐ nsp
Diversité des prises (spécifier le(s) sp)	☐ plus diversifiées	☐ moins diversifiées	☐ équivalentes	☐ nsp

C.8 A combien évaluez-vous le budget annuel total consacré à la pêche ? ……….. **CFP**

D. Perceptions

D.1 Connaissance de l'AMP et de sa réglementation

D.1.1 Avez-vous connaissance des réserves ? ☐oui ☐non

D.1.2 Est-ce que la réserve a joué un rôle dans la décision du site de pêche ?

☐ Décisif	☐ Modéré	☐ Faible, voire nul

G.3 Pour vous qu'est ce qu'une réserve ? le premier mot qui vous vient à l'esprit.

- ☐ C'est une réglementation qui vous empêche de ………………………………
- ☐ C'est un site où la faune et la flore sont protégées
- ☐ C'est un moyen d'augmenter les ressources pour la pêche
- ☐ C'est un outil pour sensibiliser à l'environnement
- ☐ Autre : ……………………………………………………..
- ☐ Nsp

G.4 Que pensez-vous des réserves dans le Grand-Nouméa ?

- ☐ Trop nombreuses ……………………………………………………………………
- ☐ Pas assez nombreuses ……………………………………………………………
- ☐ Mal réparties ………………………………………………………………………
- ☐ Bien …………………………………………………………………………………
- ☐ Nsp …………………………………………………………………………………

G.5 Connaissez-vous l'avantage des corps-morts pour l'environnement ?

- ☐ oui
- ☐ non

G.6 En général, utilisez-vous les corps-morts pour vous amarrer lors de vos sorties en mer ?

- ☐ Vous changez d'îlot si aucun corps-mort n'est libre
- ☐ Vous les utilisez s'ils sont libres
- ☐ Leur utilisation n'est pas une priorité
- ☐ Non, jamais : pourquoi ?…………………………………………………………
- ☐ N'y va pas

G.7 Avez-vous connaissance de la réglementation des réserves ? ☐oui ☐non

G.8 Avez-vous connaissance de la réglementation de la pêche ? ☐oui ☐non

D.1.3 Pensez-vous avoir suffisamment d'informations sur les réserves (objectifs, réglementations…) ?

Oui …………………………………………… Non ………………………………………………

D.1.4 Pensez-vous que ces réglementations sont ?

- ☐ Trop strictes
- ☐ Insuffisantes
- ☐ Bien adaptées
- ☐ NSP

D.1.5 Pensez-vous que les réglementations sont bien respectées ?

- ☐ oui
- ☐ non
- ☐ NSP

D.1.6 Vous estimez-vous suffisamment associé au processus de décision de l'AMP ?

☐ Tout à fait d'accord ☐ Plutôt d'accord ☐ Plutôt pas d'accord ☐ Pas du tout d'accord ☐ NSP

D.2 Perceptions des effets de l'AMP

D.2.1 Selon vous, quel est l'effet de l'AMP sur l'écosystème ?

☐ Très positif ☐ Plutôt positif ☐ Plutôt négatif ☐ Très négatif ☐ NSP

D.2.2 Selon vous, quel est l'effet de l'AMP sur l'économie locale (en termes d'emplois, tourisme…) ?

☐ Très positif ☐ Plutôt positif ☐ Plutôt négatif ☐ Très négatif ☐ NSP

D.2.3 Globalement, quel est l'effet de l'AMP sur votre activité de pêche (à vous) ?

☐ Très positif ☐ Plutôt positif ☐ Plutôt négatif ☐ Très négatif ☐ pas d'effet ☐ NSP

D.3 Quelles sont vos relations avec les autres usagers ?

Usagers	Bonnes	Conflictuelles	Inexistantes	NSP
Pêcheurs professionnels				
Pêcheurs de loisir				
Chasseurs sous-marins				
Plongeurs				
Plaisanciers				
Jet-skis				
Surfers, kite-surfers…				
Autres (précisez)				

F.1 Avez-vous des suggestions/attentes particulières :

……
……………………………………………………………………………

G.9.1 Accepteriez-vous que l'on vous recontacte pour répondre à des questions supplémentaires ?

G.9.2 Souhaitez-vous être informé des résultats de l'enquête ?

G.9.3 Coordonnées :

………

E. Données personnelles

E.1 Sexe : F M **E.2** Année de naissance : …………………

E.4.1 Pays de résidence : …………………   **E.4.2** Résidence principale : ………………

E.3 Métier : …………………………………………

Pratiquez-vous la pêche de nuit ? ☐oui ☐non

ANNEXE 11

ARTICLE SUR LA DESCRIPTION DES ACTIVITES DE PECHE PLAISANCIERE PAR TYPOLOGIE DES PRATIQUES OBSERVEES ET DECLAREES LORS DES ENQUETES DE PECHE

Cet article est en cours de rédaction. La version présentée correspond à un tout premier draft et nécessite encore un travail important. Les principaux résultats y sont présentés mais plusieurs parties sont encore à compléter.

CHARACTERISATION OF RECREATIONAL FISHING ACTIVITIES, A TYPOLOGY OF FISHING TRIP AND FISHING HABITS IN THE SOUTH-WEST LAGOON OF NEW-CALEDONIA

1. INTRODUCTION

Fishery science and fishery management have evolved mainly in the context of developed countries and the private sector, and focused on maintaining maximum yields. Fisheries oriented management approach occurred in the last decades and later people oriented have been developed especially in the case of rural and/or non professional fisheries (Marr, 1982). Although widely used, conventional measures (quotas, gear restriction, legal size, etc.) often failed to prevent depletion of many fish stocks. In some fisheries, these methods of regulation are difficult to implement because of the large number of fishers, the numerous landing site and the diversity of fishing techniques (Hollande, 1996). This is particularly true for recreational fishing and leisure activities that are not structured. Those activities considered as impacting activities, management measures tries to incorporate them in their reflection. In some places where nautical activities and recreational fishing in particular are common, those considerations have been made for decade. In that problematic, MPA is increasingly used as a management tool allowing spatial organization of the coastal areas not only of fishing (professional and recreational) but of leisure activities as well.

Recreational fishing in the South-west of New-Caledonia is a common activity impacting marine resources. To efficiently manage this area, managers need to understand this activity, including fishing techniques used by stockholders, frequented zones, time planning of the activity, impacted species, etc. In this context, we propose to describe recreational fishing activity in the South-west New-Caledonian lagoon. Unstructured recreational fisheries are difficult to control. Understanding of social aspects as motivation, economic investment, fishing area selection, etc. are necessary to built efficient management measures.

Many methods are used to study recreational fishing and provide different types of information (see Pollock *et al.*, (1992) and Sullivan *et al.*, (2006) for reviews. In the present study, we used roving survey with *in situ* interviews of fishers. Roving survey is useful when access is possible at many points like marinas, docks, piers and other landing sites. This survey method allows access to all fishers even those using private access. In the southwest lagoon of New-Caledonia, a traditional access point design study has been done by Jollit (2010) and provided consistent results on the social aspect. By contrast, access to catches was difficult as fishers were rather interested by cleaning their equipment and going back home. Roving survey gives better access to catches but at a time when fishing is not finished.

The lagoon surrounding Noumea (143 000 inhabitants) is under a relatively high fishing pressure from recreational fishers. MPA and daily quotas are the main management measures used since the beginning of the 90's. The growing population and the recent inscription to the UNESCO World Heritage list of an adjacent area lead to enforcement of management.

Management of professional fishing is mainly based on landing declarations and the inventory of the fishing vessels and fishing gears. Usually professional fleets are structured which facilitate the selection of adapted management measures. By contrast, recreational fishing is not structured by administrative procedures and any declaration. Recreational fishing is poorly known. Thus, we propose typologies of the recreational fishing activity in the Southwest lagoon of New Caledonia to describe the structure of that activity and provide fundamental information to managers. Two typologies are proposed. The first one describes the fishing trip of the day of investigation, and the second one describes the fishing habits of the fisherman interrogated. These two complementary approaches will be compared and should provide an accurate description of recreational fishing.

...

2. MATERIAL AND METHODS

Field investigations

Study of recreational fishing has been conducted using roving survey with interviews. The study site is a 1 506 km^2 lagoon area surrounding Noumea located in the South West lagoon of New-Caledonia. Two paths were selected within the area because of its size. Each path was followed alternatively every sampling day (one path per day), clockwise or anticlockwise (randomly chosen). During each journey, the position, registration plate, and fishing technique currently used of every fisher spotted were censused. If the boat was accessible, an interview was conducted.

The questionnaire used for the interviews included a first part regarding the fishing trip of the day (fishing trip information hereafter) and a second part regarding the fishing habits of the owner of the boat.

The fishing trip information consisted of 4 multiple response questions: 1-the main fishing technique used during the fishing trip, 2- the eventual use of a secondary technique, 3- fishing start time, and 4- the catch until fishing start time. Additional information was collected by the interviewer: day type (week, weekend and holidays), season, wind speed, and boat category (Table 1). The fishing time was calculated as the difference between the time of the interview and the fishing start time. The geomorphologic type of the fishing site was determined using a geomorphologic map and the geographic position of the boat.

Fishing habits information consisted of 9 multiple response questions: 1-the preferred fishing technique, 2-the eventual second preferred fishing technique, 3-the 5 main targeted species, 4-the seasonality of the fishing activity, 5-the weekly fishing planning, 6-the daily fishing planning, 6-the number of fishing trips per year, 7-the fishing experience, 8-the environmental criteria for fishing, and 9-the motivation (Table 1).

Table 1. Variables and categories description. Brackets indicate number of response within each category, and respond rate. Total number of questionnaires is 469.

Variables (number of categories, respond rate)	Categories (number of questionnaires within the category)	Abbreviations
Fishing trip of the day		
Main fishing technique (8, 100%)	Spear fishing (157) Towing (14) Angling (286) Jigging (1) Gillnet (2)	SF To An Ji Gi

	Casting (2) Cast net (3) Pole (4)	Ca CN Po
Secondary fishing technique (8, 100%)	Spear fishing (17) Towing (11) Angling (23) Gillnet (3) Casting (1) Cast net (3) Pole (1) None (410)	SF To An Gi Ca CN Po No
Site type (6, 100%)	Coastal reef (46) Reef in the lagoon(166) Barrier reef (21) Coastal lagoon (144) Intermediate lagoon (73) Barrier lagoon (19)	CR IR BR CL IL BL
Beginning hour (7, 98%)	3AM to 6AM (8) 6AM to 8AM (115) 8AM to 10AM (223) 10AM to 0PM (80) 0PM to 2PM (13) 2PM to 5PM (5) 5PM to 10PM (6) Not available (10)	3-6 6-8 8-10 10-12 12-14 14-17 17-22 NA
Day type (5, 100%)	Week day (97) Weekend day (86) Week day in holidays (55) Weekend day in holidays (121) Extended weekend (110)	WD WE WDH WEH EWE
Season (2, 100%)	Warm (318) Cool (151)	W C
Wind speed (Beaufort scale) (8, 100%)	0 (8) 1 (25) 2 (175) 3 (134) 4 (99) 5 (24) 6 (3) 7 (1)	0 1 2 3 4 5 6 7
Boat (7, 100%)	Engine powered under 5 m (246) Engine powered from 5 to 7 m (166) Engine powered from 7 to 10 m (37) Engine powered over 10 m (5) Sailboat (13) Kayak (1) Shore side fisher (1)	E<5 E5-7 E7-10 E>10 Sa Ky SSF
Catch species (12, 69.1%)	See the result part??je crois qu'il faut en dire plus avant pour éclairer ce que tu dis dans le texte sur le recodage. La nouvelle réorganisation te parait-elle OK.	
Fishing habits		
Preferred technique (7, 89.5%)	Spear fishing (143) Towing (13)	SF To

	Angling (258) Jigging (2) Gillnet (1) Cast net (1) Pole (2) Not available (49)	An Ji Gi CN Po NA
Second preferred technique (7, 89.5%)	Spear-fishing (40) Towing (18) Angling (30) Gillnet (2) Cast net (3) None (376)	SF To An Gi CN No
Daily planning (5, 88.3%)	Morning (288) Afternoon (8) Evening (8) Night (14) Indifferent (96) Not available (55)	AM PM EV NI IND NA
Weekly planning (4, 66%)	Week day (74) Weekend day (173) Holidays (19) Indifferent (47) Not available (156)	WD WE H IND NA
Yearly planning (5, 70%)	Year (256) Warm season (53) Cool season (8) Don't know (8) Indifferent (2) Not available (156)	Ye Wa Co DK IND NA
Fishing experience (6, 45%)	< 1 year (23) 1 - 5 years (26) 6 - 10 years (31) 11 - 20 years (37) 21 - 30 years (46) > 30 years (48) Not available (258)	<1 1-5 6-10 11-20 21-30 <30 NA
Environmental criteria for fishing (4, 89.5%)	Weather (250) Tide (98) Moon phase (16) Indifferent (56) Not available (49)	Wea Tid Moo IND NA
Fishing motivation (3, 89.5%)	Recreation (328) Food (49) Need (44) Not available (48)	Rec Foo Nee NA
Number of trips per year (6, 84%)	Less than once a month (11) Once a month (85) Twice a month (120) Three times a month (63) Four times a month (70) More than four times a month (44) Not available (76)	<1/M 1/M 2/M 3/M 4/M >4/M NA
Target species (7, 72.5%)	See the result part idem plus haut	

In all, 174 sampling days were completed between 2008 and 2010, 1 029 boats were spotted fishing, 514 of them have been reached and 469 interviews have been conducted. 20 fishers refused to answer the interview (3.9%) and 40 fishers had already been interviewed (7.8%). This study is based on the analysis of thee 469 interviews. Among those 469 interviews, 31 fishers did not reply to the second part of the questionnaire regarding fishing habits. Thus, data about preferred fishing came from 438 questionnaires.

Data analyses

Fishing profiles were identified using the information collected during the field investigations. One typology was determined using fishing trip information, and a second one using fishing habits. Then the two classifications were compared.

Typologies were determined using a combination of Multiple Correspondence Analysis (MCA) and Hierarchical Clustering Analysis (HCA). Most interview data consist in categorical responses to a range of questions. MCA was the appropriate multivariate technique to analyse categorical responses (Husson *et al.*, 2009). HCA was conducted with the use of Euclidian distance and Ward method. MCA and HCPC functions in R from package FactoMineR have been used.

The information collected was coded before the MCA. First, numerical variables were coded into categorical variables to enable a joint analysis. Second, several of the original categorical data had to be coded to ensure that the variables were given similar weights in the MCA. It is important that variables display approximately the same number of categories (see **Erreur ! Source du renvoi introuvable.**), to participate with same weigh in the analysis when used as active variable (Husson *et al.*, 2009). Each variable was coded with 6 to 8 classes, except for season and period of the week which were divided into 2 and 5 classes respectively. The type of site where the fishers were fishing during the interview was determined by crossing distance to coast (costal, intermediate, barrier) and habitat (reef or lagoon area), leading to six different types of site (**Erreur ! Source du renvoi introuvable.**).

Information collected on catch and target species were too detailed to be used in the analysis. 65 species or taxa were present in the catches and 56 target species were mentioned. We assumed to create catch profiles and target profiles, i.e. synthesised that information in two variables where each category is a catch profile or a target profile respectively. Then catches profile variable and target profile variables will be used as variables in the fishing trip and fishing habits typologies respectively.

Catch data has been transformed into presence/absence in order to reduce the bias induced by data from incomplete fishing activities. Moreover, as interviews occurred during fishing activity, catches were registered after an incomplete fishing time. Consequently, we used occurrences to understand the evolution of species richness in the catches with fishing time (**Erreur ! Source du renvoi introuvable.**). Two leaps appeared in the evolution of species richness with fishing time categories, the first one after 30min of fishing and the second one after 120 min of fishing. Thereby, we kept catches data from fishers that were fishing for at least 30 minutes. Thus, catches analysis has been realized on 324 questionnaires.

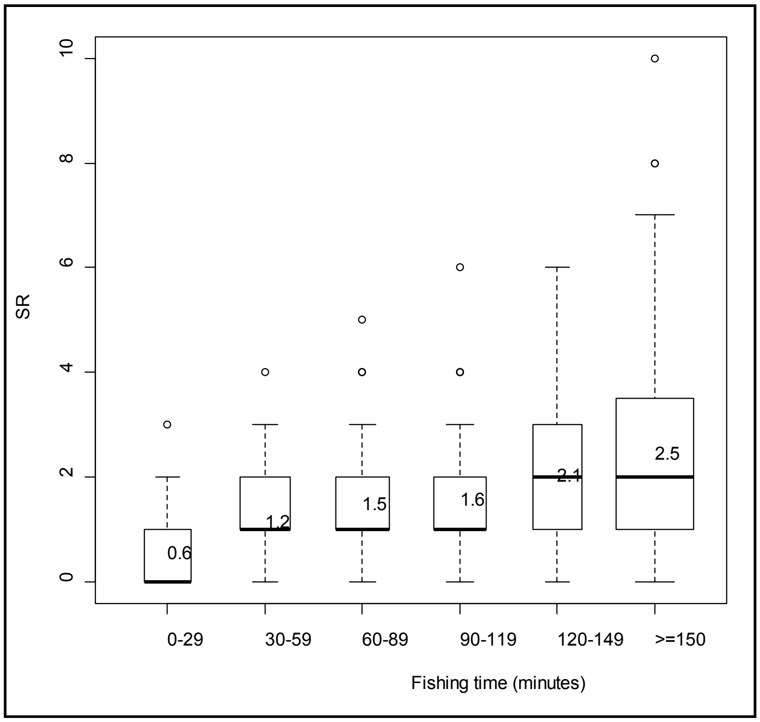


Figure 1. Species richness in the catches by fishing time categories. Bolted horizontal lines are medians, and numerical values are means; width of each boxplot is proportional to the number of individuals in the category.

Raw data on catches and target species where transformed into a single variable. Each species was thus represented by a binary variable. Few species have aggregated in higher taxonomic level (Genus or Family). Two reasons justify this pooling, first some species were hardly identifiable on field, so the taxonomic level of determination was not the species level, this is the case for some Serranidae, Carangidae, Lethrinidae, Mugillidae, Rajiidae, Sphyraenidae and Octopus. However, all the identifiable species from those taxonomic levels were identified and counted separately in the data. Secondly, some species are not differentiated from fishing point of view, which is the case for most of Scaridae, Balistidae, Parupeneus, Gobiidae, Kyphosidae, Acanthurus, Haemulidae, Siganidae. Thus, species from those families have not been counted separately in the data analysis. It is assumed that Scaridae, mainly include Scarus ghobban, Scarus niger, Scarus rivulatus, Chlorurus microrhinos. Parupeneus include Parupeneus barberinus and Parupeneus indicus. Acanthurus include Acanthurus dussumerii, Acanthurus blochii, and Acanthurus xanthopterus. Haemulidae, included Diagramma pictum, Plectorhincus albovittatus, Plectorhinchus gibbosus, Plectorhincus chaetodonoides, Plectorhincus flavomaculatus, Plectorhinchus lessonii, Plectorhincus picus and Plectorhincus lineatus. Siganidae mainly include Siganus argenteus, Siganus canaliculatus, Siganus lineatus. Moreover, we assumed to assemble some species in the following groups: sharks, crustacean (Palinuridae and Scyllaridae), Sepiidae, and shellfish (mainly Tridacnidae, Trocus and Lambis). **Erreur ! Source du renvoi introuvable.** synthesizes all the taxonomic groups used in the profile type determination.

Table 2. Species and others taxonomic groups censused during the interviews. Brackets indicate the number of questionnaires where the species (or groups of species) have been noted.

Cached species identified to the species level	Other Cached taxonomic groups	Targeted species identified to the species level	Other targeted taxonomic groups
Plectropomus leopardus (77)		*Nemipterus peronii* (126)	
	Scaridae (60)	*Plectropomus leopardus* (114)	
Nemipterus peronii (60)			Lethrinidae (112)
Lethrinus genivittatus (57)		*Lethrinus genivittatus* (96)	
Lutjanus adetti (31)			Scaridae (86)
Epinephelus maculatus (28)		*Lethrinus nebulosus* (83)	
Naso unicornis (27)		*Naso unicornis* (79)	
	Lethrinus (23)		Serranidae (61)
Lethrinus atkinsoni (22)		*Scomberomorus commerson* (52)	
Lutjanus vitta (21)		*Lutjanus vitta* (42)	
	Serranidae (19)		Siganidae (33)
	Haemulidae (19)		*Epinephelus maculatus* (22)
	Siganidae (18)		Carangidae (22)
	Acanthurus (17)		Acanthurus (16)
Priacanthus hamrur (17)		*Epinephelus cyanopodus* (15)	

Scomberomorus commerson (13)		*Aprion virescens* (15)	
	Sepiidae (12)		Sepiidae (12)
Epinephelus polyphekadion (11)		*Lethrinus atkinsoni* (10)	
Lethrinus nebulosus (11)			Thunnus (9)
Bodianus perditio (10)		*Lutjanus adetii* (9)	
	Carangidae (9)		Crustacean (7)
Gymnocranius euanus (9)		*Acanthocybium solandri* (6)	
Epinephelus cyanopodus (9)		*Priacanthus hamrur* (5)	
Lethrinus harak (9)		*Gymnocranius euanus* (4)	
	Shellfish (8)		Pristipomoides (4)
	Crustacean (8)	*Lethrinus harak* (3)	
Cromileptes altiveli (6)			Haemulidae (3)
	Sphyraena (5)	*Coryphaena hippurus* (3)	
	Octopus (5)		Octopus (3)
	Kyphosidae (5)	*Euthynnus affinis* (2)	
	Parupeneus (4)		Labridae (2)
Lethrinus miniatus (4)		*Bodianus Perditio* (1)	
Choerodon graphicus (4)		*Epinephelus malabaricus* (1)	
	Mugilidae (3)		Istiophoridae (1)
Epinephelus malabaricus (3)			Kyphosidae (1)
	Rajidae (2)		Sphyraena (1)
	Gobiidae (2)		Gobiidae (1)
	Sharks (2)		Sharks (1)
	Balistidae (2)		Shellfish (1)
Monotaxis grandoculis (2)			
Euthynnus affinis (2)			
Sargocentron spiniferum (2)			
Acanthocybium solandri (2)			
Aprion virescens (1)			
Caesio cuning (1)			
Coryphaena hippurus (1)			
Pristipomoides filamentosus (1)			
Lethrinus xanthochilus (1)			

We used catches profile variable and target profile variable as active variables in the fishing trip analysis and fishing habits analysis respectively. A set of respectively 4 and 7 active variables were selected in the MCA to build the clusters of fishing trips and fishing habits. Clusters of fishing trips were based on the following active variables: fishing techniques (main and secondary fishing technique had an equal weight), catches profile, and the type of site frequented at the time of the interview (see Table 1). Clusters of fishers' habits were based on the following active variables: main preferred fishing technique, secondary preferred technique, target profile, yearly planning, weekly planning, daily planning, and number of trip per year (see Table 1). Additional variables called illustrative were also used to help describing clusters of both typologies but did not contribute to the construction of the clusters. For fishing trip typology, illustrative variable were: boat size, residence, day type and wind speed. For fishing habits typology, illustrative variables were: boat size, residence, day planning and number of trip per year.

We determined fisher profiles using the same combination of MCA and HCA than for the fishing profiles analysis.

3. RESULTS

Catch profiles

Running the MCA on presence-absence data, led 48 axes representing 100% of variance. The first five axes accounted for 5.97%, 4.25%, 3.7% and 3.65% respectively. The main contributing species of the first axe were *Scaridae* (14.1%), *Plectropomus leopardus* (12.6%), *Naso unicornis* (9.5%), *Nemipterus peronii* (8.99%), and *Lethrinus genivittatus* (8.96%), *Acanthurus* (6.7%) which were among the most frequent species in catches (**Erreur ! Source du renvoi introuvable.**). *Gymnocranius euanus* and *Bodianus perditio* were the main contributing species to the second axe, with 23.3% and 21.9% respectively. However, both species do not appear among the most frequent species, ranked 21st (with 9 occurrences) and 25th (with 8 occurrences). Proportions of variance explained by axes and species contribution to axe are shown in annex A.

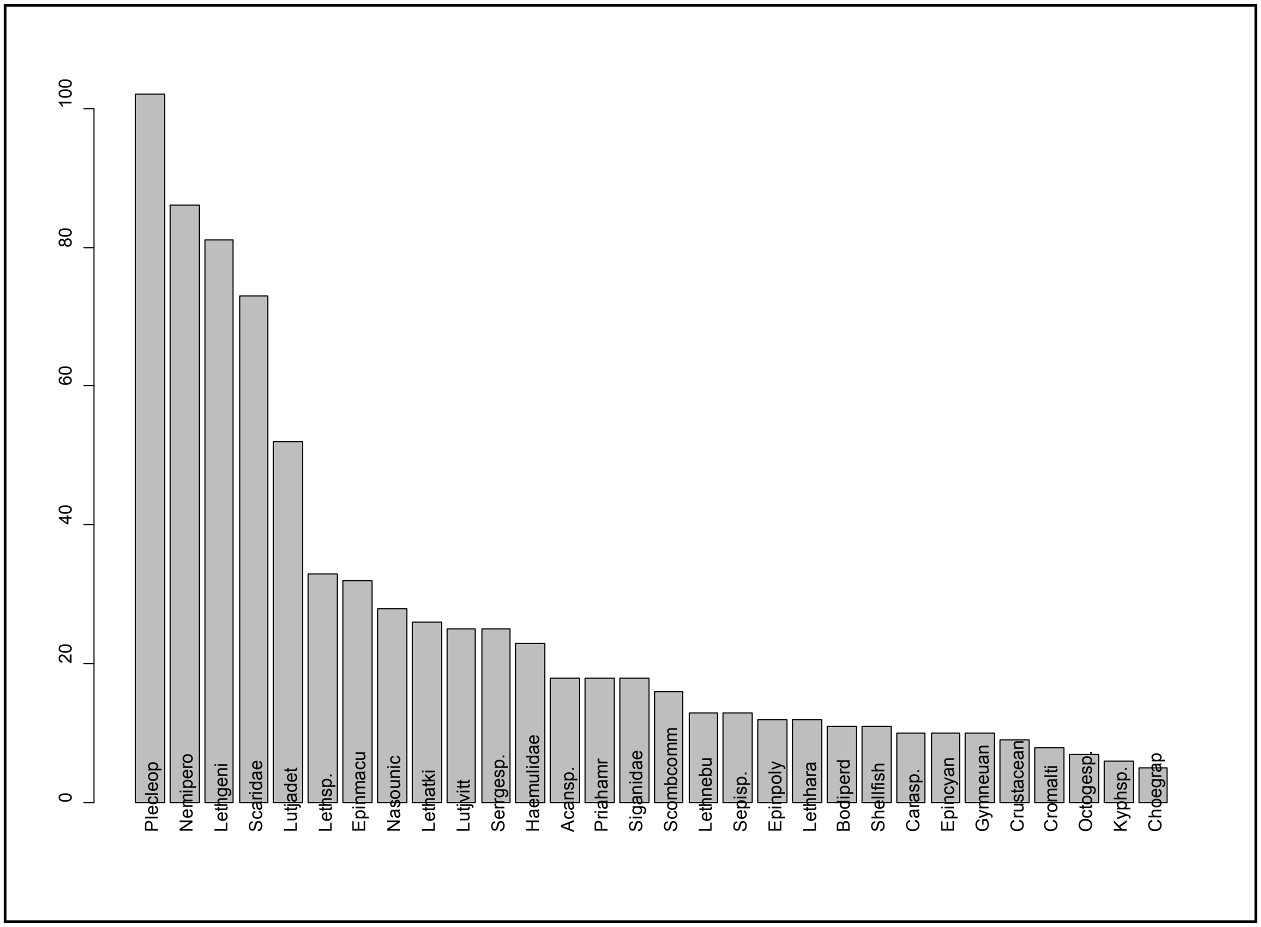


Figure 2. Occurrence of species in catches from the 324 questionnaires used in the catch analysis. Species names are abbreviated with concatenation of 4 first letters of genus and species, correspondence with complete scientific names is given in annex B.

the result tree of the HCA has been drawn from the coordinates of individuals on the 48 axes of the MCA (**Erreur ! Source du renvoi introuvable.** The first agglomerative cutting level was set to the higher relative loss of inertia (i(clusters n+1)/i(cluster n)), then this typology was characterized by analyzing two lower agglomeration levels. Clusters are characterised by the presence or absence of few discriminating species in the catches. Discriminating species are those with a proportion of presence in the cluster significantly different of the proportion of presence among all individuals. The six main discriminating species of each cluster of the first agglomeration level are listed in Table 3. Two clusters contain less than 10 individuals (cluster 2 and 3), and the two others 198 and 115 individuals. These last two clusters are characterised by the same species or taxa, but differed by species absent in one cluster and present in the other one. That agglomeration level account for 10% of the total variance. The two biggest clusters are constituted of two sub groups. Cluster 4 presents a stairs discrimination of some individuals. Two levels of agglomeration were studied to better understand which species or taxa are discriminating the sub-groups (**Erreur ! Source du renvoi introuvable.**). These two levels increased the proportion of explained variance to 32% and 49% respectively. Sub-groups of cluster 1 differed by the presence of *Nemipterus peronii*, *Lutjanus vitta*, and the absence of *Lutjanus adetti* in one case, and the opposite in the other case. Two individuals (species) constitute a third sub-group. The first sub-group of cluster 4 is differentiated from the second sub-group by the significant presence of *Lethrinidae*, *Cromileptes altivelis*, and *Lethrinus miniatus* (table 4). The remaining smaller sub-groups of cluster 4 (totalising 37 individuals) are all characterized by the presence of species or taxa occurring in one group only and by the presence of characteristic species of cluster 4 (Scaridae, *Plectropomus leopardus* and *Naso unicornis*). Those species or taxa are: Shellfish, *Octopus*, *Parupeneus*, *Epinephelus malabaricus*, sharks, *Aprion virescens*, Balistidae, Mugillidae, *Monotaxis grandoculis*, and *Pristipomoides filamentosus.*

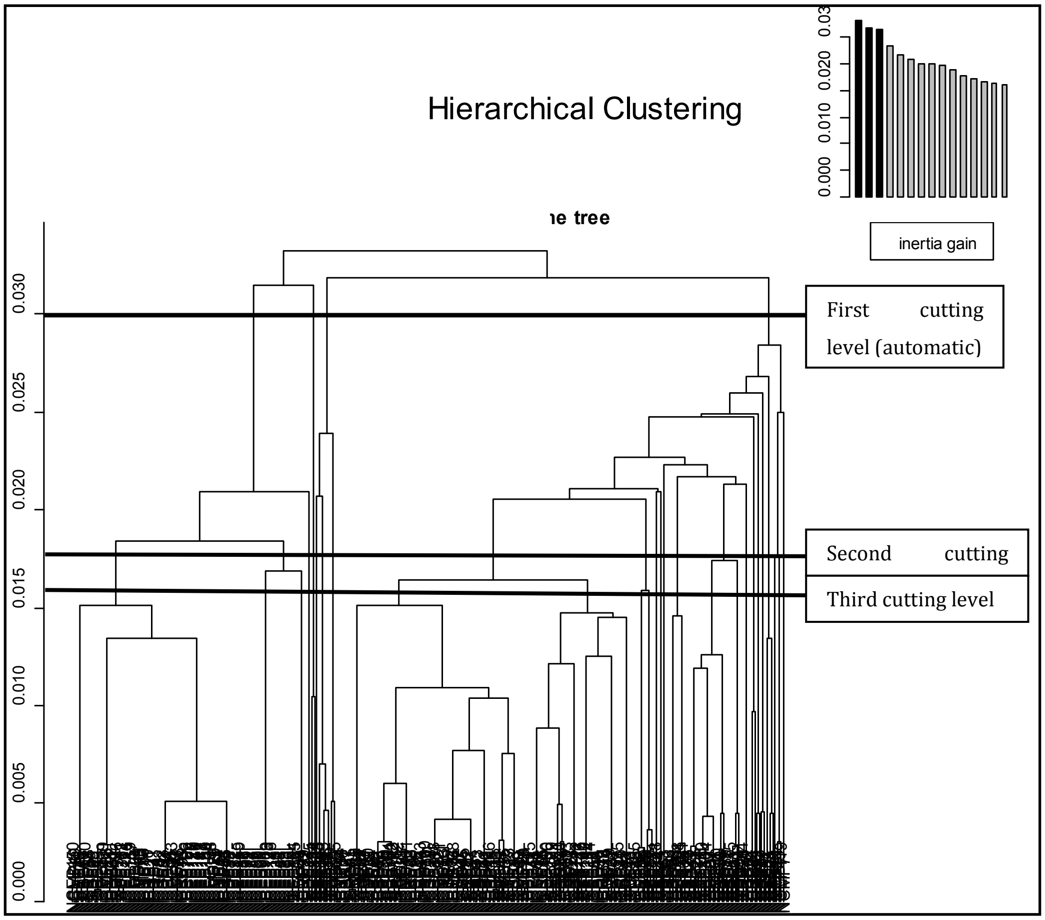


Figure 3. Hierarchical clustering tree of the catch profiles with three agglomeration levels. The absolute loss of inertia (i(cluster n)-i(cluster n+1)) is plotted in the top right of the tree.

Table 3. Main characterizing species or taxa of each cluster or sub-groups from the different agglomeration levels of catch species. The first value represents the percentage of individuals of the cluster with this modality, the second value represents the percentage of the individuals with this modality present in the cluster, and the third value represents the P-value of the comparison test between the percentage of the individuals with the modality into the cluster and the percentage of the individuals with the modality among all individuals.

Cluster	**1** (198)	**2** (2)	**3** (9)	**4** (115)
Main characterising species or taxa	*Nemipterus peronii*: 33.8%; 91.8%; 1E-10	*Acantosybium solandri*: 100%; 100%; 3.8E-5	*Gymnocranius euanus*: 88.9%; 88.9%; 5.9E-14	*Scaridae*: 48.7%; 88.9%; 1.6E-22
	Lethrinus genivittatus: 32.8%; 92.9%; 6E-11	*Coryphaena hippurus* : 50% ; 100% ; 1.2E-2	*Bodianus perditio* : 55.6% ; 50% ; 2E-6	*Plectropomus leopardus* : 50.43% ; 70.7% ; 6.8E-14

	No *Scaridae* : 96.5% ; 73.2% ; 1^{E}-19				*Sargocentron spiniferum* : 22.2% ; 100% ; 1.4^{E}-4	*Naso unicornis* : 22.6% ; 96.3% ; 1^{E}-11		
	No *Plectropomus leopardus* : 90.4% ; 74% ; 9.6^{E}-16					No *Lethrinus genivittatus* : 96.5% ; 43.7% ; 2.5^{E}-10		
	Siganidae : 99.5% ; 64.4% ; 1.3^{E}-6					No *Nemipterus peronii* : 95.7% ; 43.8% ; 5.7^{E}-10		
	Haemulidae : 98.9% ; 64.3%, 8^{E}-6					*Siganidae* : 14.8% ; 94.4% ; 2.5^{E}-7		
	Second cutting level					**Third cutting level**		
	Sub-group 1 of cluster 1 (76 individuals)	Sub-group 2 of cluster 1 (120 individuals)	2 remaining individuals			Sub-group 1 of cluster 4 (16 individuals)	Sub-group 2 of cluster 4 (62 individuals)	37 remaining individuals
	Nemipterus peronii: 76.3%; 79.4%; 1.7E-33	*Lutjanus adetii*: 27.5%; 82.5%; 8E-10				Lethrinidae: 62.5%; 100%; 5.2E-15	Scaridae: 54.8%; 54%; 2E-12	Scaridae: 37.8%;
	Lethrinus genivittatus: 56.6%; 61.4%; 5.1E-15	*Lethrinus harak*: 20%; 85.7%; 8.5E-8				*Cromileptes altivelis* : 31.2%; 83.3%; 1.8E-6	*Plectropomus leopardus*: 61.3%; 46.3%; 2.3E-11	*Plectropomus leopardus:* 32.4%;
	No Sacridae: 100%; 29.1%; 1.1E-8	No Scaridae: 95%; 43.7%; 1.4E-7				*Lethrinus miniatus*: 18.8%; 75%; 7.7E-4	*Naso unicornis*: 27.4%; 63%; 3.1E-7	*Naso unicornis:* 18.9%;
	No *Plectropomus*	No *Nemipterus*				Siganidae: 31.3%;	No *Lethrinus*	No *Nemipterus*

	leopardus: 96%; 30.2%; 1E-7	*peronii*: 92.5%; 44.2%; 3.1E-7				27.7%; 1.8E-3	*genivittatus*: 98.4%; 24%; 2E-6	*peronii:* 100%;
	Lutjanus vitta: 19.7%; 71.4%; 3.6E-6	No *Plectropomus leopardus*: 86.6%; 43%; 1.5E-4				Scaridae: 50%; 12.7%; 9.4E-3	Haemulide: 21%; 68.4%; 3.2E-6	No *Lethrinus genivittatus :* 94.6%;
	No *Lutjanus adetii* 96%; 25.7%; 1.1E-2	No *Lutjanus vitta*: 99%; 39.3%; 1.2E-3					No *Lutjanus adetii*: 100%; 21.8%; 2.2E-4	

From the MCA and HCA 7 catches profiles were defined from the three agglomeration levels (Table 3). The two isolated individuals of the third sub-group of cluster 1 have been pooled to the sub-group 2. The clusters 2 and 3 of the first agglomeration level constitute two catch profiles, and all the small groups of the chaining and characterized by rare species or taxa in catches, have been pooled in a single profile.

Target species profiles

Profiles of target species have been defined using the 340 interviews where the corresponding question had been answered. The MCA led to 39 axes to explain 100% of the variance. The first agglomeration level on the HCA result tree led to 5 clusters (figure 4). Cluster 5 is constituted of a single individual characterised by octopus and shellfish (Table

4). Three other clusters were characterised by the same species than catch species profiles: cluster 1 by *Nemipterus peronii* and *Lethrinus genivittatus* similar to the catch profile 1 ; cluster 2 by pelagic species similar to the catch profile 2 ; and cluster 4 by Scaridae, *Plectropomus leopardus* and *Naso unicornis* similar to the catch profile 4 (Table 3 and Table4). A last profile (cluster 3) is characterised by *Aprion virescens*, *Epinephelus cyanopodus* and *Plectropomus leopardus*, which not appear in the catch profiles.

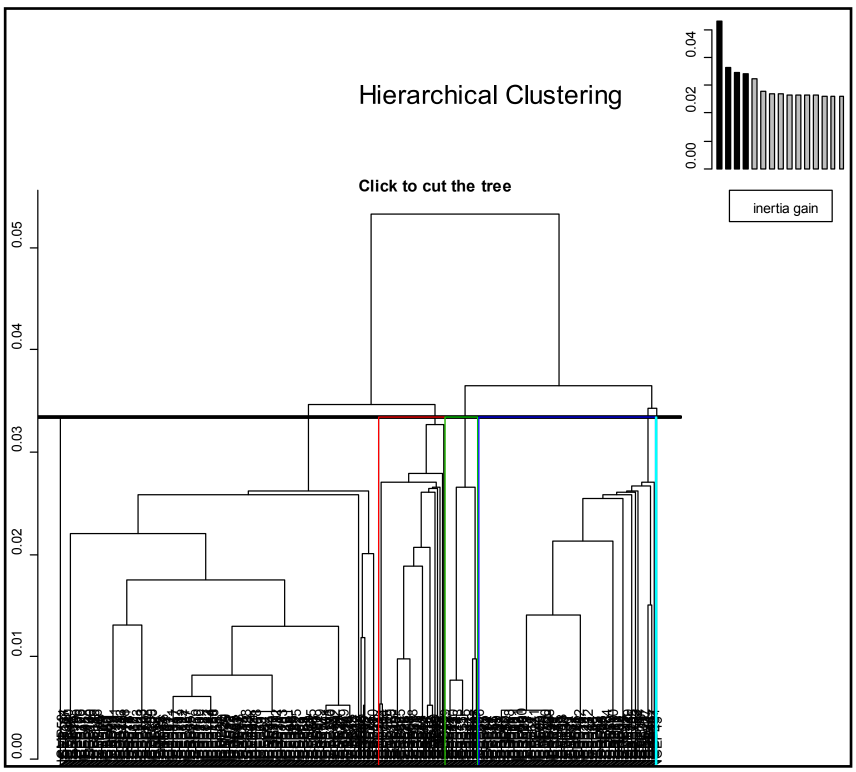


Figure 4. Hierarchical clustering tree of the target profiles with one agglomeration level. The absolute loss of inertia (i(cluster n)-i(cluster n+1)) is plotted in the top right of the tree.

Table 4. Characteric species or taxa of each cluster of target species. Brackets after the number ID of the cluster indicate the number of individuals in the cluster. Brackets after species names represent the percentage of individuals of the cluster with this modality.

Cluster	**1** (181)	**2** (38)	**3** (19)	**4** (101)	**5** (1)
Main characterising species or	*Nemipterus peronii* (64%)	*Thunus* (57%)	*Aprion virescens* (60%)	*Naso unicornis* (60%)	Octopus (100%)

taxa	*Lethrinus genivittatus* (48%)	*Acanthocybium solandri* (43%)	*Epinephelus cyanopodus* (56%)	*Scaridae* (62%)	shellfish (33%)
	Lethrinidae (43%)	*Coryphaena hippurus* (21%)	*Plectropomus leopardus* (68%)	*Plectropomus leopardus* (63%)	
	No Scaridae (98%)	*Euthinnus affinis* (14%)	No *Nemipterus peronii* (96%)	No *Nemipterus peronii* (97%)	
	No *Naso unicornis* (97%)	*Scomberomorus commerson* (43%)	No *Lethrinus genivittatus* (92%)	No *Lethrinus genivitatus* (99%)	
	No *Plectropomus leopardus* (89%)	No Scaridae (100%)		No *Lethrinus nebulosus* (92%)	
	No *Siganidae* (97%)			No *Lethrinidea* (85%)	
	No *Aprion virescens* (100%)			No *Lutjanus vitta* (99%)	
	No *Epinephelus cyanopodus* (99%)			No *Aprion virescens* (100%)	
	No *Acanthurus* (99%)			No *Epinephelus cyanopodus* (100%)	
	No *Palinuridae*				

	(100%)				
	No *Acanthocybium solandri* (100%)				

Fishing trip typology

Variable's categories represented by very few individuals were not considered in the analysis, concerned individuals stood out if integrated in the analysis. These categories (17 individuals) represent rare fishing techniques (main or secondary) (jigging, gillnet, cast net, pole and cast) and were integrated as illustrative individuals in the analysis. Two fishers who caught pelagic species trolling outside of the lagoon (*Coryphaena hippurus* and *Acanthocybium solandri*), characterized previously in the cluster 3 of the catches profiles, were also integrated as illustrative individuals. Thereby, the analysis was run on 452 questionnaires. However, 137 individuals could not be associated with a catch profile as they did not answer the question or they had fished during less than 30 minutes when investigated. These individuals were affected to a category NA (Not Answered) for this variable, which was considered as a category in the analysis. A first tree (not presented) led to the following situation : 77% of the 137 individuals with no catch profile were grouped in one cluster, characterized by the use of no secondary fishing technique (100%), warm season investigations (76%), a fishing activity on intermediate reef (42%) or lagoon (25%), and a boat from 5 to 7 m (42%). Moreover, the 9 individuals of the catch profile 4 were grouped in a single cluster characterized only by their belonging to the catch profile 4. In consequences we assumed to rerun the analysis considering the 137 individuals with no catch profile and the 9 individuals of the catch profile 4 as illustrative individuals.

Finally, 286 questionnaires have been retained to realize the typology of fishing trips. 100% of them were entirely answered. The MCA led to 13 axes to explain 100% of the variance. The resulting tree of the HCA is given in Figure 5. The first agglomeration level (maximum gain of inertia), led to 10 clusters where the main cluster (100 individuals) is characterized by fishing activity in intermediate reef areas. This cluster groups nearly all the individuals of catch profiles 5, 6 and 7. The second agglomeration level (figure 5) divided this cluster in 3 sub-groups, each one being characterized by one of the catch profiles. Clusters of this second agglomerative level are well correlated to catches profiles, mains fishing technique and fishing area (Table 5). This typology allowed explaining 78.7% of the total variance.

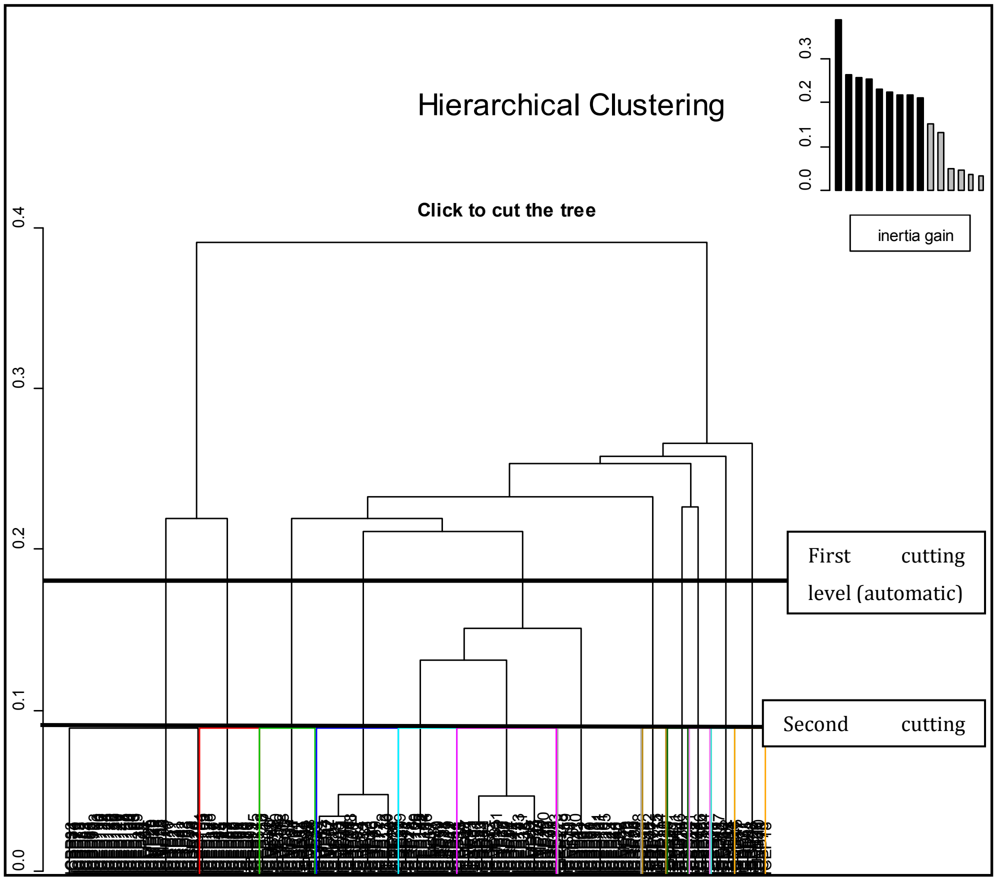


Figure 5. Hierarchical clustering tree of fishing trips typology with two agglomeration levels. The absolute loss of inertia (i(cluster n)-i(cluster n+1)) is plotted in the top right of the tree.

Table 5. Characteristic variables of each fishing trip cluster. Brackets after the number ID of the cluster indicate the number of individuals in the cluster. In each cell of the table Brackets after species names represent percentage of individuals of the cluster with this modality. Categories of active variables are bolted when categories of illustrative variables are not.

Cluster	**1** (53)	**2** (25)	**3** (23)	**4** (34)	**5** (24)	**6** (41)	**7** (35)	**8** (10)	**9** (9)	**10** (9)	**11** (10)	**12** (13)
Main characterising categories of variables	**angling as main fishing technique: 100%;**	**angling as main fishing technique: 100%;**	**costal reef area: 100%;**	**intermediate lagoon area: 100%;**	**catch profile 6: 100%;**	**catch profile 5: 90%;**	**catch profile 7: 100%;**	**barrier reef areas: 100%;**	**towing as secondary fishing technique: 100%;**	**barrier lagoon areas : 100%;**	**angling as main fishing technique: 100%; 5%;**	**Spear-fishing as main fishing technique : 100%; 13%;**
	catch profile 1: 100%;	**catch profile 2: 100%;**	≤5 m boat: 83%;	**No secondary fishing technique: 100%;**	**intermediate reef areas: 75%;**	**in intermediate reef areas: 78%;**	**in intermediate reef areas: 94%;**	**Spear-fishing as main fishing technique: 70%;**		**Spear-fishing as main fishing technique: 70%;**	**spear fishing as secondary fishing technique : 100%; 100%;**	**angling as secondary fishing technique : 100%; 100%;**
	costal lagoon area: 100%;	**costal lagoon area: 76%;**	From Païta: 49%			**No secondary fishing technique: 100%;**	**Spear-fishing as main fishing technique: 80%;**	**catch profile 7: 60%;**		week days: 44%;	week-ends: 50%;	**intermediate reef areas: 77%;**
	No secondary fishing technique : 100%;	≤5 m boat: 88%;	Not from Noumea: 91%;			Warm season: 85%;	**No secondary fishing technique: 100%;**	Week-ends: 60%;		Wind speed level 1 on Beaufort scale: 44%;	Sailing boat: 30%;	boat between 5 and 7 m: 69%;
	≤5 m boat: 72%:	Extended week-end: 72%;										

	Cold season : 55%;											
			No fishing technique or catch profile significantly characterizes that cluster.	No fishing technique or catch profile significantly characterizes that cluster. Illustrative variables do not show any information.						Similar to cluster 8.		

Typology of fishing habits

Eleven individuals with unusual main or secondary fishing techniques (Cast net, pole, gill net, jigging) have been introduced as illustrative individuals in the analysis. Cluster 5 of the target profile typology was comprised a single individual and has been excluded from the analysis. 3 individuals using a sailboat or a >10m engine powered boat were removed. Thereby, 455 questionnaires were kept to run the first analysis. Nevertheless, proportion of unanswered questions remained high in many questions (Table 6). We realized a first typology (not presented) showing a cluster that included most of the individuals with an unanswered question. Thus, these individuals were used as illustrative.

Table 6. Percentage of unanswered questions in the 455 questionnaires retained for the fishing habits typology. Brackets indicate the number of questionnaires concerned.

Active variables	Main preferred fishing technique	Secondary fishing technique	Target profile	Yearly planning	Weekly planning	Daily planning	Number of trip per year
Unanswered rate	10.8% (49)	10.8% (49)	27.9% (127)	30.8% (140)	33.8% (154)	11.9% (54)	16% (73)

Thereby, 241 questionnaires were kept for the typology of fishing habits. The MCA led to 27 axes to explain 100% of the variance. The first agglomerative level comprised four clusters (Figure 7 and table 7). Two other agglomeration levels were analyzed to better undrstand the two main clusters (cluster 1 and cluster 4). Cluster 1 is characterized by angling targeting *Nemipterus peronii* and *Lethrinus genivitatus*. A sub-group is characterized by one fishing trip per month, and no secondary fishing techniques. A second sub-groups is characterized by more than 3 trips per month, spear-fishing as secondary technique and the presence of some individuals with a target profile 2. The second main cluster (cluster 4) is characterized by spearfishing. The two main sub-groups had different secondary techniques (none for the first one and angling for the second one), different weekly planning (during holidays for the first one and no preference for the second one), different number of trips per year (2 per month for the first one and no significant tendency for the second one), and different daily planning (AM for the first one and no tendency for the second one).

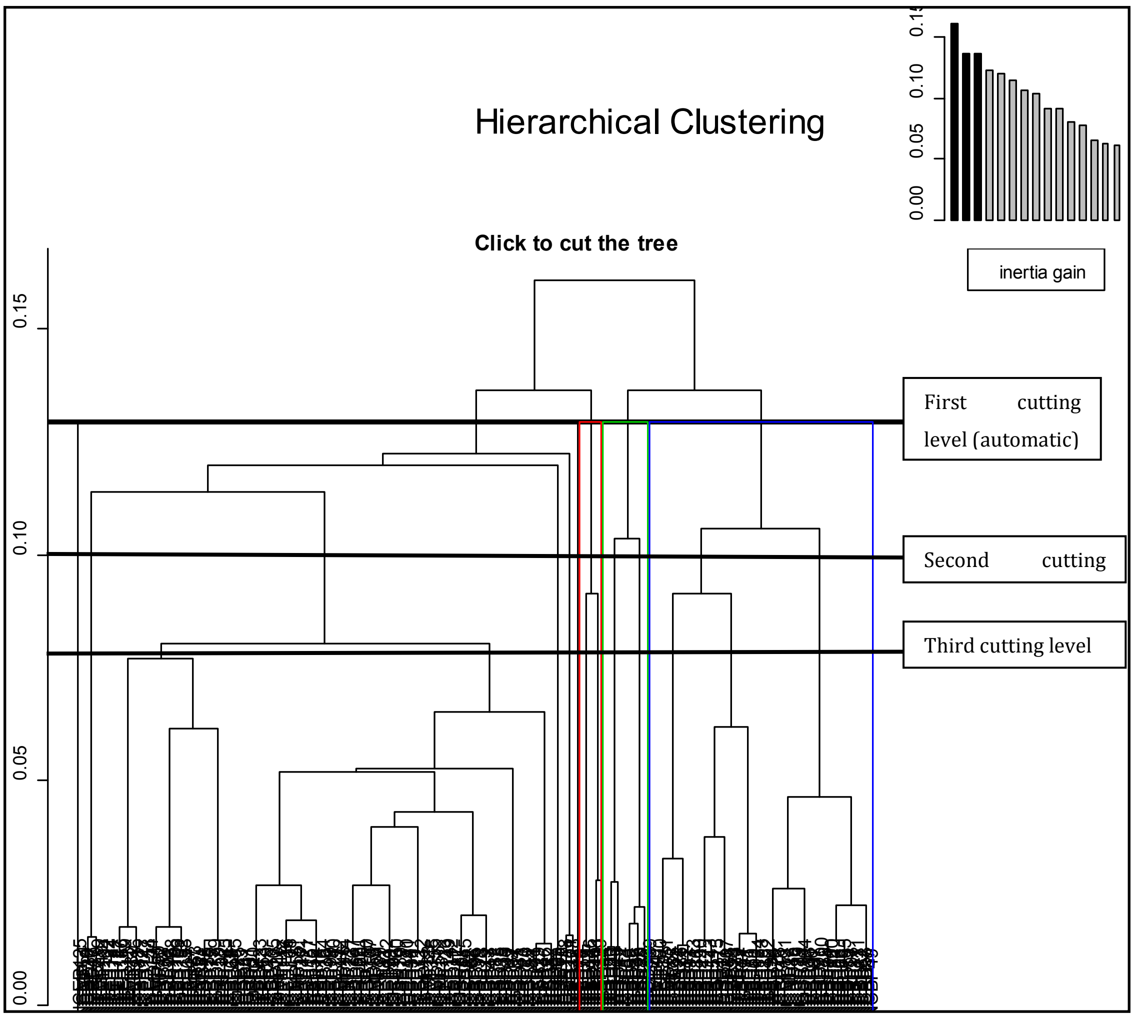


Figure 6. Hierarchical clustering tree of the fishing habits with three agglomeration levels. The absolute loss of inertia (i(cluster n)-i(cluster n+1)) is plotted in the top right of the tree.

Table 7. Characteristic variables of each fishing habits cluster. Brackets after the number ID of the cluster indicate the number of individuals in the cluster. In each cell of the table Brackets after species names represent percentage of individuals of the cluster with this modality. Categories of active variables are bolted when categories of illustrative variables are not.

Cluster	**1** (152)	**2** (7)	**3** (14)	**4** (68)
Main characterising	**angling as**	**Night fishing :**	**Less than on trip**	**spear fishing as**

categories of variables	**preferred main fishing technique: 82%;**	**71%;**	**a month : 64%;**	**main preferred fishing technique: 79%;**
	target profile 1: 67%;	**Cool season planning : 42%;**	**Do not have a yearly planning: 42%;**	**target profile 4: 56%;**
	≤ 5 m boat: 65%;	Need as motivation: 42%;	**Irrelevant weekly planning: 43%;**	**target profile 3: 19%;**
	No secondary preferred fishing technique: 82%;			**Towing as secondary preferred fishing technique: 25%;**
	Spear-fishing as secondary preferred fishing technique: 18%;			**Angling as secondary preferred fishing technique: 26%;**
	All along the year: 86%;			**Two fishing trips per month: 48%;**
	Week days: 24%;			Motivation is recreation: 94%;

Comparison of catch profiles and target profiles

Comparison of fishers regarding their catch and target profile show a good similarity (figure 8). Catch profile clusters 1, and target profile cluster 1 were both characterized by *Nemipterus peronii*, *Lethrinus genivittatus* and *Lutjanus adetii*. Catch profiles clusters 4 and target profile cluster 4 were both characterized by Scaridae, *Plectropomus leopardus*, and *Naso unicornis*. In both profiles categories a cluster was characterized by pelagic species (cluster 2 of catch profiles and cluster 2 of target profiles). However, no cluster was characterized by *Bodianus perditio* and *Gymnocranius euanus* (cluster 3 of catch profiles) in target profiles. No cluster of catch profile was characterized by octopus like cluster 5 of target species, but the few fishers who caught octopus were included in target cluster 7 characterized by Scaridae, de *Plectropomus leopardus*, *Naso unicornis* and other rarely occurring species. That is easily understandable by the fact that all those last four species and taxa are usually all cached by spear-fishing.

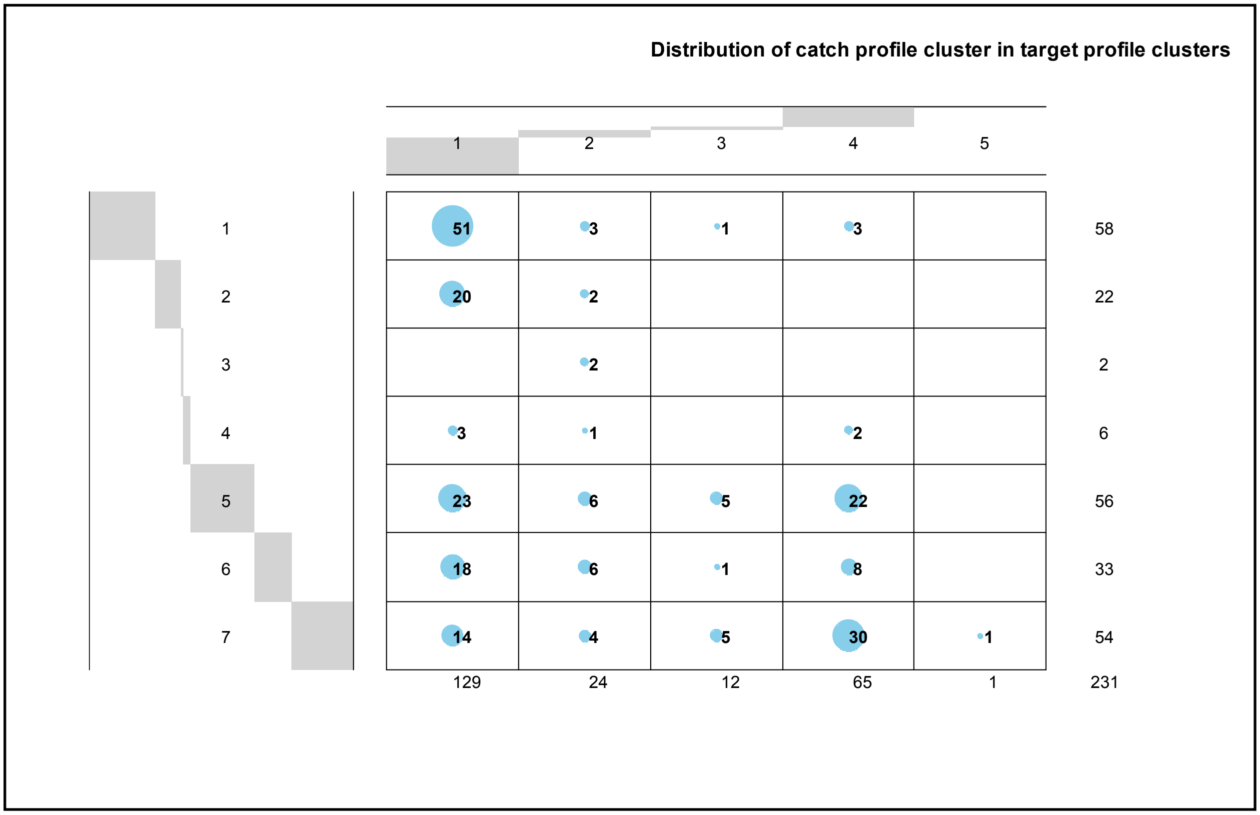


Figure 7. Correspondences of number of individuals between catch profiles and target profiles, regarding the 231 common individuals of the two typologies.

Concordance between catch profiles 5, 6 and 7, and target profiles is not as evident. However, they are mainly spread in target profiles 1 and 4.

Comparison of fishing trip profiles and fishing habits profiles

To do:

Comparing both typologies regarding 1) the assignment of fishers in each of them and 2) the global picture of the recreational fisheries shown by characterized profiles.

The question is to know if in situ survey about observed fishing activity gives the same picture of the fishery than interview (eventually ex situ) about fishing habits during the year.

…

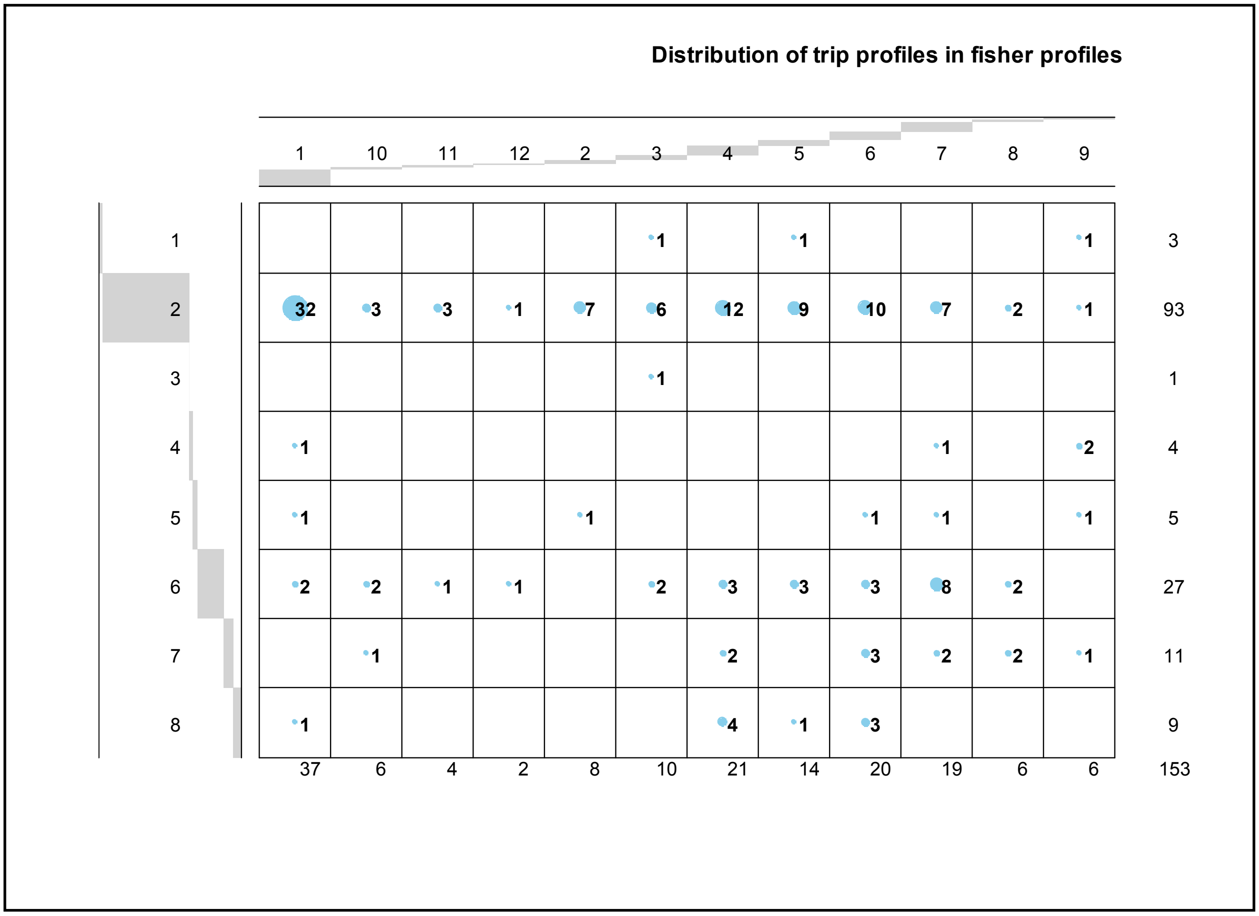


Figure 8. Correspondences of number of individuals between fishing trip typology and fishing habits typology, regarding the common individuals of the two typologies

4. <u>DISCUSSION</u>

5. To do:

Recreational fishing overcomes professional fishing on costal area in many places.

Management needs information about this activity, but there are many difficulties to describe and to quantify this activity.

…

ANNEXE 12

CATEGORIES DE NAVIRES IMMATRICULES PAR COMMUNE ET TAUX D'ACTIVITE.

Nombre de navires immatriculés par commune du propriétaire, type, taille et âge de navire.

	Flottilles					
	Païta		Nouméa Dumbéa et inconnus		Mont Dore	
Catégories d'âge des navires	**Moteur <5m**	**Moteur >5m**	**Moteur <5m**	**Moteur >5m**	**Moteur <5m**	**Moteur >5m**
2009-2006	144	44	958	615	190	80
2005-2002	116	40	906	451	168	76
2001-1998	126	31	1139	506	214	73
1997-1994	159	42	1323	531	278	91
1993-1990	112	62	847	915	211	161
1989-1986	51	42	312	451	89	115
1985-1982	15	9	130	89	27	20
1981 ou antérieur	120	87	770	921	206	224
Total	843	357	6385	4479	1383	840
Total par commune	1200		10864		2223	

Taux de navires actifs a la pêche par type, catégorie de taille et d'âge (TPL,t).

	Catégories de navires	
Catégories d'âge des navires	**Moteur <5m**	**Moteur >5m**
2009-2006	0.41	0.19
2005-2002	0.34	0.18
2001-1998	0.21	0.12
1997-1994	0.14	0.1
1993-1990	0.15	0.15
1989-1986	0.16	0.13
1985-1982	0.08	0.05
1981 ou antérieur	0.1	0.08

ANNEXE 13

QUESTIONNAIRE DE PECHE PLAISANCIERE DE NUIT UTILISE PENDANT LES SORTIES DE TERRAIN DE JOUR.

N°……

Enquêteur :

Etude de la pêche de nuit

(Questionnaire complémentaire lors des sorties en mer de jour)

Attention les questions et les réponses doivent se rapporter exclusivement à la pêche de nuit.

A.1 Heure de départ habituelle : ………..h……….. **A.2** Heure de retour habituelle : ………..h………..

A.3 Durée totale effective de la pêche : ……….h………..

B. Quelles sont vos techniques habituelles pour la pêche de nuit ? (*a priori* il n'y aura que la ligne, mais on demande quand même au cas où)**.**

- ☐ Ligne à main (palangrotte), nombre d'hameçons habituel : ….
- ☐ Chasse sous-marine
- ☐ Traine
- ☐ Pêche au lancé
- ☐ Ramassage, récolte en apnée
- ☐ Pêche à pied

C. Combien de pêcheurs êtes-vous habituellement à bord ? : ………..

D.1 Où pêchez-vous habituellement (nom du récif, îlot, ou positionnement sur une carte)? :

1)……..

2)……..

3)……..

D.2 Sur quel type de fond ? :

1)………………………………………2)…………………………………………..3)…………………………

E. Captures: Quelles espèces pêchez-vous habituellement lors de vos pêches de nuit (et quantité moyenne par sortie ; sortie avec prise nulles comprise)?

Famille	**Espèce**	**Nombre**	**Taille (ou poids si pesé)**	**Engin**	**Site (se rapporter aux réponses de D.1)**
1.					
2.					

3.					
4.					
5.					
6.					

F. Planifiez-vous vos sorties de pêche de nuit en fonction :

- ☐ Des marées
- ☐ De la lune
- ☐ De la météo
- ☐ Indifférent

G. Quels sont les 3 facteurs qui influencent le plus votre choix d'un site de pêche la nuit ? Pouvez-vous les classer du plus important (1) au moins important (3)

- ☐ Abondance des poissons
- ☐ Espèces que vous recherchez
- ☐ Météo, marées…
- ☐ Accessibilité, proximité site de pêche
- ☐ Réglementation
- ☐ Beauté du site, paysage…
- ☐ Tranquillité (faible fréquentation)
- ☐ Présence des autres pêcheurs
- ☐ Type de fond
- ☐ Autre :……………………………

H. Pêchez-vous à proximité des réserves pour y trouver plus de poisson ?

Dans quelle proportion annuelle de vos sorties ?

- ☐ 0%
- ☐ 0-25%
- ☐ 25-50%
- ☐ 50-75%
- ☐ 75-100%

I. Activité de pêche de nuit sur l'année.

I.1 En général, quand pêchez-vous de nuit?

I.1.1 Au cours de l'année ?

- ☐ Toute l'année
- ☐ Plutôt saison chaude
- ☐ Plutôt saison fraiche

I.1.2 Au cours de la semaine ?

- ☐ En semaine
- ☐ Le week-end
- ☐ Pendant les vacances
- ☐ Indifférent

I.2 Quel est le nombre moyen de sorties que vous effectuez par mois ?

	Saison chaude	Saison fraiche
Nb moyen de sorties **/ mois**		

ANNEXE 14

EFFORT, CPUE ET CAPTURES PLAISANCIERES DE BEC DE CANE (*L. NEBULOSUS*), SAUMONEE (*P. LEOPARDUS*) ET DAWA (*N. UNICORNIS*).

Effort Nominal de pêche mensuel pour les stratégies capturant le Bec de cane.

Stratégie	Janvier	Février	Mars	Avril	Mai	Juin	Juillet	Août	Septembre	Octobre	Novembre	Décembre
Nuit_<5_Paita	46.2	46.2	46.2	46.2	70.3	70.3	70.3	70.3	70.3	70.3	46.2	46.2
Nuit_>5m_Paita	11.4	11.4	11.4	11.4	17.4	17.4	17.4	17.4	17.4	17.4	11.4	11.4
Nuit_>5m_Nou	144.6	144.6	144.6	144.6	220.0	220.0	220.0	220.0	220.0	220.0	144.6	144.6
Nuit_>5m_MtD	25.8	25.8	25.8	25.8	39.3	39.3	39.3	39.3	39.3	39.3	25.8	25.8
Nuit_<5m_Nou	345.0	345.0	345.0	345.0	525.0	525.0	525.0	525.0	525.0	525.0	345.0	345.0
Nuit_<5m_MtD	71.0	71.0	71.0	71.0	108.1	108.1	108.1	108.1	108.1	108.1	71.0	71.0

Effort Nominal de pêche mensuel pour les stratégies capturant la Saumonée.

Stratégie	Janvier	Février	Mars	Avril	Mai	Juin	Juillet	Août	Septembre	Octobre	Novembre	Décembre
<5m Paita CHA	557.1	557.1	557.1	557.1	471.4	471.4	471.4	471.4	471.4	471.4	557.1	557.1
<5m Paita PALA	656.3	656.3	656.3	656.3	613.5	613.5	613.5	613.5	613.5	613.5	656.3	656.3
<5m Nou CHA	5386.0	5386.0	5386.0	5386.0	4435.6	4435.6	4435.6	4435.6	4435.6	4435.6	5386.0	5386.0
<5m Nou PALA	2493.5	2493.5	2493.5	2493.5	2380.2	2380.2	2380.2	2380.2	2380.2	2380.2	2493.5	2493.5
<5m MtD CHA	311.4	311.4	311.4	311.4	322.9	322.9	322.9	322.9	322.9	322.9	311.4	311.4
<5m MtD PALA	1076.7	1076.7	1076.7	1076.7	740.2	740.2	740.2	740.2	740.2	740.2	1076.7	1076.7
>5m Paita CHA	329.2	329.2	329.2	329.2	282.8	282.8	282.8	282.8	282.8	282.8	329.2	329.2
>5m Paita PALA	150.2	150.2	150.2	150.2	111.9	111.9	111.9	111.9	111.9	111.9	150.2	150.2
>5m Nou CHA	2702.8	2702.8	2702.8	2702.8	2342.4	2342.4	2342.4	2342.4	2342.4	2342.4	2702.8	2702.8
>5m Nou PALA	1697.4	1697.4	1697.4	1697.4	1573.2	1573.2	1573.2	1573.2	1573.2	1573.2	1697.4	1697.4
>5m MtD CHA	464.9	464.9	464.9	464.9	300.2	300.2	300.2	300.2	300.2	300.2	464.9	464.9
>5m MtD PALA	249.5	249.5	249.5	249.5	101.8	101.8	101.8	101.8	101.8	101.8	249.5	249.5
Corne Sud	248.2	200.2	132.7	199.2	254.2	198.7	216.2	189.6	194.6	133.9	196.3	240.1

Effort Nominal de pêche mensuel pour les stratégies capturant le Dawa.

Stratégie	Janvier	Février	Mars	Avril	Mai	Juin	Juillet	Août	Septembre	Octobre	Novembre	Décembre
<5m Paita CHA	557.1	557.1	557.1	557.1	471.4	471.4	471.4	471.4	471.4	471.4	557.1	557.1
<5m Nou CHA	5386.0	5386.0	5386.0	5386.0	4435.6	4435.6	4435.6	4435.6	4435.6	4435.6	5386.0	5386.0
<5m MtD CHA	311.4	311.4	311.4	311.4	322.9	322.9	322.9	322.9	322.9	322.9	311.4	311.4
>5m Paita CHA	329.2	329.2	329.2	329.2	282.8	282.8	282.8	282.8	282.8	282.8	329.2	329.2
>5m Nou CHA	2702.8	2702.8	2702.8	2702.8	2342.4	2342.4	2342.4	2342.4	2342.4	2342.4	2702.8	2702.8
>5m MtD CHA	464.9	464.9	464.9	464.9	300.2	300.2	300.2	300.2	300.2	300.2	464.9	464.9
Corne Sud	248.2	200.2	132.7	199.2	254.2	198.7	216.2	189.6	194.6	133.9	196.3	240.1

CPUE (en kg par heure) pour chacune des espèces et chacune des stratégies.

Stratégie	Bec de Cane	Saumonée	Dawa
<5m Paita CHA	-	0.6	0.5
<5m Paita PALA	-	0.0	0.0
<5m Nou CHA	-	1.0	0.1
<5m Nou PALA	-	0.3	0.0
<5m MtD CHA	-	1.9	0.2
<5m MtD PALA	-	0.8	0.0
>5m Paita CHA	-	1.4	0.3
>5m Paita PALA	-	0.1	0.0
>5m Nou CHA	-	1.5	0.6
>5m Nou PALA	-	0.1	0.0
>5m MtD CHA	-	1.3	0.0
>5m MtD PALA	-	0.0	0.0
Corne Sud CHA	-	1.2	0.3
Corne Sud PALA	-	0.2	0.5
Nuit_<5_Paita	0.6	-	-
Nuit_>5m_Paita	0.6	-	-
Nuit_>5m_Nou	0.6	-	-
Nuit_>5m_MtD	0.6	-	-
Nuit_<5m_Nou	0.6	-	-
Nuit_<5m_MtD	0.6	-	-

Estimation des captures de Bec de Cane (en kg) par les stratégies de pêche de nuit.

Stratégie	Janvier	Février	Mars	Avril	Mai	Juin	Juillet	Août	Septembre	Octobre	Novembre	Décembre	Totaux
Nuit_<5m_Paita	27.6	27.6	27.6	27.6	42.0	42.0	42.0	42.0	42.0	42.0	27.6	27.6	417.2
Nuit_>5m_Paita	6.8	6.8	6.8	6.8	10.4	10.4	10.4	10.4	10.4	10.4	6.8	6.8	103.2
Nuit_>5m_Nou	86.3	86.3	86.3	86.3	131.3	131.3	131.3	131.3	131.3	131.3	86.3	86.3	1305.3
Nuit_>5m_MtD	15.4	15.4	15.4	15.4	23.5	23.5	23.5	23.5	23.5	23.5	15.4	15.4	233.3
Nuit_<5m_Nou	205.9	205.9	205.9	205.9	313.3	313.3	313.3	313.3	313.3	313.3	205.9	205.9	3115.3
Nuit_<5m_MtD	42.4	42.4	42.4	42.4	64.5	64.5	64.5	64.5	64.5	64.5	42.4	42.4	641.4
Totaux	384.4	384.4	384.4	384.4	584.9	584.9	584.9	584.9	584.9	584.9	384.4	384.4	5815.6

Estimation des captures de Saumonée (en kg) par les stratégies ciblant cette espèce.

Stratégie	Janvier	Février	Mars	Avril	Mai	Juin	Juillet	Août	Septembre	Octobre	Novembre	Décembre	Totaux
<5m Paita CHA	332.8	332.8	332.8	332.8	281.6	281.6	281.6	281.6	281.6	281.6	332.8	332.8	3686.4
<5m Paita PALA	9.5	9.5	9.5	9.5	8.9	8.9	8.9	8.9	8.9	8.9	9.5	9.5	110.8
<5m Nou CHA	5423.3	5423.3	5423.3	5423.3	4466.2	4466.2	4466.2	4466.2	4466.2	4466.2	5423.3	5423.3	59337.0
<5m Nou PALA	686.8	686.8	686.8	686.8	655.6	655.6	655.6	655.6	655.6	655.6	686.8	686.8	8054.3
<5m MtD CHA	592.2	592.2	592.2	592.2	614.1	614.1	614.1	614.1	614.1	614.1	592.2	592.2	7237.8
<5m MtD PALA	840.5	840.5	840.5	840.5	577.8	577.8	577.8	577.8	577.8	577.8	840.5	840.5	8510.1
>5m Paita CHA	474.6	474.6	474.6	474.6	407.8	407.8	407.8	407.8	407.8	407.8	474.6	474.6	5294.2
>5m Paita PALA	20.8	20.8	20.8	20.8	15.5	15.5	15.5	15.5	15.5	15.5	20.8	20.8	218.2
>5m Nou CHA	3978.7	3978.7	3978.7	3978.7	3448.2	3448.2	3448.2	3448.2	3448.2	3448.2	3978.7	3978.7	44561.1

>5m Nou PALA	216.1	216.1	216.1	216.1	200.3	200.3	200.3	200.3	200.3	200.3	216.1	216.1	2498.8
>5m MtD CHA	607.8	607.8	607.8	607.8	392.5	392.5	392.5	392.5	392.5	392.5	607.8	607.8	6002.1
>5m MtD PALA	3.1	3.1	3.1	3.1	1.3	1.3	1.3	1.3	1.3	1.3	3.1	3.1	26.2
Corne Sud	192.0	154.8	102.7	154.1	196.6	153.7	167.3	146.7	150.6	103.6	151.9	185.7	1859.6
Totaux	13378.2	13341.1	13288.9	13340.3	11266.5	14154.6	11237.2	11216.5	11220.4	11173.5	13338.1	13372.0	147396.4

Estimation des captures de Dawa (en kg) par les stratégies ciblant cette espèce.

Stratégie	Janvier	Février	Mars	Avril	Mai	Juin	Juillet	Août	Septembre	Octobre	Novembre	Décembre	Totaux
<5m Paita CHA	301.4	301.4	301.4	301.4	255.0	255.0	255.0	255.0	255.0	255.0	301.4	301.4	3338.2
<5m Nou CHA	457.6	457.6	457.6	457.6	376.8	376.8	376.8	376.8	376.8	376.8	457.6	457.6	5006.7
<5m MtD CHA	76.2	76.2	76.2	76.2	79.0	79.0	79.0	79.0	79.0	79.0	76.2	76.2	931.3
>5m Paita CHA	88.4	88.4	88.4	88.4	75.9	75.9	75.9	75.9	75.9	75.9	88.4	88.4	986.1
>5m Nou CHA	1488.5	1488.5	1488.5	1488.5	1290.0	1290.0	1290.0	1290.0	1290.0	1290.0	1488.5	1488.5	16671.1
>5m MtD CHA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Corne Sud	73.2	59.0	39.2	58.8	75.0	58.6	63.8	55.9	57.4	39.5	57.9	70.8	709.1
Totaux	2485.3	2471.1	2451.2	2470.8	2151.8	2135.5	2140.6	2132.8	2134.3	2116.3	2470.0	2482.9	27642.5

ANNEXE 15

SCRIPT REALISE POUR LA CALIBRATION DU MODELE DE *LETHRINUS NEBULOSUS*

```
package analyseplans;

import static org.nuiton.i18n.I18n._;

import java.io.File;
import java.io.FileReader;
import java.util.ArrayList;
import java.util.Arrays;
import java.util.Collections;
import java.util.List;

import org.apache.commons.logging.Log;
import org.apache.commons.logging.LogFactory;
import org.nuiton.math.matrix.MatrixFactory;
import org.nuiton.math.matrix.MatrixIterator;
import org.nuiton.math.matrix.MatrixND;
import org.nuiton.topia.TopiaContext;
import org.nuiton.util.FileUtil;
import org.nuiton.util.StringUtil;

import scripts.ResultName;
//import scripts.SiMatrix;

import fr.ifremer.isisfish.datastore.ResultStorage;
import fr.ifremer.isisfish.datastore.SimulationStorage;
import fr.ifremer.isisfish.entities.Population;
import fr.ifremer.isisfish.entities.PopulationGroup;
import fr.ifremer.isisfish.simulator.AnalysePlan;
import fr.ifremer.isisfish.simulator.AnalysePlanContext;
import fr.ifremer.isisfish.simulator.SimulationParameter;
import fr.ifremer.isisfish.util.Doc;
import fr.ifremer.isisfish.entities.*;
// import fr.ifremer.isisfish.types.Date;

/**
 * Calibration_Simplexe_Capturabilite_Bec.
 *
 * Created: 31 mai 2011
 *
 * @author   Bastien Preuss (from original by B. Poussin)
 * @version 2
 *
 * Last update: Décembre 2011
 * by : Bastien Preuss
 */

public class Calibration_Simplexe_Capturabilite_Bec implements
      AnalysePlan {

   /** to use log facility, just put in your code: log.info("..."); */
   static private Log log = LogFactory
         .getLog(Calibration_Simplexe_Capturabilite_Bec.class);

   enum State {
      STATE_INIT, STATE_0, STATE_1, STATE_2, STATE_3, STATE_4
```

```
};

/////***here must appear the path to export the historic file ("Historic.csv")
//where q1, q2 and criteria computed at each simulation are written

protected File exportHistoric = new File("C:/Documents and
Settings/Administrateur/Bureau/Calibration/HistoricBecDeCane2.csv");
protected String exportHisto = "";

@Doc("Population which parameters are calibrated")
public Population param_Population = null;
@Doc("First initial point of the simplex: de la forme(\"xx;yy\")")
public String param_M1 = "6.42e-7;4.11e-5";// devient un parametre du plan d analyse
@Doc("Second initial point of the simplex")
public String param_M2 = "3.34e-8;5.59e-8";// devient un parametre du plan d analyse
@Doc("Third initial point of the simplex")
public String param_M3 = "1.59e-3;2.41e-1";// devient un parametre du plan d analyse

///// ***put here the path and name of the file containing the data on which you calibrate your fichery ( here
observed catches)
//in row : time (months) ; in column : sum over classe
@Doc(value = "file name and path of observed landings")
public String debarquements_Ligne_GN_Bec = "C:/Documents and
Settings/Administrateur/Bureau/Calibration/Metier_capture_nulle.csv";// Matrix for metier 1
public String debarquements_Ligne_CS_Bec = "C:/Documents and
Settings/Administrateur/Bureau/Calibration/Metier_capture_nulle.csv";// Matrix for metier 2
public String debarquements_Filet_GN_Bec = "C:/Documents and
Settings/Administrateur/Bureau/Calibration/cmt_PRO_Filet_CS_FondLag.csv";// Matrix for metier 3
public String debarquements_Filet_CS_Bec = "C:/Documents and
Settings/Administrateur/Bureau/Calibration/Metier_capture_nulle.csv";// Matrix for metier 4
public String debarquements_Filet_GN = "C:/Documents and
Settings/Administrateur/Bureau/Calibration/Metier_capture_nulle.csv";// Matrix for metier 5
public String debarquements_Filet_CS = "C:/Documents and
Settings/Administrateur/Bureau/Calibration/cmt_PRO_Ligne_CS_FondLag.csv";// Matrix for metier 6
public String debarquements_Ligne_GN = "C:/Documents and
Settings/Administrateur/Bureau/Calibration/cmt_PRO_Ligne_GN_FondLag.csv";// Matrix for metier 7
public String debarquements_Ligne_CS = "C:/Documents and
Settings/Administrateur/Bureau/Calibration/cmt_PRO_Filet_GN_FondLag.csv";// Matrix for metier 8
protected File debarquementsObserves1;
protected File debarquementsObserves2;
protected File debarquementsObserves3;
protected File debarquementsObserves4;
protected File debarquementsObserves5;
protected File debarquementsObserves6;
protected File debarquementsObserves7;
protected File debarquementsObserves8;
protected File debarquementsObserves;

protected MatrixND matrixDebarquement1;
protected MatrixND matrixDebarquement2;
protected MatrixND matrixDebarquement3;
protected MatrixND matrixDebarquement4;
protected MatrixND matrixDebarquement5;
protected MatrixND matrixDebarquement6;
protected MatrixND matrixDebarquement7;
```

```
   protected MatrixND matrixDebarquement8;
   protected MatrixND matrixDebarquement;


   protected State state = State.STATE_INIT;
   public Experiences experiences = new Experiences();
   public String[] necessaryResult = { ResultName.MATRIX_CATCH_WEIGHT_PER_STRATEGY_MET_PER_ZONE_POP };


   public String[] getNecessaryResult() {
      return this.necessaryResult;
   }


   public String getDescription() throws Exception {
      return _("Calibration using variable step Simplex method (Walters): user gives a file of observations (here
catches) by time step (.csv), output will try to approach oservations by changing the values of catchability");
   }

   /**
    * Appele au demarrage de la simulation, cette methode permet d'initialiser
    * des valeurs
    * @param context La simulation pour lequel on utilise cette regle
    */
    // Initialisation du plan de simu avec les donnes importees.
   public void init(AnalysePlanContext context) throws Exception {
      if (debarquements_Ligne_GN_Bec == null && debarquements_Ligne_CS_Bec == null &&
            debarquements_Filet_GN_Bec == null && debarquements_Filet_CS_Bec == null&&
            debarquements_Filet_GN == null && debarquements_Filet_CS == null&&
            debarquements_Ligne_GN == null && debarquements_Ligne_CS == null ||
            "".equals(debarquements_Ligne_GN_Bec) && "".equals(debarquements_Ligne_CS_Bec) &&
            "".equals(debarquements_Filet_GN_Bec) && "".equals(debarquements_Filet_CS_Bec)&&
            "".equals(debarquements_Filet_GN) && "".equals(debarquements_Filet_CS)&&
            "".equals(debarquements_Ligne_GN) && "".equals(debarquements_Ligne_CS)) {
         debarquementsObserves1 = FileUtil.getFile(".*.csv", "fichier csv separateur ';'");
         debarquementsObserves2 = FileUtil.getFile(".*.csv", "fichier csv separateur ';'");
         debarquementsObserves3 = FileUtil.getFile(".*.csv", "fichier csv separateur ';'");
         debarquementsObserves4 = FileUtil.getFile(".*.csv", "fichier csv separateur ';'");
         debarquementsObserves5 = FileUtil.getFile(".*.csv", "fichier csv separateur ';'");
         debarquementsObserves6 = FileUtil.getFile(".*.csv", "fichier csv separateur ';'");
         debarquementsObserves7 = FileUtil.getFile(".*.csv", "fichier csv separateur ';'");
         debarquementsObserves8 = FileUtil.getFile(".*.csv", "fichier csv separateur ';'");
      } else { // Si les objets ne sont pas vides, on recupere les valeurs deja existantes (a confirmer).
         debarquementsObserves1 = new File(debarquements_Ligne_GN_Bec);
         debarquementsObserves2 = new File(debarquements_Ligne_CS_Bec);
         debarquementsObserves3 = new File(debarquements_Filet_GN_Bec);
         debarquementsObserves4 = new File(debarquements_Filet_CS_Bec);
         debarquementsObserves5 = new File(debarquements_Filet_GN);
         debarquementsObserves6 = new File(debarquements_Filet_CS);
         debarquementsObserves7 = new File(debarquements_Ligne_GN);
         debarquementsObserves8 = new File(debarquements_Ligne_CS);
      }

      int nbYear = context.getParam().getNumberOfYear();
```

```
//TopiaContext db = context.getParam().getRegion().getStorage().beginTransaction();
//Population pop = (Population) db.findByTopiaId(param_Population.getTopiaId());

/////*** specify dimention of the matrix containning observations (observed landings for instance)
/////*** numbers of group/columns : could be equal to your number of classes in ISIS but may also be different
if your had only aggregated data

/////*** enter number of observation per year = lines of the observations file
int nbTrim = nbYear * 12;
/////*** enter the number of metiers
int nbMet = 8;
int[] dimMatrix2 = { nbTrim };
int[] dimMatrix = {nbTrim, nbMet};
matrixDebarquement = MatrixFactory.getInstance().create(dimMatrix);
matrixDebarquement1 = MatrixFactory.getInstance().create(dimMatrix2);
matrixDebarquement2 = MatrixFactory.getInstance().create(dimMatrix2);
matrixDebarquement3 = MatrixFactory.getInstance().create(dimMatrix2);
matrixDebarquement4 = MatrixFactory.getInstance().create(dimMatrix2);
matrixDebarquement5 = MatrixFactory.getInstance().create(dimMatrix2);
matrixDebarquement6 = MatrixFactory.getInstance().create(dimMatrix2);
matrixDebarquement7 = MatrixFactory.getInstance().create(dimMatrix2);
matrixDebarquement8 = MatrixFactory.getInstance().create(dimMatrix2);

matrixDebarquement1.importCSV(new FileReader(debarquementsObserves1), new int[] {0 });
matrixDebarquement2.importCSV(new FileReader(debarquementsObserves2), new int[] {0 });
matrixDebarquement3.importCSV(new FileReader(debarquementsObserves3), new int[] {0 });
matrixDebarquement4.importCSV(new FileReader(debarquementsObserves4), new int[] {0 });
matrixDebarquement5.importCSV(new FileReader(debarquementsObserves5), new int[] {0 });
matrixDebarquement6.importCSV(new FileReader(debarquementsObserves6), new int[] {0 });
matrixDebarquement7.importCSV(new FileReader(debarquementsObserves7), new int[] {0 });
matrixDebarquement8.importCSV(new FileReader(debarquementsObserves8), new int[] {0 });


// Remplissage de la matrice matrixDebarquement avec les 4 matrices de debarquement (une par metier).
for( MatrixIterator i=matrixDebarquement.iterator(); i.hasNext();){ i.next(); int [] debarquementsObserves =
i.getCoordinates();
    if (debarquementsObserves[1] == 0){
            i.setValue(matrixDebarquement1.getValue(debarquementsObserves[0]));
           }else if (debarquementsObserves[1] == 1){
            i.setValue(matrixDebarquement2.getValue(debarquementsObserves[0]));
           }else if (debarquementsObserves[1] == 2){
            i.setValue(matrixDebarquement3.getValue(debarquementsObserves[0]));
           }else if (debarquementsObserves[1] == 3){
            i.setValue(matrixDebarquement4.getValue(debarquementsObserves[0]));
           }else if (debarquementsObserves[1] == 4){
            i.setValue(matrixDebarquement5.getValue(debarquementsObserves[0]));
           }else if (debarquementsObserves[1] == 5){
            i.setValue(matrixDebarquement6.getValue(debarquementsObserves[0]));
           }else if (debarquementsObserves[1] == 6){
            i.setValue(matrixDebarquement7.getValue(debarquementsObserves[0]));
           }else if (debarquementsObserves[1] == 7){
            i.setValue(matrixDebarquement8.getValue(debarquementsObserves[0]));
           }

}
```

```
      log.info("MatrixDebarquement : " + matrixDebarquement);
   }

   double g1;
   double g2;
   double worst1;
   double worst2;

   /**
    * Call before each simulation
    * @param context plan context
    * @param nextSimulation storage used for next simulation
    * @return true if we must do next simulation, false to stop plan
    * @throws Exception
    */
   public boolean beforeSimulation(AnalysePlanContext context,
         SimulationStorage nextSimulation) throws Exception {
      boolean doNext = true;
      boolean doBoucle = true;
      log.info("before simulation");

      int number = nextSimulation.getParameter().getAnalysePlanNumber();

      if (number < 3) {
         log.info("number<3");

         String[] M1 = param_M1.split(";");
         String[] M2 = param_M2.split(";");
         String[] M3 = param_M3.split(";");

         double[] q1 = StringUtil.toArrayDouble(M1[0], M2[0], M3[0]);
         double[] q2 = StringUtil.toArrayDouble(M1[1], M2[1], M3[1]);
         experiences.getExperience(number).q1 = q1[number];
         experiences.getExperience(number).q2 = q2[number];

         changeDB(experiences.getExperience(number), nextSimulation);

      } else {

         double q1 = 1000;
         double q2 = 1000;
         double lastCritere = experiences.getExperience(number - 1).criteria;
         while (doBoucle) {
            doBoucle = false;
            if (state == State.STATE_INIT) {
               doBoucle = false;
               log.info("state init");

               //ordonne les 3 premieres experiences selon leur critere
               Collections.sort(experiences.current);
               //log.info("SIMPLEXE : current 0 = " + experiences.current.get(0).criteria + "current 1 = " +
experiences.current.get(1).criteria  + "current 2 = " +  experiences.current.get(2).criteria  );
               log.info("SIMPLEXE : current 0 = "
                     + experiences.current.get(0).criteria
                     + "current 1 = "
```

```
        + experiences.current.get(1).criteria
        + "current 2 = "
        + experiences.current.get(2).criteria);
    log.info("SIMPLEXE : Best q1 = "
        + experiences.current.get(0).q1 + " q2 = "
        + experiences.current.get(0).q2);
    log.info("SIMPLEXE : NextBest q1 = "
        + experiences.current.get(1).q1 + " q2 = "
        + experiences.current.get(1).q2);
    log.info("SIMPLEXE : Worst q1 = "
        + experiences.current.get(2).q1 + " q2 = "
        + experiences.current.get(2).q2);

    //Calcul et evaluation de R
    double g1 = (experiences.current.get(0).q1 + experiences.current
        .get(1).q1) / 2.0;
    double g2 = (experiences.current.get(0).q2 + experiences.current
        .get(1).q2) / 2.0;
    double worst1 = experiences.current.get(2).q1;
    double worst2 = experiences.current.get(2).q2;

    state = State.STATE_0;

    q1 = 2 * g1 - worst1;
    q2 = 2 * g2 - worst2;

    log.info("R : q1 = " + q1 + " q2 = " + q2);

} else if (state == State.STATE_0) {
    doBoucle = false;
    log.info("state 0");

    // on fait la 5eme avec des q qui dependent de la 4eme dans le dernier cas
    //log.info("g1 = " + g1 + " " + "g2 = " + g2);
    //log.info("worst1 = " + worst1 + " " + "worst2 = " + worst2);

    if (lastCritere > experiences.current.get(2).criteria) {
        log.info("State 0 : R : lastCtritere > current2 : R pire de W");
        state = State.STATE_1;
        //calcul de Cw
        q1 = ((experiences.current.get(0).q1 + experiences.current
            .get(1).q1) / 2.0)
            - (((experiences.current.get(0).q1 + experiences.current
                .get(1).q1) / 2.0) - experiences.current
                .get(2).q1) / 2.0;
        q2 = ((experiences.current.get(0).q2 + experiences.current
            .get(1).q2) / 2.0)
            - (((experiences.current.get(0).q2 + experiences.current
                .get(1).q2) / 2.0) - experiences.current
                .get(2).q2) / 2.0;
        log.info("Cw : q1 = " + q1 + " q2 = " + q2);

    } else if (lastCritere > experiences.current.get(1).criteria) {
        log.info("State 0 :R : lastCritere > current 1 : R meilleur que W et moins bon que N");
        state = State.STATE_2;
```

```
                // calcul de Cr
                q1 = ((experiences.current.get(0).q1 + experiences.current
                        .get(1).q1) / 2.0)
                        + ((((experiences.current.get(0).q1 + experiences.current
                                .get(1).q1) / 2.0) - experiences.current
                                .get(2).q1) / 2.0;
                q2 = ((experiences.current.get(0).q2 + experiences.current
                        .get(1).q2) / 2.0)
                        + ((((experiences.current.get(0).q2 + experiences.current
                                .get(1).q2) / 2.0) - experiences.current
                                .get(2).q2) / 2.0;
                log.info("Cr : q1 = " + q1 + " q2 = " + q2);

            } else if (lastCritere > experiences.current.get(0).criteria) {
                log.info("State 0 :R : lastCritere > current0 : R meilleur que N et moins bon que B");
                state = State.STATE_INIT;
                experiences.current.remove(2);//remove(3)avant
                doBoucle = true;
                log.info("remove W, simplex BNR");

            } else { // dernier cas possible: if (lastCritere < experiences.current.get(0).critere) {
                log.info("State 0 :R : lastCritere < current 0 : R meilleur que B, calcul de E");
                state = State.STATE_4;

                q1 = experiences.getExperience(number - 1).q1
                        + (experiences.current.get(0).q1 + experiences.current
                                .get(1).q1) / 2.0
                        - experiences.current.get(2).q1;
                q2 = experiences.getExperience(number - 1).q2
                        + (experiences.current.get(0).q2 + experiences.current
                                .get(1).q2) / 2.0
                        - experiences.current.get(2).q2;
                //q1 = experiences.current.get(3).q1 + (experiences.current.get(0).q1 + experiences.current.get(1).q1) /
2.0 - experiences.current.get(2).q1;
                //q2 = experiences.current.get(3).q2 + (experiences.current.get(0).q2 + experiences.current.get(1).q2) /
2.0 - experiences.current.get(2).q2;
                log.info("E : q1 = " + q1 + " q2 = " + q2);
            }

        } else if (state == State.STATE_1) {
            log.info("state 1, simplex BNCw");
            experiences.current.remove(3);
            experiences.current.remove(2);
            state = State.STATE_INIT;
            doBoucle = true;

        } else if (state == State.STATE_2) {
            log.info("state 2, simplex BNCr");
            experiences.current.remove(3);
            experiences.current.remove(2);
            state = State.STATE_INIT;
            doBoucle = true;

        } else if (state == State.STATE_4) {
            log.info("state 4 :comparaison de E a B");
```

```
            doBoucle = true;
            if (lastCritere < experiences.current.get(0).criteria) {
              log.info("E meilleur que B, remove 2 et 3 : simplex BNE");
              experiences.current.remove(3);
              experiences.current.remove(2);
            } else {
              log.info("E moins bon que B, remove 2 et 4, simplex BNR");
              experiences.current.remove(4);
              experiences.current.remove(2);
            }

            state = State.STATE_INIT;
          }

        }//fin du while
        //on remplit la table experiences
        experiences.getExperience(number).q1 = q1;
        experiences.getExperience(number).q2 = q2;

        log.info("on change Q dans la DB avec : q1 = " + q1 + " " + "q2 = " + q2);

        // on change la valeur de q dans la DB
        changeDB(experiences.getExperience(number), nextSimulation);
      }// fin du else (number > 3)
      return doNext;
    }// fin du before simulation

    /**

     * Call after each simulation, compute criteria for last simulation
     * @param context plan context
     * @param lastSimulation storage used for next simulation
     * @return true if we must do next simulation, false to stop plan
     * @throws Exception
    */
    public boolean afterSimulation(AnalysePlanContext context,
        SimulationStorage lastSimulation) throws Exception {
      boolean doNext = true;
      log.info("after simulation");
      int number = lastSimulation.getParameter().getAnalysePlanNumber();
      ResultStorage result = lastSimulation.getResultStorage();

     /////*** Simulated catches can be cumulated over months(0), strategies(1), metiers(2), groups(3), and area(4).

      MatrixND L2 = result.getMatrix(param_Population,
ResultName.MATRIX_CATCH_WEIGHT_PER_STRATEGY_MET_PER_ZONE_POP);
      log.info("dim de L2" + " " + Arrays.toString(L2.getDim()));
      System.out.println("matriceObs :"+ matrixDebarquement);
           System.out.println("matriceSimule :"+ L2);
      // log.info("dim de L2" + " " + Arrays.toString(L2.getDim()));

      /////***  MatrixND L = L2.getSubMatrix(a,b,c).copy(); as follow :
      /////*** a = 1 if you want to exclude strategies, 2 if metiers and 4 if areas
      /////*** b = indice of the first object considered
      /////*** c = number of object to keep after b, b included
```

```
List<Strategy> listStrat = (List<Strategy>)L2.getSemantic(1);
        int[] indexStratagarder = new int[2];
        for(Strategy s : listStrat){
        if(s.getName().equals("PRO_Occasionnel")) indexStratagarder [0] = listStrat.indexOf(s);
        else if(s.getName().equals("PRO_Regulier")) indexStratagarder [1] = listStrat.indexOf(s);
        }
        log.info("indexStratagarder :"+ indexStratagarder);
        MatrixND L1 = L2.getSubMatrix(1, indexStratagarder).copy();

List<Metier> listmet = (List<Metier>)L1.getSemantic(2);
int[] indexMetagarder = new int[8];
for(Metier m : listmet){
      if(m.getName().equals("PRO_Ligne_GranNou_Recif")) indexMetagarder [0] = listmet.indexOf(m);
      else if(m.getName().equals("PRO_Filet_GranNou_Recif")) indexMetagarder [1] = listmet.indexOf(m);
  else if(m.getName().equals("PRO_Filet_CorneSud_FondLagon")) indexMetagarder [2] = listmet.indexOf(m);
  else if(m.getName().equals("PRO_Filet_CorneSud_Recif")) indexMetagarder [3] = listmet.indexOf(m);
  else if(m.getName().equals("PRO_Ligne_CorneSud_Recif")) indexMetagarder [4] = listmet.indexOf(m);
  else if(m.getName().equals("PRO_Ligne_CorneSud_FondLagon")) indexMetagarder [5] = listmet.indexOf(m);
      else if(m.getName().equals("PRO_Ligne_GranNou_FondLagon")) indexMetagarder [6] = listmet.indexOf(m);
      else if(m.getName().equals("PRO_Filet_GranNou_FondLagon")) indexMetagarder [7] = listmet.indexOf(m);
}
log.info("indexMetagarder" + " " + indexMetagarder);
MatrixND L = L1.getSubMatrix(2, indexMetagarder).copy();

log.info("sous matrice extraite");
log.info("matriceSimule Strategies PRO :"+ L);
L = L.sumOverDim(1);// sum over strategies

L = L.sumOverDim(4);// sum over zones

L = L.sumOverDim(3);// sum over groups

        log.info("sommes sur les strategies, zones et groupes faites");

L = L.reduce();

        log.info("dim de obs" + " " + Arrays.toString(matrixDebarquement.getDim()));
        log.info("dim de L Reduce" + " " + Arrays.toString(L.getDim()));
        log.info("matriceObs :"+ matrixDebarquement);
        log.info("matriceSimule Reduce:" + L);


//////////////////Calcul du critere/////////////////
log.info("calcul du critere");

double crit = 0;
for (MatrixIterator g = L.iterator(); g.hasNext();) {
   g.next();
   //boucle sur les trimestres et les classes d age

   int[] dim = g.getCoordinates();

   double obs = matrixDebarquement.getValue(dim);
   double simules = g.getValue();
```

```
                        log.info("obs  =  " + obs);
                        log.info("simule  =  " + simules);

            crit += Math.pow(obs - simules, 2); // crit = crit + (obs-simules)^2
        }// fin du for
        log.info("critere " + number + " = " + crit);

        //ajoute le critere dans la table experiences
        experiences.getExperience(number).criteria = crit;

        //ecriture de la table historic
        exportHisto += experiences.getExperience(number).q1 + ";"
                + experiences.getExperience(number).q2 + ";"
                + experiences.getExperience(number).criteria + "\n";
        org.nuiton.util.FileUtil.writeString(exportHistoric, exportHisto);

        return doNext;

    }// fin du after simulation

    /**
     * Modify nextSimulation database with q1 and q2 in exp.
     *
     * @param exp
     * @param nextSimulation
     * @throws Exception
     */
    protected void changeDB(Experience exp, SimulationStorage nextSimulation)
            throws Exception {
        //methode appelee dans before simualtion
        TopiaContext db = nextSimulation.getStorage().beginTransaction();//ouvrir un context pour modifier les
donnees
        Population pop = (Population) db.findByTopiaId(param_Population.getTopiaId()); //reccupere la pop ciblee
        MatrixND c = pop.getCapturability(); // reccupere la matrice de capturabilite

        //log.info("Pour cette simulation : q1 = " + exp.q1 + ";" + "q2 = " + exp.q2 );

        /////*** that is where you explain how to fill the catchability matrix with q1 and q2
        for (MatrixIterator i = c.iterator(); i.hasNext();) {
            i.next();
            Object[] sem = i.getSemanticsCoordinates();
            PopulationGroup group = (PopulationGroup) sem[0];
            //PopulationSeasonInfo season = (PopulationSeasonInfo) sem[1];

            ////*** exemple when q2 corresponds to the 12 first groups (groups 0 to 11)
            if (group.getId() >= 2 && group.getId() < 4) {
                i.setValue(exp.q1);
            } else if (group.getId() >= 4) {
                i.setValue(exp.q2);
            }

            /////*** exemple when it depends on seasons and groups
            /*                          if (season.getFirstMonth().after(Month.JULY) && group.getId() >=18){ //month >=
aout && groupID >= 18
```

```
                    i.setValue(exp.q2);
                            }else {
                                    i.setValue(exp.q1);
                    }
    */

  }//fin du for

  db.commitTransaction(); // effectue la modification
  db.closeContext(); // ferme le context
}

static public class Experiences {
  // cree la liste experiences ou sont stoques q1,q2 et critere pour chaque simulation

  /** contains last simplex and potentialy 2 more simulation */
  public List<Experience> current = new ArrayList<Experience>();

  /** contains all experience done */
  public List<Experience> history = new ArrayList<Experience>();

  /**
   * return experience requested, if this experience doesn't exist
   * create it.
   *
   * @param i simulation number
   * @return experience with simulation number fixed if new experience
   * is returned
   */
  public Experience getExperience(int i) {
    Experience result;
    if (i < history.size()) {
      result = history.get(i);
    } else {
      result = new Experience();
      result.simNumber = i;
      history.add(i, result);
      current.add(result);
    }
    return result;
  }//fin de la definition de getExperience

  /**
       * @return the history
       */
  public List<Experience> getHistory() {
    return this.history;
  }
}// fin de la creation des listes experiences

static public class Experience implements Comparable<Experience> {
  public int simNumber;
  public double criteria;
  public double q1;
  public double q2;
```

```
        /**
        * Permit to order experience, first is experience with smallest criteria
        */
        public int compareTo(Experience other) {
            int result = Double.compare(this.criteria, other.criteria);
            return result;
        }
    }

}
```

ANNEXE 16

EFFECTIFS INITIAUX

<u>Effectifs initiaux de *Lethrinus nebulosus* utilisés dans les simulations.</u>

<u>Zones</u>	Classe 0	Classe 1	Classe 2	Classe 3	Classe 4	Classe 5	Classe 6	Classe 7	Classe 8	Classe 9
Préadultes_Nord	0	0	5.19E+06	0	0	0	0	0	0	0
Préadultes _Sud	0	0	6.29E+05	0	0	0	0	0	0	0
Préadultes _Corne_Sud	0	0	4.85E+06	0	0	0	0	0	0	0
Zone_Reproduction_Centre	0	0	0	0	0	3.88E+02	4.00E+02	2.77E+02	1.42E+02	1.03E+02
Zone_Reproduction_Sud	0	0	0	0	0	3.97E+02	4.10E+02	2.84E+02	1.45E+02	1.06E+02
Zone_Reproduction_Corne_Sud	0	0	0	0	0	1.29E+03	1.33E+03	9.19E+02	4.70E+02	3.43E+02
Zone_Reproduction_Nord	0	0	0	0	0	2.62E+02	2.70E+02	1.87E+02	9.58E+01	6.95E+01
Juvéniles	8.05E+08	8.64E+07	0	0	0	0	0	0	0	0
Adultes_Corne_Sud	0	0	0	3.42E+06	1.15E+06	5.49E+05	3.70E+05	2.26E+05	1.15E+05	8.41E+04
AMP_Préadultes _Centre	0	0	6.12E+05	0	0	0	0	0	0	0
AMP_Bec_Adu_Centre	0	0	0	1.73E+05	5.84E+04	2.78E+04	1.88E+04	1.14E+04	5.85E+03	4.27E+03
Préadultes _Centre	0	0	9.75E+06	0	0	0	0	0	0	0
Adultes _Centre	0	0	0	1.03E+06	3.47E+05	1.65E+05	1.11E+05	6.79E+04	3.47E+04	2.54E+04
Adultes _Nord	0	0	0	6.96E+05	2.35E+05	1.12E+05	7.53E+04	4.59E+04	2.35E+04	1.71E+04
Bec_Zone_Reproduction_AMP_Centre	0	0	0	0	0	6.52E+01	6.72E+01	4.66E+01	2.38E+01	1.74E+01
ScenarioAMP_AMP_ Adultes	0	0	0	3.43E+05	1.16E+05	5.52E+04	3.72E+04	2.27E+04	1.16E+04	8.46E+03
ScenarioAMP_ Adultes	0	0	0	1.05E+06	3.56E+05	1.70E+05	1.14E+05	6.96E+04	3.56E+04	2.60E+04
Zone_Reproduction_AMP_Sud	0	0	0	0	0	1.29E+02	1.33E+02	9.24E+01	4.72E+01	3.45E+01

Effectifs initiaux de *Plectropomus leopardus* utilisés dans les simulations.

Zones	Classe 0	Classe 1	Classe 2	Classe 3	Classe 4	Classe 5	Classe 6	Classe 7	Classe 8	Classe 9	Classe 10	Classe 11	Classe 12	Classe 13	Classe 14	Classe 15
Nord_Cote	0	1.81E+05	7.17E+04	2.82E+04	1.08E+04	2.71E+03	3.98E+01	1.69E-01	5.36E-05	2.31E-05	1.02E-05	4.71E-06	2.29E-06	1.03E-06	4.38E-07	3.49E-07
Nord_Int	0	1.81E+05	7.17E+04	2.80E+04	1.04E+04	7.15E+02	3.24E-01	1.59E-03	4.21E-04	1.89E-04	8.39E-05	3.85E-05	1.87E-05	8.44E-06	3.58E-06	2.86E-06
Nord_Barr	0	3.62E+05	1.43E+05	5.65E+04	2.19E+04	6.70E+03	2.91E+02	1.01E+01	1.07E+00	4.79E-01	2.12E-01	9.71E-02	4.71E-02	2.12E-02	8.97E-03	7.13E-03
Sud_Cote	0	1.81E+05	7.17E+04	2.82E+04	1.09E+04	3.69E+03	3.18E+02	1.47E+01	3.01E-02	1.79E-04	5.31E-05	2.44E-05	1.18E-05	5.33E-06	2.26E-06	1.81E-06
Sud_Barr	0	1.81E+05	7.17E+04	2.83E+04	1.10E+04	4.36E+03	8.97E+02	1.43E+02	7.17E+00	1.32E+00	5.20E-01	2.36E-01	1.15E-01	5.15E-02	2.18E-02	1.73E-02
Centre_Cote	0	1.81E+05	7.17E+04	2.83E+04	1.11E+04	3.37E+03	1.41E+02	2.84E+00	9.33E-02	4.17E-02	1.85E-02	8.50E-03	4.13E-03	1.86E-03	7.90E-04	6.30E-04
Adultes_Corne_ Sud	0	0	0	2.01E+06	8.22E+05	3.86E+05	1.80E+05	8.39E+04	3.76E+04	1.67E+04	7.26E+03	3.28E+03	1.57E+03	6.96E+02	2.91E+02	2.25E+02
Juvéniles_Corne _Sud	0	1.28E+07	5.09E+06	0	0	0	0	0	0	0	0	0	0	0	0	0
Recrutement	9.40E+07	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
AMP_Juvéniles_ Centre_Barr	0	6.03E+06	2.39E+06	0	0	0	0	0	0	0	0	0	0	0	0	0
AMP_ Adultes_Centre_ Barr	0	0	0	9.51E+05	4.01E+05	1.94E+05	8.88E+04	4.07E+04	1.85E+04	8.31E+03	3.68E+03	1.69E+03	8.17E+02	3.68E+02	1.56E+02	1.24E+02
Adultes_Centre_ Barr	0	0	0	2.85E+04	1.19E+04	5.17E+03	1.36E+03	2.92E+02	2.25E+01	3.10E+00	9.33E-01	3.99E-01	1.92E-01	8.61E-02	3.65E-02	2.90E-02
Centre_Int	0	3.62E+05	1.43E+05	5.61E+04	2.10E+04	2.07E+03	4.57E+00	7.02E-02	1.77E-02	7.93E-03	3.51E-03	1.61E-03	7.80E-04	3.51E-04	1.49E-04	1.18E-04
AMP _Centre_Int	0	3.02E+06	1.20E+06	4.73E+05	1.90E+05	8.83E+04	4.03E+04	1.85E+04	8.43E+03	3.79E+03	1.68E+03	7.72E+02	3.75E+02	1.69E+02	7.17E+01	5.72E+01
Juvéniles_Centr e_Barr	0	1.81E+05	7.17E+04	0	0	0	0	0	0	0	0	0	0	0	0	0
ScenarioAMP	0	1.81E+05	7.17E+04	2.82E+04	1.09E+04	3.76E+03	3.56E+02	1.96E+01	2.49E-01	8.82E-02	3.90E-02	1.79E-02	8.71E-03	3.92E-03	1.67E-03	1.33E-03
ScenarioAMP_A MP	0	1.81E+05	7.17E+04	2.82E+04	1.09E+04	3.76E+03	3.56E+02	1.96E+01	2.49E-01	8.82E-02	3.90E-02	1.79E-02	8.71E-03	3.92E-03	1.67E-03	1.33E-03

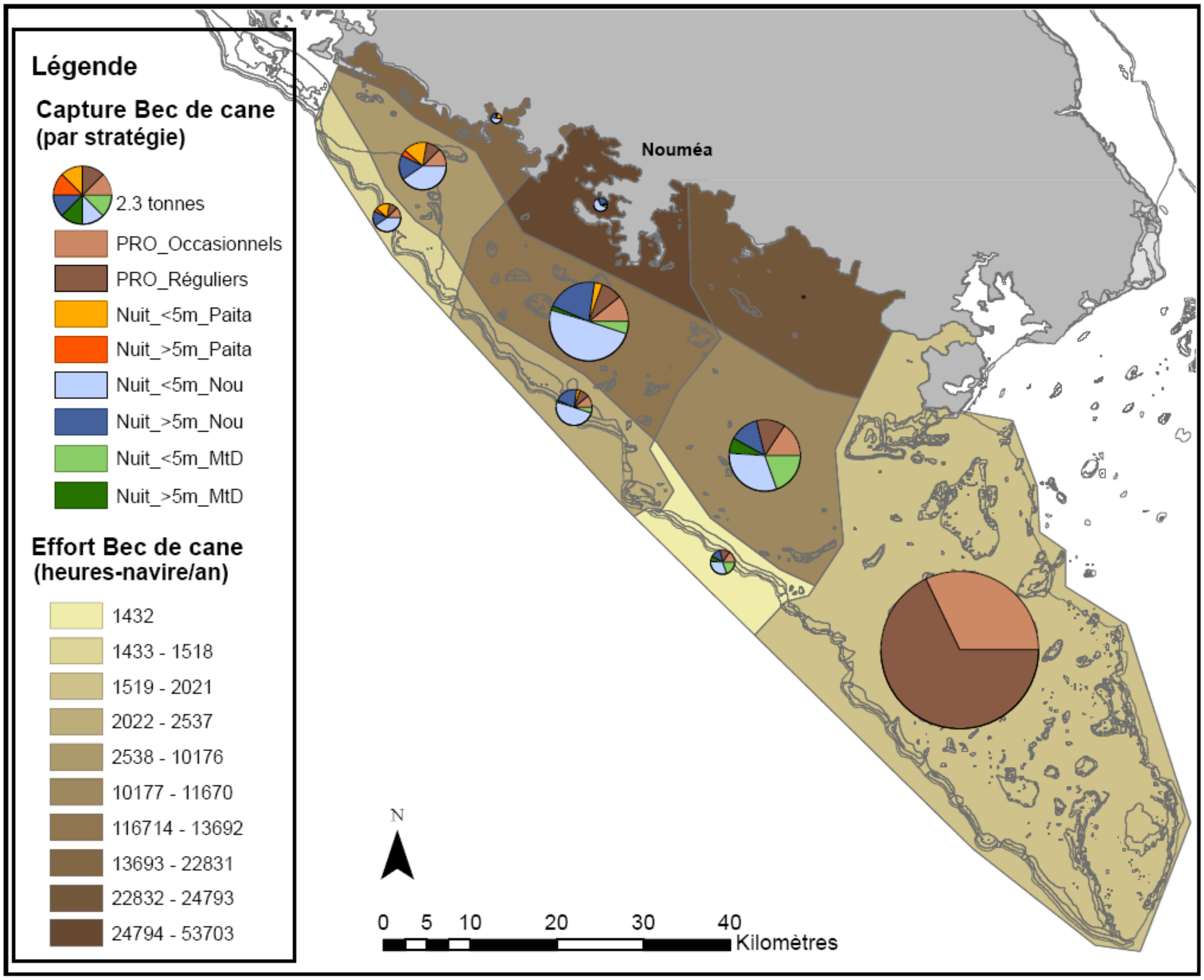
Effectifs initiaux de *Naso unicornis* utilisés dans les simulations.

Zones	Classe 0	Classe 1	Classe 2	Classe 3	Classe 4	Classe 5	Classe 6	Classe 7	Classe 8	Classe 9
Nord_Cote	0	1.86E+05	5.18E+04	2.46E+04	1.22E+04	5.97E+03	2.88E+03	1.38E+03	6.62E+02	6.12E+02
Nord_Int	0	1.24E+05	3.45E+04	1.82E+04	9.94E+03	5.08E+03	2.45E+03	1.18E+03	5.69E+02	5.32E+02
Nord_Barr	0	2.02E+05	5.61E+04	2.71E+04	1.38E+04	6.89E+03	3.42E+03	1.69E+03	8.36E+02	8.24E+02
Sud_Barr	0	1.24E+05	3.45E+04	1.72E+04	9.36E+03	5.03E+03	2.69E+03	1.43E+03	7.61E+02	8.56E+02
Juvéniles_Corne_Sud	0	2.10E+06	0	0	0	0	0	0	0	0
Reproduction_Corne_Sud	0	0	3.08E+04	3.24E+04	1.70E+04	8.88E+03	4.65E+03	2.42E+03	1.26E+03	1.37E+03
Recrutement	2.44E+07	0	0	0	0	0	0	0	0	0
Reproduction_Nord_Int	0	0	1.82E+03	2.02E+03	1.11E+03	5.65E+02	2.73E+02	1.31E+02	6.33E+01	5.92E+01
Reproduction_Nord_Cote	0	0	2.73E+03	2.73E+03	1.36E+03	6.65E+02	3.20E+02	1.54E+02	7.37E+01	6.81E+01
Reproduction_Nord_Barr	0	0	2.95E+03	3.01E+03	1.53E+03	7.68E+02	3.81E+02	1.88E+02	9.32E+01	9.19E+01
Reproduction_Centre_Cot e	0	0	4.54E+02	5.02E+02	2.76E+02	1.48E+02	7.79E+01	4.05E+01	2.10E+01	2.21E+01
Reproduction_Centre_Int	0	0	2.27E+03	2.36E+03	1.23E+03	6.08E+02	2.89E+02	1.38E+02	6.58E+01	6.16E+01
Reproduction_Centre_Barr	0	0	9.09E+02	1.02E+03	5.67E+02	3.13E+02	1.71E+02	9.27E+01	5.01E+01	5.87E+01
Reproduction_Sud_Cote	0	0	4.54E+02	4.78E+02	2.59E+02	1.39E+02	7.39E+01	3.90E+01	2.06E+01	2.27E+01
Reproduction_Sud_Int	0	0	1.36E+03	1.44E+03	7.83E+02	4.21E+02	2.24E+02	1.19E+02	6.27E+01	6.95E+01
Reproduction_Sud_Barr	0	0	1.82E+03	1.92E+03	1.04E+03	5.61E+02	3.00E+02	1.59E+02	8.47E+01	9.53E+01
AMP_Centre_Cote	0	3.62E+04	1.01E+04	4.82E+03	2.43E+03	1.23E+03	6.23E+02	3.14E+02	1.58E+02	1.61E+02
AMP_ Centre_Int	0	2.90E+05	8.05E+04	3.98E+04	2.07E+04	1.09E+04	5.67E+03	2.95E+03	1.53E+03	1.64E+03
AMP_ Juvéniles_Centre_Barr	0	5.07E+05	0	0	0	0	0	0	0	0
AMP_ Adultes_Centre_Barr	0	0	1.41E+05	7.10E+04	3.78E+04	2.00E+04	1.06E+04	5.57E+03	2.91E+03	3.17E+03
AMP _Sud_Cote	0	3.62E+04	1.01E+04	4.72E+03	2.33E+03	1.15E+03	5.69E+02	2.80E+02	1.38E+02	1.35E+02
Centre_Cote	0	3.11E+04	8.63E+03	4.52E+03	2.48E+03	1.33E+03	6.99E+02	3.63E+02	1.88E+02	1.98E+02
Centre_Int	0	1.55E+05	4.32E+04	2.12E+04	1.10E+04	5.41E+03	2.57E+03	1.22E+03	5.86E+02	5.49E+02
Juvéniles_Centre_Barr	0	6.21E+04	0	0	0	0	0	0	0	0
Adultes_Centre_Barr	0	0	1.73E+04	9.16E+03	5.10E+03	2.81E+03	1.54E+03	8.33E+02	4.50E+02	5.28E+02

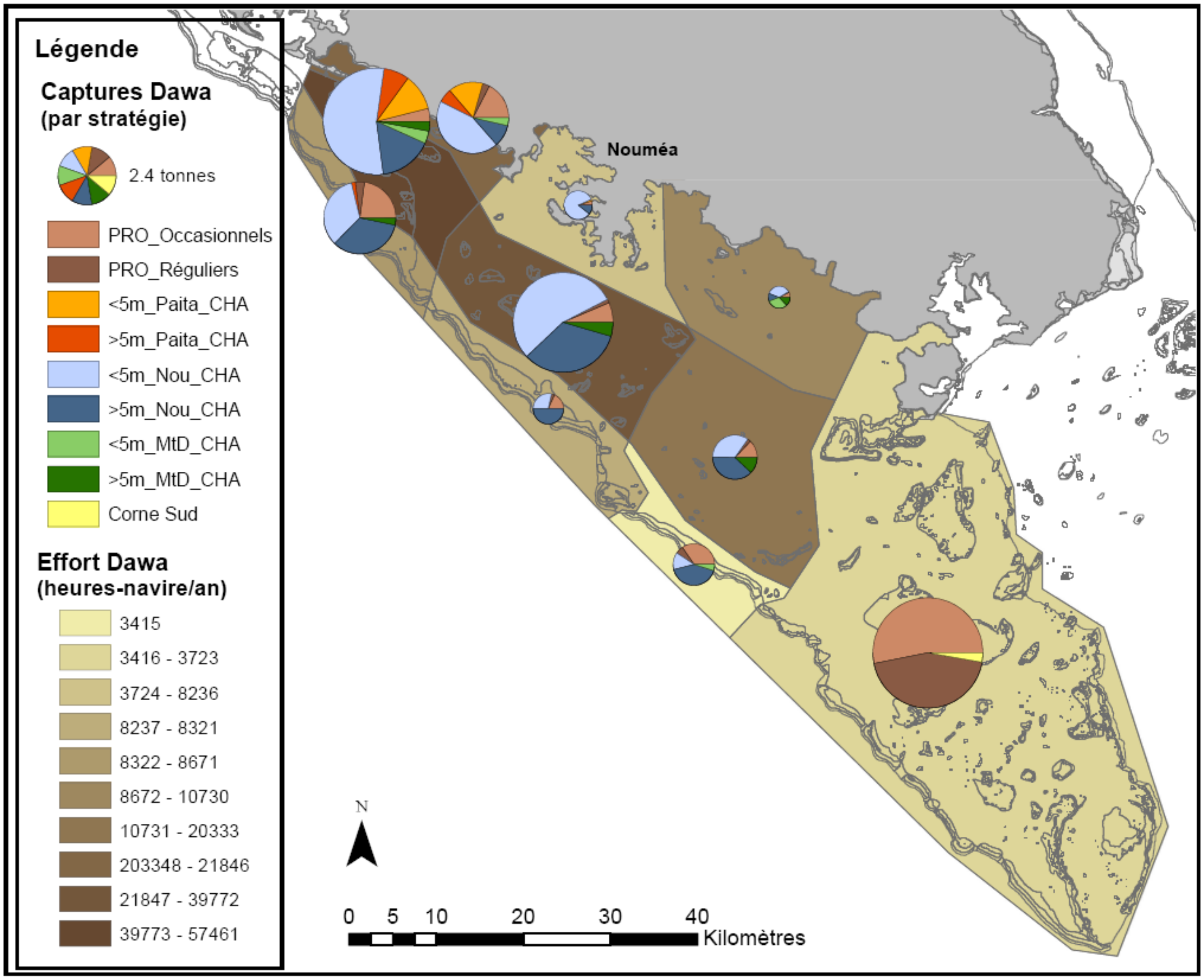
Sud_Cote	0	3.11E+04	8.63E+03	4.30E+03	2.33E+03	1.25E+03	6.63E+02	3.50E+02	1.85E+02	2.04E+02
Reproduction_AMP_Adu_Centre_Barr	0	0	7.42E+03	7.89E+03	4.20E+03	2.23E+03	1.18E+03	6.19E+02	3.24E+02	3.52E+02
Reproduction_AMP_Centre_Int	0	0	4.24E+03	4.42E+03	2.31E+03	1.21E+03	6.30E+02	3.27E+02	1.70E+02	1.82E+02
Reproduction_AMP_Centre_Cote	0	0	5.30E+02	5.36E+02	2.70E+02	1.37E+02	6.93E+01	3.49E+01	1.76E+01	1.79E+01
Reproduction_AMP_Sud_Cote	0	0	5.30E+02	5.24E+02	2.58E+02	1.28E+02	6.32E+01	3.11E+01	1.54E+01	1.50E+01
Adultes_Corne_Sud	0	0	5.85E+05	2.92E+05	1.53E+05	7.99E+04	4.18E+04	2.18E+04	1.13E+04	1.23E+04
ScenarioAMP	0	9.32E+04	2.59E+04	1.30E+04	7.03E+03	3.78E+03	2.01E+03	1.07E+03	5.63E+02	6.25E+02
ScenarioAMP_AMP	0	3.11E+04	8.63E+03	4.32E+03	2.35E+03	1.27E+03	6.77E+02	3.59E+02	1.90E+02	2.11E+02
Reproduction_AMP_Sud_Int	0	0	4.54E+02	4.80E+02	2.62E+02	1.41E+02	7.53E+01	3.99E+01	2.11E+01	2.35E+01

ANNEXE 17

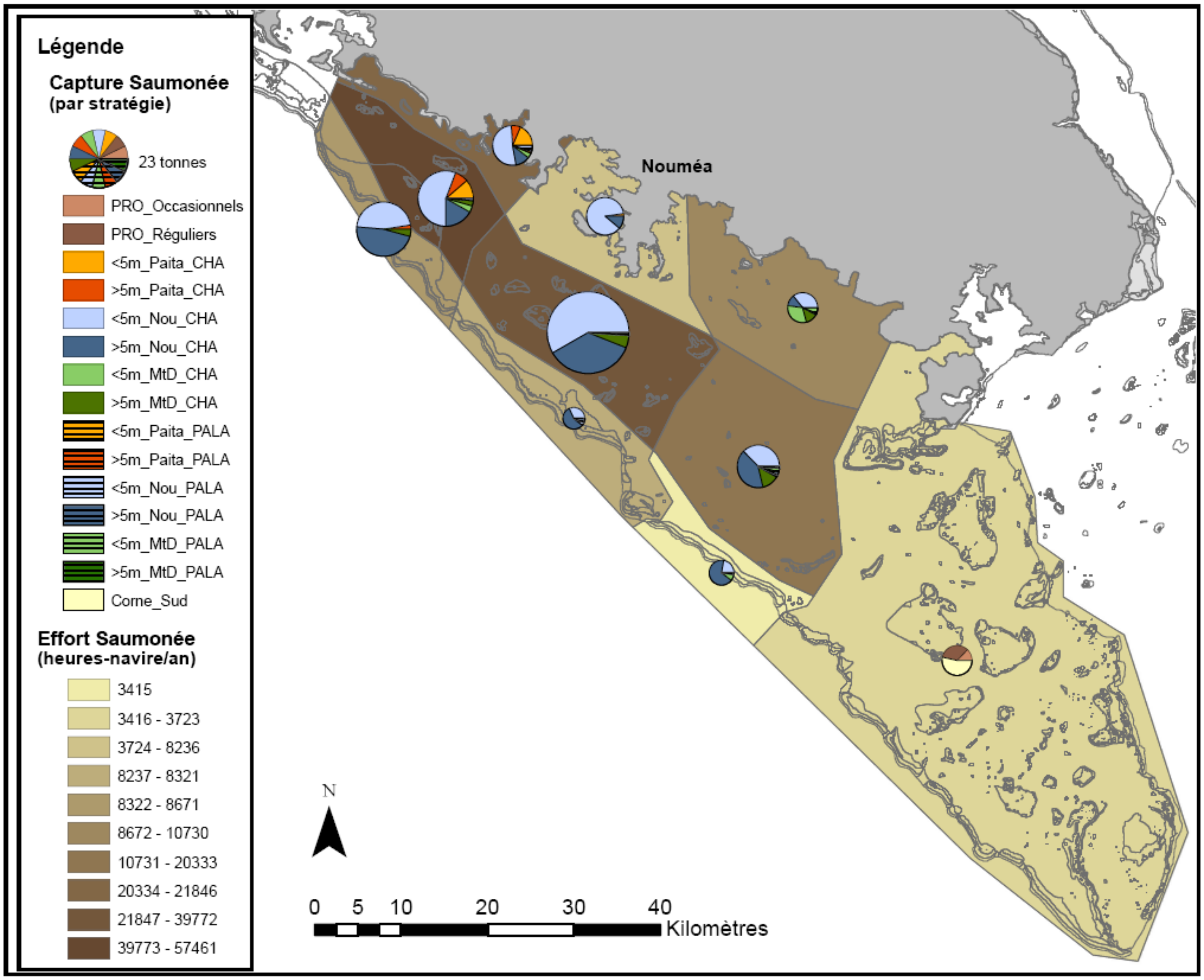
CARTOGRAPHIE DE L'EFFORT DE PECHE ANNUEL ET DES CAPTURES ASSOCIEES POUR *L. NEBULOSUS*, *P. LEOPARDUS* ET *N. UNICORNIS*.



Effort de pêche annuel toutes activités de pêche confondues ciblant le Bec de cane (couleur de fond) et captures annuelles par stratégie.



Effort de pêche annuel toutes activités de pêche confondues ciblant la Saumonée (couleur de fond) et captures annuelles par stratégie.



Effort de pêche annuel toutes activités de pêche confondues ciblant le Dawa (couleur de fond) et captures annuelles par stratégie.

ANNEXE 18

DETAILS DE LA METHODE D'ANALYSE DE SENSIBILITE PAR PLAN D'EXPERIENCE DE MORRIS

Avec la méthode de Morris, la sensibilité du modèle à la variation des paramètres est évaluée à travers le calcul de l'indice μ^*_j qui correspond à la moyenne des effets élémentaires d'un paramètre *j*, dont on prend la valeur absolue (afin d'éviter les compensations de signe) des variations $\Delta^i_j G$ sur la sortie du modèle pour chaque valeur de *i* :

$$\mu^*_j = \frac{1}{N}\sum_{i=1}^{N}\left|\Delta^i_j\, G\right| \tag{1}$$

Un second indice appelé σ_j permet de caractériser la présence d'interaction entre un paramètre *j* et d'autres paramètres, sans toutefois permettre de savoir avec lesquels :

$$\sigma_j = \sqrt{\frac{1}{N-1}\sum_{k}\left(\Delta^i_j\, G - \mu_j\right)^2} \tag{2}$$

Où μ_j est calculé de la même manière que μ^*_j mais en conservant le signe de la variation ΔG. Et *k* le nombre de paramètres étudiés.

Une représentation graphique des paramètres selon ces 2 indices permet alors de les ordonner 1) selon leur influence sur le modèle et 2) selon leur niveau d'interaction avec d'autres paramètres :

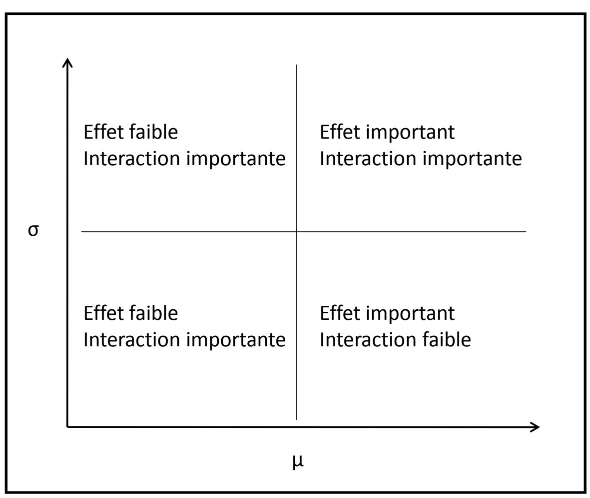


Schéma du type de résultat que permet d'obtenir la méthode de Morris.