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Influence of settings management and protection status on recreational uses and pressures in marine protected areas

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Abstract :

Coastal populations and tourism are growing worldwide. Consequently outdoor recreational activity is increasing and diversifying. While Marine Protected Areas (MPAs) are valuable for mitigating anthropogenic impacts, recreational uses are rarely monitored and studied, resulting in a lack of knowledge on users' practices, motivation and impacts. Based on boat counts and interview data collected in New Caledonia, we i) explored factors affecting user practices and motivations, ii) constructed fine-scale pressure indices covering activities and associated behaviors, and iii) assessed the relationships between user practices and site selection. User practices were found to depend on protection status, boat type and user characteristics. Pressure indices were higher within no-take MPAs, except for fishing. We found significant relationships between user practices and settings characteristics. In the context of increasing recreational uses, these results highlight options for managing such uses through settings management without jeopardizing the social acceptance of MPAs or the attainment of conservation goals.

Highlights

► Recreational users count and survey data were collected on same sites. ► Practices and site selection criteria depend on protection status and boat type. ► Marine Protected Areas concentrate most of recreational users' pressures. ► Site selection depends on settings conditions and intended practices. ► Site selection depends on managerial conditions and accessibility.

Keywords : Marine protected areas, Recreational users, Pressure assessment, Motivation, Recreational opportunity spectrum, New-Caledonia

1. Introduction

Marine protected areas (MPAs) are a key instrument for ecosystem-based management of coastal areas. Faced with increases in population (Duedall and Maul, 2005) and recreational activity (Sidman and Fick, 2005; Widmer and Underwood, 2004) in coastal areas, MPAs are valuable for mitigating anthropogenic impact (Gray et al. 2010) by regulating practices at given areas and for specific periods. Meta-analysis at a regional or global scale show that MPAs have positive effects on marine ecosystems, e.g. increased fish-related metrics such as species richness (Claudet et al., 2008; Côté et al., 2001; Halpern, 2003; Lester et al., 2009; Mosqueira et al., 2000; Stewart et al., 2009), density (Claudet et al., 2008; Côté et al., 2001; Maliao et al., 2009; Molloy et al., 2009; Mosqueira et al., 2000), biomass (Halpern, 2003; Lester et al., 2009; Stewart et al., 2009) and size of organisms (Halpern, 2003; Lester et al., 2009). In addition, positive effects of MPAs have also been observed for habitat (see Pelletier et al., 2005 for review). Consequently, thanks to the protection provided by MPAs from local stressors (e.g. overexploitation), the expected benefits of MPAs can include greater ecosystem resilience to global stressors such as climate change (Molloy et al., 2009; Francour, 1994; Hughes et al., 2003).

Most MPAs allow recreational uses, at least through boat access (Shivlani and Suman, 2000; Smallwood et al., 2012a) and even fishing (Toropova et al., 2010), with only 12.8% of MPAs being no-take areas (Wood et al., 2008). Because outdoor recreational activities are developing worldwide (Cole, 1996; Ceballos-Lascurain, 1996; Pickering and Hill, 2007), the question arises of the potential environmental impacts caused by recreational users (see reviews by Davenport and Davenport, 2006; Hardiman and Burgin, 2010; Whitfield and Becker, 2014). Numerous studies based on field data considered both the intensity and nature of the pressure, with regard to assessing impacts of recreational uses upon biotic habitat (Backhurst and Cole, 2000, Liu et al., 2012; Juhasz et al., 2010; Leujak and Ormond, 2008; Milazzo et al., 2002; Hasler and Ott, 2008; Zakai et al., 2002), fishes (Codarin et al., 2009) and mammals (Rako et al., 2013). Thus there is a strong need for managers to assess pressures from recreational users in terms of both quantitative and qualitative data, so as to encourage appropriate remediation and thus ensure the attainment of MPA goals.

Unfortunately, data and knowledge on recreational users is either scarce or lacking because the social aspects of MPAs have been studied less than their ecological aspects (Christie et al., 2003; Farr et al., 2014; Gruby et al., 2015; Le Corre et al., 2012; Sutton, 2005). The situation is somewhat different for fisheries, where the social effects of MPAs on commercial fishers have been studied more than the social effects on recreational users (see Mascia et al., 2010 for a review). In existing studies, the number of recreational users has been identified as the main measurement required for protected area management (Griffin et al., 2010). Such information is particularly useful when explicitly described over space and time (Eagles, 2002). Moreover, activities (e.g. fishing) have been taken into account to describe practices of recreational users and their distribution in space and time (Mangi et al., 2008; Smallwood et al., 2013). However, users' practices concern both the activity itself and how it is practiced. Behavior is precisely defined in this study as the way a given activity is undertaken. Such qualitative information is particularly useful when associated with user counts for assessing the impact of recreational user on environmental and social conditions (Le Corre et al., 2012). However, unlike fisheries-related studies, which consider fishing behaviors (fishing tactics, e.g. the targeted species and the fishing gear) in order to assess fishing pressure and distribution (Pelletier and Ferraris, 2000), recreational users' behaviors have not been taken into account for impact assessment. Such knowledge is also relevant for planning and managing recreational uses. For instance, quantifying and ranking sites according to the number of users visiting them, and being able to anticipate related behaviors, may help to identify potential management actions, either regulatory or related to amenities and education, aimed at controlling visitor flows and practices. In a multiple-use park, such quantification and ranking provides guidance for selecting appropriate management actions for different sites and zones.

To obtain such information, direct observation methods such as counting recreational users have been used to determine their spatio-temporal distribution (Valentine et al., 1997), either per boat category (Smallwood and Beckley, 2008; Smallwood et al., 2012b; Widmer and Underwood, 2004) or per activity (Liu et al., 2012; Smallwood and Beckley, 2008; Smallwood et al., 2011; Smallwood et al., 2012b). In addition, questionnaire-based surveys provide specific information on users' socio-economic characteristics, motivations, perceptions and practices (see Gray et al. 2011 for a review). In the light of a quantitative assessment of user pressures, it is necessary to combine results from boat and visitor counts with those from such questionnaire-based surveys.

MPAs are attractive for recreational activities (Gonson et al., 2016; Shivlani and Suman, 2000; Smallwood et al., 2012a), for various reasons, including environmental, social and geographic context-specific considerations. Such environmental, managerial and social conditions affect the quality of users' experience and thus their satisfaction (Clark and Stankey, 1979). Previous studies showed that recreational users in coastal areas were able to identify their preferred settings in accordance with managerial, social and natural conditions (Gray et al., 2010; Roman et al., 2007; Shafer and Inglis, 2000; Sorice et al., 2007). To better understand users' choices, questionnaire-based surveys can be implemented using the recreation opportunity spectrum (ROS) framework (Clark and Stankey, 1979). ROS is based on the hypothesis that recreational users' experience and motivation to visit a given site can be formalized in terms of a combination of environmental, managerial and social factors (Clark and Stankey, 1979). ROS has been applied to outdoor recreation in marine environment (Sorice et al., 2007; Uyarra et al., 2009; Roman et al., 2007) and in particular within marine parks (Gray et al., 2010; Shafer and Inglis, 2000). However, in these studies, there was no account taken of the effect of MPAs on settings preferences, nor was there any quantification of users with regard to preferential settings. In contexts where access to sites is not regulated, such an approach may help managers to identify the most effective management measures for each site, by channeling visitors and favoring specific practices.

In this study, we first investigated the effects of MPAs on recreational users' practices and motivations near the main urban center of New Caledonia, using a questionnaire-based survey. Then, by combining questionnaires and boat count data, we estimated pressures for a range of activities and behaviors, as well as user site selection criteria. In a third step, we examined the influence of protection status on these pressure estimates and investigated the relationship between motivation and practices. Finally, we identified recreational users' settings preferences for each site and discuss results from a management perspective.

2. Materials and methods

2.1. Study site

In the lagoon facing Noumea city, the main urban center of New Caledonia (180,000 population in 2014 (ISEE, 2014)), coral reef islets are popular destinations for recreational users (Gonson et al., 2016; Jollit, 2010). Over the last thirty years, the southern province of New Caledonia has established twenty-one MPAs for terrestrial and marine conservation purpose. Almost half of these MPAs are close to Noumea (Figure 1). They have two distinct protection statuses, the first being "Natural Reserve" (NR), where fishing and shellfish and wood collection are prohibited. On NR islets, fires are allowed only in barbecues installed by MPA managers, and forbidden elsewhere. The second type of MPA is the "Sustainable Management of Resources Area" (SMRA). Each SMRA has its own management plan and rules. Those rules also generally forbid extractive practices, but commercial activities for visitors are permitted. SMRAs aim to support economic development, usually entailing the presence of amenities and organized collective boat transportation. For example Maître (Figure 1), which lies off Noumea, has a kite-surfing school, a hotel and a restaurant and is serviced by three shuttle transport companies.

Our study focuses on 6 islets comprising three MPAs (two NRs and one SMRA) and three islets without any protection status (Figure 1). On Maître islet, which is the SMRA islet considered in this study, restrictions on fishing, wood collection and fires are similar to those of NR islets. The 6 islets differ with regard to their land surface area, distance from Noumea (which has the most marinas and launch ramps), the nature and extent of onsite amenities, and regulations. Around all of these islets speed activities (kite-surfing, wind-surfing and jet-skiing) are allowed. According to ROS (Clark and Stankey 1979), The SMRA (Maître) is a "modern islet", with easy access by continuous rotation of taxi-boats, a number of amenities and tight restriction on extractive activities and lighting fires. Both NR (Larégnère and Signal) may be classified as "semi-modern" settings. Compared to the SMRA, they have fewer amenities and are less accessible, being further from Noumea and with taxi-boat fares three or four times higher. The three non-protected islets (OR) don't have the same ROS status. Pandanus may be termed a "semi-primitive islet", as it is remote from Noumea, though close to the coast north of the city. There are no regulations and it has only one shelter. Finally, Mbe Kouen and Mbo can be classified as "primitive islets", in that they are remote from both Noumea and the coast and because there are no amenities or regulations. During the warm season only, landing on Mbe Kouen may be prohibited if birds are nesting. In practice, this access restriction does not apply every year. All these islets are also subject to species-specific fishing management rules (catch size, protection from indiscriminate fishing) that apply throughout the lagoon.

2.2. Data collection

Recreational boats were counted from March 2013 to February 2014 over 50 field trips with a design that was temporally stratified by day type (weekday or weekend) and quarter-yearly. Day trips lasted between thirty minutes and one hour and took place between 8 a.m. and 4 p.m. Departure times and weather conditions of trips were randomly defined within each stratum. For each islet, the total number of boats observed per boat type was recorded. Boat types included sailboat, motorboat, dinghy and jet-ski. In contrast to motorboats, dinghies are shorter than 5 meters in length and the pilot sits at the rear of the boat holding the helm of the motor. Dinghies were not counted when they were used solely to go between the main boat (motorboat or sailboat) and the islet. In addition, we recorded the number of visitors on the islet and boats around it during the questionnaire-based survey, by going around the islet before interviewing users for each site. Recording the number of users and boats took between five and thirty minutes depending on the size of the islet.

A questionnaire was designed for collecting information about users' activities and behavior and on-site selection criteria covering islet characteristics. Questionnaires were administered in face-to face interviews with recreational users during their trip on the islet. Recreational users generally comprise a party of several persons who spend their time on the islet together and arrive and leave on the same boat or taxi-boat. A party (termed group in the rest of the paper) was the observation unit, and a single questionnaire was administered for each group. Questionnaires covered four types of information with closed-ended questions. The first related to user experience in the area and annual frequency of visits. These answers were collected from only one user within each group (randomly chosen among users older than 16). The second category of questions dealt with trip characteristics: boat type, number of users and duration of the trip. The third category pertained to activity, and considered both participation and associated behaviors. Activities covered were fishing, speed activities, swimming activities and on-land activities (Figure 2). Behaviors are activity-specific and concern, on the one hand, the location of the activity: i) for fishing (around the islet or elsewhere); ii) for speed water sports (within mooring areas or elsewhere), and iii) on land (location of fires); and on the other, the way the activity is undertaken: i) for speed water sports (motorized or non-motorized), ii) swimming activities (swimming versus snorkeling) and iii) land-based activities (lighting fires and collecting wood on the islet). Motorized water sports are mainly jet-ski and non-motorized speed activity is mainly kite-surfing. If the user interviewed in the group displayed behavior associated with a higher level of pressure (Figure 2), we considered that the whole group was participating in that activity. The fourth type of question concerned the criteria for selecting the islet during the current trip. For this purpose, ROS characteristic settings were adapted to the specifics of the diverse conditions of Noumea's islets. Through a non-ranked multiple choice question, each group was asked to select criteria among three categories: manageable (i.e. managers may have some leverage with respect to this criterion), non-manageable and environmental quality.

Manageable selection criteria included quietness (seeking a quiet place), the existence of regulations (protection status - applying only on NR and SMRA islets), existing amenities (distinguishing between marine and terrestrial amenities), and the activity envisaged (distinguishing between fishing, speed water sports, and excursions, which itself covers swimming and on-land activities). Manageable selection criteria are viewed as a categorical variable for determining the potential leeway of management measures for each islet among those available. Quietness is considered to be manageable because limiting the number of visitors is a potential management measure.

Non-manageable selection criteria comprised weather conditions, random selection of the site and accessibility (geographical proximity to the coast/Noumea);

Environmental quality selection criteria covered the beauty of the marine environment, marine biodiversity and the beauty of the islet. Environmental quality is important because it is an expected outcome of protection (terrestrial or marine) and has been shown to be a major motivation for recreational users (Manning, 1999).

When it wasn't possible to interview every group on the islet, groups were sampled with a view to being representative of the size of user groups and their location on the islet. At Maître, customers of the hotel, who were spending the night there or simply having a meal in the restaurant, were not interviewed or counted, because the study focused on uses associated with the lagoon environment. However, these users were possibly interviewed and counted when located outside the hotel/restaurant area. At each site and for each boat type, the sample rate was estimated as the ratio of the number of interviews conducted to the number of visitors counted. When a boat type was not observed at a given islet, the sampling rate could not be calculated for that boat type (Table 1).

A total of 463 questionnaires were completed between November 2014 and March 2015 during 5 field trips at weekends and 3 field trips on weekdays. Field trips involved one or 2 consecutive days of the same type (weekday or weekend), when it was not possible to sample the six islets in a single day. Interviews took place between 9 a.m. and 5 p.m. Data collection was undertaken only during the warm season, on the assumption of low variability of practices (type of activity and behavior) between seasons (personal observation and unpublished data).

2.3. Statistical analysis

As mentioned in the introduction, assessing users' recreational pressures and motivations involves identifying factors that account for their activity and behaviors. Among these factors, user-related (e.g. experiences, visit frequency) and trip-related factors (e.g. boat type, length of stay) were shown to have significant effects on settings preferences and the decision to participate in particular activity (Asikkutlu and Muderrisoglu, 2011; Cole, 2001; Cole et al., 2009; Eagles et al., 2002; Farr et al., 2014).

Logistic binomial models were used to model i) group participation in a given activity and associated behaviors; and ii) islet choice according to a selection criterion. For each activity considered, behaviors were modeled only for the subset of groups participating in that activity. Dependent variables (activity/behavior and selection criteria) were modeled as a function of three categories of independent factors: protection status, trips and user characteristics. Protection statuses were SMRA, NR and outside reserve (OR). Trip characteristics were boat type, the size of the group (number of persons), and duration of the trip. User characteristics were the number of years they have been visiting islets in the area, and the number of trips usually made each year. These characteristics correspond to the user interviewed. For site selection, the dependent variable of each model was the binary variable equal to 1 when the criterion was mentioned as influencing the selection of the site visited during the present trip (see subsection 2.2 for a description of activities and selection criteria).

For each binary variable considered, model selection was based on the likelihood ratio test (Venables and Ripley, 2003), including only factors significant at a 10% confidence level. This confidence level was chosen to accommodate the large variability of responses to questionnaires. Each model was validated through a goodness-of-fit test (Faraway, 2006). For all selected models the deviance explained by each factor was computed, in order to rank their respective influence on the response variable. For factors with more than two levels, multiple comparisons based on Tukey's Honest Significant Difference method (Tukey, 1977) were used to test significant differences between factor categories.

2.4. Estimating pressure index and the number of groups per selection criterion by combining boat counts and survey data

Once on the islet, recreational users may impact local environmental and/or social conditions, depending on their activities and behaviors. Activity was defined here as the purpose of the trip, while behaviors define the way the activity was undertaken in accordance with the group's specific practices. Activities and behaviors considered may be ranked according to the expected pressure gradient which relates to environmental and/or social views. These were selected on the basis of being the most common practices of visitors observed on islets.

Eleven pressure indices were computed corresponding to the annual number of groups participating in a given activity and behavior as presented in Figure 2. Accordingly, the number of users on each site was computed at the year scale, for each activity, behavior and selection criterion. To obtain this figure, the number of boats per islet and boat type was first calculated at year scale based on the sampling scheme (Appendix, eqs. (1) and (2)). Associated variance was also computed to report between-day variability due to weather conditions and to within-day variation in user distribution. The number of users was derived from the number of boats previously calculated by multiplying it by the mean number of users per boat type and islet (eq. (3)). To determine these numbers according to activities and behaviors, we multiplied them by the mean proportion of groups (at each site and for each boat type) that displayed a given activity or behavior (eq. (4)). These estimates were used to determine the total number of groups over a year in terms of: i) boats (eq. (2)); and ii) users landed on each islet (eq. (5)). In addition, for each of these pressure metrics, the associated variance was computed by considering between-day and within-day variability of the proportion of the group engaging in the given practice (eqs. (1) to (5)).

To determine the number of visitors who came by taxi-boat, for each islet we multiplied the mean proportion of groups who came by taxi-boat by the number of visitors who landed on islet (eq. (5)), based on the assumption that the proportion of groups and visitors who came by taxi-boat is similar for each islet. Moreover, the number of users who came by taxi-boat on Maître islet is available from the official report of the South province of New Caledonia (unpublished data). This number was divided by the mean number of customers per taxi-boat group, obtained from questionnaires at Maître islet.

2.5. Relationship between practices and selection criteria

Users' preferences for settings have been shown to differ depending on user groups (Gray et al., 2010). These authors highlight differences between boat types, but underline the diversity of perceptions between users (e.g. perception of crowding, perception of environmental quality). In the present study, we address differences in different groups' settings preferences on the basis of activity participation and behaviors. Such relationships allow us to directly link users' site selection criteria with their practices and thus with the associated pressures.

The relationships between behaviors associated with fishing, speed, on-land and swimming activities were explored through Multiple Correspondence Analysis (MCA). Activities and behaviors were active variables of the MCA, while selection criteria, islets and boat types were illustrative, i.e. they were only projected on the factorial plans to display their relationships with the active variables. For each activity (fishing, speed activity, swimming and on-land activity), each group was assigned a single behavior (see Figure 2). For on-land behaviors, users lighting a fire in a new place and who brought wood were not observed during the survey, and were thus not taken into account in the MCA.

Associations of categories between variables were interpreted by means of the direction and significance of correlation between variable categories and factorial axes, as evaluated from test-values (Lebart et al. 1984).

2.6. Characterization of settings preference

We analyzed the associations of selection criteria so as to characterize visitor expectations in terms of settings at any given visited site and by taking into account the three categories defined above (i.e. Manageable, Non-manageable, and Environmental). Three categories of recreational conditions were considered to i) identify for each islet the potential effect of settings management on visitors' islet selection and ii) assess the number of groups per islet selection criterion. We computed the mean proportion of response of each selection criterion, per islet, boat type and trip. With eight field trips and four boat types, thirty-two combinations of selection criteria were obtained for each islet. For each boat type at each islet, any combination was randomly resampled with replacement, with a sample size being the corresponding number of groups for this boat type and islet. This non-parametric bootstrap procedure provided the probability density of combinations, which were subsequently plotted in a ternary barycentric coordinate system for each islet (produced with the ggtern R package (http://www.ggtern.com/home). In the ternary barycentric coordinate system the position of a point is specified as the center of mass (barycenter) of the proportion of the three categories positioned at the vertices of an equilateral triangle. Each vertex of the triangle refers to a distinct selection criteria category (manageable, environmental quality and non-manageable). Hence, in a ternary plot, the proportions of the three categories for a given point sum to one. At each islet, the density patterns were then analyzed and were assumed to be representative of the outdoor recreational conditions expected by islet visitors.

3. Results

3.1. Description of recreational uses around coral reef islets offshore of an urban center

The MPA islets closest to Noumea were the most visited (Figure 3), particularly Maître with almost 25,000 groups of visitors over the year. When accounting for the surface of the mooring area, Signal exhibited the largest boat density, with 350 boats/ha during the year, versus 261 at Larégnère and 170 at Maître. At non-MPA islets, boat density ranged between 55 and 26 boats/ha over the year. Boat densities significantly differed between MPAs and OR islets, and not among sites within a given protection status. Conversely, the annual density of visitors on land significantly differed between islets. The visitor pressure index was highest at Maître (10,618 visitors per inland hectare over the year) and Larégnère (16,761 visitors per inland hectare over the year). Although not an MPA, Mbe Kouen had a higher visitor pressure index (4,530 visitors per inland hectare over the year) than the MPA Signal (2,673 visitors per inland hectare over the year). The reason for this was that the inland surface of Signal is more than three times larger than that of Mbe Kouen. With similar inland surface areas, Mbe Kouen and Larégnère showed major differences in pressure index, with Larégnère supporting an annual density of visitors almost four times as large as that of Mbe Kouen.

The proportion of groups per boat type significantly differed between islets (Chi-square test, $p < 0.0001$). The main boat types were the taxi-boat at Maître (67%), sailboat at Mbe Kouen (48%) and motorboats at Signal (59%), Larégnère (40%), Pandanus (60%) and Mbo (61%). The size of the groups interviewed ranged between four and five persons with a minimum of one and a maximum of thirty-four. Logically, mean group size significantly differed between boat types (Kruskal-Wallis test $p < 0.001$), with on average more than five users for motor boats, between four and five users for sailboats, dinghies and taxi-boats, and fewer than three for jet-skis. Trip duration significantly differed between protection statuses. At non-MPA islets, the majority of groups stayed at least one night, while this was not the case for MPAs (Kruskal-Wallis test, $p < 0.001$). Of the users interviewed, 26% made fewer than eleven trips to any islet in a given year, 28% between eleven and twenty trips a year, and 46% more than twenty trips a year.

3.2. Practices and islet selection depends on protection status and trip characteristics

All models of activity and behaviors were validated, and significantly explained the data (Table 2). User activities and behaviors significantly differed as a function of protection status, except for disembarkment on the islet and motorized speed activity. Unsurprisingly, the proportion of groups fishing during the trip was larger at OR islets either when fishing took place around the islet (38% at OR islets versus 0% on MPA islets) and when fishing took place in other lagoon areas (45% at OR islets versus 9% at MPA islets). Speed activity was the favorite activity at Maître (SMRA) with 6,884 groups per year. Swimming was practiced more at NR islets (97%) than at Maître (81%) (SMRA). Similarly, a larger proportion of visitors lit fires on NR islets (35%) and OR islets (55%) than on the SMRA islet (6%), even though barbecues were observed on the latter. Conversely, snorkeling activity among swimmers did not differ markedly between protection statuses ($p < 0.1$). Overall, among the significant explanatory factors, between-islet differences were mostly explained by protection status, except for snorkeling, speed activity, and lighting fires.

Trip characteristics also significantly explained activities and behaviors, especially boat type (Table 2). Groups in dinghies fished more often during their trips (45%) than motorboat groups (17%) or visitors who came by taxi-boat (2%). Jet-ski groups, unsurprisingly, mostly engaged in speed activity (79%). Visitors in motorboats landed more often on islets (86%) than sailboat visitors (73%) ($p < 0.001$). Among disembarking visitors, those who came by motorboat, dinghy or taxi-boat more often lit fires on islets than sailboat visitors (14% for sailboats versus 32% for motorboats, 48% for dinghies and 33% for taxi-boats). Finally, visitors who came by taxi-boats practiced more snorkeling when swimming (89%) than visitors in motorboats (78%) or dinghies (67%). Aside from activity and behavior, bigger groups more often disembarked, lit fires and swam. In addition, overnight visitors were more likely to fish, practice a speed activity, land on islets, light a fire, swim and snorkel.

Participation in activity and behaviors was partly determined by user characteristics, as relatively recent users of the Noumea lagoon (1 to 5 years) were more likely to light a fire (43%) than those with longer experience (22%) ($p < 0.001$). Moreover, users making fewer trips per year swam more often than the rest (96% for users having fewer than 20 trips per year versus 86% for others) ($p < 0.01$).

Accessibility was the most frequently mentioned criterion for choosing a site (46% in total). This criterion was proportionally more cited by users at the SMRA islet (54%) than at NR islets (43%) and OR islets (38%). For all other criteria, the proportion significantly depended on whether or not the site was an MPA, with the exception of i) criteria only relevant for MPAs and ii) the fishing criterion, which was only relevant outside MPAs (Table 3). The effect of boat type was always significant, while other trips and user characteristics had a significant effect on fewer criteria. Hence, boat type was found to be largely linked to selection criteria.

The SMRA islet was significantly more visited for engaging in speed and excursion activities. At NR islets, random site selection was relatively more mentioned by visitors than for the SMRA islet. At NR islets, users more often mentioned environmental assets (marine biodiversity, submarine landscape and islet beauty) as determining their selection of islet, while protection status per se was not. Quietness was significantly more mentioned at OR islets and it was more important for users at NR islets than at the SMRA islet.

Site selection also strongly depends on boat type. Taxi-boat visitors more often select islets at random and significantly less for protection status and excursion activity criteria than motorboat and sailboat users. Sailboat users more often mentioned marine amenities (permanent mooring) as determining their choice than motorboat and dinghy users, while the reverse was the case for terrestrial amenities. Unsurprisingly, weather conditions were less mentioned by taxi-boat users, who were less concerned by navigation conditions than other users.

The choice of an islet was not related to group size, while visitors spending at least one night at sea were more influenced by the existence of terrestrial amenities. In addition, excursion practice was determining in selecting a destination. Daytrips more often corresponded to random site selection.

In general, protection status and trip characteristics were found to have a greater effect on islet selection than user characteristics. For experienced users (> 20 years in Noumea's lagoon) islet selection was less motivated by the practice of speed activities. This result was explained by the fact that speed activity was mainly practiced by significantly younger users (Kruskal-Wallis test $p < 0.001$), who were also significantly less experienced (Kruskal-Wallis test $p < 0.01$).

3.3. Estimation of pressure indices and number of groups per selection criterion

Pressure indices pertaining to landing, speed, and swimming activities appeared to be highest on MPA islets, which thus suffered from the highest level of pressure from these activities and behaviors (Figure 4) ($p < 0.05$). Unsurprisingly, fishing activity pressure around islets was only found at OR islets, with a maximum at Pandanus. This finding held true whether users fished around the islet or further away from it. However, a large number of groups at NR and SMRA islets had fished earlier or were planning to fish during their trip. These groups were more numerous at the NR islets than at the Mbe Kouen or Mbo OR islets, although these differences were not significant.

With the highest number of groups, the SMRA islet also hosted the highest numbers of groups with swimmers, snorkelers, and practitioners of speed activity (Figure 4).

Although fire practices are regulated on MPAs islets, pressure indices with regard to new fire places and wood collected on the islet were respectively highest at Larégnère (NR) and Maître (SMRA) (Figure 4).

Accessibility was the main criterion mentioned (56% of visitors) for selecting a particular islet (Figure 5). Management conditions or environmental quality mattered less for the users interviewed. This finding supports the hypothesis that the spatial distribution of recreational users among islets was mostly explained by distance from the place of departure. The second most important criterion concerned weather conditions (25%). Random selection was mentioned by 21% of visitors.

Expected environmental quality was determining for almost a quarter of visitors. 17% and 19% of visitors chose the islet for speed and excursion activities respectively, which are permitted at all the islets. Fewer people chose the islet for its protection status (8%), amenities (between 11% and 14%), or being able to practice an activity prohibited in MPAs (1%). Practice of an activity determined site selection for 17% and 19% of the visitors for speed and excursion activities respectively.

Thus there was a major specificity of islet effect not related to management in visitors' choice. Quietness applied to only 14% of visitors at these 6 islets. However, this proportion increases to 49% at Mbe Kouen and 59% at Mbo.

3.4. Relationship between behaviors and site selection

The first two axes of the MCA explained 19% and 13% respectively of the data variance, thus highlighting the large variability of behavior between groups (Figure 6). The first axis discriminated swimming from speed activity, while the second mainly distinguished fishing from land behaviors and jet-ski.

Regarding fishing, there was an unsurprisingly high positive correlation between fishing activity and selection of islet for fishing purpose. In addition, fishing was mostly associated with dinghies and OR islets. Less intuitively, marine environmental quality selection criterion was negatively correlated with fishing. The proportion of fishers' groups either landing, or when landing, collecting wood and choosing a new fire place was lower than for other activities.

Kite-surfers and groups undertaking speed activity in mooring areas most often did not swim, as the main purpose of their trip was to engage in speed activity. They were mostly encountered at Maître and Signal, where they came on a jet-ski or by taxi-boat. These users chose the islet visited less for islet beauty, quietness and weather conditions.

Snorkelers did not practice speed activities. They often lit a fire at an existing fire place, with or without wood collection. Selection criteria for these groups generally involved environmental quality, terrestrial amenities and quietness. They were mostly found at Signal, Pandanus and Mbo.

Groups interviewed at Larégnère and Mbe Kouen, as well as groups on sailboats, were not associated with any particular activity or behavior.

3.5. Settings preferences

Ternary diagrams display the diversity of selection criteria combinations among the islets (Figure 6) in close relation to the conditions expected by visitors at each islet. These patterns were found to be consistent on weekdays and at weekends.

Results were summarized in accordance with three main patterns. The first concerns Signal and Larégnère, for which environmental quality was more mentioned than at the other islets, with 44% mentions for Larégnère and 48% for Signal. Note, however, that other criteria were equally mentioned for these two islets. The second pattern was observed at Mbo and Mbe Kouen, where manageable selection criteria were the most mentioned, with respectively 83% and 92%. Quietness was important for groups visiting these islets. The third pattern concerned Maître and Pandanus, for which accessibility was determining, with respectively 85% and 72% of mentions. These islets are the closest to the mainland. For them, other selection criteria differed between Maître and Pandanus, which were respectively mostly chosen for speed and fishing activity.

4. Discussion

4.1. Pressure indices are higher in MPAs

In this paper, we computed pressure indices as the product of the number of visitors and the proportion of users displaying specific impacting behaviors, such as fishing, snorkeling, scuba-diving, wood collection or setting new fire places. Our results showed higher pressure indices inside MPAs. This finding is explained by the much higher number of visitors within MPAs than ORs, consistently with previous studies on the spatial distribution of recreational uses in the same area (Gonson et al., 2016), in the Florida Keys National Marine Sanctuary, United States (Shivlani and Suman, 2000), and in the Ningaloo Reef Marine Park, Australia (Smallwood et al. 2012b). The fact that impacting behaviors were less frequent in MPAs than ORs did not compensate for the large number of visitors in the resulting pressure indices.

In this study undertaken in New Caledonia, two different kinds of MPA were considered: i) Sustainable Management of Resources Area (SMRA) protection status, which aims at promoting economic activity as well as environmental conservation; and ii) Natural Reserve (NR) status, for which environmental conservation (both marine and terrestrial) is the main objective. The SMRA islet was characterized by a high proportion of users practicing speed activity (especially kite-surf and jet-ski). This is currently a concern for managers as these activities might cause i) disturbances for other users (Widmer and Underwood, 2004; McAuliffe et al., 2014) or ii) impacts on species and habitats (see Davenport and Davenport, 2006; Whitfield and Becker, 2014 for a review). Because there was only one SMRA site in this study (Maître), it was unfortunately not possible to disentangle the effect of SMRA protection status from a strictly site-specific effect. Such difficulty had been highlighted by Willis et al. (2003) for the effect of MPAs on the environment. The sustainability of economic activities in SMRAs calls for a minimum number of visitors. In many cases, these activities depend on the existence of amenities, which increase the site's attractiveness (Monz et al., 2010), but also its environmental impact. As a consequence, user experience may be affected for activities that require environmental quality, e.g. boating, snorkeling and scuba-diving.

In contrast to SMRAs, our results showed that activities directly depending on environmental quality such as snorkeling were more practiced at NR islets. This finding confirms that users of NRs preferred nature-oriented activities (snorkeling, swimming, lighting a fire) and is consistent with other studies showing that the main satisfaction factor for snorkelers in coral reefs is the perceived abundance of coral and fish (Inglis et al., 1999; Shafer and Inglis, 2000; Shelby and Heberlein, 1984). The NR islets studied were established in the 1980s, and fish assemblages have since been replenished (Wantiez et al., 1997, 2004). As a consequence of environmental quality and facilities and the possibility of camping, NR islets have a larger number of visitors than OR areas, resulting in high pressure levels on both the marine (swimming, snorkeling) and terrestrial natural environment (campfire and trampling) even if behaviors observed at NR sites are less detrimental than at OR islets (e.g. relatively less wood collection and fewer new fire places).

Outside MPAs (OR), fishers were unsurprisingly more numerous, and fishing activity was not observed in any of the three MPAs considered, which are long established and well complied with. In addition, groups mentioning fishing activity during the trip were observed more at OR islets than at MPA islets. For activities other than fishing, pressure indices were lower at OR sites, due to of the fewer visitors, although their behaviors were more impacting on land, notably through wood collection and setting new fire places.

4.2. Site selection depends on protection status and practices

Results first show that site selection depends on protection status. The SMRA site was selected for speed activity and excursions, while NR islets were chosen more for environmental quality. OR islets were obviously selected for fishing, but also for their quietness. In addition, site selection differed depending on boat type especially regarding amenities and weather conditions.

Our results provide information on the attractiveness of amenities in relation to boat type, thus providing a valuable insight for managers.

Second, we observed that site selection depends on the intended activities, in particular for speed and fishing. Specific practices were explained by the fact that a site is favorable for an activity. For instance, for spending the day there, fishers chose sites where fishing was allowed, or sites close to fishing areas. Within the study area, the MPA network is designed in such a way that the barrier reef facing OR islets is also OR, whereas it is an NR facing MPA islets. Similarly, jet-skiers and kite-surfers selected the islet on the basis of their favorable settings like the presence of a large area of shallow water and a kite-surf school and a jet-ski rental company. In other areas, the practice of jet-ski was not related to any specific setting, as the jet-ski was mostly used to travel to the islet. The link between site selection and specific practices is consistent with the results of previous studies in a terrestrial context. Hence, Tarrant et al. (1999) presented users' motivations for participating in a specific activity or behavior so as to enhance the quality of their experience. Clark and Stankey (1979) studied the effect of setting conditions on visitors' experience in relation with the practice they want to engage in through the ROS framework.

In this study, the ROS setting classes were helpful for categorizing users' motivation patterns based on environmental, manageable and non-manageable selection criterion categories. Accessibility, which was considered as non-manageable, emerged as the main criterion. The degree of accessibility must be taken into account by managers in regulating the spatial distribution of users in the coastal area, including through the location of new marinas.

As regards manageable criteria, islet amenities and quietness were mentioned in particular for site selection, e.g. swimmers, especially said that they choose their destination for its quietness. Yet quietness does not appear to be exclusive to a particular site or setting. This may be because perception of quietness might be variable among individuals (Gray et al. 2010). A large proportion of users seeking quietness were observed in sites more remote from the coast, and thus having lower visitor densities. Some users said that they chose remote sites following previous experiences in more accessible but crowded areas. So-called coping strategies (Kuentzel and Heberlein, 1992) were also observed in outdoor recreation studies (Arnberger and Brandenburg, 2007; Kuentzel and Heberlein, 1992; Manning, 1999; Manning and Valliere, 2001; Shelby and Heberlein, 1984). In addition, we observed that users mentioning land amenities as a selection criterion were also more often associated with less impacting behaviors (e.g. lighting fires in installed fire places without collecting wood). However, such amenities might be viewed as decreasing the wildness of the area visited and thus affecting the quality of users' experience (Driver and Brown, 1978).

Environmental quality was the primary and most influential satisfaction factor for snorkelers. Similar outcomes were obtained by Shelby et al. (1984), Inglis et al. (1999) and Shafer and Inglis (2000). A previous study conducted in French MPAs, including in the same area, showed that MPAs were perceived by visitors as providing a better environment (Pelletier et al. 2011). Similar results were also found in the Mediterranean for recreational scuba divers, since such nature-oriented activity directly depends on environmental quality (Roncin et al 2008). In parallel, MPAs are an opportunity for managers to promote environmental education, as for instance, at another MPA islet near Noumea, where an underwater trail has been established.

In our study area, human populations and boating infrastructure (launch ramps, marinas) are concentrated in Noumea. The way the ROS approach was adapted in this study revealed the link between site selection and user practices. This approach could be utilized to anticipate changes in the distribution of recreational user pressures and to provide guidance for the development of shore-based nautical infrastructure. This is particularly important in a context where demographic change is heterogeneously distributed, with neighboring cities (Dumbea, Païta and Mont-Dore) undergoing a greater population increase than Noumea city itself.

4.3. Production of specific pressure indices

In this paper, pressure indices linked to recreational uses were computed by explicitly integrating counts and interview data, which to our knowledge was not found in the literature. These indices were defined by activity and behavior, and as such provide specific indices that can be more easily related to impacts. The need to explore new response variables for studying the use-impact relationship was highlighted by Monz et al. (2010). Note that pressure indices alone do not allow the associated impacts to be assessed, and additional data are needed for this purpose, since the relationship between pressures and environmental impacts also depends on the sensitivity of species and habitats (Cole and Monz, 2004). In addition, within area where multiple use (e.g. fishing, speed activity) are undertaken, conflict among user is likely to occur (Cicin-Sain and. Knecht, 1998; Vallega, 1999; Douvere et al. 2007). We intend to use our pressure indices in forthcoming work involving ecological data on habitat and marine species collected in the same area and at comparable temporal and spatial scales as well as consider conflict among users issues through the assessment of social carrying capacity of recreational settings include in this study. Such work could be undertake by using a geographical information system like it was used by Douvere et al. (2007) in the context of marine spatial planning in Belgium.

To our knowledge, this is also the first study providing pressure indices with associated uncertainty estimates. The precision of pressure indices was estimated by considering sources of sampling variability associated with both counts and interviews. Seasonal variability was included in the estimation of pressure indices through count estimates. Due to sampling costs, boat counts and interview data were collected at different dates (at one year interval, but during the same season). Our results are thus based on the reasonable assumption that user responses could be combined with boat counts collected over the previous year. The obtained confidence intervals were relatively low, especially for the most common practices (e.g. disembarkment, swimming, snorkeling), thereby providing managers with reliable activity-specific information. The precision of estimates also enabled to detect significant differences in pressure indices between protection statuses and between recreational settings.

To summarize, our results highlight the importance and interest of considering both quantitative and qualitative information on recreational uses for assessing related pressures.

4.4. Implications for management

Our results are based on data collection that could be repeated over time within a monitoring perspective. This study is based on survey data collected from a low proportion of users given the number of users visiting islets considered annually. However, this study might be useful for managers in several ways.

First, the approach provides an estimation of pressure indices regarding particular practices and behaviors for a set of recreational activities. Pressure indices defined in this way are needed to evaluate impacts through comparison with ecological data. Furthermore, such information is of primary importance for carrying capacity assessment, since it takes into account both the number of users and their practices. Indeed, user counts were used to assess carrying capacity in previous studies, either for social carrying capacity (Leujak and Ormond, 2007), environmental carrying capacity (Simeone et al. 2012) or both (Salerno et al., 2013). However none of these studies consider activity or behaviors, whereas these may affect the carrying capacity assessment. In fact, this lack of knowledge was highlighted by Simeone et al. (2012) for the environmental carrying capacity of beaches.

Second, we have been able to identify relationships between settings characteristics, user selection criteria and user practices. Consequently, these relationships allow to anticipating pressures based on setting characteristics. Existing studies applying ROS in an MPA context have focused on the relationship between setting characteristics and visitor experience quality (Gray et al., 2010; Shafer and Inglis, 2000). And, by controlling settings, managers influence visitors' quality of experience (Cole and Hall, 2009) and thus users finding specific practices satisfying (Driver and Brown, 1978). Although users' quality of experience was not explicitly addressed here, our results provide insights for managers for managing settings in order to promote or restrict specific practices.

Third, our results provide new insights for managing recreational users. Faced with a clear increase in the number of visitors, especially within MPAs, as is the case in our study area (Gonson et al., 2016), limiting access is an option for managers. However, any access restriction might result in conflicts among users and thereby potentially jeopardize management effectiveness by reducing the acceptance of MPAs (Force and Gubbay, 2009). Access restriction is thus sometimes viewed as a radical solution (Alden, 1997). Here, we showed that accessibility was the main reason for selecting a given site, irrespective of its protection status. For highly accessible sites, protection measures such as a fishing ban and installed fire places mitigate visitors' potential environmental impacts. Yet site selection often depends on several criteria. Hence managers have to consider the characteristics of site specific settings when applying management measures in recreational settings.

The main objectives of NR islets concern conservation. At these islets, positive effects of protection on fish communities and habitats have been demonstrated (Wantiez et al., 1997, 2004). Furthermore, the importance of environmental quality selection criteria for users within these sites might be seen as an indirect sign of protection performance. Such an effect can explain the high proportion of users engaging in nature-oriented activities (e.g. snorkeling) and the wilderness experience (e.g. lighting a fire), which directly depend on environmental quality. Thus, at these sites, the expected outcomes of protection are an important satisfaction factor for recreational users, highlighting the attractiveness of MPAs' environmental quality. Consequently, banning additional activities that impact the environment (e.g. jet-ski) or annoy users looking for the wilderness experience (e.g. speed activities on the leeward side of the islet) is an option for managers.

The most remote sites were shown to be more visited for quietness, given the high recreational activity in more accessible areas. At these islets, we found fewer visitors and boats, thus resulting in lower pressure indices. Unfortunately, the relationship between environmental impact and amount of use is not linear. Indeed, when the pressure level is low, a small increase may cause a significant increase in impact, while this may not be the case when the degree of pressure is already high (Cole, 2004). In New Caledonia, areas hosting bird populations are particularly sensitive to disturbances during the nesting period, and even a small number of visitors can cause considerable damage. Thus regulations (e.g. protection status, access limitation) should be considered for those remote sites, as has been done at Mbe Kouen, where landing on islet is prohibited when marine birds are nesting.

Conclusion

Faced with the increase of population and tourism in coastal areas, MPAs are subject to high levels of pressure associated with recreational activities. Concentration of pressure within no-take areas is explained by the attractiveness of specific activities, either associated with the development of commercial infrastructure or due to the environmental quality afforded by protection. Pressure indices not only depend on user numbers and distribution but also on their practices. Appropriate management of site settings can be helpful for influencing the distribution of pressures without resorting to access restriction.

In order to affect users' distribution without restricting access and thus jeopardizing the acceptance and success of MPAs, settings management can foster less-impacting behaviors. However, the effect of changes in settings management should be investigated by monitoring users' practices and perceptions. Such information over time could allow better adaptive management of recreational users and thus achieve a balance between recreational uses and environmental protection.

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Table 1: Number of questionnaires administrated per boat type and islet and mean sampling rate (shown in parentheses) per boat type and islet over the 8 field trips.

Islet	Motorboat (Number / Percent)	Dinghy (Number / Percent)	Sailboat (Number / Percent)	Jet-ski (Number / Percent)	Taxi-boat (Number / Percent)
Maître	43 / 53	7 / 30	32 / 45	6 / 30	64 / 50
Larégnère	51 / 61	5 / 34	28 / 39	6 / 35	20 / 65
Signal	71 / 74	6 / 42	23 / 72	2 / 38	26 / 72
Pandanus	23 / 42	8 / 7	5 / 67	0 / -	1 / 84
Mbo	11 / 61	5 / 75	3 / 39	0 / -	1 / 82
Mbe Kouen	4 / 33	0 / -	8 / 32	0 / -	0 / -

Table n°2: Outcomes of the models of user's practices (***: 0.1% significance level, **: 1% significance level, *: 5% significance level, .: 10% significance level, Ns: non-significant). Multiple comparisons provided the direction of effect between significantly different categories (termed "Direction of effect" below). R^2 statistics were computed as the ratio of the deviance explained by the model and the deviance to that of the null model. n was the sample size for each response. For each significant factor, partial R^2 is shown in parentheses.

Response variables	n	R^2		Explanatory factors					
					Trip characteristics			Users characteristics	
				Protection status	Boat type	Number of users within the group	Number of nights	Number of trip per year	Experience
Fishing activity	458	24	p-value (partial R^2)	***(6)	***(5)	Ns	*(2)	. (1)	Ns
			Direction of effects	OR>SMRA*** OR >NR***	Dinghy>Motorboat . Dinghy>Taxi-boat** Dinghy>Sailboat . Motorboat>Taxi-boat .		1+ > 0*	"11-20" > "<11"	
Fishing activity around the islet (among fishers visitors)	69	34	p-value (partial R^2)	***(34)	Ns	Ns	Ns	Ns	Ns
			Direction of effects						
Speed activity	463	17	p-value (partial R^2)	***(6)	***(9)	Ns	. (1)	Ns	. (1)
			Direction of effects	SMRA>NR ***	Jet-ski>Motorboat *** Jet-ski>Dinghy *** Jet-ski>Sailboat *** Jet-ski>Taxi-boat ***		1+ > 0 .		
Motorized speed activity (among visitors having speed activity)	67	79	p-value (partial R^2)	Ns	***(79)	Ns	Ns	Ns	Ns
			Direction of effects						
Speed activity in mooring area (among visitors having speed activity)	67	61	p-value (partial R^2)	**(13)	*(14)	Ns	***(19)	*(10)	Ns
			Direction of effects	SMRA>NR* NR>OR .			0 > 1+ *		
Swimming activity	463	26	p-value (partial R^2)	***(5)	Ns	*(4)	***(5)	***(7)	Ns
			Direction of effects	NR>SMRA**		7+ > 1-2 .	1+ > 0 **	"<11" > ">20" ** "11-20" >">20"*	
Snorkeler activity (among swimmers)	425	5	p-value (partial R^2)	. (1)	*(3)	Ns	. (1)	Ns	Ns
			Direction of effects	NR > SMRA *	Taxi-boat>Motorboat . Taxi-boat>dinghy*		1+ > 0.		
Landing on islet (except Taxi-boat)	348	22	p-value (partial R^2)	Ns	***(7)	***(11)	***(5)	Ns	**(4)
			Direction of effects		Motorboat>Sailboat ** Dinghy>Sailboat .	4-6 > 1-2*** 4-6 > 3-4 . 7+ > 1-2*** 7+ > 3-4**	1+ > 0***		1-5 > 5+ .
Fire (among users who land on islet)	404	46	p-value (partial R^2)	**(6)	***(12)	*(1)	***(14)		***(4)
			Direction of effects	NR >SMRA * OR>SMRA*	Motorboat>Sailboat*** Dinghy>Sailboat*** Taxi-boat>Sailboat***	7+ > 1-2 *	1+ > 0***		1-5 > 5+***
Fire on a new spot (among users who make a fire)	118	10	p-value (partial R^2)	**(10)	Ns	Ns	. (4)	Ns	Ns
			Direction of effects	OR>NR *			0 > 1+ .		
Wood collection on islet (among users who make a fire)	118	10	p-value (partial R^2)	**(10)	Ns	Ns	Ns	Ns	Ns
			Direction of effects	OR>NR ** NR > SMRA *	Taxi-boat>Motorboat . Taxi-boat>dinghy*		1+ > 0.		

Table n°3: Outcomes of the models of the site selection criteria (***: 0.1% significance level, **: 1% significance level, *: 5% significance level, .: 10% significance level, Ns: non-significant). Multiple comparisons provided the direction of effect between significantly different categories (termed "Direction of effect" below). R^2 statistics were computed as the ratio of the deviance explained by the model and the deviance to that of the null model. n was the sample size for each response. For each significant factor, partial R^2 is shown in parentheses.

	Selection criteria	n	R^2		Explanatory factors					
						Trip characteristics			Users characteristics	
					Protection status	Boat type	Numb of users within the group	Number of nights	Number of trip per year	Experience
Manageable	**Quietness / solitude**	463	11	p-value (R^2) Direction of effects	***(8) NR >SMRA * OR >SMRA*** OR > NR ***	*(2) Motorboat > Sailboat . Taxi-boat > Sailboat .	Ns	Ns	. (1)	Ns
	Protection status (among users interviewed on MPA's islet)	392	10	p-value (R^2) Direction of effects	Ns	***(10) Motorboat > Taxi-boat* Sailboat > Taxi-boat**	Ns	Ns	Ns	Ns
	Marine amenities (among users interviewed on MPA's islet)	392	21	p-value (R^2) Direction of effects	Ns	***(21) Sailboat > Motorboat* Sailboat > Dinghy .	Ns	Ns	Ns	Ns
	Terrestrial amenities (among users interviewed on MPA's islet)	392	4	p-value (R^2) Direction of effects	Ns	*(3) Motorboat > Sailboat* Dinghy > Sailboat*	Ns	**(3) 1+ > 0 **	Ns	Ns
	Speed activity	463	15	p-value (R^2) Direction of effects	***(8) SMRA>NR***	. (3)	Ns	Ns	Ns	*(4) "1-5" > ">20"
	Fishing activity	71	22	p-value (R^2) Direction of effects	Ns	**(22)	Ns	Ns	Ns	Ns
	Excursion activity	463	12	p-value (R^2) Direction of effects	**(2) SMRA > OR ** NR > OR *	***(4) Motorboat > Taxi-boat ** Sailboat > Taxiboat **	Ns	***(2) 1+ > 0 ***	. (1) "<11" < "11-20" .	Ns
Environmental quality	**Environmental marine quality (submarine landscape, marine biodiversity)**	463	8	p-value (R^2) Direction of effects	***(6) NR >SMRA** NR > OR *** SMRA > OR *	*(2)	Ns	Ns	Ns	Ns
	Islet beauty	463	9	p-value (R^2) Direction of effects	***(3) NR >SMRA*** OR > SMRA .	**(3)	Ns	Ns	Ns	. (2)
Unmanageable	**Random selection**	463	10	p-value (R^2) Direction of effects	**(5) NR > SMRA *	**(7) Taxi-boat > Motorboat . Jet-ski > Motorboat **	Ns	. (2) 0 > 1+ .	Ns	Ns
	Weather condition	463	22	p-value (R^2) Direction of effects	*(1) SMRA > OR * NR > OR .	***(14) Jet-ski > Taxi-boat ** Motorboat > Taxi-boat *** Dinghy > Taxi-boat *** Sailboat > Taxi-boat ***	Ns	Ns	Ns	**(3) ">20" > "<1"

Figure 1: Islets and MPAs considered in this study with their geographical and managerial characteristics.

Figure 2: Relationship between users' activities and behaviors with associated pressure levels on the islet.

Figure 3: Estimated annual number of groups and number of visitors landing on the islet for each boat type. Size and proportion of sectorial diagrams are proportional to the number of groups per boat type

Figure 4: For each activity, number of groups displaying a given behavior at a given islet with 95% CI. Plots related to landing and speed activities were truncated for clarity. The number of groups (and associated 95% CI) disembarking and practicing speed activity at Maître islet was added to the plot (white figures).

Figure 5: Number of user groups per islet with 95% CI. Top: manageable selection criteria; bottom left: non manageable criteria, and bottom right: environmental quality. The overall number of groups (summed over sites) (and with 95% CI) for each criterion is displayed above the corresponding barplot

Figure 6: Projection of activity and behavior categories (A) for speed (out MA: speed activity outside mooring area, in MA: speed activity inside mooring area), swimming, fishing and on land activity on factorial plans of the MCA. Selection criteria, islets (bold) and boat type (italics) only were projected on the factorial plan (B). Only categories significantly different from origin based on v test are displayed.

Figure 7: Ternary diagrams depicting the selection criteria characteristic of each islet. Each tip of a ternary diagram corresponds to a criterion category: environmental quality (both on the islet and underwater) (top), manageable criteria (i.e. practice of an activity, existence of amenities, quietness or protection status) (bottom left) and non manageable criteria (accessibility, weather conditions or random selection) (bottom right). Darker grey patches represent a higher proportion of users mentioning the corresponding combination of selection criteria. Percentages displayed at each tip represent the annual proportion of groups mentioning a criterion in that category.

Appendix A :

Let us denote *s* the site, *b* the boat type, *i* the the trip index, *q* the quarter, and *d* the day type. s, i, q and d vary between 1 and respectively S=6, I=50, Q=4, and D=2. N_{qd} is the number of days per quarter and day type. n_{sqd} is the number of trips per site, quarter, and day type, and B_{sqdb} is the number of boats per site, quarter, day type and boat type

(1) Mean number of boats per islet, quarter, day type and boat type	(1) $\overline{B_{sqdb}} = \frac{\sum_{i=1}^{n_{sqd}} B_{isqdb}}{n_{sqd}}$ $\hat{V}\left(\overline{B_{sqdb}}\right) = \frac{1}{n_{sqd}\left(n_{sqd}-1\right)} \times \left(1-\frac{n_{sqd}}{N_{qd}}\right) \times \sum_{i=1}^{n_{sqd}} (B_{isqdb} - \overline{B_{sqdb}})^2$
(2) Total number of boat per boat type and islet over the year	(2) $\widehat{B_{sb}} = \sum_{q=1}^{T} \sum_{d=1}^{D} (N_{qd} \times \overline{B_{sqdb}})$ $\hat{V}(\widehat{B_{sb}}) = \sum_{t=1}^{T} \sum_{d=1}^{D} ({N_{qd}}^2 \times \hat{V}(\overline{B_{sqdb}}))$

P_{jsb} = number of users per group

$_j$ = group index (with *J* number of group)

(3) Mean number of users for boat type b and islet s	$\overline{P_{sb}} = \frac{\sum_{j=1}^{J_{sb}} P_{jsb}}{J_{sb}}$ $\hat{V}(\overline{P_{sb}}) = \frac{\sum_{j=1}^{J_{sb}} (P_{jsb} - \overline{P_{sb}})^2}{J_{sb}}$

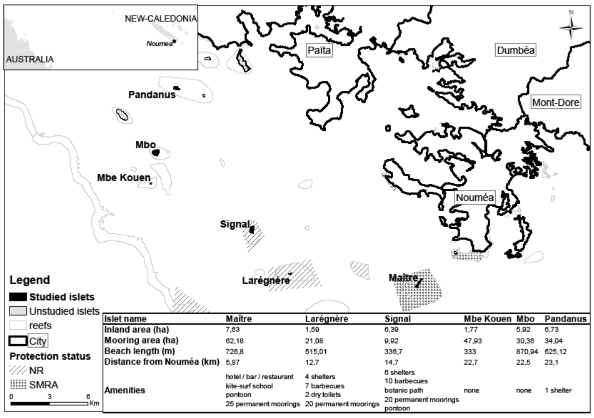
$_m$ = survey trip index (with *M*=8 number of survey trip)

f_{sjm} = sample rate per islet, boat type and survey trip

k = group's category according to a given practice or selection criteria

Prop = group's category proportion

(4) Mean number of groups for category k (i.e. a given practice or selection criteria)	(4) $\overline{Prop_{ksb}} = \frac{\sum_{i=1}^{I} Prop_{iksb}}{M_s}$ $\hat{V}(\overline{Prop_{ksb}}) = \frac{\sum_{i=1}^{I} (Prop_{iksb} - \overline{Prop_{ksb}})^2}{n_i} + \frac{\sum_{i=1}^{I} (1-f_{\mathrm{sjm}}) \times Prop_{iksb} \times (1-Prop_{iksb})}{n_i}$
(5) Total number of users over the year, for islet s for and category k	(5) $\widehat{P_{sk}} = \sum_{b=1}^{b} \widehat{B_{sb}} \times \overline{P_{sb}} \times \overline{Prop_{ksb}}$ $\hat{V}\left(\widehat{P_{sk}}\right) = \sum_{b=1}^{TB} \hat{V}\left(\widehat{B_{sb}}\right) \times \hat{V}(\overline{P_{sb}}) \times \hat{V}(\overline{Prop_{ksb}})$



Islet name	Maître	Larégnère	Signal	Mbe Kouen	Mbo	Pandanus
Inland area (ha)	7,63	1,59	6,39	1,77	5,92	6,73
Mooring area (ha)	62,18	21,08	9,92	47,93	30,36	34,04
Beach length (m)	726,8	515,01	336,7	333	870,94	625,12
Distance from Nouméa (km)	5,87	12,7	14,7	22,7	22,5	23,1
Amenities	hotel / bar / restaurant kite-surf school pontoon 25 permanent moorings	4 shelters 7 barbecues 2 dry toilets 20 permanent moorings	6 shelters 10 barbecues botanic path 20 permanent moorings pontoon	none	none	1 shelter

Figure 1: Islets and MPAs considered in this study with their geographical and managerial characteristics.

Table 1: Number of questionnaires administrated per boat type and islet and mean sampling rate per boat type and islet over the 8 field trips.

Islet	Motorboat		Dinghy		Sailboat		Jet-ski		Taxi-boat	
	Nb	%	Nb	%	Nb	%	Nb	%	Nb	%
Maître	43	53	7	30	32	45	6	30	64	50
Larégnère	51	61	5	34	28	39	6	35	20	65
Signal	71	74	6	42	23	72	2	38	26	72
Pandanus	23	42	8	7	5	67	0	-	1	84
Mbo	11	61	5	75	3	39	0	-	1	82
Mbe Kouen	4	33	0	-	8	32	0	-	0	-

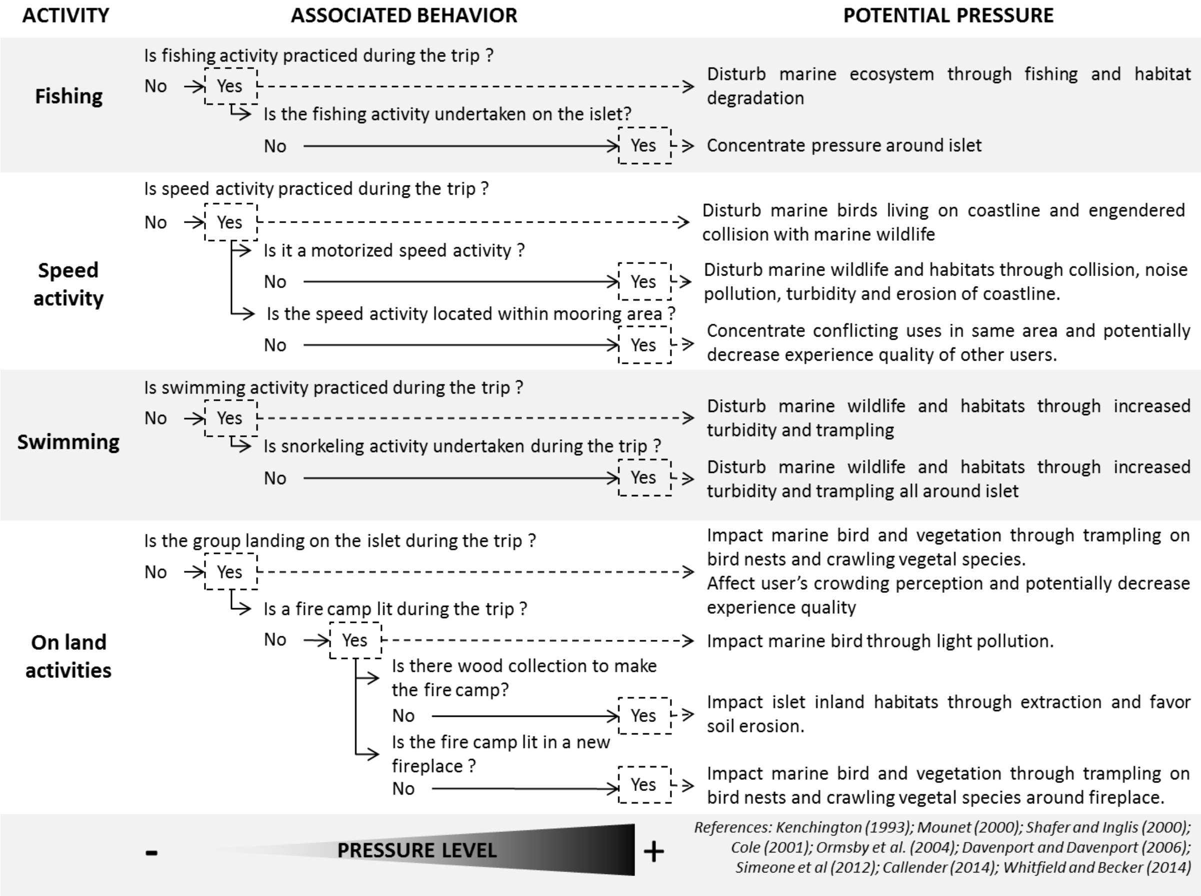


Figure 2: Relationship between users' activities and behaviors with associated pressure levels on the islet.

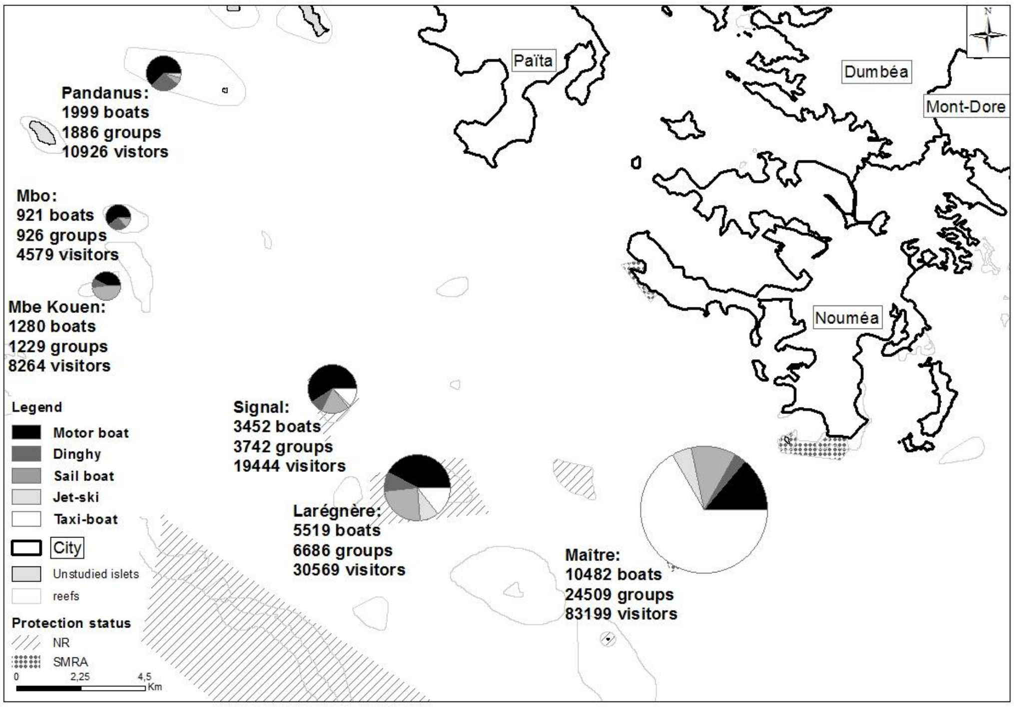


Figure 3: Estimated annual number of groups and number of visitors landing on the islet for each boat type. Size and proportion of sectorial diagrams are proportional to the number of groups per boat type.

Table n°2: Outcomes of the models of user's practices (***: 0.1% significance level, **: 1% significance level, *: 5% significance level, .: 10% significance level, Ns: non-significant). Multiple comparisons provided the direction of effect between significantly different categories (termed "Direction of effect" below). R^2 statistics were computed as the ratio of the deviance explained by the model and the deviance to that of the null model. n was the sample size for each response. For each significant factor, partial R^2 is shown parentheses.

				Explanatory factors					
					Trip characteristics			Users characteristics	
Response variables	**n**	**R^2**		**Protection status**	**Boat type**	**Number of users within the group**	**Number of nights**	**Number of trip per year**	**Experience**
Fishing activity	458	24	p-value (partial R^2) Direction of effects	***(6) OR>SMRA*** OR >NR***	***(5) Dinghy>Motorboat . Dinghy>Taxi-boat** Dinghy>Sailboat . Motorboat>Taxi-boat .	Ns	*(2) 1+ > 0*	. (1) "11-20" > "<11"	Ns
Fishing activity around the islet (among fishers visitors)	69	34	p-value (partial R^2) Direction of effects	***(34)	Ns	Ns	Ns	Ns	Ns
Speed activity	463	17	p-value (partial R^2) Direction of effects	***(6) SMRA>NR ***	***(9) Jet-ski>Motorboat *** Jet-ski>Dinghy *** Jet-ski>Sailboat *** Jet-ski>Taxi-boat ***	Ns	. (1) 1+ > 0 .	Ns	. (1)
Motorized speed activity (among visitors having speed activity)	67	79	p-value (partial R^2) Direction of effects	Ns	***(79)	Ns	Ns	Ns	Ns
Speed activity in mooring area (among visitors having speed activity)	67	61	p-value (partial R^2) Direction of effects	**(13) SMRA>NR* NR>OR .	*(14)	Ns	***(19) 0 > 1+ *	*(10)	Ns
Swimming activity	463	26	p-value (partial R^2) Direction of effects	***(5) NR>SMRA**	Ns	*(4) 7+ > 1-2 .	***(5) 1+ > 0 **	***(7) "<11" > ">20" ** "11-20" >">20"*	Ns
Snorkeler activity (among swimmers)	425	5	p-value (partial R^2) Direction of effects	. (1) NR > SMRA *	*(3) Taxi-boat>Motorboat . Taxi-boat>dinghy*	Ns	. (1) 1+ > 0.	Ns	Ns
Landing on islet (except Taxi-boat)	348	22	p-value (partial R^2) Direction of effects	Ns	***(7) Motorboat>Sailboat ** Dinghy>Sailboat .	***(11) 4-6 > 1-2*** 4-6 > 3-4 . 7+ > 1-2*** 7+ > 3-4**	***(5) 1+ > 0***	Ns	**(4) 1-5 > 5+ .
Fire (among users who land on islet)	404	46	p-value (partial R^2) Direction of effects	**(6) NR >SMRA * OR>SMRA*	***(12) Motorboat>Sailboat*** Dinghy>Sailboat*** Taxi-boat>Sailboat***	*(1) 7+ > 1-2 *	***(14) 1+ > 0***		***(4) 1-5 > 5+***
Fire on a new spot (among users who make a fire)	118	10	p-value (partial R^2) Direction of effects	**(10) OR>NR *	Ns	Ns	. (4) 0 > 1+ .	Ns	Ns
Wood collection on islet (among users who make a fire)	118	10	p-value (partial R^2) Direction of effects	**(10) OR>NR ** NR > SMRA *	Ns Taxi-boat>Motorboat . Taxi-boat>dinghy*	Ns	Ns 1+ > 0.	Ns	Ns

Table n°3: Outcomes of the models of the site selection criteria (***: 0.1% significance level, **: 1% significance level, *: 5% significance level, .: 10% significance level, Ns: non-significant). Multiple comparisons provided the direction of effect between significantly different categories (termed "Direction of effect" below). R^2 statistics were computed as the ratio of the deviance explained by the model and the deviance to that of the null model. n was the sample size for each response. For each significant factor, partial R^2 is shown in parentheses.

	Selection criteria	n	R^2		Explanatory factors					
						Trip characteristics			Users characteristics	
					Protection status	Boat type	Numb of users within the group	Number of nights	Number of trip per year	Experience
Manageable	Quietness / solitude	463	11	p-value (R^2) Direction of effects	***(8) NR >SMRA * OR >SMRA*** OR > NR ***	*(2) Motorboat > Sailboat . Taxi-boat > Sailboat .	Ns	Ns	. (1)	Ns
	Protection status (among users interviewed on MPA's islet)	392	10	p-value (R^2) Direction of effects	Ns	***(10) Motorboat > Taxi-boat* Sailboat > Taxi-boat**	Ns	Ns	Ns	Ns
	Marine amenities (among users interviewed on MPA's islet)	392	21	p-value (R^2) Direction of effects	Ns	***(21) Sailboat > Motorboat* Sailboat > Dinghy .	Ns	Ns	Ns	Ns
	Terrestrial amenities (among users interviewed on MPA's islet)	392	4	p-value (R^2) Direction of effects	Ns	*(3) Motorboat > Sailboat* Dinghy > Sailboat*	Ns	**(3) 1+ > 0 **	Ns	Ns
	Speed activity	463	15	p-value (R^2) Direction of effects	***(8) SMRA>NR***	. (3)	Ns	Ns	Ns	*(4) "1-5" > ">20"
	Fishing activity	71	22	p-value (R^2) Direction of effects	Ns	**(22)	Ns	Ns	Ns	Ns
	Excursion activity	463	12	p-value (R^2) Direction of effects	**(2) SMRA > OR ** NR > OR *	***(4) Motorboat > Taxi-boat ** Sailboat > Taxiboat **	Ns	***(2) 1+ > 0 ***	. (1) "<11" < "11-20" .	Ns
Environmental quality	Environmental marine quality (submarine landscape, marine biodiversity)	463	8	p-value (R^2) Direction of effects	***(6) NR >SMRA** NR > OR *** SMRA > OR *	*(2)	Ns	Ns	Ns	Ns
	Islet beauty	463	9	p-value (R^2) Direction of effects	***(3) NR >SMRA*** OR > SMRA .	**(3)	Ns	Ns	Ns	. (2)
Unmanageable	Random selection	463	10	p-value (R^2) Direction of effects	**(5) NR > SMRA *	**(7) Taxi-boat > Motorboat . Jet-ski > Motorboat **	Ns	. (2) 0 > 1+ .	Ns	Ns
	Weather condition	463	22	p-value (R^2) Direction of effects	*(1) SMRA > OR * NR > OR .	***(14) Jet-ski > Taxi-boat ** Motorboat > Taxi-boat *** Dinghy > Taxi-boat *** Sailboat > Taxi-boat ***	Ns	Ns	Ns	**(3) ">20" > "<1"

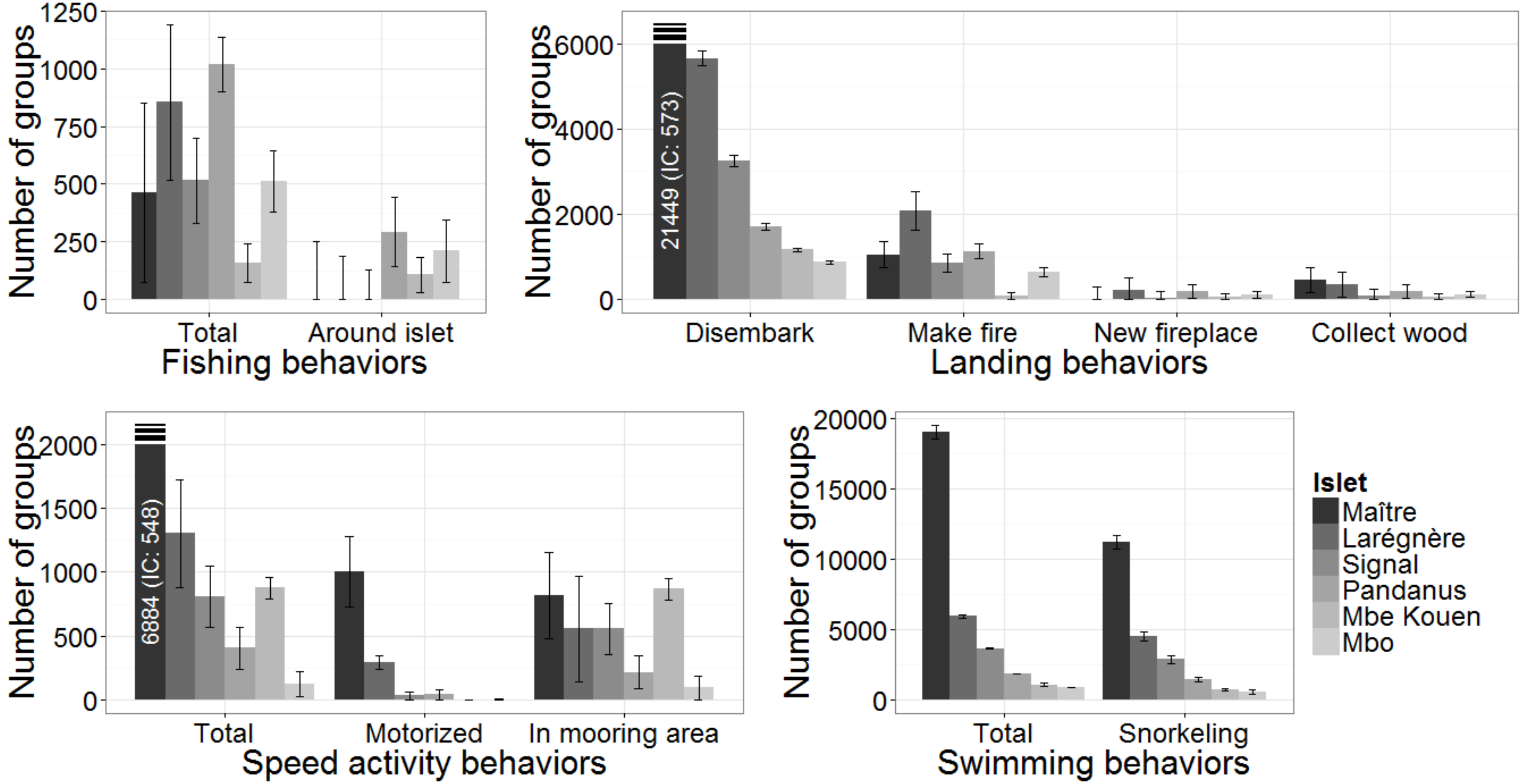


Figure n°4: For each activity, number of groups displaying a given behavior at a given islet with 95% CI. Plots related to landing and speed activities were truncated for clarity. The number of groups (and associated 95% CI) disembarking and practicing speed activity at Maître islet was added to the plot (white figures).

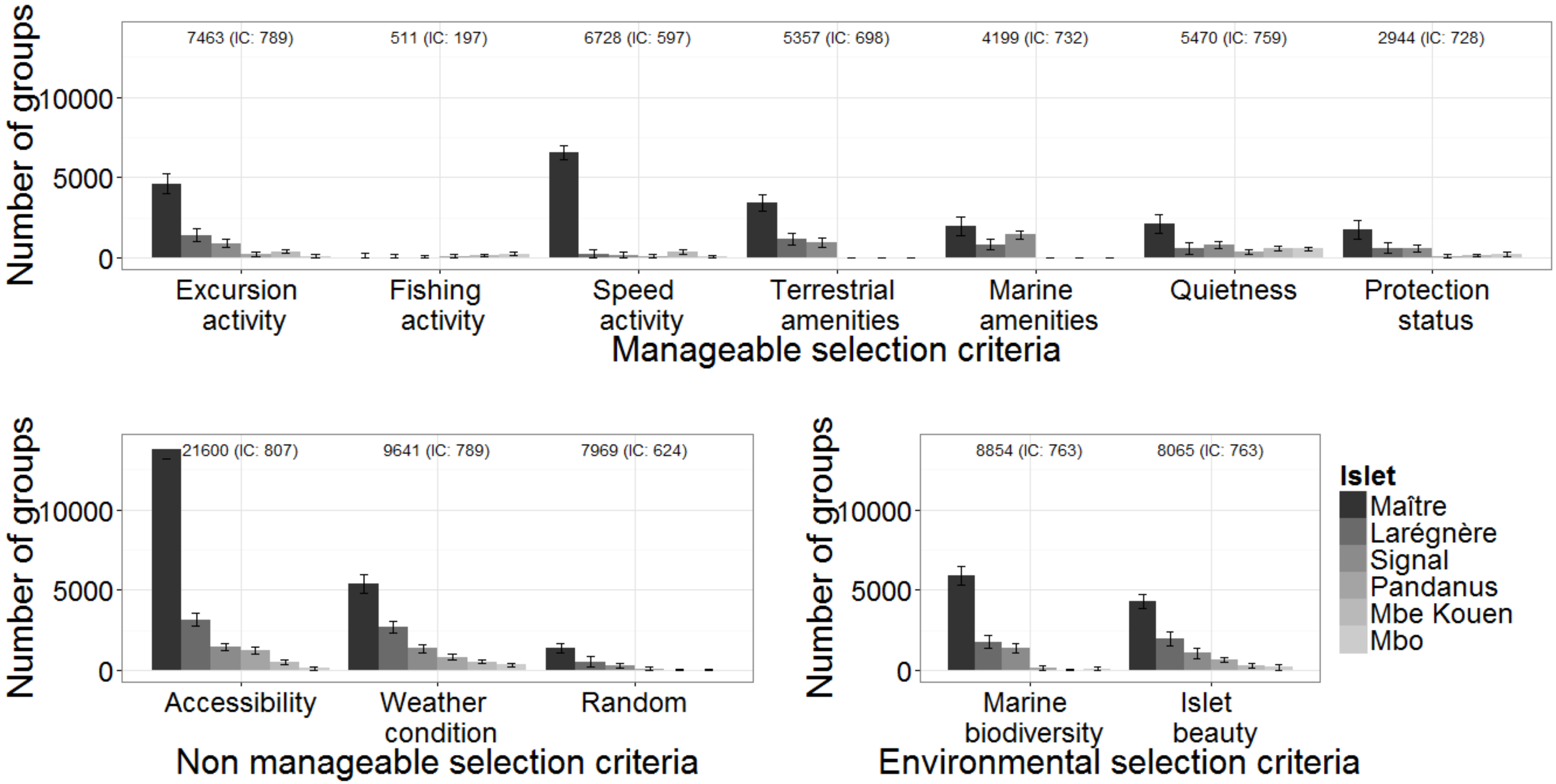


Figure n°5: Number of user groups per islet with 95% CI. Top: manageable selection criteria; bottom left: non manageable criteria, and bottom right: environmental quality. The overall number of groups (summed over sites) (and with 95% CI) for each criterion is displayed above the corresponding barplot.

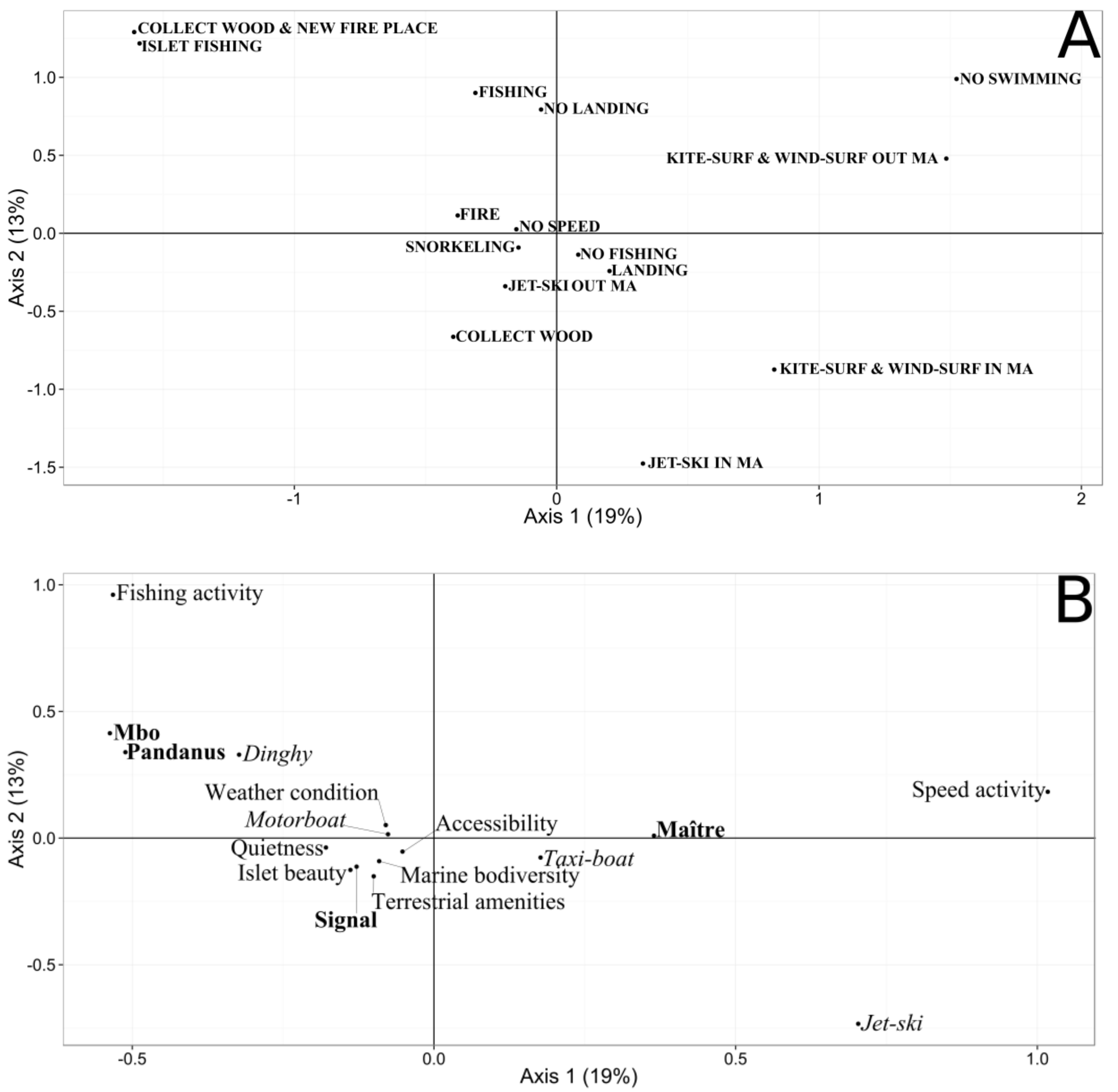


Figure 6: Projection of activity and behavior categories (A) for speed (out MA: speed activity outside mooring area, in MA: speed activity inside mooring area), swimming, fishing and on land activity on factorial plans of the MCA. Selection criteria, islets (bold) and boat type (italics) only were projected on the factorial plan (B). Only categories significantly different from origin based on v test are displayed.

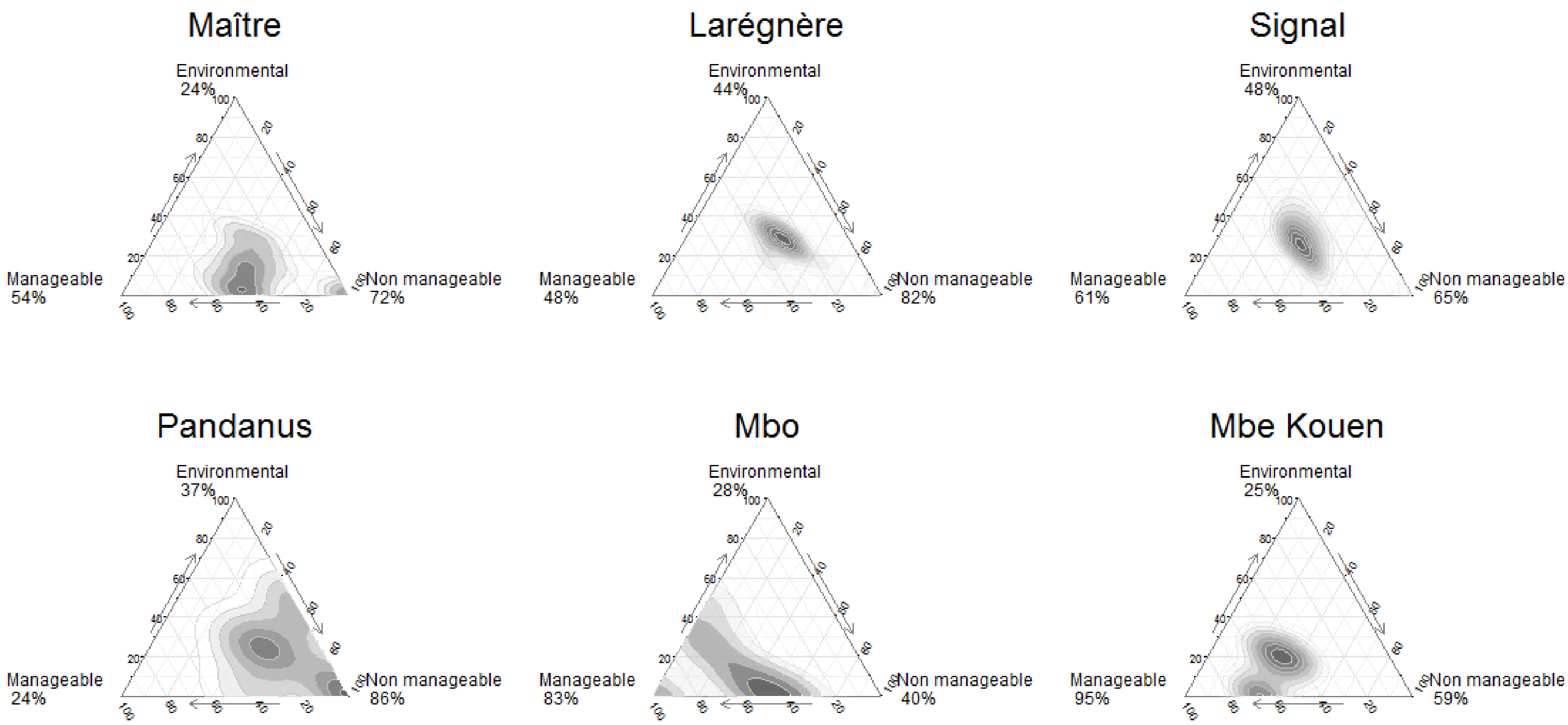


Figure 7: Ternary diagrams depicting the selection criteria characteristic of each islet. Each tip of a ternary diagram corresponds to a criterion category: environmental quality (both on the islet and underwater) (top), manageable criteria (i.e. practice of an activity, existence of amenities, quietness or protection status) (bottom left) and non manageable criteria (accessibility, weather conditions or random selection) (bottom right). Darker grey patches represent a higher proportion of users mentioning the corresponding combination of selection criteria. Percentages displayed at each tip represent the annual proportion of groups mentioning a criterion in that category.

Appendix A :

Let us denote *s* the site, *b* the boat type, *i* the the trip index, *q* the quarter, and *d* the day type. s, i, q and d vary between 1 and respectively S=6, I=50, Q=4, and D=2. N_{qd} is the number of days per quarter and day type. n_{sqd} is the number of trips per site, quarter, and day type, and B_{sqdb} is the number of boats per site, quarter, day type and boat type

Mean number of boats per islet, quarter, day type and boat type	(1) $\overline{B_{sqdb}} = \frac{\sum_{i=1}^{n_{sqd}} B_{isqdb}}{n_{sqd}}$ $\hat{V}\left(\overline{B_{sqdb}}\right) = \frac{1}{n_{sqd}\left(n_{sqd}-1\right)} \times \left(1 - \frac{n_{sqd}}{N_{qd}}\right) \times \sum_{i=1}^{n_{sqd}} (B_{isqdb} - \overline{B_{sqdb}})^2$
Total number of boat per boat type and islet over the year	(2) $\widehat{B_{sb}} = \sum_{q=1}^{T}\sum_{d=1}^{D}(N_{qd} \times \overline{B_{sqdb}})$ $\hat{V}(\widehat{B_{sb}}) = \sum_{t=1}^{T}\sum_{d=1}^{D}({N_{qd}}^2 \times \hat{V}(\overline{B_{sqdb}}))$

P_{jsb} = number of users per group

$_j$ = group index (with *J* number of group)

Mean number of users for boat type b and islet s	(3) $\overline{P_{sb}} = \frac{\sum_{j=1}^{J_{sb}} P_{jsb}}{J_{sb}}$ $\hat{V}(\overline{P_{sb}}) = \frac{\sum_{j=1}^{J_{sb}}(P_{jsb} - \overline{P_{sb}})^2}{J_{sb}}$

$_m$ = survey trip index (with *M*=8 number of survey trip)

f_{sjm} = sample rate per islet, boat type and survey trip

k = group's category according to a given practice or selection criteria

Prop = group's category proportion

Mean number of groups for category k (i.e. a given practice or selection criteria)	(4) $\overline{Prop_{ksb}} = \frac{\sum_{i=1}^{I} Prop_{iksb}}{M_s}$ $\hat{V}(\overline{Prop_{ksb}}) = \frac{\sum_{i=1}^{I}(Prop_{iksb} - \overline{Prop_{ksb}})^2}{n_i} + \frac{\sum_{i=1}^{I}(1-f_{\mathrm{sjm}}) \times Prop_{iksb} \times (1 - Prop_{iksb})}{n_i}$
Total number of users over the year, for islet s for and category k	(5) $\widehat{P_{sk}} = \sum_{b=1}^{b} \widehat{B_{sb}} \times \overline{P_{sb}} \times \overline{Prop_{ksb}}$ $\hat{V}\left(\widehat{P_{sk}}\right) = \sum_{b=1}^{TB} \hat{V}\left(\widehat{B_{sb}}\right) \times \hat{V}(\overline{P_{sb}}) \times \hat{V}(\overline{Prop_{ksb}})$