Displacement of fishing effort by Large Scale Marine Protected Areas

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Abstract

Large-scale Marine Protected Areas (LSMPAs) have seen a significant increase over the last years. Fishing effort is effectively eliminated within these protected areas upon implementation. The benefits of reducing effort have been largely studied, and include increases in abundance, biomass, and diversity within the bounded regions. These no-take zones may produce spillover effects, which provide fish for outside areas. However, the economic and ecological implications of displacing fishing effort are not yet fully understood. Novel data products that track fishing effort at the vessel-level allow us to identify changes in fleet- and vessel-level behavior upon the implementation of protected areas, as well as how these redistribute. This papers evaluates the implications of implementing LSMPA, by evaluating changes in fishing hours, showing that vessels in the effected region reduce fishing effort after the implementation of PIPA. Our results are robust to a set of specifications. We also track the relative spatial allocation of fishing events thorugh time, and identify that areas closer to PIPA show an increase in relative fishing hourse due to the displacement of PIPA-fishing vessels. Our results not only provide an impact evaluation of the effect of LSMPAs on fishing activity, but provide insights into vessel redistribution dynamics, which may have ecological and economic implications.

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To do

- [x] Divide pipa vessels by type of boat (longline vs. purse seine)
- [x] Identify two counterfactuals:
  - [x] A: PNA, similar vessel, never fished inside PIPA
  - [ ] ~~B: Taiwan, Never in PNA, Similar region~~
- [x] Change in fishing hours before vs after

- [ ] ~~Change in total hours before vs after~~
- [ ] Change in distance before vs after
- [x] Where do PIPA vessels go?
- [x] Make sure I have full tracks of all mmsis

Introduction

This work identifies the behavioral changes of fishing vessels due to the implementation of PIPA. Not only can we identify temporal changes in fishing patterns (*i.e.* time and distance), but also spatial patterns. Our vessel-level tracks allow us to see where PIPA-fishing vessels go after the closure, providing empirical insights about the redistribution of fishing effort after the implementaion of a MPA.

Methods

This section is divided into two main parts. First, we provide a general description of AIS data and the process of identification of vessel-level events done by Global Fishing Watch [1]. Alongside, we describe the subset of data that we use for these analyses. When relevant, we also point out possible shortcommings in the data, or factors that must be considered in the later analyses. Then we move on to explain our identification strategy, and the main analyses that we undertake.

Data

AIS data

Automatic Identification Systems are on-board devices intended to provide at-sea saftey and prevent ship collisions by broadcasting vessel locations to surrounding vessels. These broadcasted positions can be recorded by satellites and land-based antenas. GFW uses a neural network to infer vessel characteristics and whether each broadcasted position represents a fishing event, thus allowing us to estimate near real-time fishing events globally[1]. The recent addition of satellites that can receive AIS signals causes an apparent increase in the number of broadcasted AIS messages (*i.e.* points) and therefore fishing hours. It is therefore important to be cautious when comparing temporal trends. The variability in AIS data and dynamic ocean conditions require that temporal trends be taken into account. We do that by incorporating a series of controls, which are defined in the following section.

PIPA data

The GFW data contain 233 purse seiners and longliners that have fished within PIPA waters. From these, only 217 did so at least once before 2015, but only 183 continued to fish after 2015[2]. Vessels that fished within PIPA before implementation might stop fishing afterwards, therefore not being observable in the post-treatment period. New vessels might have also entered the fishery after PIPA closure, and were likely not exposed to the policy intervention in the pre-treatment period. Therefore, we define our treatment and control groups as follows. The treatment group contains all vessels that fished within PIPA at least once before the closure, and that continued to fish elsewhere afterwards. The control group has vessels that never fished within PIPA waters, belong to other PNA countries, and have fished in surrounding areas (*i.e.* PNA-countries' EEZ) before and after PIPA closure. Figure 1 provides a visual representation of the vessel-level that make up each of group through time.

Tables 1, 2, and 3 show the number of vessels, number of vessels following a BACI design, and fishing hours, respectively. Tables show data grouped by gear (longlines, purse seines), group (treated, control), and period (before, after). The relative change (After / Before) is also shown. Table 1 shows information for all fishing vessels in the dataset, while Tables 2 and 3 show information for vessels that meet the BACI design (i.e. excludes vessels that only appear at one point in time).

[1] Global Fishing Watch

[2] The 34 missing vessels might have exited the fishery, been decomissioned or sold (therefore chaning their AIS and mmsi), or turned off their AIS transmiters. On either case, we are not able to observe these.

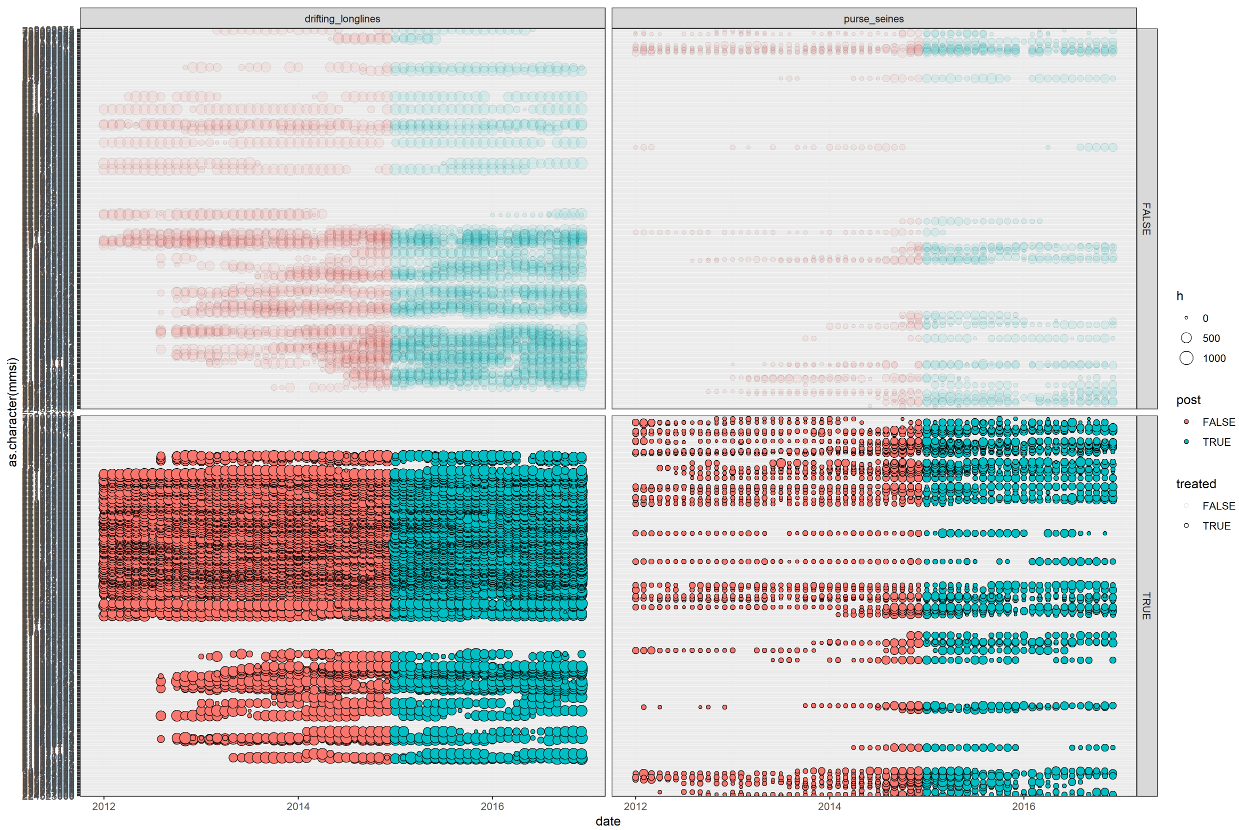

Figure 1: Stream of fishing events by vessels (stacked on the y-axis due to space) through time (x-axis). Each dot represent a vessel-month, with colors indicating the pre and post periods, and pannels separating between gear and treated or control groups.

Table 1: Number of fishing vessels (identified by mmsi) for each gear before and after PIPA implementation.

Gear	Treatment	Before	After	Change (A / B)
drifting_longlines	FALSE	105	218	2.0761905
drifting_longlines	TRUE	139	118	0.8489209
purse_seines	FALSE	49	89	1.8163265
purse_seines	TRUE	78	81	1.0384615

Table 2: Number of fishing vessels (identified by mmsi) for each gear before and after PIPA implementation.

Gear	Treatment	Before	After	Change (A / B)
drifting_longlines	FALSE	88	88	1
drifting_longlines	TRUE	115	115	1
purse_seines	FALSE	38	38	1
purse_seines	TRUE	68	68	1

Table 3: Mean fishing hours for each gear before and after

Gear	Treatment	Before	After	Change (A / B)
drifting_longlines	FALSE	481.42502	473.5823	0.9837094
drifting_longlines	TRUE	548.22580	524.8121	0.9572919
purse_seines	FALSE	66.50483	172.3775	2.5919548
purse_seines	TRUE	56.87322	146.2015	2.5706563

Analysis

The current approach is to estimate what percentage of fishing effort from the PNA was displaced by PIPA and use this to infer something about Palau. While this provides a measure of the displacement, it does not fully address the possibility of costs increasing. I believ we can use individual tracks (as opposed to just the gridded effort) and obtain show how their behavior changed (*i.e.* are they fishing further away, are they fishing more, where are they now?).

Model specifications

Our model specification uses a DiD approach. In this case, we interact the before-after dummy with a treatment dummy. The treatment and control groups follow our definition in the data description. The model takes the form of:

$$H_{ijkl} = \alpha + \beta Post_i \times Treat + \mu_j + \phi_k + \gamma_l + \epsilon_{ijk}$$

Where μ_j, ϕ_k, and γ_l represent month-, year-, and flag-level fixed effects. I use total hours at the vessel-month level.

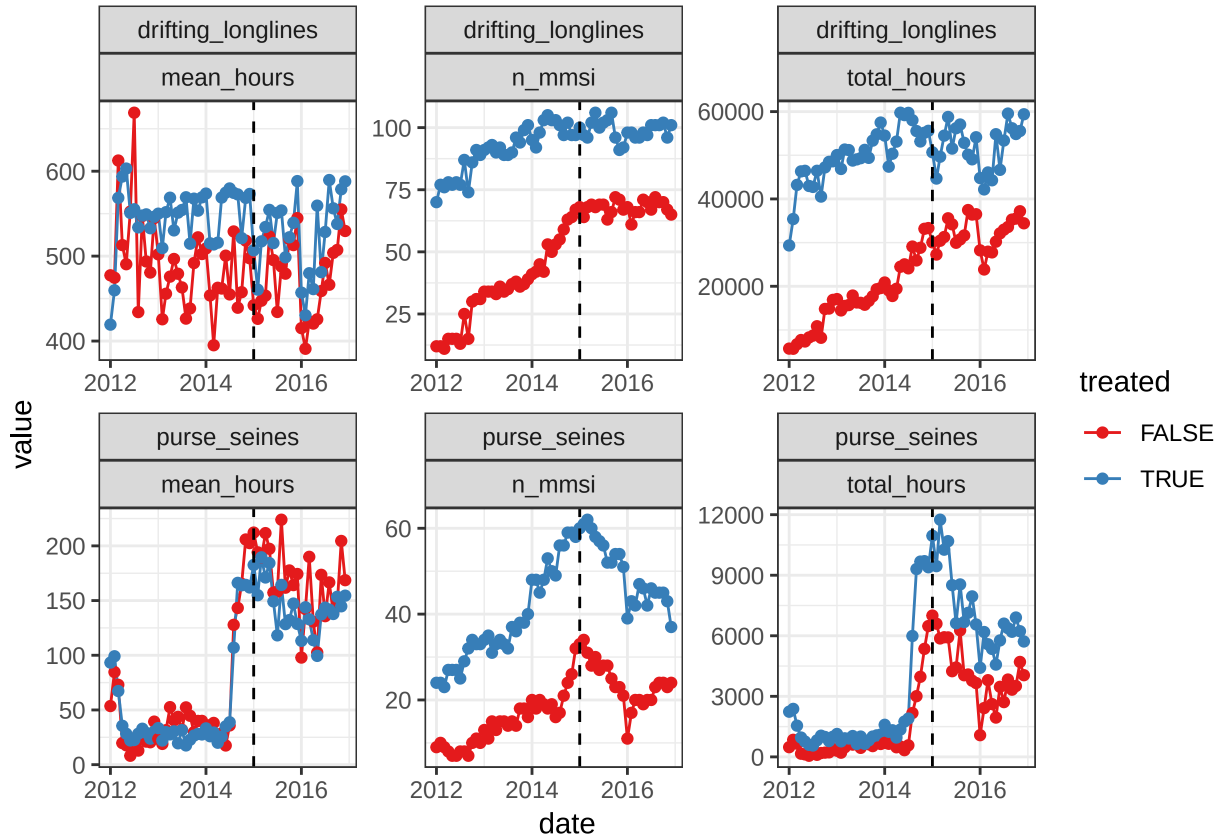

Figure 2: Fishing hours and number of vessels by month for all vessels. Vertical dashed line indicates PIPA closure.

Results

Fig. 2 shows that mean fishing hours for purse seiners have an abrupt increase, just before January 1st, 2015. This trend is observed for both treated and control groups. Longliners, however, show a more stable trend. The number of mmsi codes increases through time. This can largel be explained by the addition of more satellits, which increasedetectability of vessels. As expected total fishing hours follow a similar trend to that of mmsi numbers. Results of the regressions for each gear type are shown in Tables 4 and 5. Column (1) presents the DiD regression with no fixed effects, column (2) includes month fixed effects, column (3) includes month and year fixed effects, and column (4) includes month, year, and flag fixed effects. Figures 3 and 4 represent the same coefficient estimates.

Purse seiners

Table 4: Fishing hours from GFW for purse seiners (n = 106; 38 control, 68 treatment). Asterisks indicate significance levels. Numbers in parenthesis represent heteroskedastic-robuste standard errors.

	Dependent variable:			
	hours			
	(1)	(2)	(3)	(4)
post	105.873***	107.859***	113.466***	102.890***
	(5.532)	(5.364)	(5.887)	(6.076)
treated	−9.632**	−8.924**	−8.334**	−3.076
	(4.257)	(4.023)	(3.725)	(4.540)
post:treated	−16.544**	−16.889***	−17.235***	−11.150*
	(6.481)	(6.358)	(6.126)	(6.162)
Constant	66.505***	61.758***	40.085***	61.569***
	(3.780)	(5.352)	(5.699)	(9.753)
Month FE	No	Yes	Yes	Yes
Year FE	No	No	Yes	Yes
Flag FE	No	No	No	Yes
Observations	3,692	3,692	3,692	3,692
R^2	0.238	0.262	0.312	0.339
Note:			*p<0.1; **p<0.05; ***p<0.01	

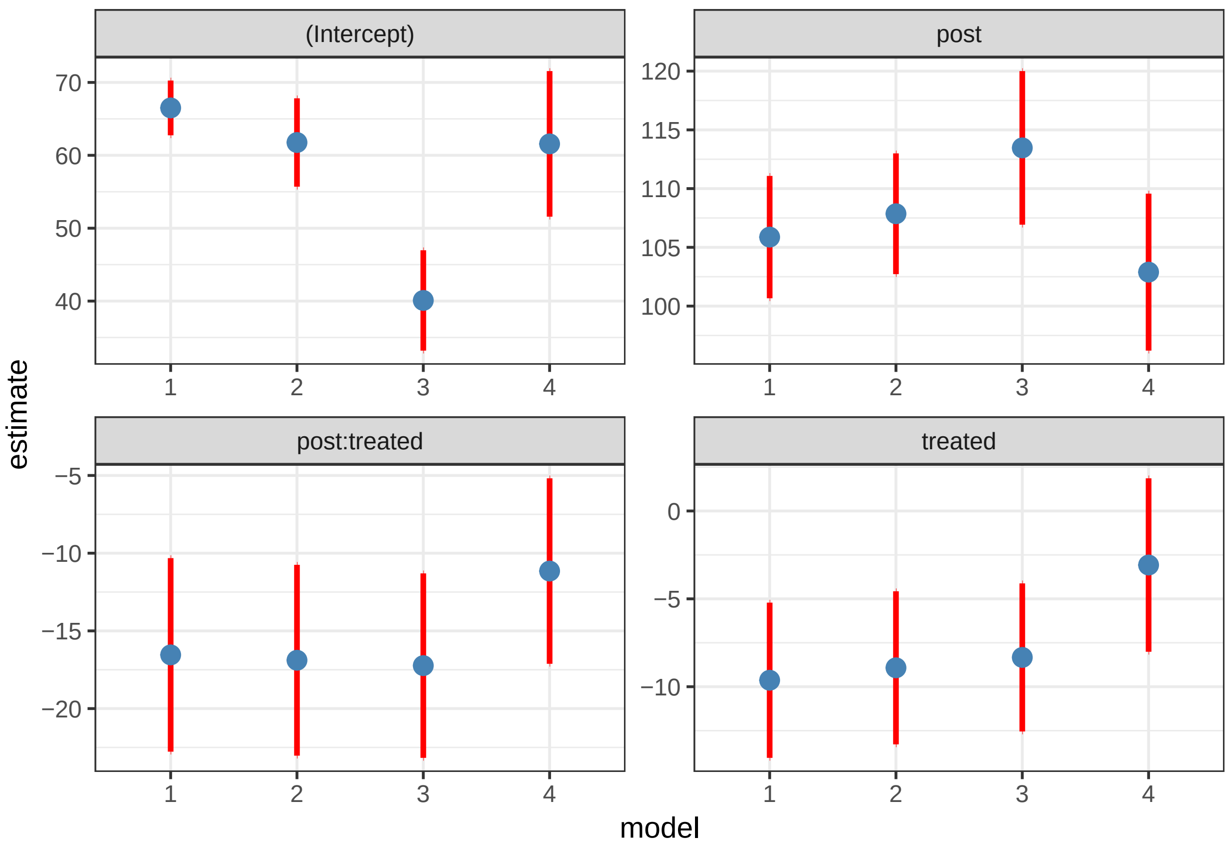

Figure 3: Coefficient estimates for each model. Top pannel indicates variable, x-axis represents model specification, and y-axis coefficient estimate.

Longliners

Table 5: Fishing hours from GFW for longliners (n = 203; 88 control, 115 treatment).. Asterisks indicate significance levels. Numbers in parenthesis represent heteroskedastic-robuste standard errors.

	Dependent variable:			
	hours			
	(1)	(2)	(3)	(4)
post	−7.843	−4.894	−7.580	24.708***
	(7.514)	(7.480)	(9.336)	(9.315)
treated	66.801***	69.434***	69.959***	18.878***
	(6.541)	(6.549)	(6.603)	(7.257)
post:treated	−15.571*	−17.806**	−18.340**	−25.775***
	(8.958)	(8.899)	(8.936)	(8.743)
Constant	481.425***	450.475***	447.866***	430.947***
	(5.733)	(9.239)	(10.280)	(24.476)
Month FE	No	Yes	Yes	Yes
Year FE	No	No	Yes	Yes
Flag FE	No	No	No	Yes
Observations	8,558	8,558	8,558	8,558
R^2	0.026	0.044	0.044	0.107
Note:				*p<0.1; **p<0.05; ***p<0.01

References

1. Kroodsma, D. A., Mayorga, J., Hochberg, T., Miller, N. A., Boerder, K., Ferretti, F., Wilson, A., Bergman, B., White, T. D., Block, B. A., Woods, P., Sullivan, B., Costello, C., and Worm, B. *Science* **359**(6378), 904–908 feb (2018).

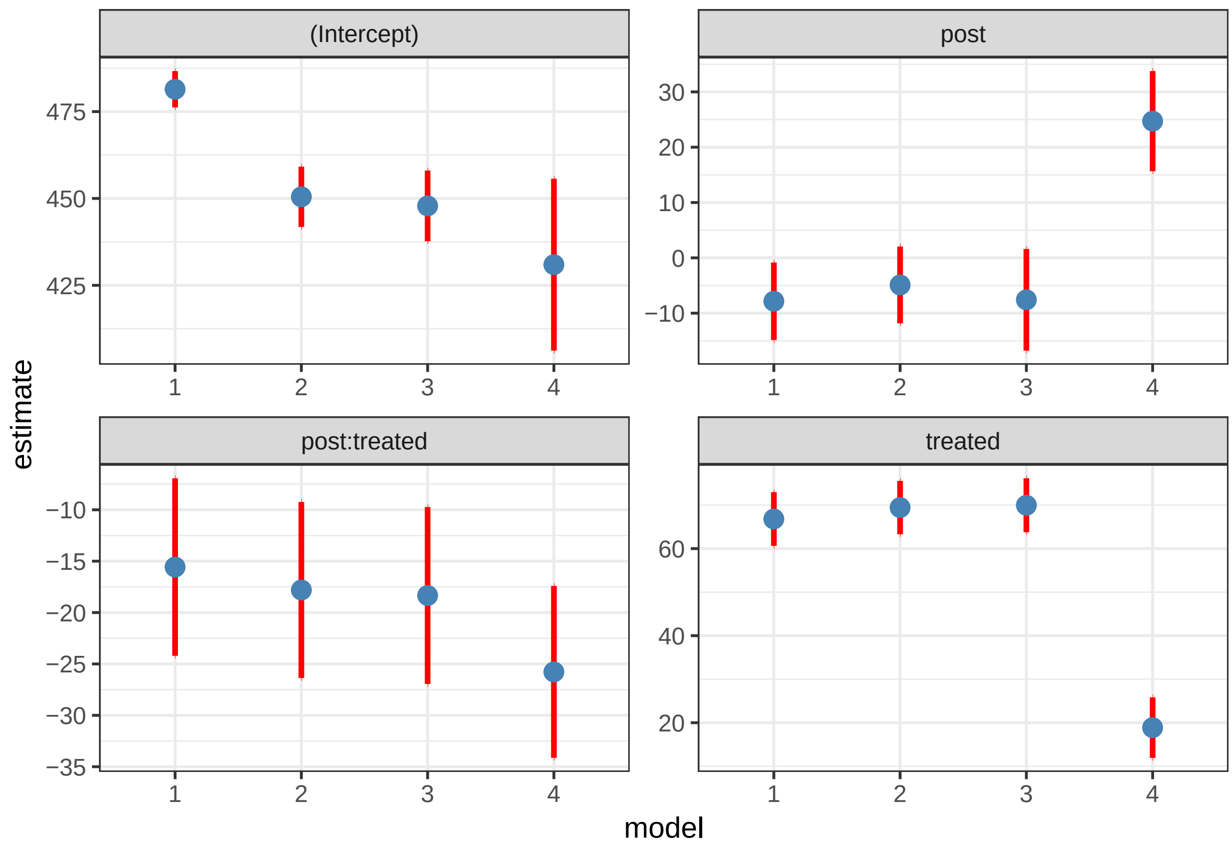

Figure 4: Coefficient estimates for each model. Top pannel indicates variable, x-axis represents model specification, and y-axis coefficient estimate.