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# The nutritional impacts of marine protected area expansion: going beyond an input-output analysis

*Research problem: By which mechanisms do marine protected areas address malnutrition in developing coastal communities? To what extent does MPA management and design have a key role to play in influencing the nutritional outcomes of adjacent communities?*

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Young boys standing proudly with fish in Madagascar. Credits : C. Golden

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# 1 - Introduction

Given that the world population is expected to approach 10 billion people by 2050, there is great interest to determine how global food production can meet nutritional needs. Adequate intakes of both macronutrients (such as proteins) and micronutrients (such as vitamins and minerals) are both crucial for human health. (T.T Lilly, 2017; B.P Mohanty, 2015). With this in mind, fisheries play a key nutritional role in developing countries for two main reasons.

First, fish are the dominant source of animal proteins in many of those countries. Indeed, 60% of people from developing countries depend upon fish for over 30% of their animal protein supplies. (FAO, 2005) In 2015, fish still accounted for about 26% of animal protein intake in least developed countries and 19% in other developing countries. This trend had been increasing but has stagnated in recent years due to the growing consumption of other animal proteins (FAO, 2018). However, the unit cost of production of fish is lower compared to other dietary protein sources such as chicken, pork or beef (Balami, 2019).

Second, beyond protein, fish are also important globally for many reasons. Micronutrients such as zinc, iron, calcium, vitamins, and fatty acids are abundant in fish species (Hicks et al., 2019; Vaitla et al., 2018). Furthermore, these micronutrients tend to be more easily available than those from plant foods (T.T Lily, 2017). Micronutrient deficiencies in developing countries cause over one million premature deaths per year, with over 2 billion people lacking one or more micronutrients (Black et al., 2013), particularly vitamin A, iron and zinc (Kawarazuka and Béné, 2011). Consuming enough of these micronutrients is important in preventing several health problems associated with malnutrition. For example, iodine deficiency in pregnancy has long been linked to cretinism and possible fetal wastage (Black et al., 2013). At the same time, vitamin A deficiency, affecting some 250 million people mainly in developing countries, weakens the immune system and is a primary cause of anemia (O. Müller and M. Krawinkel, 2005).

In the context of these major trends in malnutrition, fisheries resources are being overfished and consequently, catches are declining (Pauly and Zeller, 2016 ; Costello et al., 2012). Fisheries production has decreased in the last decade, disproportionately affecting developing nations (Zeller et al., 2016). Additionally, research has shown that reductions in fish stocks due to poor governance and climate change may increase undernutrition, particularly in developing countries dependent on wild fish (Golden et al., 2016).

According to the IUCN definition, marine protected areas (MPAs) are areas of the ocean that are a "clearly defined geographical space, recognised, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values" (Dudley, 2008) MPAs can be broadly categorized into no-take areas where fishing is prohibited (corresponding to IUCN's MPAs category I), sustainable use areas where fisheries are managed (IUCN's MPAs category VI) and a mix of the two (IUCN's categories among I and VI) (Day et al., 2019).

Throughout this master's thesis, and inspired by these IUCN's MPA categories, we consider MPAs as any managed area in the ocean, encompassing locations where fishing is and isn't allowed.

Both no-take and sustainable use MPAs have been shown to have significant positive effects on the abundance and diversity of fish inside MPA borders compared to open-access areas outside the MPAs (Gill et al., 2017; Harasti et al., 2018).

In addition to conservation benefits, several MPAs provide important fisheries benefits. Generalization of these benefits is challenging because MPAs could have positive or negative effects depending on the social, economic and political context (HLPE, 2014 ; Garcia and al, 2013) and the temporal time scale. Yet, several examples of sustainable-use MPAs have shown positive effects for improved fisheries governance on local fisheries (Di Lorenzo et al., 2016; Russ et al., 2004 ; Halpern and Warner, 2003).

Increases of fishing catch and efficiency has led to important health and economic benefits to local communities (Ban et al., 2019). MPAs can also provide important economic benefits derived from tourism (Viana et al., 2017) which can be a very important source of income for local communities through the establishment of user fees (Cadiz et al., 2000), the generation of direct and indirect jobs (Goyet, 2008) or the multiplier effects in local businesses associated with tourism (Kenchington et al., 2003).

# 2 - Context of the study

In 2010, the Conference of the Parties (COP) to the Convention on Biological Diversity (CBD) adopted the goal of protecting at least 10% of representative and well-connected coastal and marine areas of particular importance to biodiversity by 2020 (Report of the Tenth Meeting of the Conference of the Parties to the CBD, 2010).The CBD COP will be meeting again in 2021 to re-evaluate that 10% target. Currently, there is an enormous push from the international community to significantly increase MPA cover by 2030. For instance, the International Union for Conservation of Nature (IUCN) adopted a 30% target to protect marine habitats (IUCN World conservation Congress, 2016). Unfortunately, nutrition has not been part of the main stream discourse in fisheries management sciences at global levels in the past. (Béné et al., 2015 ; HLPE, 2014).

With that in mind, further work is needed to globally assess the potential human health impacts of marine protected areas across a broader range of health outcomes and ecosystems and to inform the development of novel policy interventions for the benefit of humans and nature

Hence, Conservation International, Duke University, and Harvard TH Chan School of Public Health researchers have identified a promising area of collaboration to link human health and food security to marine conservation efforts. A project launched in January 2020 aims to test the nutritional effects of different MPA expansion scenarios in order to examine the impacts of MPAs for human nutrition globally. The researchers involved in this project will analyze a series of unique global databases (i.e., MPA management and impacts, fish populations, and human nutrition) using an integrated modeling approach, to generate a series of studies that will rigorously, quantitatively, and globally document the current and potential future human health impacts of marine protected areas.

Alongside this global analysis covering marine protected areas from nearly every tropical, coastal country on earth, specific case studies are needed to further examine the role of governance, design, and context of MPAs in delivering nutritional benefits. This detailed approach, complementary to the global one, is necessary because earlier studies stressing the importance of fish in relation to food security seems to be incomplete (Kawarazuka, 2010 ; Westlund, 2017). Indeed, at the moment, there has been little holistic analysis of how MPAs will impact human nutrition of those relying on fish for their nutritional needs (Westlund, 2017). The conclusion made by Allison (2013) is a compelling example of this: "Despite abundant claims, evidence linking governance innovations for marine resources to poverty reduction and/or food security is scarce at best […]. Not only is the evidence itself scarce, but there are shortcomings in all analyses due to inherent difficulties in measuring, estimating and/or comparing 'successful outcomes' of governance regimes – especially where poverty and food security are concerned." In fact, the black-box nature of many studies (e.g. Alva et al., 2016 ; Andam et al., 2010) does not allow them to adequately link fishery governance and nutrition. Indeed, their approaches do not take into consideration the intermediate outcomes and the pathways which potentially link MPAs and human nutrition. In particular, it is still not clear whether the positive/ negative impact observed on human nutrition is really related to the creation of the reserve, environmental oscillations or changes in the overall area context (demography, demand, trade, migrations, climate change, etc.).
In other words, the black-box approach which characterizes most of past analyses is not well designed to capture the complexity of the mechanism which link MPAs and human nutrition (Westlund, 2017). Thus, these findings are not detailed enough to appropriately inform policies related to MPAs.

As a consequence, the point of this master thesis is to focus on specific case studies in order to understand the multiple ways in which MPAs affect human nutrition, both directly and indirectly. This detailed

understanding is crucial in order to identify relevant opportunities for policy engagement at national and global scales. Therefore, the challenge of this thesis is two-fold:

- To build a conceptual framework which describes the multiple causal pathways linking MPAs and human nutrition, taking into consideration how contextual factors can influence this link. Then, the challenge is to understand the logics underlying each causal pathway, and identify entry points where rigorous quantitative assessment of the causal pathways can be conducted.

- To test this conceptual framework through a monographic case study and to identify the role of governance regimes on the strengths and weaknesses of the causal pathways linking MPAs and human nutrition. Meanwhile, two crossing view case studies are expected to shed light upon the nuances and complexities of these pathways. Based on this analysis, we expect to discuss the pros and cons of these case studies in order to draw policy lessons.

# 3 - Conceptual framework

## 3.1 - Methodology : using a "theory-based impact evaluation" to assess the impact of MPAs in delivering nutritional benefits

Evaluating the potential impact of MPAs in delivering nutritional benefits to local populations is a complex process underpinned by intricate mechanisms. Therefore, applying a TBIE approach is justified. Theory-based impact evaluation (TBIE), which means examining the links underlying the causal chain from input (here, MPAs creation) to impact (here, change in nutrient intakes), is a well-established approach (Westlund, 2017 ; Carvalho and White, 2004 ; Barnett and Gregorowski, 2013 ; see Pressey, Visconti and Ferraro, 2015 for an application in a protected area project). Before making an evaluation of impact using a counterfactual, the first key principles of a theory-based impact evaluation is to map out the causal chain using a Theory of Change (ToC).

### 3.1.1 - The global Theory of Change (ToC)

The central element of the TBIE method is the building of a generic Theory Of Change (ToC) (White, 2009). Although this theory has achieved a steep rise in recent years (see Vogel, 2012 ; Barnett et al., 2013 ; Biggs et al., 2017 ; R. Margoluis et al., 2009), it builds on earlier work on the use of programme theory in evaluations (see Weiss, 1972 ; Weiss, 1997). ToC is a description of how and why a desired change is expected to happen in a particular context. The strength of this theory is to focus and map out the entire causal chain between what a program does and how an intervention may lead to a clearly desired goal. (Rogers, 2014)
In order to assess the impact of MPAs in delivering nutritional benefits, we created this initial ToC.

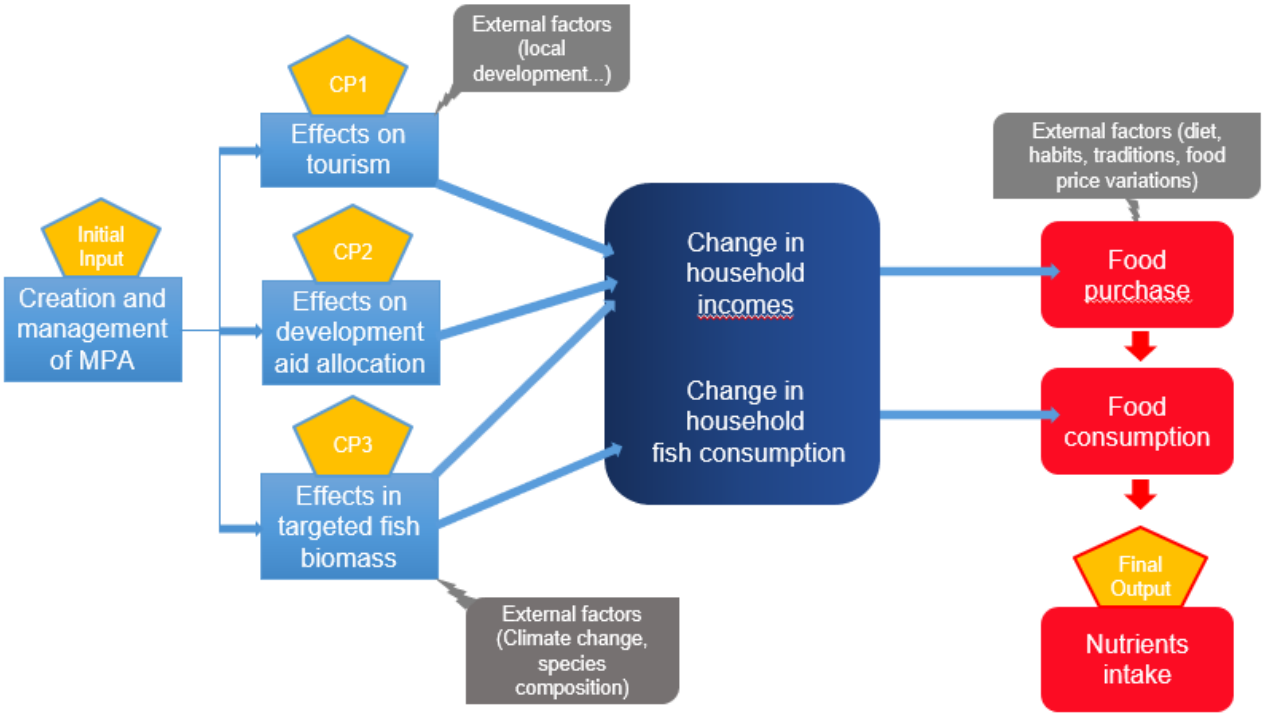



*Figure 1: Initial ToC (Theory of Change) showing the three main causal pathway linking the initial input (Creation and management of MPA) to the final output (Nutrient intakes).*

In order to continue to follow the TBIE key principles, I would like to make an evaluation of impact (using a counterfactual), by identifying the entry points where rigorous assessments in the ToC can be conducted. For this purpose, I need to dive deeper in this first ToC.

### 3.1.2 - Details of the ToC

On the left side of the global ToC (figure 1), we represented four components: one initial input "Creation and management of MPA", and three causal pathways which make the link between the initial input and the final output "Nutrient intakes". Understanding these four components, which I detail below, is necessary to link MPAs to nutrition. These four components are detailed below. Please note that all of these four components can have both positive and negative effects on the final output.

### 3.1.2.1 - Initial input : MPA's creation and management

In assessing the initial input of the ToC corresponding to the "creation and management of MPA", I decided to build on the work of Elinor Ostrom. In her 1990 book, *Governing the Commons*, Elinor Ostrom offered design principles for how commons can be governed sustainably and equitably in a community (Ostrom 1990). The principles were generated based on her extensive work on cases of small-scale common-pool resource management, both successful and not. The principles have since been reviewed by a multitude of studies, and are largely supported (Michael Cox, Gwen Arnold, and Sergio Villamayor Tomás 2010 in Devereaux, 2018). Moreover, to broaden the analysis, I decided to create a unique evaluation grid by enriching Ostrom's principles and categorizing the principles within three distinctive categories. Theoretically, the degree to which each village aligns with the evaluation grid reflects how the MPA's are managed, and therefore the likelihood that they will succeed in the long-term. This evaluation grid will be used to give marks for each village (cf. part 5.1.1.1 of this document) and to understand how the structure of management regimes and their implementations in practice can have an impact on the "strength" of the three causal pathways. The evaluation grid created and used is detailed below. The scoring system state the situations which deserve the highest mark (10 on 10) while situations which deserve the lowest mak (0 on 10) correspond to the opposite situation. Marks ranging between 0 and 10 correspond to intermediate situations. If we take as an example the "clearly defined boundaries criteria", the corresponding situation for a mark of zero is defined as follow: "Individuals or households who have rights to withdraw resource units from the MPA are not clearly defined at all. Meanwhile, the MPA's boundaries are not clearly defined at all".

*Tab 1: Evaluation grid and scoring system created by enriching Ostrom's principles and categorizing the principles within three distinctive categories.*

| Categories | Principles | Situation corresponding to 10 |
|---|---|---|
| **Institutional aspects of the MPAs creation** | Consensus building process | The MPA's rules are defined through an overwhelming agreement involving a good faith effort among relevant stakeholder. |
| | Legal environment | The MPA's creation and functioning is built and supported upon a clear legal and regulatory framework. |
| | Clearly defined boundaries | Fishers who have rights to withdraw resource units from the MPA must be clearly defined, as must the boundaries of the MPA itself. |

| | | |
|---|---|---|
| **Local adoption characteristics** | Level of commitment | The way in which locals are committed to craft the MPA's rules is constructive. |
| | Influence of local voices | The rights of locals to devise their own institutions are not challenged by external governmental authorities. |
| | Collective choice arrangement | Fishers affected by the operational rules can participate in modifying them. |
| **Operational aspect of the MPAs lives** | Strictness of rules in the MPA | The MPA's related rules are rough enough to play a significant role in the conservation of the resource. |
| | Compliance with the rules | The MPA's related rules are complied with in practice. |
| | Monitoring and enforcement | There are monitors, who actively enforce MPA's rules. They are accountable to the fishers. |
| | Conflict resolution mechanism | Locals and their officials have rapid access to low-cost local arenas to resolve conflicts among locals or between locals and officials. |
| | Graduated sanctions | Fishers who violate operational rules are likely to be assessed graduated sanctions by other appropriators, by officials accountable to these fishers, or by both. |

### 3.1.2.2 - Tourism causal pathway

Based on the existing literature, it seems that MPAs can be a very important source of income for local communities thanks to the stimulation of the tourism sector through three different mechanisms. The first benefit comes in the form of direct and indirect job creation through diving operations, snorkeling, cultural outings and boat tourism within the MPAs. (Mascia et al., 2010 ; Pascoe et al., 2014 ; Dixon, 1993). Secondly, regarding the willingness of visitors to pay to benefit the surrounding environment, an increase in incomes due to an increase in tourism can be generated directly through user fees (Ransom et al., 2010 ; Wielgus et al., 2010 ; Green, E et al., 2003) and indirectly through multiplier effects (increasing revenue of local businesses related to tourism such as hotels or restaurants). (Kenchington et al., 2003 ; Viana et al., 2017).

Please note that the multiplier effect can be referred as a negative aspect of an increase in fish demand due to tourism leading to reduced access and consumption for local consumers. A portion of the user fees can be used for "development aid" purposes instead of having a direct impact on households incomes.

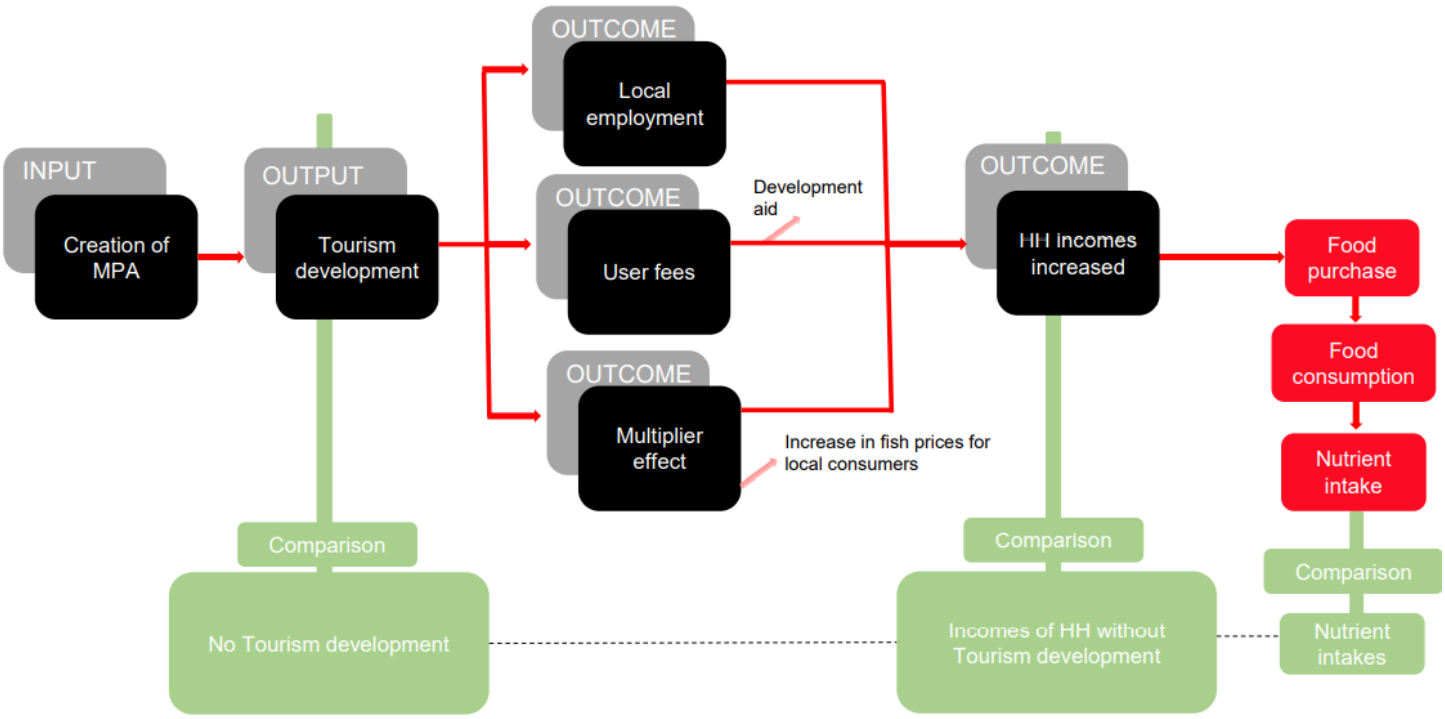



*Figure 2: Logic underlying the tourism causal pathway. Here, HH means household.*

### 3.1.2.3 - Development aid causal pathway

The creation of an MPA involves the necessity to cover management costs (Balmford et al., 2004). Hence, the allocation of development aid (money coming from government, NGO's, etc) is necessary and used not only to create local employment, but also to directly compensate local people or enhance community services. Below, I point out some key information about the three outcomes in the middle of the figure 3.

First, the intended outcomes of MPAs may be compromised not only by a low capacity of enforcement and compliance with MPA objectives but also by a lack of stakeholder engagement. (Giakoumi et al., 2018). These factors leading to the failure of MPAs can be prevented through enforcement and engaging with community members (G.J Watson et al., 2015 ; Giakoumi et al., 2018). Hence, in addition to the

routine costs of MPA administration, enforcement budgets for MPAs management must support the cost of conducting patrols, educating and engaging stakeholders (Christopher J. Brown et al., 2018).

Second and third, given that that an increase in tourism does not necessarily involve that local populations are the main beneficiaries, compensation and accompanying measures (also called AIGAs : Alternative Income Generation Activities) are often implemented as part of MPA's creation. These AIGAs are proposed until the MPA benefits are fully realized and the MPAs are well received by the local population. (Garcia et al., 2013) These AIGAs can take two different forms.

- Measures providing compensation for management restrictions on fishing operations either taking the form of direct compensation (for instance donation of gears) or indirect assistance (for instance valorization of catch). Direct assistance udually contributes more strongly to the increase in fishing effort, which may lead to the so called perverse effect (see note below).
- Measures contributing to the reduction of fishing effort while reducing poverty: To limit the pressure on fishing areas, management interventions can provide alternative income-generating activities for fishermen, also called "community service" such as development of land-based animal, vegetal production or aquaculture . (Garcia et al., 2013)

Please note that AIGAs can lead to a "perverse effect" which are effects that are contrary to the objectives of MPAs and/or contrary to the sustainable management of fisheries. For instance, giving motors to fishers as a compensation measure increase the fishing effort, which is contrary to the objectives of MPAs and contrary to the sustainable management of fisheries.

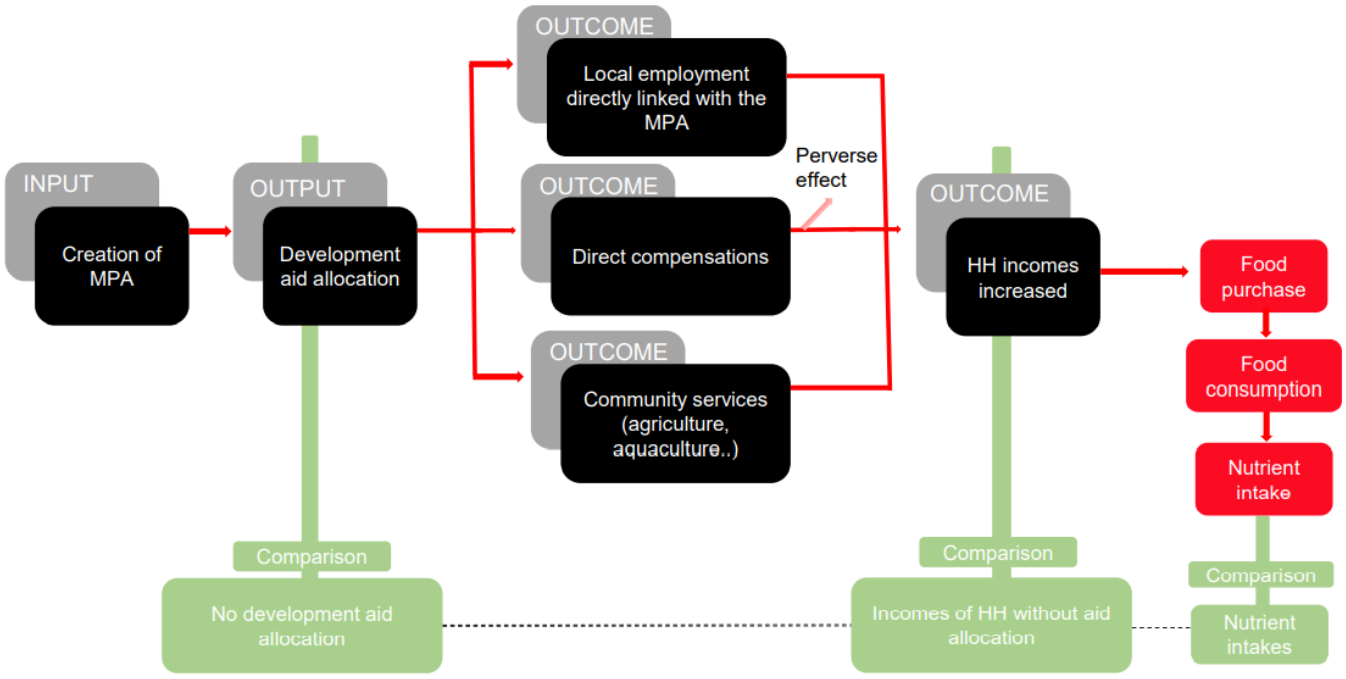



*Figure 3: Logic underlying the development aid causal pathway. Here, HH means household.*

### 3.1.2.4 - Fish catch causal pathway

The last causal pathway is an increase in targeted fish biomass for local fishers which provides a change in nutrient intakes.

A change in targeted fish biomass for local fishermen can trigger two simultaneous effects:
First, the catch will either be consumed by the fishermen (auto-consumption) or commercially sold. In the case where the fish is sold, it can be sold locally, which means that the fish is consumed within the community and fishermen earn some money. If the fish is sold for export, the fish is not consumed within the community but regardless, the fishermen are still paid.
Second, a change in targeted fish biomass for local fishermen may cause a change in species composition, either in their size or biomass. These physiological factors can lead to fluctuations in local and exported fish prices. For example, extra benefit for the fishers may be gained if the fish caught have a price premium (Enric Sala et al., 2016).

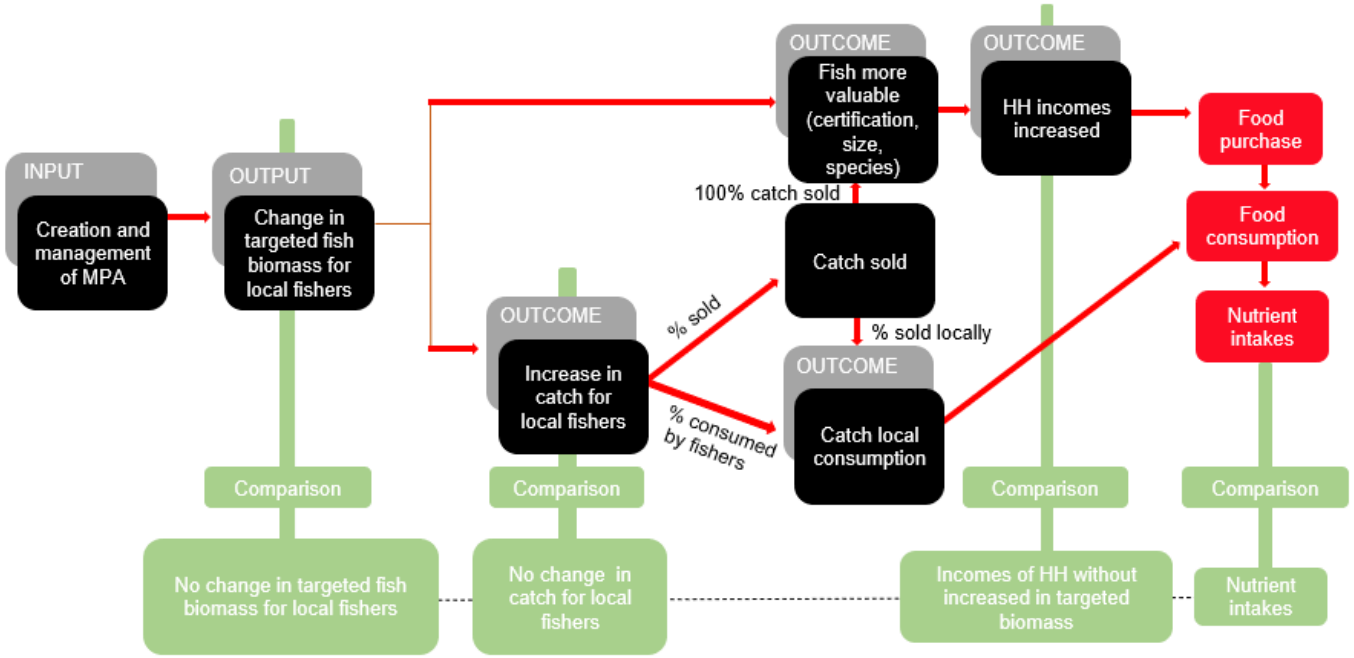



*Figure 4: Logic underlying the fish catch causal pathway. Catch can be either sold or consumed by fishers. We consider 100% of the catch sold to evaluate the households incomes (either locally sold or exported). Here, HH means household.*

# 4 - Methods

## 4.1 - Site selection

### 4.1.1 - Primary and comparative case studies

Prior to the design of this master's thesis, I reviewed the literature linking MPAs management and human nutrition. This prior literature review work has pointed out that there is a lack of clear studies trying to quantitatively document the role of MPAs in human nutrition. Site selection is crucial to study generalizability, and involved two distinct components based on different criteria :

- Primary case study. I selected the Antongil Bay in northeastern Madagascar as the focal case study of this master's thesis. Because counterfactual methodologies became a standard approach to identify causal policy effects in the last few years (Khandker et al., 2010 ; Massimo, 2012), it was necessary to find a location comprising coastal communities in which it's possible to identify an adequate control group that would play the role of "counterfactual" communities. The work from Golden et al. (2019) perfectly shows that there is a range of management type in this location : "In the Antongil Bay, fisheries governance takes three general forms: traditional management, marine national parks, and co-management. Traditional management involves little to no involvement by the national government or non-governmental organizations, and focuses on culturally accepted Malagasy community practices that tend not to restrict fishing gear or protect certain locations from harvest. In terms of formal restrictions on capture, traditional management tends to be the least strict of the three management forms. Marine national parks are managed by the national government and often involve "no-take zones" enforced by local government agents; they are the strictest form of fisheries management. Co-management is often enabled through financing and training by a NGO partner. The Wildlife Conservation Society (WCS) has been implementing co-management efforts through a series of LMMAs". Moreover, access to both quantitative (catch per unit effort, types of fish caught, compliance with MPA's rules, tourism, etc.) and qualitative (MPA's management, MPA's history, local feeling about MPAs, etc.) data was a strong criteria.

- Comparative case studies. To complement the primary case study, I also evaluated two "comparative case studies" to shed light upon different aspects of the conceptual framework not present in the monographic case study. In both these case studies, communities were selected due to their dependence on fish and/ or tourism, MPA management types, and the potential impact of MPAs on fishing catch and effort. These two comparative study locations included: 1) Bunaken National Marine Park at the northern tip of Sulawesi Island in central Indonesia; and 2) Apo Island Marine Reserve near Negros Island in the central region of the Philippines.

This portfolio of sites represents a diversity of isolated, rural communities which manage fisheries through three different types of legal mechanisms, where:

- Madagascar : rely heavily upon fishing as a primary source of both household income and animal-based protein
- Indonesia : big collaboratively managed national MPAs with high population densities
- Phillipines : and small, co-managed national MPAs with low coastal population density

The table below shows the differences among the three case studies in terms of age, human population, MPA size and management regime.

*Tab 2: Basic information on the study sites*

| | Site | Management regime | Area (Ha) | Number of inhabitants | MPA's creation date |
|---|---|---|---|---|---|
| Monographic case study : Antongil Bay, Madagascar | Village 1 | LMMA | Approx 100 | 1000 | 2009 |
| | Village 2 | LMMA | Approx 100 | 500 | 2009 |
| | Village 3 | Traditional | Nil | 200 | Nil |
| | Village 4 | Marine Park | Approx 1000 | 400 | 2005 |
| | Village 5 | Traditional | Nil | 300 | Nil |
| Comparative case study 1 | Bunaken National Park, Indonesia | Co-management among national government, local governments, community, tourism operators and academia | 89000 | 39000 | 1992 |
| Comparative case study 2 | Apo Island, Philippines | Co-management between the national government and the community | 74 | 700 | 1987 |

### 4.1.2 - Counterfactual comparison

To determine the effect of MPA on human nutrition, we need to compare an MPA site with a non-MPA site with similar characteristics. To choose the best treated and control villages, I will considered severall characteristics.
With regard to the choice of the control village, we have the choice between the two traditionally-managed villages. Village 5 is different from the other villages in terms of the species caught and marine habitat, which makes it a weak candidate for control site. On the other hand, village 2 is similar to the other villages in term of species caught and habitat. For this reason, I chose village 2 as the control site for this study.
As the the treated village, I decided to choose the village number 3 for a number of reasons. First, village 3 is one of the most similar with village 2 in term of species caught. Second, the fish auto-consumption values between village 3 and 2 are similar. Third, the ratio "number of fishermen to number of inhabitants" is almost equal in these villages. Lastly, the two villages have the same characteristics in term of isolation from the rest of the bay.

# 4.2 - Data collection

## 4.2.1 - Monographic case study

### 4.2.1.1 - Quantitative data

The quantitative data used for the primary case study have been collected during the MAHERY (Madagascar Health and Environmental Research) - Antongil cohort study which was set up in September 2015 and included 28 months of surveillance (cf. Golden et al., 2019 for more information). More precisely, I used data from the survey/ interview part of the study which included dietary intake, direct household food observation, socio-economic status, and catch-per-unit effort fishing. In view of the aim of this study, namely studying the impact of MPAs on human nutrition, we decided to work only with data related demersal and reef associated species. Indeed, we made the assumption that the MPAs in Antongil Bay are more likely to have an impact on the fisheries related to demersal and reef associated species instead of pelagic species. This choice has been made in the light of the scientific literature which suggests that MPA performance is highest for the least mobile species (Sergei S. Pilyugin et al., 2010 ; Claudet et al., 2010) which rely on narrower habitats.

To assess how change in income affect food purchase, I used information from the U.S. Departement of Agriculture (cf. Muhammad et al., 2011). This study uses the marginal shares method to measure how an additional dollar of income in is allocated across eight food subgroups. These data are coming from the national Madagascar level. Hence, they are not village specific.

The auto-consumption of "other-products" (i.e. consumption by the fishers or farmers of their own productions) are coming from an internal data of Harvard T.H Chan School of Public Health (Golden Lab). The conversion from product consumption (fish and the eight food subgroups above mentioned) in kilograms to nutrient intakes has been made thanks to internal data from the Harvard T.H Chan School of Public Health (Golden Lab). This database contain nutritional coefficient which permit to convert one hundred grams of fish or one hundred grams of the eight food subgroups above mentioned into different nutrient intakes such as proteins, Polyinsaturated fatty acids or Calcium. Due to the different species composition among villages, this database is village specific with regard to nutrient intakes attributed to fish consumption. Finally, the fish edible portions have been estimated based on the ufish database from FAO.

### 4.2.1.2 - Qualitative data

Regarding the qualitative data used in the monographic case study, we used data from an undergraduate thesis that examined governance regimes of fishing villages in the Antongil Bay (Devereaux, 2018). This thesis was made on the basis of a field survey that was performed during summer 2017. The survey was implemented in the five villages of the monographic case study. The principles behind the survey were also discussed with a number of experts with experience working on Madagascar's small-scale fisheries, including Dr. Christopher Golden (Assistant professor, Harvard School of Public Health), Dr. Josh Cinner (Australian Research Council's Centre of Excellence for Coral Reef Studies, James Cook University), Dr. Edward Allison (Professor, University of Washington College of the Environment) Dr. Michele Barnes (Research fellow, James Cook University), and a high-level representative of Madagascar's Ministry of Fisheries and Marine Resources.

## 4.2.2 - Comparative case studies

The qualitative data used in the comparative case studies were obtained from a literature review. My approach was to focus primarily on the qualitative data. I did this analysis with the intention of assesing the conceptual framework in other contexts and provide a better understanding of the mechanisms behinf the ToC.

# 4.3 - Analytical methods

## 4.3.1 - Management assesment

Based on the work of Devereaux, 2018, I gave marks for each criteria in each village by using the evaluation grid above detailed. Due to the qualitative dimension of the data, I tried to give marks without being influenced by the management regimes occuring in each village. However, my work still entail a subjective dimension.

## 4.3.2 - From US dollars to fish edible portion

To convert incomes earned from fish sale, tourism and development aid, I used the following equation to convert US dollars to fish edible portion, based on the US Department of Agriculture (Muhammad et al., 2011).

*EQUATION 1:*

$$Fish\ edible\ portions = Fish\ marginal\ share * Fish\ price^{-1} * Fish\ edible\ portion\ coefficient * Income$$

$With\ Fish\ edible\ portion\ coefficient\ without\ unit$
$With\ Fish\ Price\ in\ US\ dollars * kg^{-1}$
$With\ Income\ in\ US\ dollars * average\ household^{-1} * day^{-1}$
$With\ Fish\ edible\ portions\ in\ kg * average\ household^{-1} * day^{-1}$
$With\ Fish\ marginal\ share\ without\ unit. In\ Madagascar, one\ dollar\ is\ allocated\ as\ follow.$

*Tab 3: Marginal shares used, coming from the US Department of Agriculture (Muhammad et al., 2011). For instance, for one dollar, a mean malagasy people will use US$0,023244 to buy fish.*

| | Fish | Meats | Cereals | Dairy | Oils & fats | Vegetables | Beverages | Other foods |
|---|---|---|---|---|---|---|---|---|
| Marginal shares | 0,023244 | 0,0644815 | 0,08493 | 0,036207 | 0,016986 | 0,073755 | 0,063474 | 0,083142 |

### 4.3.3 - From catch to fish edible portion

To estimate the fish available for consumption, I used the following equation to convert catch to fish edible portion.

**Fishers households**

*EQUATION 2:*

$$\begin{aligned} &Fish\ edible\ portions\ FH \\ &= [[Catch * Auto\ consumption\ rate] + [(Catch - Catch * Auto\ consumption\ rate) \\ &* Fish\ Price^{-1} * Fish\ marginal\ share * Fish\ Price]] \\ &* Fish\ edible\ portion\ coefficient \end{aligned}$$

$With\ Fish\ edible\ portions\ FH\ in\ kg * fishers\ household^{-1} *\ day^{-1}$
$With\ Catch\ in\ kg * fisher\ household^{-1} * day^{-1}$
$With\ Fish\ marginal\ share\ without\ unit$
$With\ Fish\ edible\ portion\ coefficient\ without\ unit$
$With\ Auto\ consumption\ rate\ in\ percents$
$With\ fish\ price\ in\ US\ dollars *\ kg^{-1}$

**Other household**

*EQUATION 3:*

$$\begin{aligned} &Fish\ edible\ portion\ OH \\ &= \big(Catch \\ &- (Fish\ edible\ portion\ FH * Fish\ edible\ portion\ coefficient^{-1} \\ &* Number\ of\ fishers\ households)\big) * Number\ of\ other\ households^{-1} \end{aligned}$$

$With\ Fish\ edible\ portion\ OH\ in\ kg\ * other\ household^{-1} *\ day^{-1}$
$With\ Fish\ edible\ portions\ FH\ in\ kg\ * fisher\ household^{-1} *\ day^{-1}\ (see\ equation\ 2)$
$With\ Catch\ in\ kg * fisher\ household^{-1} * day^{-1}$
$With\ Fish\ edible\ portion\ coefficient\ without\ unit$
$With\ Number\ of\ other\ households\ in\ inhabitants$
$With\ Number\ of\ fishers\ households\ in\ inhabitants$

**Mean household**

*EQUATION 4:*

To calculate the fish edible portion for a mean household, I used the weighted arithmetic mean defined as follow.

$$Weighted\ arithmetic\ mean = \sum_{i=1}^{n} a_i m_i * [\sum_{i=1}^{n} a_i]^{-1}$$

$With\ a = \{a_1, \dots, a_n\}\ representing\ the\ weights$
$With\ m = \{m_1, \dots, m_n\}\ representing\ the\ data$

## 4.3.4 - From fish edible portions to key nutrient intakes

I used the following equation to convert fish edible portions to key nutrient intakes.

*EQUATION 5:*

$$Nutrient\ intakes = Fish\ edible\ portion * Fish\ edible\ portion\ coefficient^{-1} * Nutritional\ coefficient$$

$With\ nutrient\ intakes\ in\ gr\ or\ kg$
$With\ Fish\ edible\ portion\ in\ kg\ * fishers\ household^{-1} * day^{-1}\ or\ kg\ * other\ household^{-1} * day^{-1}$
$With\ Fish\ edible\ portion\ coefficient\ without\ unit$
$With\ nutritional\ coefficient\ in\ gr * kg^{-1}\ or\ mg * kg^{-1}$

## 4.3.5 - From non seafood auto consumption to key nutrient intakes

To convert the consumption by the fishers or farmers of their own productions (auto consumption of the eight subgroups above mentioned) to key nutrient intakes, I used the amount eaten of the eight food subgroups (per capita per day in each village) in the following equation.

*EQUATION 6:*

$$Nutrient\ intakes = Auto\ consumption\ of\ other\ products * Nutritional\ coefficient$$

$With\ Nutrient\ intakes\ in\ mg\ * fishers\ household^{-1} * day^{-1}\ or\ gr * fishers\ household^{-1} * day^{-1}\ or\ mg\ * other\ household^{-1} * day^{-1}\ or\ gr * other\ household^{-1} * day^{-1}$
$With\ Auto\ consumption\ of\ other\ products\ in\ kg\ * fishers\ household^{-1} * day^{-1}\ or\ kg * other\ household^{-1} * day^{-1}$
$With\ nutritional\ coefficient\ in\ gr * kg^{-1}\ or\ mg * kg^{-1}$

### 4.3.6 - Seafood contribution on total nutrient intakes

I used the following equations to calculate the contribution of each key nutrient on the total intakes of these nutrients.

**Fishers households**

*EQUATION 7:*

$$Contribution = 100 * nutrient\ intakes\ from\ fish\ edible\ portions * (nutrient\ intakes\ from\ fish\ edible\ portions + nutrient\ intakes\ due\ to\ global\ incomes - nutrient\ intakes\ due\ to\ fish\ related\ incomes + nutrient\ intakes\ due\ to\ non\ seafood\ auto\ consumption)^{-1}$$

$With\ nutrient\ intakes\ from\ fish\ edible\ portions\ in\ gr * fishers\ households^{-1} * day^{-1}\ or\ kg * fishers\ households^{-1} * day^{-1}\ (see\ equation\ 5)$
$With\ nutrient\ intakes\ due\ to\ global\ incomes\ in\ gr * fishers\ households^{-1} * day^{-1}\ or\ kg * fishers\ households^{-1} * day^{-1}\ (see\ equation\ 1\ \&\ 5)$
$With\ nutrient\ intakes\ due\ to\ fish\ related\ incomes\ in\ gr * fishers\ households^{-1} * day^{-1}\ or\ kg * fishers\ households^{-1} * day^{-1}\ (see\ equation\ 1\ \&\ 5)$
$With\ nutrient\ intakes\ due\ to\ non\ seafood\ auto\ consumption\ in\ gr * fishers\ households^{-1} * day^{-1}\ or\ kg * fishers\ households^{-1} * day^{-1}\ (see\ equation\ 6)$

**Other household**

*EQUATION 8*

$$Contribution = 100 * nutrient\ intakes\ from\ fish\ edible\ portions * (nutrient\ intakes\ from\ fish\ edible\ portions + nutrient\ intakes\ due\ to\ global\ incomes + nutrient\ intakes\ due\ to\ non\ seafood\ auto\ consumption)^{-1}$$

$With\ nutrient\ intakes\ from\ fish\ edible\ portions\ in\ gr * fishers\ households^{-1} * day^{-1}\ or\ kg * fishers\ households^{-1} * day^{-1}\ (see\ equation\ 5)$
$With\ nutrient\ intakes\ due\ to\ global\ incomes\ in\ gr * fishers\ households^{-1} * day^{-1}\ or\ kg * fishers\ households^{-1} * day^{-1}\ (see\ equation\ 1\ \&\ 5)$
$With\ nutrient\ intakes\ due\ to\ non\ seafood\ auto\ consumption\ in\ gr * fishers\ households^{-1} * day^{-1}\ or\ kg * fishers\ households^{-1} * day^{-1}\ (see\ equation\ 6)$

**Mean household / Mean per household type**

I decided to take the mean values (weighted arithmetic means) to represent the seafood contribution on total nutrient intakes for an average household in each village. In the view of implementing MPAs to address malnutrition, I think it's relevant to know, in average, what are the MPA's impact on average households in the Antongil Bay.

### 4.3.7 - Statistical analyses

Statistical processing of the data from the MAHERY (Madagascar Health and Environmental Research) - Antongil cohort study is detailed below. I mainly focused on four variables : catch, catch per unit effort (CPUE), fish auto-consumption (i.e. consumption by the fishers households of their own production), and fish price.

**CATCH:**

- The confidence intervals (ci.mean r fucntion with parameters by default) show that we have statistically different groups.

**CPUE:**

- The following global linear model with log transformation has been chosen : log(cpue) ~ year + month + village + gear + fish_type + year*village + year*gear + year*fish_type + month*fish_type + village*fish_type + year*village*fish_type. This particular interactions among factors have been chosen after a thoroughly assesment of the factorial design. Moreover, regarding AIC criteria, this model was the best. I had to use a log transfromation because linear models without transformation did not verify the normality of the residuals basic condition.
- A non parametric Anova (pairwise.wilcox.test r function) and 95% confidence interval (ci.mean r function with parameters by default) show that we have the same 3 distinctive groups as in the catch variable analysis. It was not possible to use parametric anova because homogeinity of variances was not verified.

**FISH AUTO-CONSUMPTION:**

- A non parametric Anova (pairwise.wilcox.test r function) and 95% confidence interval (ci.mean r function with parameters by default) show that we have 2 statistically different groups. It was not possible to use parametric anova because homogeinity of variances was not verified.
- In my view, it did not make any sense to create global it is not relevant to figure out if variables such as "gear" have a significant impact on the "auto-consuption" variable.

**FISH PRICE:**

- I made the choice to use weighted arithmetic means defined in the equation 4 since it's important to take into consideration the volume of species landed to calculate a mean price. Here, the data m are the fish prices, while the weights a are the production of each fish in the villages.

# 5 - Monographic case study: Antongil bay in Madagascar

## 5.1 - Management assessment

As mentioned above, I created a unique evaluation grid made up of diferent criterias to evaluate management capacity in each village. I categorized the assessment in three distinctive categories: institutional aspects, local adoption characteristics and operational aspects. For each criteria and village, I gave a mark ranging from 0 to 10 by following the process explained in Table 1.

Please find below the results followed by explanations on particular points which I consider relevant to highlight.

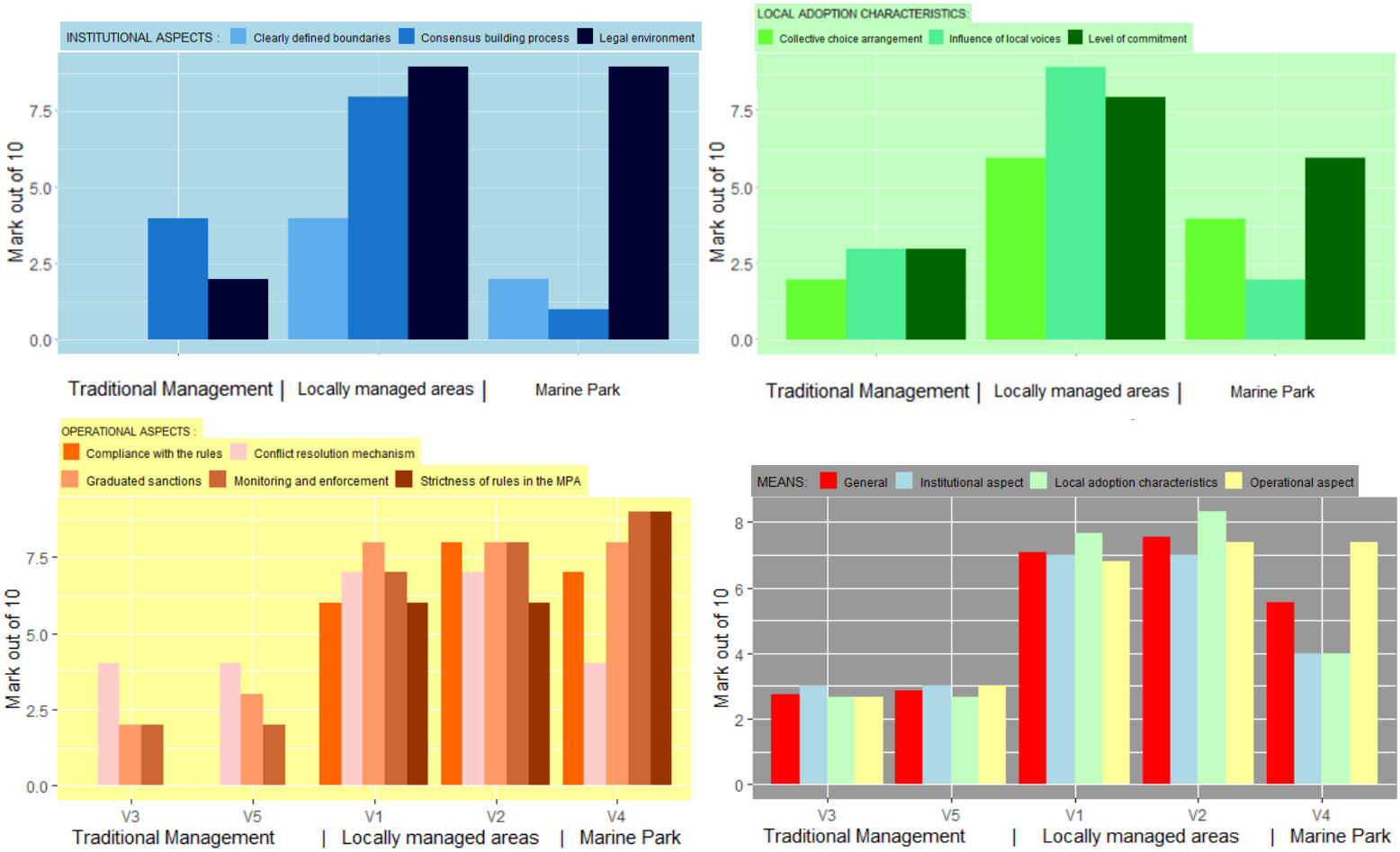



*Figure 5 : Results of the management assesment using the evaluation grid. Marks are ranging from 0 to 10. On the top of the figure, the distinction between villages managed in the same way has not been made due to their similarities.*

### 5.1.1 - Institutional aspects

- ***Consensus building process criteria***

In villages traditionally managed, The Wildlife Conservation Society (WCS) has communicated some rules set out in the government's "Plan d'amenagement" (drafted by the governement in a consensus building process with the local populations). However, this is done in an unclear way. Indeed, the villagers have the feeling that their views have not been taken into consideration about the process of implementing the rules: WCS is randomly coming in the villages to communicate in an ambiguous way. For example, locals are told that they "should not" beach seine and "should" try to stop others from beach seining. This explains the fact that those villages not score very well for this criteria.

In LMMAs, the process of establishing an MPA begins with a public consultation, in which WCS officials (Wildlife conservation society, an NGO deeply involved in environmental management in the Antongil bay) meet with local leaders to discuss the reasons behind implementing certain rules (Rakotonirina and Regis 2017 in Sabrina undergrad…). Then, villagers are consulted before the establishment of any new rule. All this explain the good scores of the LMMAs regarding this criteria.

In the marine park, the rules currently implemented in Marofototra were based on ecological assessments and interviews with stakeholders from other villages in the region (Odendaal, Kroese, and Jaomanana 1995 in Sabrina). This goes against the literature on MPA success, and that's why the marine park has a bad mark in term of "consensus building process".

- ***Legal environment criteria***

In traditionally managed villages, the rules governing the local fishery are those traditionally established among villagers. These traditionally-managed villages still officially fall under the purview of Madagascar's Ministry of Fisheries. Although national fisheries regulations legally apply, the government simply does not possess the capacity to enforce its laws (Mcclanahan et al. 2014 in Sabrina). In this way, traditionally-managed villages in Antongil Bay exist in a political gray area: governed by laws that are not enforced.

An important milestone in term of legal environment in LMMA is the decree number 37.069/2014 "Plan d'Amenagement Concerte des Pecheries de la Baie d'Antongil", which was enacted in 2014 (MIDI Madagasikara 2015 in Sabrina). Indeed, the decree actively encourages the expansion of LMMAs by giving them legal legitimacy. Moreover, the MIHARI (Madagascar Locally Managed Marine Area) network was established in June 2012 with the aim to improve communication between LMMA communities in Madagascar. Finally, we can say that there has been a great step forward in the last decade regarding the legal environment in the LMMAs.

Many rules in the marine park are inspired by federal laws, communicated by NGOs or local officials and then incorporated into local policy. For Marofototra, the Marine National Park and the national Ministry of Fisheries coordinate everything that has to do with fisheries. The legal environment in the Marine Park is strong and reflects well the the top down process whereby the park was created.

### 5.1.2 - Local adoption characteristics

- ***Level of commitment criteria***

In the two traditional villages, fishers are theoretically involved in fisheries management through fisher associations, however, it still remains ineffective. Fishers remain part of the associations only through one reason: they have the impression that a rule would be implemented preventing non-members from fishing in local waters. This commitment regime related to the fear does not permit to move forward in term of fisheries management. That's why the traditional management villages do not have a good mark for this criteria.

In the LMMAs, it is likely that fishermen are involved in the management since WCS did pedagogical work during the consensus building process. Fishers have the feeling that they have a key role to play in the fisheries management. That's the way they are commited and this situation deserve a good mark for this criteria.

In the marine park, environmental benefits are sometimes cited by fishers as reasons for their support in fisheries management. Several fishermen in Marofototra noted that they supported management in order to preserve the resource for future generations, or to maintain catch for the near future. This is the way they are commited and this way deserve a less good mark compared to the commitment regime in the LMMAs.

- ***Collective choice arrangement criteria***

In traditionally managed villages, there are gear restrictions imposed by the federal government that are not respected by local fishers because it does not correspond with their reality. Hence, it seems that villagers are not involved in modifying operational rules.

Of the fishermen surveyed in both LMMAs, nearly 60% viewed themselves as active participants in fisheries management. The WCS official assigned to both Maintimbato and Rantohely makes the link between policy-makers and locals. He is well acquainted with local fishermen, speaks the local dialect, and spends much of his time in the villages. All of these factors increase the perception that local opinion influences management decisions.

In the marine park, an MNP official noted that the institution's actions are often conflated with government actions by local villagers, and that "in general, people around the reserve think that MNP is managing the entire region" (Rakotovao Andrianarivo 2017). Of the fishermen surveyed, the majority (55%) stated that they do not support local fisheries management. This lack of support, and the top down process occuring in management of the MPA does not incentivize people to modify the operational rules.

### 5.1.3 - Operational aspect

- ***Monitoring and enforcement criteria***

In traditionally managed villages, The CSP (Centre de Surveillance des Pêches) was established in 2006, and has the power to act as the region's fishery patrol center, with authority over any infraction of the government's rules. However, in 2009 the person in charge of the CSP passed away suddenly and was never replaced. Yet, apart from sporadic gear confiscations, there has been no consistent efforts to enforce communicated rules.

WCS helps to establish Control and Surveillance Committees (CCS) in each of their LMMAs. These committees consist of local volunteers who are trained and equipped to carry out surveillance and enforcement missions in local waters (Clausen 2016 in Sabrina).

The Marine National Park possess some of the most robust monitoring and enforcement policies in the region. Two MNP officials are permanently posted in in the village close to the marine park. These officials theoretically patrol ten days per month (Rakotovao Andrianarivo, 2017 in Devereaux, 2018).

### 5.1.3.1 - Tourism impact

The results related to the tourism causal pathway of the ToC are quick to describe and comment. In fact, as you can see on the figure 6 below, the MPA's creation has an effect on tourism only in the village number four, which is the Marine National Park.

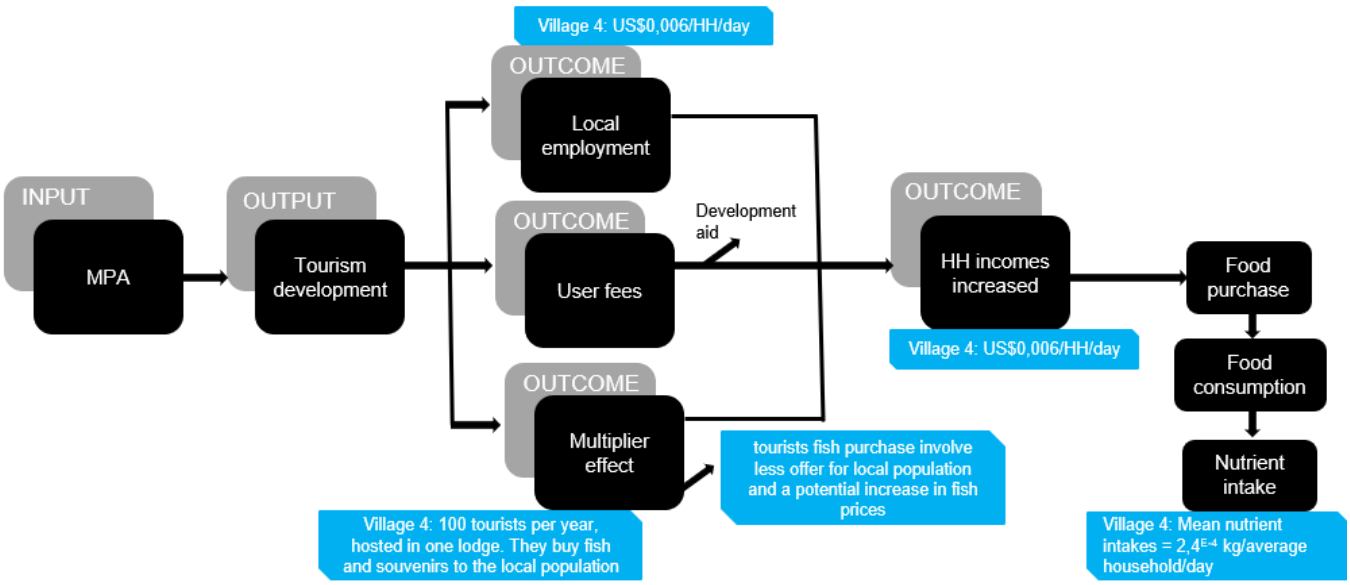



*Figure 6: Results of the tourism causal pathway in the case of the Antongil Bay.*

In spite of the fact that this causal pathway is only related to the village number four, there are key points to remember:
First, there is clearly an effect on tourism due to the fact that the village 4 is close to the marine park. Based on interviews with tourism professionals on the ground, it's the label "marine park" which attracts tourists. However, the number of tourists per year is weak (one hundred) and it was not possible to quantify their average spending. The interesting insight is that tourists are trading with locals, which could trigger two effects. On the negative side, the supply in fish for locals can decrease because fish is being consumed by tourists. On the positive side, tourists buy souvenirs and fish to the locals, which could be seen as a benefit for locals earnings.
Second, the presence of the Marine National Park involve the creation of local employment for villagers as staff in the lodge. Nevertheless, with only three employees from the village number four, this employment still remain anecdotal.

Finally, the impact of the MPA on nutrient intakes through this causal pathway is very low. The conversion of US$0,006/HH/day into nutrient intakes give a mean nutrient intakes result of only $2,4^{E-4}$ gr/HH/day.

### 5.1.3.2 - Development aid impact

By taking a look at the figure below, we understand that as in the last causal pathway seen above, the MPA's creation has an effect on development aid only in the village number four, which is the Marine National Park.

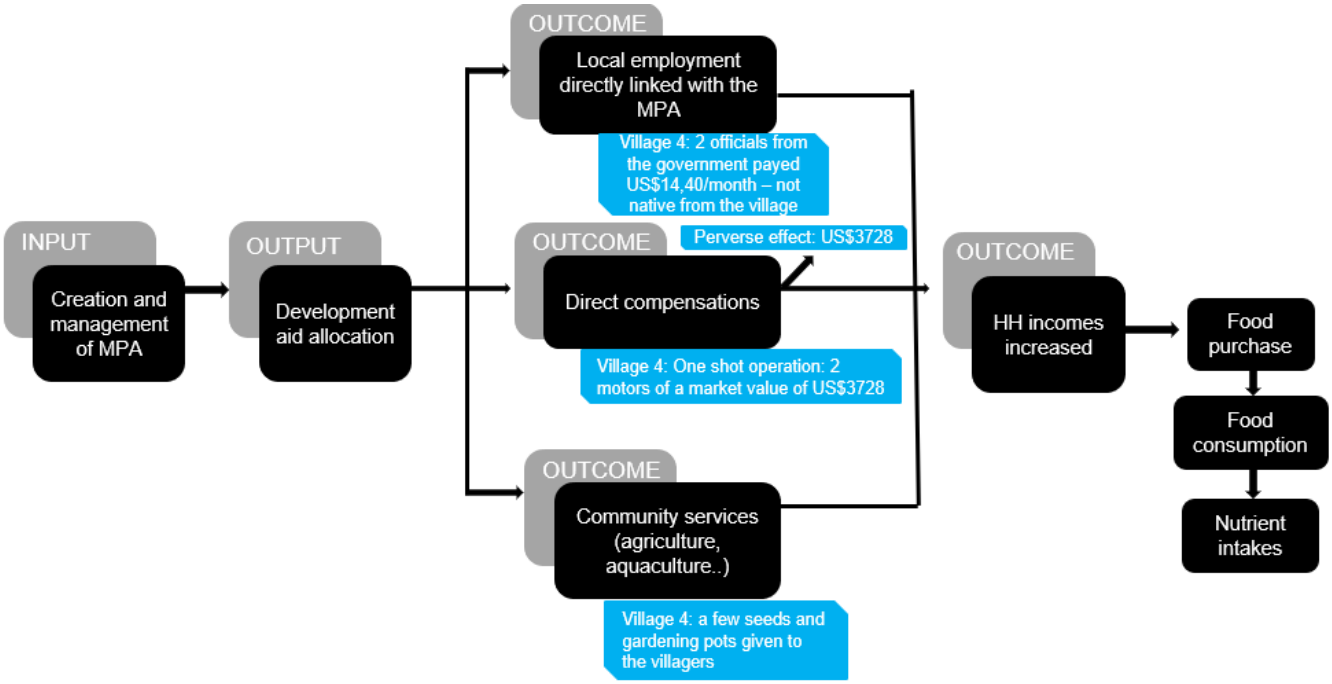
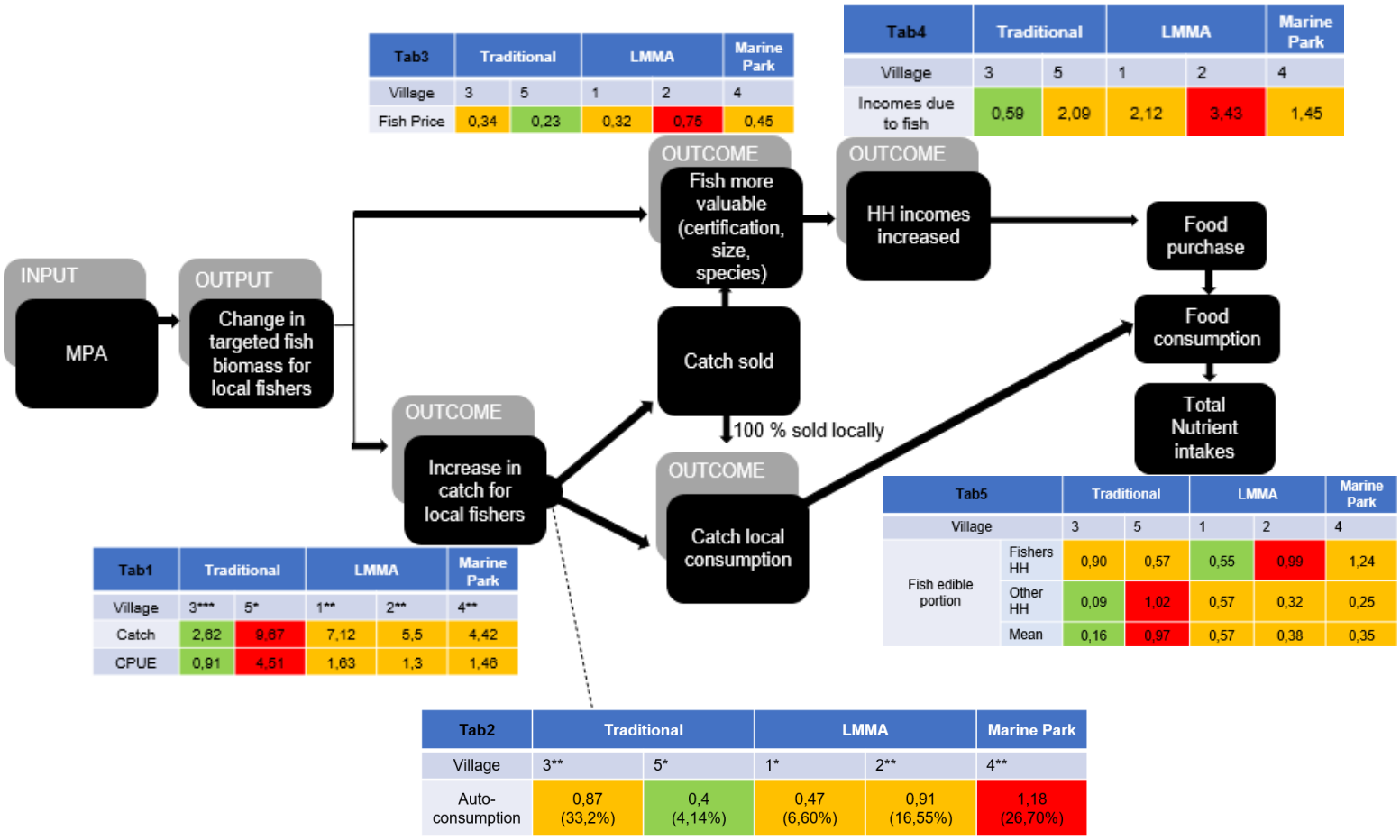



*Figure 7: Results of the development aid causal pathway in the case of the Antongil Bay.*

Unfortunately, the local employement created directly linked with the Marine park comes with 2 official people well payed, but not coming from the village. Hence, I decided to not make the conversion of this additional money into nutrient intakes for the local people.
Unfortunately again, the only direct compensation came in the form of two motors of a market value of 3728$. I consider that this kind of direct compensation falls under the so called "perverse effect": giving motors increase the fishing effort, which is contrary to the objectives of MPAs and contrary to the sustainable management of fisheries.
In term of community services, beyond the seeds and gardening pots given to the villagers, an important infrastructure project was the construction of a local dam. The dam was meant to collect irrigation water, making rice agriculture easier and more productive. Although promised in compensation for establishing the Tampolo marine reserve, no channel was ever constructed to carry the water from the dam to the village where it could be used for agriculture.
Therefore, in my view, this causal pathway does not have any impact on the nutrient intakes of the local population, or at least a very marginal impact compared to the following causal pathway about fish catch which comes next.

### 5.1.3.3 - Fisheries catch impact

Last but not least, the fisheries catch causal pathway is the most interesting not only because contributes the most to nutrient intakes in the five villages studied, but also because it's possible to study precisely the mechanisms which link an increase in targeted fish biomass for local fishers to a change in nutrient intakes. Find below the results of this causal pathway, presented in the fo rm of one global figure followed by detailed explanations.




| Tab3 | Traditional | | LMMA | | Marine Park |
|---|---|---|---|---|---|
| Village | 3 | 5 | 1 | 2 | 4 |
| Fish Price | 0,34 | 0,23 | 0,32 | 0,75 | 0,45 |

| Tab4 | Traditional | | LMMA | | Marine Park |
|---|---|---|---|---|---|
| Village | 3 | 5 | 1 | 2 | 4 |
| Incomes due to fish | 0,59 | 2,09 | 2,12 | 3,43 | 1,45 |

| Tab1 | Traditional | | LMMA | | Marine Park |
|---|---|---|---|---|---|
| Village | 3*** | 5* | 1** | 2** | 4** |
| Catch | 2,62 | 9,67 | 7,12 | 5,5 | 4,42 |
| CPUE | 0,91 | 4,51 | 1,63 | 1,3 | 1,46 |

| Tab5 | | Traditional | | LMMA | | Marine Park |
|---|---|---|---|---|---|---|
| Village | | 3 | 5 | 1 | 2 | 4 |
| Fish edible portion | Fishers HH | 0,90 | 0,57 | 0,55 | 0,99 | 1,24 |
| | Other HH | 0,09 | 1,02 | 0,57 | 0,32 | 0,25 |
| | Mean | 0,16 | 0,97 | 0,57 | 0,38 | 0,35 |

| Tab2 | Traditional | | LMMA | | Marine Park |
|---|---|---|---|---|---|
| Village | 3** | 5* | 1* | 2** | 4** |
| Auto-consumption | 0,87 (33,2%) | 0,4 (4,14%) | 0,47 (6,60%) | 0,91 (16,55%) | 1,18 (26,70%) |

*Figure 8: Results of the fish catch causal pathway in the case of the Antongil Bay. In TAB 1 and TAB 2, the stars represents the significative differences among villages or groups of villages (e.g. in the TAB 1, we have 3 significantly different groups : village three ; villages one, two and four ; village five. In all the TAB, the red boxes contain the greatest values, the green boxes represent the poorest values while the orange boxes represent the other values. In TAB 1, catch unit is kg/fisher/day ; CPUE unit is kg/fisher/hour. In TAB 2, auto-consumption correspond to the quantity of fish caught by fishers eaten by fishers themselves. Auto-consumption unit is kg/fishers households/day.The percentages represent the auto consumption part of the total catch. TAB 3 represents the fish prices in USD/kg. TAB 4 represents the incomes due to fish in USD/fishers/day. TAB 5 represents the fish edible portions in kg/households/day.*

TAB 1 contains the mean catch per village in kg/fisher/day and the mean CPUE per village in kg/fisher/hour. There are three groups significantly different for both catch and CPUE values: villages three (poorest values), villages one two and four (average values), and village fice (greatest values). Traditionally managed village five has the greatest values because the species caught in this village are unique. Contrary to the other villages, village five is characterized by landing a massive amount of shrimps. In this village, there are two shrimp species in the top five species caught. Having said that, it is important to underline that there is a correlation between the greatest values of both catch and CPUE and the fact that the villages have scored well in term of fisheries management. It is important to note that I cannot conclude from this analysis if there is a causal relationship or not.

After being caught, fish are sold locally (100% of catch sold are sold within the village) or auto-consumed (consumption by fishers household of their own catch). TAB 2 shows the amount of the catch which are auto-consumed in kg/fishers household/day and as the percentage of catch. Here, there are two groups significantly different : villages one and five have the poorest values while villages two, three and four have the greatest values.

TAB 3 contains the mean fish price/ kg in dollars in each village. The worst fish price occurs in village 5, which is probably due to the amount of shrimp caught there. The other fish price are similar, except in village 2 which catch a large volume of rare and expensive species.

On the top right corner of the page, TAB 4 shows income due to fish in dollars/ fisher/day. The 2nd village stand out from the others due to higher fish prices as I already pointed out. On the contrary, village three has a weak value due to the combination of the small amount of catch, the great amount of catch for auto-consumption and low fish price.

Lastly, the TAB 5 on the bottom right corner contains the fish edible portions in grams/ habitants/ day. In the case of fishers households, the values are both coming from fish bought thanks to income from fish sale and from autoconsumption. In the case of the other households, the values are coming from the rest of the fish avaible in each village. Indeed, almost 100% of fish are sold locally in the villages.
In all villages, the differences in the allocations between households types are due to the amount of catch auto-consumed. Mean vaules on TAB 5 represent the fish edible portions corresponding to an average household (fishers and non-fishers). It turns out that the villages are ranked similar to catch values. Indeed, due to the fact that the majority of fish caught in a village is consumed within the village (all the catch are sold locally or auto-consumed), the correlation between the greatest values in catch and the good marks in term of management can be extended to the fish edible portions in the villages.
Concerning fishers households, it's important to stress the fact that increase in incomes does not contribute equally than the local consumption of catch in fish edible portions. The mean contribution in fish edible portions of the increased in incomes range from 4% to 30%, depending on villages.

#### 5.1.3.4 - Counterfactual comparison

In order to assess the relationship between MPAs and human nutrition, we need to follow the counterfactual methodology with the perspective of identify a causal relationship. Thus, we must compare the outcomes in a village having benefitted from MPA creation (village three) with a similar village in all respects to the treatment group (village two). This comparison will be done by using the entry points where rigorous assessments in the ToC can be conducted.

Given that the tourism and develoment aid causal pathway do not have any impact on human nutrition for villages two and three, we can focus on the fish catch causal pathway. This is the most easily understandable causal pathway since its impacts on human nutrition are the most direct.

TAB 4 from figure 8 showed statistically significant differences between villages two and three in term of fish catch and fish edible portions. Thanks to the figure below, we can dive deeper and focus on specific nutrients. I made the choice to focus on ten key nutrients which are abundant in fish species and key for adequate human body function.

*Tab 4 : Nutrient intakes related to the fish catch causal pathway in grams (nutrients followed by one star) or milligrams (nutrients followed by two stars). I used weighted arithmetic mean to calculate the mean values, where the data are the nutrient intakes corresponding to fishers households and other household, while the weights are the number of fishers or non fishers people in each village. Please note that nutrient intakes for fishers households are both coming from products bought thanks to incomes due to fish and from fish autoconsumption.*

| | | | Key nutrients | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Management regime | Village | | Protein * | Polyinsaturated fatty acids * | K ** | Ca ** | P ** | Na ** | Fe ** | Zn ** | Vitamin C ** | Vitamin B6 ** |
| Traditional | 3 | Fishers HH | 191,97 | 6,7 | 137,2 | 3,74 | 184,63 | 1857,65 | 2974,9 | 555,01 | 5,09 | 5,22 |
| | | Other HH | 19,74 | 0,66 | 10,8 | 0,36 | 9,6 | 187,2 | 274,2 | 47,4 | 0,36 | 0,48 |
| | | Mean | **32,66** | **1,11** | **20,28** | **0,61** | **22,73** | **312,48** | **476,75** | **85,47** | **0,71** | **0,84** |
| LMMA | 2 | Fishers HH | 259,8 | 10,26 | 417,19 | 8,25 | 634,63 | 1407,04 | 3796,64 | 1115,28 | 13,62 | 7,8 |
| | | Other HH | 72,4 | 2,4 | 68 | 2 | 28 | 276 | 488 | 156 | 1,2 | 1,2 |
| | | Mean | **88,52** | **3,08** | **98,03** | **2,54** | **80,17** | **373,27** | **772,54** | **238,50** | **2,27** | **1,77** |

Mean values on Tab 4 clearly shows a clear difference in key nutrient intakes due to the fish catch causal pathway between villages two and three. Village two has always greatest values. Furthermore, for both villages, nutrient intakes is greater for fishers households.
It is important to underline the fact that mean differences between the two villages are not the same for each nutrient. Indeed, species composition in each village and the number of fishers households and other households can play a key role in the nutrient intakes values.
In addition, contribution of fish auto-consumption side of the fish catch causal pathway is predominant. This means that, regarding these key nutrient, local people are much more relying on fish consumption than other products that can be bought thanks to the money earned by fish selling.

Based on the above mentioned reasons, we are confident to say that there is a causal relationship between fisheries management on one side and catch, fish edible portions, and key nutrient intakes on the other side.

### 5.1.3.5 - What role fisheries hold in overall nutrient intake ?

Beyond the fact that fish and nutrients related to fish are more available in MPA's villages, it is interesting to investigate to what extent these nutrients are predominant in overall nutrient intake. The figure below shows the percent contribution of fish in overall nutrient intake, considering all other food types. The global nutrient intakes gather the nutritional values linked to the food bought by local thanks to their incomes, and the consumption by the fishers or farmers of their own productions. For instance, in village 3, fishers households are relying on seafood for about 37% of their total protein intake. The Tab below clearly shows that seafood play a key role in terms of nutrient intake, especially for proteins, polyinsaturated fatty acids and vitamin B6.
In all the cases, role of fisheries in global nutrient intakes is higher or comparable in fishers households than in other households. This is due to the fact that fishers households eat more fish than other households.

*Tab 5: Percent contribution of fish in global nutrient intakes. The mean values on the right are classic arithmetic means. I used weighted arithmetic mean to calculate the mean values for each village, where the data are the percentages corresponding to fish*

| Management regime | Village | | Key nutrients | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Protein | Polyinsaturated fatty acids | Vit C | Vit B6 | Ca | P | K | Na | Fe | Zn | Mean |
| Traditional | 3 | Fishers HH | 37,20 | 19,89 | 3,96 | 16,01 | 2,32 | 24,80 | 8,38 | 8,37 | 3,27 | 10,17 | **13,44** |
| | | Other HH | 5,49 | 2,38 | 0,41 | 1,83 | 0,23 | 3,15 | 0,91 | 0,88 | 0,33 | 1,11 | **1,67** |
| | | Mean | 7,87 | 3,69 | 0,68 | 2,90 | 0,39 | 4,78 | 1,47 | 1,44 | 0,55 | 1,79 | **2,55** |
| | 5 | Fishers HH | 37,95 | 13,26 | 2,45 | 9,19 | 27,09 | 18,07 | 3,74 | 18,72 | 9,58 | 14,63 | **15,47** |
| | | Other HH | 50,59 | 20,42 | 4,09 | 14,48 | 37,97 | 27,07 | 6,20 | 27,65 | 15,16 | 22,39 | **22,60** |
| | | Mean | 49,01 | 19,52 | 3,89 | 13,82 | 36,61 | 25,94 | 5,89 | 26,54 | 14,46 | 21,42 | **21,71** |
| LMMA | 1 | Fishers HH | 28,48 | 14,19 | 4,54 | 16,26 | 1,26 | 8,18 | 2,90 | 5,22 | 2,02 | 4,93 | **8,80** |
| | | Other HH | 27,41 | 13,57 | 4,40 | 15,53 | 1,17 | 7,84 | 2,81 | 4,91 | 1,94 | 4,72 | **8,43** |
| | | Mean | 27,52 | 13,63 | 4,42 | 15,60 | 1,18 | 7,87 | 2,82 | 4,94 | 1,95 | 4,74 | **8,47** |
| | 2 | Fishers HH | 41,70 | 22,90 | 7,87 | 25,87 | 2,23 | 13,80 | 5,09 | 9,01 | 3,58 | 8,53 | **14,06** |
| | | Other HH | 17,35 | 8,02 | 2,50 | 9,27 | 0,65 | 4,52 | 1,59 | 2,79 | 1,09 | 2,68 | **5,05** |
| | | Mean | 19,44 | 9,30 | 2,96 | 10,69 | 0,79 | 5,32 | 1,89 | 3,32 | 1,30 | 3,19 | **5,82** |
| Marine Park | 4 | Fishers HH | 47,21 | 27,09 | 9,65 | 30,37 | 2,78 | 16,68 | 6,28 | 11,01 | 4,44 | 10,44 | **16,59** |
| | | Other HH | 14,88 | 6,78 | 2,07 | 7,85 | 0,55 | 3,78 | 1,31 | 2,35 | 0,91 | 2,24 | **4,27** |
| | | Mean | 18,12 | 8,81 | 2,83 | 10,10 | 0,77 | 5,07 | 1,81 | 3,21 | 1,26 | 3,06 | **5,50** |
| MEAN | | | **25,35** | **12,01** | **3,66** | **13,03** | **4,07** | **8,20** | **2,63** | **6,04** | **2,72** | **5,44** | |

# 6 - Comparative case study 1 : Apo Island

Apo Island is a small island surrounded by coral reefs located in the central part of the Philippines. Apo Island is 74 hectares in area with approximately 700 residents. Fishing followed by tourism are the primary livelihoods (Maypa et al., 2002). A "no take" marine reserve 400 m long lies along the south-eastern portion of the island. It occupies ~10% of the coral-reef area (Russ and Alcala 1999). This reserve has been protected since 1982 and Apo Island is known for its strict implementation of reserve regulations (Russ and Alcala 1999 in J.H Van Beukering, 2015). Apo Island has been extensively studied over the past 20 years.

MANAGEMENT

The MPA was formally established in 1986 and given national protection in 1994. (J.H Van Beukering, 2015). Before 1998, the community-based phase of management was seen by many as highly successful, with Apo becoming one of the first MPAs to demonstrate spillover of fish biomass to adjoining fishing areas (E.J Hind et al., 2010). A milestone in the MPA's history was the establishment of PAMB (Protected Area Management Board) in 1998, which was the start of a centralised coastal resource management system. Apo is now co-managed by a board made up of key stakeholders including the national government and elected community members, the island leaders, and the mayor of the local municipality of Dauin.

Overall, there is strong support for the MPA at Apo Island, which primarily due to the recognition of the importance of preserving marine resources for the future and the benefits the MPA generates (J.H Van Beukering, 2015). However, there is still some debate within the community concerning the management of the protected area. On one hand, some say that the PAMB is neutral and fear that those who control the island's economic and political aspects would dominate the decision-making process if management were transferred back to the community.

On the other hand, others say that there is a need to restore an element of local stakeholder participation in the governance of Apo's MPA (E.J Hind et al., 2010).

In addition, women are very active in the MPA's management. They recognize well the importance of the MPA and they want to be heard concerning its management. Moreover, since 2006, there were also women trained as dive rangers (J.H Van Beukering, 2015).

TOURISM

The MPA has created new livelihoods mostly related to tourism. There are now two resorts on the island, bed-and-breakfasts, t-shirt vendors, fishing boat charters, dive masters, and guards for the MPA. Tourism generates more income than fishing for the island, and about half the island households have some work in the island's tourist trade. Tourist numbers are limited to 15 divers a day "per area", and each tourist pays the equivalent of US$7.60 a day. The national government keeps 25% of the entrance fees and returns 75% to the community but often more than a year after the revenue was collected (J.H Van Beukering, 2015). Several articles mention that fishing communities such as Apo Island can benefit from community-based MPA management through tourism. However, it is important to note that tourism in Apo Island occurs in a sustainable way. However, the community of Apo Island has some complaints about the management of their MPA by the national government due to the above mentioned delay in return of the user fees related revenues to the local government and to the community. (Cabral and Geronimo, 2018).

Thanks to tourism, many women are now doing alternative income generating activities instead of doing the traditional mat weaving, which did not generate suficient income. For instance, when a tourist boat arrives, they lined up on the shore displaying their products such as shirts and souvenirs (J.H Van Beukering, 2015).

DEVELOPMENT AID

While conservation is the main concern of PAMB, some alternative livelihood programs have been implemented, such as mangrove plantation along the coast, and the construction of fish ponds. Unfortunately, there have been no economic benefits and most of them have been withdrawn. The island has also received assistance from foreign non-governmental organizations to establish and grow a bakery. Through development aid, the marine sanctuary has changed the role of women considerably. Indeed, there was an attempt to keep the mat weavers tradition by improving the quality of mats produced through a development project (J.H Van Beukering, 2015).

FISH CATCH

Although a boom in diving tourism has been recorder in Apo Island, fishing is still the main livelihood for most families. About 90% of community members are engaged in fishing. Even the families who are now engaging in other livelihoods still fish occasionally. (J.H Van Beukering, 2015).
Indeed, since the establishment of the MPA, an increase in fish abundance and density was generated within the no-take portion of the MPA and the fish "spilled over" to the surrounding waters where traditional fishing is allowed. This MPA represent one of the best evidence that reserves can benefit fisheries by spillover (Garcia et al., 2013 ; J.H Van Beukering, 2015 ; Russ et al., 2015)

HUMAN NUTRITION

The people of Apo Island know the importance of the MPA in providing food and livelihoods. Even though there is no clear evidence of change in fish consumption, it is interesting to note that the MPA community indicated that their "preference for fish has changed". Thus, the net financial benefit from the MPA in 2000 was US$90,000 or about US$720 for each of Apo's 125 households. (J.H Van Beukering, 2015).

# 7 - Comparative case study 2 : Bunaken

Located at the northern tip of Sulawesi Island in central Indonesia, BNP (Bunaken National Park) was established in 1991. The total area of the park is 89,065 hectares including five islands, where 22 villages are inhabited by approximately 30,000 residents (Erdmann et al., 2003). Fishing and farming were the traditional livelihoods in the area (J.H Van Beukering, 2015), which is home to some of the best coral reef diving in the world. Located less than 10km from the provincial capital of Manado, BNP is serviced by an international airport.

MANAGEMENT

Bunaken is collaboratively managed by the national government and an advisory board. The board is made up of the key stakeholders and has 19 members representing national, provincial and city governments, local communities, private-sector tourism operators, and academics. Collaborative management has been adopted as a strategy that includes participatory zonation revision process, the implementation of an innovative entrance fee system for sustainable conservation financing but also a joint ranger-villager patrol system (J.H Van Beukering, 2015).
However, fishery laws are still poorly implemented partly due to lack of participation among stakeholders. Hence, willingness to comply with these laws is still low (Flora P. Kalalo, 2017).
Two primary factors behind the management failures have been a problematic zonation system and an increasingly fractious relationship between the park management authority and the local government (Ir. M. Arief Toengkagie, undated).

TOURISM

Since the park became famous, there are about 25 land-based dive operators, and a wide range of accommodations which welcome approximately 25,000 guests/year, with domestic tourists outnumbering international guests. (Erdmann et al., 2003 ; Ir. M. Arief Toengkagie, undated).

To ensure local people benefit from the tourism, thirty percent of the park entrance fees are earmarked for community development activities, and tourism operators in the area must hire at least 80 percent of their staff from the local community. (J.H Van Beukering, 2015).

Nearly 1100 jobs have been created by the tourism industry in and around Bunaken National Park, with percentage of the workforce employed due to tourism which can reach 83% in villages most impacted by tourism. The total economic impact of dive tourism on the local economy

Is $220,000,000 with an annual adjusted running cost impact of $30,000,000. Consequently, it seems that dive-based tourism is a viable means of financing alternative employment in the Bunaken National Park (Tyler Davis, 2005). However, criticisms on tourism in Bunaken comes mainly in two distinctive forms. First, tourism activities have not been oriented for environmental conservation, which can become problematic in the long run. (Adrian Pangemanan et al., 2012 ; Diane Tangian et al., 2015). Second, local city government claim rights to a larger

percentage of the entrance fee revenues by complaining in local newspapers. (Erdmann et al., 2003). In fact, some stakeholders do not feel that economic benefits are equitably shared, which is a fundamental condition for long-term success of MPAs (Pollnac et al. 2001, 2003; Pomeroy et al. 2003 in Erdmann et al., 2003 and Patrick Christie, 2004.).

Despite this problem, a key factor in the global success of the MPA entrance fee system related to tourism has been the continuous engagement with all levels of the tourism sector to obtain feedback and adapt the system to any perceived shortcomings. Indeed, a clear requirement from the community has been the need of full transparency regarding the use of entrance fee money (Erdmann et al., 2003).

DEVELOPMENT AID

As a national park, the park receives an annual operating budget that averages US$100,000 per year. This is enough to pay for the 40 people working in the park office, but also for the office operational costs and at most one waterborne patrol per month (Erdmann et al., 2003).

In order to diversify and maintain an income stream, the BNP has been working to develop a range of additional funding mechanisms to cover the inherent budgetary variations from the entrance fee system. These efforts can take diferent forms. First, dive operators have sponsored a wide range of programs. For instance, a handicrafts program provides village men and women with significant extra income from sale of reef-friendly handicrafts. Second, through partneships between the BNP and NGOs, an international volunteers systems can place volunteers from all over the world, making them a hugely valuable asset to park management. Besides their individual expertise and ability to carry out important management functions (an important cost savings for the park), these volunteers have also proven invaluable in their assistance with preparing international grant proposals to support park programs. This brings us to the third point : grants from national and international donors can provide an extremely important source of additional funding for one-time equipment, workshops cost, and other non-routine expenditures. The advisory board has only begun to develop this part of its funding portfolio, but has already been quite successful in attracting grants from WWF, International Coral Reef Action Network, and USAID (Erdmann et al., 2003).

FISH CATCH

The biggest criticism about MPAs is their potential negative impact on fishing activities. Indeed, the park zoning has not been completely implemented, and enforcement of the zones that are agreed has not been entirely effective. Moreover, fishers have lower incomes than people working on tourism. Hence, many people in the area who moved into tourism used to work as fishers. There is, in general, a perception that there are plenty of fish to catch for subsistence and for sale, particularly to tourist resorts and restaurants. Under the zoning system, there is a zone close to the communities where harvesting is permitted, there, fishers reported a rise in fish availability due to the spillover impact of the no-take zones (J.H Van Beukering, 2015).

HUMAN NUTRITION

Tourism households are probably more dependent on cash for subsistence than fisher households because fishers tipically get some of their food from their catch. Many locals state that they consume the same or less fish compared to five years ago. Even fishers themselves consume less fish than they use to. Indeed, the price for fish has risen. Moreover, a cultural phenomenon happened : the wealthier a family becomes, the more they consume chicken and red meat instead of fish. Much of the increase in local incomes has come from greater opportunities for employment in the tourism sector and from farmers and fishers selling their harvests to the tourism sector (J.H Van Beukering, 2015).

# 8 - Case studies comparison and policy recommendations at national/ regional level

## 8.1 - Case studies comparison

Please find in the next page a table summarizing the lessons learned for both monographic and comparative case studies.

| Case study location | Management | Tourism | Development aid | Fish catch | Nutrition |
|---|---|---|---|---|---|
| **Antongil Bay** | Three types of management in this region: 1) traditional; 2) locally managed marine areas (LMMAs); and 3) marine national parks (MNP). When local voices are recognized, such as in LMMAs, it appears that better outcomes are achieved at lower costs in term of rules compliance. | Marine national parks attract tourists. Trade between locals and tourists can trigger two effects. On the negative side, the supply in fish for locals can decrease available seafood is diverted to tourists. On the positive side, tourists can increase local incomes, leading to livelihood benefits. This pathway is of little importance in this region. | Employment directly linked with the MPA may not directly benefit local people. Direct compensation of improved gear may have perverse effects, leading to increasing fishing effort. This pathway is of little importance in this region. | Fisheries management leads to changes in fish catch, and changes in fish catch lead to changes in consumption rates and nutrition. This pathway is of primary importance in this region. | Managing fisheries can address malnutrition, particularly in fishers' households who eat their own catch. This impact is explained mainly through the fish catch causal pathway. |
| **Bunaken** | Collaborative management creates an array of stakeholders. Unfortunately, it seems that fisheries management is challenged by an increasingly fractious relationship between the park management authority and the local government. | Transportation infrastructure facilitates mass tourism, which benefits local people through park entrance fees and job creation. However, tourism activities have not been designed sustainably, which can lead to future failure of this pathway. | To cover the inherent variations from the entrance fee system, the park has developed a range of additional financing resources. Competent people are necessary to develop these additional fundings. | As sustainable tourism was not a focus, fisheries management was also not well designed. There are fewer fishers, and these fishers have lower incomes than people working in tourism. | The majority of local people (even fishers) consume less fish than they reported historically. This is due to two causes: 1) reductions in the available fish stock from inadequate management; and 2) diverted seafood sales to tourists. There is no evidence of increased income leading to improved nutrition. |
| **Apo Island** | Community-based MPA governance, where co-management is led by a board made up of key stakeholders. Although still the subject of debate, there is strong overall support for the MPA. The presence of a board prevents political leaders from controlling the operation and benefits of the MPA. Women are very active in MPA management, but many still suggest increasing local stakeholder participation in the governance system. | Tourist carrying capacity prevent the island from mass tourism. Nevertheless, the fishing community benefits from community-based MPA management through tourism. With an entrance fee system, tourism has created new jobs and livelihoods, generating more income than fishing. | Very few development projects took place, which led to improvements in the role of women within the community. | This MPA provides robust evidence that protected areas can benefit fisheries by increasing productivity, leading to spillover. Hence, fishing is still the main livelihood for most families. About 90% of community members are engaged in fishing. Even the families who are now engaging in other livelihoods still fish occasionally. | Even though there is no clear evidence of a change in fish consumption, it is interesting to note that the MPA community indicated that their "preference for fish has changed" (less preferred). |

## 8.2 - Discussion and policy recommendations

Using a comparative approach, I will discuss the nuances and complexities of three case study locations, highlighting distinct causal pathways linking MPAs and human nutrition. These causal pathways are: 1) the tourism pathway; 2) the development aid pathway; and 3) the direct consumption of seafood pathway. This discussion will take the form of policy recommendations to address malnutrition, focusing on MPA management and design.

Marine parks attract tourists (monographic and comparative case studies). However, it is difficult to trace the role of the tourism industry in MPAs to indirectly benefit the nutrition of people living adjacent to marine parks. Tourism can be a key strategy in reducing local people's dependence on fish by creating alternative livelihoods and acting as a supplemental source of income (comparative case studies). On the other hand, it turns out that tourism can have negative effects on local communities through different mechanisms. First, when fishers sell their catch to tourists, those seafood-based nutrients are no longer available for local people. Second, tourism activities can have an impact on marine environmental integrity, leading to reductions in diversity and abundance of fish populations. These effects can become more pronounced if tourism becomes overly popular without proper management.

In contrast, sustainable tourism within MPAs can have a positive impact on nutrition. Therefore, I recommend the development of infrastructure to enable sustainable tourism. First, using a user fee system can be efficient to address the problem of park financing (comparative case study 2). Second, given that many conflicts with biological conservation arise as a result of the travel and tourism industry, defining a maximum level of recreational use in term of number of visitors accommodated in the MPA seems to be a good strategy (comparative case study 1). Obviously, the crux of the problem lies in the implementation of these recommendations. This master's thesis does not presume to provide full insights on the matter, but rather outlines strategies to minimize risk of negative impacts. In terms of the implementation of the user fee systems, I would recommend creating a strong legal basis to appropriately distribute the revenue generated from the park. Finally, I would like to underline that reliable and efficient transportation is a pre-requisite to develop tourism in a given region. For instance, in the Antongil Bay, transportation and tourism infrastructure are too weak to attract enough tourists.

Regarding the development aid causal pathway, I recommend employing local people in the MPA office for two reasons. First, the opportunity to increase local people's income can lead to a positive impact on nutrient intake (monographic and comparative case studies). Second, in a broader view, during the first step of the MPA establishment, employing local people is important to gain local support for the presence of the park. Moreover, securing a wide range of financial support is essential to diversify the MPA's funding portofolio because relying on a single source is risky (comparative case study 2). Adequate financing can reduce fishing pressure by diversifying livelihoods through development projects. However, in order to really secure a stream of income, such as grants from national and international donors, it is necessary to rely on people with higher education, which may be difficult to find within local populations.

I would like to place particular emphasis on direct compensation. It is necessary to understand the impact of direct compensation, and ensure that the result of providing payments or raising incomes does not lead to outcomes contrary to the MPAs objectives (monographic case study). For instance, it is counter-productive to implement measures compensating restrictions on fishing effort (compensation of opportunity costs) by increasing the fishing effort (such as donations of gears or motors).

The most direct causal pathway is the impact of increased fisheries catch on human nutrition. Here, a key external factor to take into consideration is the local species' composition (monographic case study). I do believe that the fisheries management side of an MPA should be emphasized. First, managing fisheries is the best way to have a direct impact on human nutrition. Second, in the aim of pushing for sustainable and resilient communities, it is better to use renewable resources from the ocean rather than depend on developed countries through tourism or development aid. However, sustainable management is necessary to maintain these benefits in the long term.

It is also important to note that, particularly in developing countries, any increase in fish catch can have a nutritional impact mainly on fishers' households. Hence, it is likely that any political action in favor of establishing MPAs may have a clear nutritional objective for fishers (monographic and comparative case studies).

Finally, I would advise any policy-maker interested in addressing malnutrition through MPAs management to find the right balance among the three pathways previously identified and described in detail. And, these pathways are not independent and can interact with each other in complex ways. For instance, a limitation of fishing effort may protect coral reef fish stocks. This increase in the health of coral reefs and associated fish may attract tourists. The increasing number of tourists may later affect the corals and related fish stocks. These complex social-ecological feedbacks must be thoroughly understood.

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Titre français : L'impact nutritionnel des aires marines protégées : dépasser l'approche classique « entrée – sortie »

Titre anglais : The nutritional impacts of marine protected area expansion : going beyond an input-output analysis

Résumé: La convention sur la diversité biologique se réunira en 2021 pour réévaluer l'objectif de protection des zones marines en Aires Marines Protégées (AMP). Actuellement, la communauté internationale fait pression pour augmenter la couverture des AMP d'ici 2030. Malheureusement, les analyses systémiques sur la façon dont les AMP peuvent avoir un impact sur la nutrition humaine manquent cruellement. C'est ainsi que le but de ce mémoire est double. Premièrement, il se propose d'expliquer en détails les liens de causalité entre les AMP et la nutrition humaine. Deuxièmement,ce mémoire teste ces liens à travers une étude de cas monographique. Les résultats montrent que la gestion des pêches peut avoir un impact sur les apports nutritionnels. Parallèlement, grâce à des études de cas comparatives, des aperçus sur les nuances et la complexité des liens de causalité sont donnés.

Abstract: The Conference of the Parties to the Convention on Biological Diversity will be meeting in 2021 to re-evaluate the goal of protecting at least 10% of representative and well-connected coastal and marine areas of particular importance to biodiversity. Currently, there is an enormous push from the international community to significantly increase MPA cover by 2030. Unfortunately, nutrition has not been part of the main stream discourse in fisheries management sciences at global levels in the past and there has been little holistic analysis of how MPAs will impact human nutrition of those relying on fish for their nutritional needs. With that in mind, this thesis proposes two key outputs.
First, it explains how three causal pathway can conceptually describe the links between MPAs and human nutrition. Second, this thesis test the conceptual framework through a monographic case study (Antongil Bay, Madagascar). Results show that fisheries management can have an impact on specific nutrient intakes of local communities, mainly on fishers households. Meanwhile, thanks to comparative case studies, insights on nuances and complexities of the pathways are given. Finally, I would advise any policy-maker interested in addressing malnutrition through MPAs management to find the right balance among the three pathways identified.

Mots-clés : Aires marines protégées ; Théories du changement ; Nutrition humaine

Key Words: Marine Protected areas ; Theory of change ; Coastal communities ; Nutrition ; Human well-being

* *Elément qui permet d'enregistrer les notices auteurs dans le catalogue des bibliothèques universitaires*