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IMPACT OF MARINE PROTECTED AREAS ON FISHERS' CATCH PRODUCTIVITY AND INCOME: A PROPENSITY SCORE MATCHING ANALYSIS

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Abstract

Marine Protected Areas or MPAs have been established to protect coastal and marine habitat. This study aims to examine the efficiency of MPAs in the province of Leyte, Philippines. Mann-Whitney U test, a nonparametric analysis, was used to compare fishers both from MPA and non-MPA sites using selected fishing variables. Multiple regression analysis was applied to identify variable/s that significantly influences fish catch and fishing income. Propensity score matching or PSM quantifies the impact of MPAs. Based on the results, in terms of catch, revenue, costs, and travel time to fishing areas MPA sites are significantly higher than non-MPA sites. By regression analysis, only motorized boats showed to significantly increase the catch as well as the income. By PSM, MPA fishing grounds lead to higher fish catch of small-scale fishers which is considered a positive impact of MPA. MPA increases fish catch by 0.3470 kg and income by MPA sites increases their monthly income by PHP 95.44

Key words*: *propensity score matching, impact assessment, marine protected areas

INTRODUCTION

The Philippines is one of the world's centers of marine biodiversity [4]. The Philippine Archipelago consists of around 7,107 islands with a total coastline length of approximately 36,289 kilometers. The territorial sea of the country is more than twice the total land area estimated at about 679,000 km^2 and more than a third of this comprise coastal waters (226,000 km^2).

A marine protected area is a region of land or water that is regulated by law or other practical methods with the goal of preserving biological diversity, the environment, and related cultural resources [6]. It contributes to the restoration and replenishment of resources for social, economic, and cultural enrichment [12]. MPA is essentially a space in the ocean where human activity is more severely monitored than in the surrounding waters. These places are given special protections for natural or historic marine resources by local, state, territorial, native, regional, or national authorities [8].

The marine resources of the Philippines are experiencing the highest level of anthropogenic and climatic threats [10]. A strategy for developing sustainable fisheries is the establishment of "no-take" marine reserves, which totally exclude fishing pressure from important locations such spawning, nursery, feeding, and sheltering habitats. Under these management conditions, targeted fish stocks and the larger communities of which they are a part of are given the opportunity to rebound [3].

Marine Protected Areas (MPAs) have been established to safeguard marine and coastal environments. It is considered as one of the solutions to address the threats afflicting marine life [4]. MPAs can result in fisheries advantages in nearby areas through "spill over" and conservation benefits to fish assemblages within no-take zones. They are a mainstream management tool for conserving biodiversity assisting resource management in all the world's oceans and seas. They are increasingly used to protect threatened habitats [1].

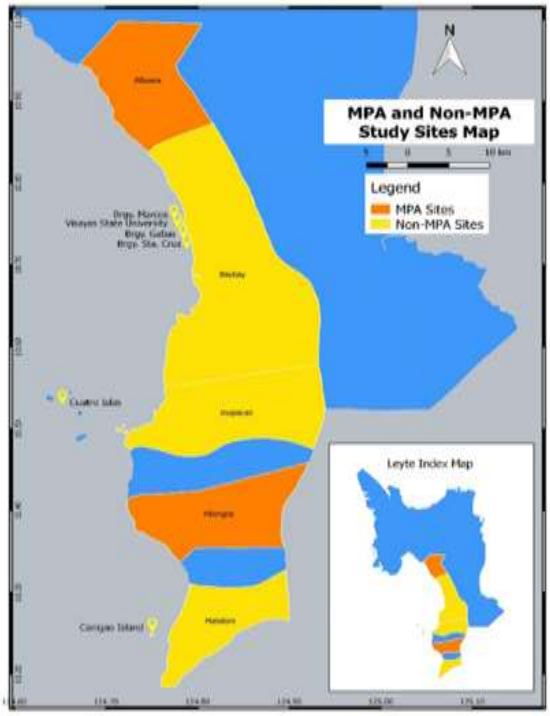
The first marine protected areas were proclaimed early in the 20th century. [9] listed 430 marine protected areas created in 1985 but mostly covering relatively small coastal areas. Many more MPAs were proclaimed in the last two decades of the 20th century. By 1995, there were at least 1,306 sub-tidal MPAs with a median size of 1,584 hectares globally [5]. There have been several MPAs that were created, and the government spent resources in creation of these MPAs. In fact, there are over 1,800 MPAs in the Philippines and they can be categorized into two governance levels, namely: national and local established MPAs [2]. The government invested a significant number of resources in the creation of MPAs thus it is appropriate to subject this to an impact assessment to determine the actual impacts to its beneficiaries, the fishers, whether the project has achieved its desired effects. It plays a key role in ensuring accountability in resource allocation among projects and offering concrete evidence of positive benefits. In assessing the impact of marine protected areas in the province of Leyte, this paper uses PSM or propensity score matching. PSM is a quasi-experimental method in which an artificial control group were constructed through matching each treated unit (MPA) with a non-treated unit (non-MPA) of similar characteristics. Using these matches, the impact of MPAs was estimated.

MATERIALS AND METHODS

Study sites

Leyte Gulf is among the major fishing grounds in the Philippines with a shelf area of 13,147 km^2 covering the islands of Samar and Leyte [11].

This study included fishing grounds that are close to and those that are far from Marine Protected Areas. The localities with fishing grounds near to the Marine Protected Areas (MPAs) include the municipalities of Hilongos and Albuera. On the other hand, the localities with fishing grounds that are far from MPAs include the municipalities of Matalom, Inopacan, and Baybay. The map with the studied sites, MPA and non-MPA is shown on the next column (Map 1).



Map 1. Study sites, MPA and non-MPA
Source: [7].

Data Collection

Structured face-to-face interviews were conducted by trained enumerators in collecting the cross-sectional data. Fisher respondents were selected randomly from each fishing site. The necessary data for the study was obtained using a pre-tested survey questionnaire. The survey instrument consisted of two sections: respondent socio-demographic profile, and selected fishing characteristics. The instrument was translated from English to Cebuano to ensure comprehension of the context of the survey.

Sample Size Determination

The study makes use of a 95% confidence interval, which implies that 95% of the time the sample is certain. Due to the limited information, it was presumed that the proportion is 0.5. A conservative assumption of 6% was applied to the margin of error. The sample size decreases with increasing margin of error and increases with decreasing margin of error. Using the equation below, the estimated sample size for the study areas is computed:

$$n_0 = \frac{Z^2_{\alpha/2}(p)*(1-p)}{e^2}$$

$$n_o = \frac{1.96^2(0.5)*(1-0.5)}{0.06^2} = 266$$

where:
n_o = sample size to be determined
$Z_{\alpha/2}$ = confidence interval (95%)
p = proportion (0.5)
e = margin of error (6%)

Data Analysis

Nonparametric analysis: Mann-Whitney U test compares fishing areas that are close to and far from MPAs. This nonparametric option for the independent samples means comparison test replaces the t-test. The following theories were investigated in order to ascertain the impact of MPA creation utilizing the selected fishing variables:
Ho: No significant difference between fishing grounds distant and nearby of MPAs.
Ha: Fishing grounds that are distant from and near to MPAs vary significantly.

Multiple regression: In identifying the variables that significantly influence catch and fishing income, the multiple regression analysis was applied. The dependent variables were fish catch in kg and fishing revenue in Philippine pesos while the independent variables were fishing variables and selected socio-economic characteristics.
The following model was estimated:

$$Y_i = \beta_0 + \beta_1\ high\_educ_i + \beta_2\ motor\_boat_i + \beta_3\ boat\_own_i + \beta_4 org\_member_i + \beta_5\ fishing\_days_i + \beta_6 MPA_i + u_i$$

where:
$\beta 0$ = y-intercept
u_i = error term
Y_i = dependent variable/s which captures the average fish catch in kilograms and fishing income in Philippine peso;
$high\_educ_i$ = dummy variable representing the highest educational attainment of fisher respondents (1=at least high school education, 0=otherwise);
$motor\_boat_i$ = dummy variable which representing type of boat being used (0= non-motorized boat, 1= motorized boat);
$boat\_own_i$ = dummy variable representing ownership of fishing boat (0=not owned, 1=owned);
org_member_i = dummy variable that captures the membership in a fisher's organization (0=not member, 1=member);
$fishing\_days_i$ = a continuous variable representing the number of fishing days in a week;
MPAi = dummy variable representing fishing grounds nearby marine protected area (1=MPA, 0=non-MPA).

Impact estimation: To estimate the impact, propensity score matching (PSM) was employed to quantify the effect of the marine protected areas since there is no available baseline data, and the assignment of fishers is not randomly taken. Through PSM, the selection bias was reduced by matching similar individuals from the treatment (MPA) and the control group (non-MPA). To match the treated and control group, propensity scores were computed using the respondents' socio-demographic indicators and other fishing variables. These variables were considered to have important relationships and assumed as significant factors in the outcome variables based on the related studies. The propensity score is the probability of a fisher being a part of MPA group, given a similar pre-condition of socio-economic characteristics. Propensity scores were estimated through the probit model:

$$Pi = E(T_i=1|X) = \beta_0 + \beta_1 high\_educi + \beta_2\ motor\_boat_i + \beta_0 boat\_own_i + \beta_0 org\_member_i + \beta_0\ fishing\_days_i + u_i$$

where:
P_i = probability of a fisher being in the treatment group (MPA)
E = the expected value of being part of the treatment group given the indicators
T = 1 if fisher is in the treatment group (MPA) and 0 for control group (non-MPA)
X = is a set of explanatory variables
β_0 = is the intercept
β_1 = the regression coefficients

The explanatory variables include the following:
$high\_educ_i$ = a dummy variable representing at least high school education (1=at least high school, 0=otherwise)

$motor\_boat_i$ = dummy variable which representing type of boat being used (0= non-motorized boat, 1= motorized boat);
$boat\_own_i$ = dummy variable representing ownership of fishing boat (0=not owned, 1=owned);
org_member_i = dummy variable that captures the membership in a fisher's organization (0=not member, 1=member);
fishing_days = number of days fishing in a week
ui = error term

RESULTS AND DISCUSSIONS

For MPA fishers, most of them (61%) owned the boats they use for fishing while more than half (63.8%) of the non-MPA fishers did not own the boats they use. Majority of the fisher-respondents from non-MPA went fishing with other fishers.

Sixty percent of MPA fishers do fishing in the morning. Approximately 50% of fisher-respondents from both sites were not members in any organization for fishers.

The membership of some of the fishers in this kind of organization encourages them to participate in open forums on fisheries management planning in small-scale fishing communities.

Also, those fishers who were members will be oriented on MPA establishment in their community (Table 1).

Table 1. Comparison of MPA and non-MPA

Variables	**Categories**	**Non MPA**		**MPA**	
		Count	%	Count	%
Boat ownership	Owned	83	61.0	53	39.0
	Not owned	47	36.2	83	63.8
Presence of companion	Without	36	40.0	54	60.0
	With	94	53.4	82	46.6
Time in fishing	Morning	25	39.7	38	60.3
	Evening	102	52.6	92	47.4
	Both	4	36.4	7	63.6
Membership in organization	Not member	81	48.5	86	51.5
	Member	49	50	49	50

Source: Author's calculation and analysis (2024).

Non-parametric Analysis: Mann Whitney U Test

The Mann Whitney U Test was used to compare MPA and non-MPA fishing sites based on specific fishing factors. This test employs a non-parametric approach to compare two groups subsequent to the normality assumption test's failure. Based on the results, no statistically significant evidence was found to support the claim that non-MPA fishers fished for longer hours than MPA fishers. Although non-MPA fishers have more fishing companions than MPA fishers (non-MPA= 9, MPA=7), the difference was not significant. This outcome presents itself due to varied fishing methods utilized by fishers.

Some fishing techniques, like *sinsoro*, which was mostly employed in non-MPA areas, called for the participation of multiple fishers. Techniques like *undak*, which were common in MPA fishing areas, only need a small number of people, if any. Consequently, there was no statistical proof that the net revenue of MPA and non-MPA fishers differed from one another. (non-MPA=214.04, MPA=179.13).

The fisher's income was dependent on the type of fish caught and this make sense because different species have their varying prices which in turn, resulted to no significant difference across groups. Furthermore, MPA fishers took longer hours of travel from the shoreline to fishing area but still the number of hours spent depends on the type of fishing method employed (non-MPA=1.11 MPA=1.72) and the disparity was statistically significant.

This implies that MPA fishers will go fishing in distant sites since restricted fishing grounds exist in the surrounding waters in no-take MPAs which cause them to travel longer hours. Furthermore, non-MPA sites awee not constrained with regard to fishing areas so they will not go to far-off fishing grounds just to catch fish. At a closer look, non-MPA fishers spent more days fishing than MPA fishers (non-MPA=6, MPA=5).

Talking about fishing costs, fishers near MPA spent more than non-MPA fishers (MPA=341.90, non-MPA=214.84). This is to confirm that majority of MPA fishers were using fishing methods specifically *undak* that were more costly than using *sinsoro,* which was commonly used method in MPA.

Fishing grounds close to MPAs exhibited statistically higher daily catch than fishing grounds farther from MPAs (MPA= 3.02, non-MPA= 2.69). This situation arose as a result of the fish spillover effect, which increased the productivity of fish catch to nearby fishing grounds and validated the effectiveness of MPA development (Table 2).

Table 2. Mean values between MPA and non-MPA

Variables	Non MPA	MPA	Difference
Average daily catch (kg)	2.69	3.02	0.33***
Average revenue (pesos)	428.8	521.03	92.23***
Average daily fishing cost (pesos)	214.84	341.90	127.06***
Average travel time from shoreline to fishing area (hours)	1.11	1.72	0.61***
Average fishing days in a week	6	5	1**
Average fishing effort (hours)	7	6	1
Number of companions in fishing	9	7	2
Net income	214.04	179.13	34.91

Source: Author's calculation and analysis (2024).
*, **, *** indicates significance at the 90%, 95%, and 99% levels, respectively

Multiple Regression Analysis

The model postulates that the following explanatory variables will affect the dependent variables: education level, number of fishing days, ownership of a boat, involvement in a fishing organization, use of motorized boats, and fishing grounds nearby MPAs. Only the use of motorized boats has the greatest impact on the quantity of fish caught out of all the factors thought to be highly significant.

The use of motorized boats requires the operator to possess skills specific to the type of boats they are using, either motorized or non- motorized boats. When operating a powered boat, either a motorized or non-motorized boat, the operator needs to have skills unique to that kind of boat. The analysis showed that fisher's use of motorized boats had a beneficial effect on the amount of fish caught. Because motorized boats can go beyond the reef and may allow taking catch in comparison to boats not driven by engines, fishers using motorized boats had a 55% greater catch rate than those using non-motorized boats. Conversely, fishers using non-motorized boats may find it more difficult to fish offshore, especially during inclement weather. However, the estimate for other variables such as membership in a fisher's organization, high level of education, fishing days, boat ownership, membership in a fishing group, and fishing grounds close to MPAs didn't affect significantly. This means that there were no actual evidence based on the data gathered showing that the estimate was significantly different from zero (Table 3).

Table 3. Results of multiple regression analysis with fish catch as dependent variable

Variables	Coefficient	Standard Error
MPA	.2677827	.2090137
High education	.1134599	.1337008
Motorized boat	.5452587**	.2424547
Boat ownership	-.3409084	.2388907
Org membership	.1048119	.2120023
Fishing days	.0655962	.055708
Constant	2.139156	.4172719

Source: Author's calculation and analysis (2024).
** indicates significance at the 95% levels

The same is true with the second model having fishing income as dependent variable, the usage of motorized boats appeared to be statistically significant at 10% level (Table 4).

Table 4. Results of multiple regression analysis with fishing income as dependent variable

Variables	Coefficient	Standard Error
MPA	77.94312	37.59263
High education	31.169	24.04705
Motorized boat	83.07398*	43.60723
Boat ownership	-28.06779	42.96622
Org membership	26.424	38.13015
Fishing days	26.424	10.01949
cons	294.5264	75.04937

Source: Author's calculation and analysis (2024)
* indicates significance at the 90 significance levels

Impact on Fish Catch

The impact of marine protected areas on fish catch was estimated through the average treatment effect of the treated (ATT) using the three matching algorithms namely nearest neighbour, radius matching and kernel matching. A comparison of these algorithms checks the robustness of the result.

Table 5 shows that only radius matching, and kernel matching are exhibiting significant impact estimates where the ATT is around 0.35 kg however nearest neighbour matching appeared to be have no significant impact on estimates.

Table 5. Impact estimate of fish catch (kg) using the average treatment effect of the treated (ATT) of three matching algorithms

Fish catch (in kg)	Nearest neighbour	Radius matching	Kernel matching
MPA	3.0406	3.0406	3.0406
Control group (non-MPA)	2.8708	2.6937	2.6938
ATT	0.1698	0.3470*	0.3468*
Bootstrapped SE (100 reps)	0.2745	0.1865	0.2027
Standard error	0.2953	.1425	.2399
Test statistic	0.58	2.43	1.45
Z	0.62	1.86	1.71
P>|z|	0.536	0.063	0.087
Sample size of MPA	130	130	130
Sample size of non-MPA	131	131	131

Source: Author's calculation and analysis (2024).

In this study, the radius matching technique was used to estimate the average treatment effect of the treated. It shows that the ATT is 0.3470 kg which means that MPA has increased the fish catch of fishers from MPA sites, significant at a 1% level.

Thus, the MPA leads to higher fish catch of small-scale fishers which is considered a positive impact of MPA.

Impact on fishing income

For impact estimation of fishing income, the same techniques were applied to check the robustness of the results.

Only the two algorithms exhibit a significant average treatment effect of the treated (ATT) for the income of small-scale fishers. The ATT ranges ranging from PHP 57.62 to PHP 99.85 using different sample sizes of the matched respondents (Table 6).

Using the radius matching technique, the estimated ATT on the monthly income is PHP 95.44 from the matched 261 respondents.

This suggests that the MPA brought a positive impact on the small-scale fishers in terms of income.

There is enough evidence that the monthly income of fishers from MPA sites increases their monthly income by PHP 95.44, significant at 1% level.

Table 6. Impact estimate of income in fishing (in Philippine peso) using the average treatment effect of the treated (ATT) of three matching algorithms

Revenue	Nearest neighbor	Radius matching	Kernel matching
MPA	524.3187	524.3187	524.31870
Control group (non-MPA)	466.6972	428.8808	424.4681
ATT	57.6215	95.4379	99.8506
Bootstrapped SE (100 reps)	49.3097	36.5247	38.9022
Standard error	50.4264	26.8657	42.0313
Test statistic	1.14	3.55	2.38
P>|z|	0.243	0.009	0.010
Sample size of MPA	131	131	131
Sample size of non-MPA	130	130	130

Source: Author's calculation and analysis (2024).

CONCLUSIONS

The study's findings showed that the use of motorized boats increased fisher's income and productivity in catching fish. This outcome suggests assistance from local governments of the municipalities in providing fishers with motorized boats that would help them increase their earnings. Additionally, the promotion of livelihood options for the fishers to augment their income should also be considered since fishers are earning less and are economically poor. Income-generating activities and access to micro-enterprise development track that may provide participants with access to funds and training to set up their own microenterprise. Based on the impact estimates using propensity score matching, marine protected areas showed a positive impact to fishers' catch and income. Hence, according to this study, LGU and other organizations should adopt regulations and provide support for the creation of new MPA sites to increase overall fisheries productivity and enhance the living conditions of fishers. Management policies to preserve and protect new MPA sites should also be implemented for sustainability. There must be institutional coordination in support to MPA establishment since the design, implementation, and monitoring of MPAs require effective institutional structures at local levels of management. Sufficient regulatory funding for monitoring, research, and enforcement must be made available in order to carry out management plans and preserve public support for protected areas.

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