Effects of Fishing Activity Reduction in Jardines de la Reina Marine Reserve, Cuba

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ABSTRACT

Several studies compare fisheries among areas under different fishing pressure (from heavily exploited to marine protected areas). However, few researches study fisheries quantitatively before the declaration of marine reserves to know the effects of this activity on fish communities before and after their establishment and very few focus on non commercial fisheries (game, collateral, poaching and subsistence). These aspects were studied on Jardines de la Reina archipelago, where the largest marine reserve of the Caribbean is located. We analysed catch and effort statistics and made underwater visual censuses, interviews and sampling of capture. The declaration of the marine reserve reduced fishing effort inside the reserve by about two thirds. One third of the original total effort was completely eliminated but the other third was relocated to the surrounding zones near the reserve. As a consequence, total landings from the archipelago area were reduced by a third. Finfish fisheries made by lobster's fishermen and poachers boats are the most important harvesting activities inside the marine reserve. The homogeneous distribution of finfish catches through Jardines de la Reina archipelago before the declaration of the reserve and the strong relationship between catch and abundance after it, support the hypothesis of positive effects of the Jardines de la Reina Marine Reserve on the conservation of fisheries resources on this Cuban archipelago.

KEY WORDS: Commercial fisheries, non-commercial fisheries, marine reserves, marine protected areas, fish abundance.

Efectos de la Reducción de la Actividad Pesquera en Jardines de la Reina, Cuba

Varios trabajos comparan las pesquerías entre áreas sometidas a esfuerzos pesqueros diferentes (desde intensamente explotadas hasta áreas protegidas marinas). Sin embargo, muy pocos trabajos analizan cuantitativamente las pesquerías antes de la declaración de las reservas marinas para determinar la posible influencia de esta actividad en la pasada y presente estructura de las comunidades de peces y menos aún dirigen su atención a la captura no comercial (deportiva, colateral, furtiva, subsistencia). Estos aspectos fueron investigados en el archipiélago Jardines de la Reina, que incluye a la mayor Reserva Marina del Caribe, mediante el análisis de la estadística pesquera, censos visuales, entrevistas y muestreos de captura. El establecimiento de la Reserva Marina redujo el esfuerzo pesquero dentro de esta en casi dos tercios, un tercio fue eliminado completamente pero el otro se reacomodó a las zonas de pesca aledañas dentro del archipiélago. Esto condujo a una reducción de un tercio de la captura en todo el grupo insular. Las pesquerías de peces asociadas a langosteros y furtivos representan el grueso de las capturas dentro de la Reserva Marina. La captura homogénea a lo largo del archipiélago Jardines de la Reina, antes de la declaración de la Reserva Marina y la fuerte relación entre la captura y la abundancia después de la declaración de esta, hablan a favor de la Reserva Marina como elemento importante en la conservación de los recursos pesqueros en este archipiélago cubano.

PALABRAS CLAVES: Pesca comercial, pesca no comercial, reservas marinas, áreas protegidas marinas, abundancia de peces

INTRODUCTION

Fishing has been the most extended use of marine resources and also the one that has produced the biggest impacts on them (Baisre 2004). Finfish are the main target of tropical fishing resources and they support fisheries of socioeconomic importance in the world (Munro and Williams 1985) and in Cuba (Claro *et al*. 2001, Baisre 2004, Claro *et al*. 2004).

It is broadly known that fishing causes changes in the abundance and biomass of fishing species. Several papers compare fisheries among areas intensely fished and others lightly exploited or that are marine reserves (Watson and Ormond 1994, Jennings and Polunin 1996, Jennings *et al*. 1996, Russ and Alcala 1998, Alcala *et al*. 2005).

However, very few works quantitatively analyze fisheries before the declaration of marine reserves to determine the possible influence of this activity in the past and present of fish assemblages (Russ and Alcala 1989, Alcala and Russ 1990, Polacek 1990, Russ *et al*. 1992, Carr and Reed 1993, Rowley 1994, Jennings *et al*. 1996, Nowlis and Roberts 1997, Russ and Alcala 1998, Halpern 2003, Alcala *et al*. 2005). Four of these works are based on the same place (Sumilon and Apo islands in the Philippines) and six are modeling or meta analysis. These authors point out that the intensity of fishing in areas adjacent to marine reserves or before their establishment can have a great impact in the effects that produce these protected areas, because change rates between before - after or outside - inside the reserve will be greater as fishing activity is more intense. This analysis gains importance for studies in marine reserves where species abundance or biomass estimates have not been obtained before declaration of such areas, making conclusions of many studies inconsistent (Polunin and Roberts 1993, Roberts 1995, Sluka *et al*. 1997, Chapman and Kramer 1999, Edgar and Barrett 1999).

Most of the previous works quantify commercial or subsistence fishing directed to fish but very few focus on the catch by sport fishermen (Craik 1981, Johnson *et al*. 1999, Westera *et al*. 2003) or boats that center their activity

on other species (example, lobster). ,Only a few articles mention, but do not quantify, catch in marine reserves by poachers, inhabitants and local institutions with fishing concessions (Klima *et al*. 1986, Jennings and Polunin 1996, Jennings *et al*. 1996, Edgar and Barrett 1999, Halpern 2003).

A study that compared a marine protected area with sport fishing to a no take marine reserve, found greater total abundances of target species and of letrinids in the reserve (but equal for snappers and groupers), concluding that sport fishing can negatively impact fish populations, which was not recognized in previous studies (Westera *et al*. 2003).

In the case of poaching and fishing concessions to locals, Jennings and Polunin (1996) point out that both activities should be carefully regulated in marine reserves. They detected that the elimination of 5% of the fish biomass can cause significant structural changes in fish assemblages. However, Jennings *et al*. (1996) recognize that this extraction will not necessarily jeopardize a profitable tourist activity based on diving.

In the Cuban context, this research is the first effort to quantitatively assess fishing activity before – after, outside - inside a marine reserve and to relate it with target species abundances estimated by means of visual censuses. An attempt to analyse the relationship between fishing activity and marine reserves made by Alcolado *et al*. (2001) for Jardines de la Reina region, is just anecdotal and has not any quantitative basis. Claro *et al*. (2004) estimate the catch of private boats in the largest Cuban archipelago, Sabana – Camagüey, in around 1,800 tons (around 20% of the total), without estimating the proportion per species or the areas under such fishing effort.

MATERIALS AND METHODS

Study Area

The Jardines de la Reina Archipelago stretches along 360 km, from the Gulf of Guacanayabo to Casilda Bay, south of Cuba (Figure 1). It is made up of 661 keys. The archipelago has three groups of keys and the most important one is that of Las Doce Leguas (The Twelve Leagues), located in the westernmost end, south of the provinces of Ciego de Ávila and Camagüey. Since 1996 about 950 km^2 were proclaimed as Zone Under Special Regime of Use and Protection (ZUSRUP), according to Resolution 562/96 from the Ministry of Fisheries. This protection category is equivalent to the internationally known Marine Reserves, and so will be termed in this paper. The entire archipelago is proposed as a National Park and is pending of approval by the Cuban government.

Sampling Method

According to anecdotal information and statistics of fishing effort, the Jardines de la Reina Archipelago can be divided into 5 zones. From West to East these are: 1) from Cayo Bretón to Pasa de Boca Grande (No Reserve West - NRW); 2) from Pasa de Boca Grande to Pasa de Caballones (Reserve West - RW); 3) from Pasa de Caballones to Cayo Cachiboca (Reserve Center - RC); 4) from Cayo Cachiboca to Pasa de Juan Grin (Reserve East - RE) and 5) from Pasa de Juan Grin to Cabeza del Este (No Reserve East - NRE). These zones can be ranked from most protected with very low fishing pressure to least or no protected with increasing fishing activities as follows: RC, RW, RE, NRW to the NRE (Figure 1).

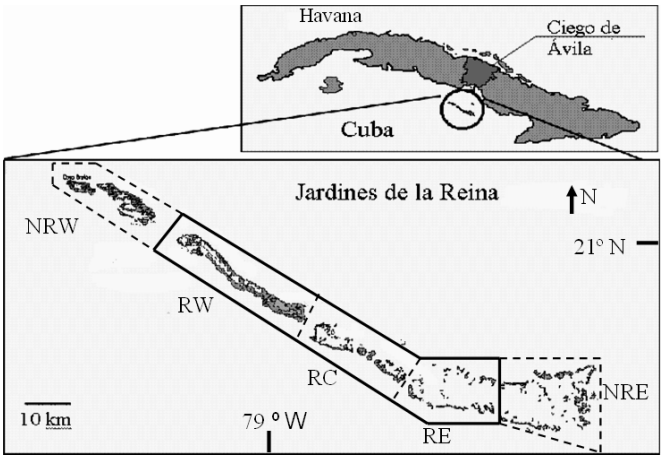

Figure 1. Map of Jardines de la Reina. The continuous line is the Marine Reserve and the discontinuous ones the zones according to their protection.

Information on catch and fishing effort detailed by zones, boats, fishing gears and commercial fish species was obtained from the Fisheries Establishment of Júcaro. Information on fishing effort was not so exhaustive and required estimates based on fishing data and interviews to 17 fishing boat skippers from Casilda, Júcaro, Playa Florida and Santa Cruz del Sur. Commercial fishing was banned in the region established as Marine Reserve in 1996. For that reason, there has been no commercial fishing since 1997 in RW, RC and RE.

However, in the whole area of Jardines de la Reina, including the marine reserve, other kinds of finfish harvest take place. The most important one, based in the volume of catch, is that of lobster fishing boats. Second in importance is that of private boats, legal outside the Marine Reserve and illegal inside. Last, is the self-consumption fishing of the tourist company Azulmar, unique finfishing concession inside the Reserve since 1997.

Information on finfish catch for self-consumption made by lobster boats was obtained by means of interviews with lobster fishermen (crews of 11 boats) from the south coast of the provinces of Sancti Spíritus, Ciego de Ávila, and Camagüey. These interviews were carried out either in their home towns or while at work, in an informal way and are absolutely confidential. Information on catch, fishing effort, zones, and main species and their evolution before and after declaration of the Marine Reserve was obtained. The anecdotal information obtained was validated by means

of sampling catch 17 times along 2005.

Private boats fishing information was obtained by means of interviews with lobster fishermen (crews from 11 lobster boats), private (crews from five private boats) and Azulmar personnel (nine workers) of the southern coast of the provinces of Sancti Spíritus, Ciego de Ávila, and Camagüey. These interviews were carried out either in their home towns or while at work, in an informal way and are absolutely confidential. Information on catch, fishing effort, zones and main species and their evolution before and after the declaration of the Marine Reserve was obtained. This information could not be validated as it was not possible to sample catch of private boats.

Information on Azulmar self-consumption finfishing was obtained in the following way: from January to March 2006 catch for Tortuga Hotel corresponding to seven weeks of operations (43 days of follow up with catch in 33 days) was sampled. Two hundred and ninety fish were measured and weighed using a 90 cm ichthyometer and a 10 kg capacity and 10 g precision scale. During those 7 weeks Tortuga Hotel accommodated 57 tourists. That quantity represents 10 % of the average amount of visitors Azulmar has received from 2000 to 2005.

A fisheries-independent fish abundance estimate was obtained by means of visual censuses. During June 2004 and January, April, September, and December of 2005, 25 sites in reef slopes (5 sites randomly selected in each zone) and 12 sites in reef crests (4 sites randomly selected in each zone) were sampled. In the reef slope, each site was sampled twice in every period by means of belt transects, 800 m long X 10 m wide to obtain 10 replicates inside each zone. In the reef crest sites, two belt transects were also carried out, although they were shorter (500 m long X 10 m wide), with eight replicates per zone. In a previous pilot work, it was calculated that with this design a power of 80 % is obtained for the ANOVAs. During the previous pilot work each belt transect was marked with bottom buoys, underwater reference points were photographed and coordinates were determined using a Global Positioning System (GPS). Before beginning the belt transects, the observers became acquainted with their width (10 m) using a metric tape.

Data Analysis

Species that are subject to fishing by most fishing activities and which at the same time are properly assessed by means of visual censuses were chosen for the analysis. These species are: mutton snapper (*Lutjanus analis*), cubera snapper (*L. cyanopterus*), dog snapper (*L. jocu*), jacks (Carangidae), black grouper (*Mycteroperca bonaci*), Nassau grouper (*Epinephelus striatus*) and hogfish (*Lachnolaimus maximus*). Horse eye jack (*Caranx latus*), crevalle jack (*C. hippos*), yellow jack (*C. bartholomaei*) and bar jack (*C. ruber*) were grouped as "jacks" because catch information does not allow to reliably separate them.

The total catch per species in the period after the Marine Reserve and the visual census counts were standardized to mean zero and unit standard deviation to correlate catch in weight (fishing) with abundance in number (visual censuses) pooling all data for the selected species.

RESULTS

Commercial Catches

Commercial fisheries in Jardines de la Reina does not focus in bony demersal fish. From 1989 to 2006, around 80% of annual catch focus on sharks, rays, mackerels and sardines, species caught close to the archipelago. This fishing is carried out mainly with gill nets.

Species selected for this research are caught mainly during spawning seasons (mutton snapper, cubera snapper and jacks) or incidentally (dog snapper, black grouper, Nassau grouper and hogfish). Only cubera snapper, mutton snapper and jacks have great fishing importance, totaling around 10% of annual landings, while the other four do not total more than 0.3%. In general terms, before the declaration of the Marine Reserve, only in the spawning seasons boats focused their effort on Jardines de la Reina to catch the aforementioned species and other bony demersal fish by means of line fishing, corals, and gill nets. Fishing effort was distributed homogeneously through Jardines de la Reina and did not surpass 150 days/sea a year for each zone. Fishing effort data are not referring to particular species which limits the analysis. According to fishermen, the NRW zone traditionally contributed a bit more than half of the catch of the other zones because it had less abundance of target species and many of the boats that operated in that zone moved to the other zones of Jardines de la Reina during spawning seasons to improve catch (Table 1).

Since the Marine Reserve was established, commercial finfishing ceased in the zones RW, RC and RE of Jardines de la Reina. The effort moved partly to the NRW and NRE with around 250 days/sea annually. This increase of the fishing effort justifies the increment of the catch of NRE but not that of NRW. In the latter, catch was almost doubled with a 60% increase of the fishing effort. In general, fishing effort in Jardines de la Reina went from around 750 to 500 days/sea, with a reduction of a third (Table 1).

AZULMAR FISHING ACTIVITY

Quantitative information of Azulmar catch in the period previous to the Marine Reserve is not available but interviews do not reveal a change in them so it is assumed that they are similar to those obtained for the second period (after the declaration of Marine Reserve). According to samplings, Azulmar makes use of about 15 species as food but the seven considered in our research represent around 90% of total weight (jacks (31%), mutton snapper (21%), cubera snapper (15%), dog snapper (9%), hogfish (7%) and

Nassau grouper (6%)). Three fifths of that catch occurs in the RC and the rest in RW and RE. Self-consumption catch does not take place practically in the NRE and NRW (Table 2).

Table 1. Average catch (± standard error) devoted to commercial finfishing. Catch data in kg and fishing effort (E) in days/sea.

	1989-1996					1997-2006	
	NRW	RW	RC	RE	NRE	NRW	NRE
Mutton snapper	1978±387	3385±723	3421±672	4354±894	4423±901	5605±1119	9341±1828
Cubera snapper	1699±331	2779±549	2814±571	3762±719	3833±752	2223±436	4327±839
Jacks	1365±281	2669±491	2702±539	2614±509	2729±528	2006±384	3916±792
Dog snapper	102±18	192±33	210±38	156±30	189±40	200±37	102±18
Black grouper	27±6	39±6	42±7	34±4	39±3	36±4	24±2
Nassau grouper	21±4	28±4	27±5	32±3	32±7	0	0
Hogfish	9±2	16±1	26±4	16±5	11±3	135±24	222±41
TOTAL	5201±957	9108±1986	9242±2003	10968±2247	11256±2259	10205±2102	17932±3594
E	144±21	126±16	116±13	129±17	149±21	266±31	243±28

Table 2. Estimated Azulmar annual catch. Catch data in kg.

	RW	RC	RE
Mutton snapper	156	468	156
Cubera snapper	120	360	120
Jacks	338	1014	338
Dog snapper	94	282	94
Nassau grouper	64	192	64
Hogfish	70	210	70
Total	842	2526	842

Fishing Activity of Lobster Boats

Before the declaration of the Marine Reserve around 50 lobster fishing boats operated in Jardines de la Reina, distributed homogeneously in all five zones. Each boat fished around 8 months per year, with two fishing journeys per month totaling 20 days every month. In each journey the boats' finfish average catches was 75 kg (a box and a half with 50 kg weight per box) made up by around 25 kg of mutton snapper and hog fish and the rest by cubera snapper and dog snapper. Lobster boats that operated in NRW have a smaller catch, similar to that of finfishing boats (Figure 2).

With the declaration of the Marine Reserve, lobster boats showed no change in catch composition, but a 50% decrease of the number of boats fishing in NRW, RW and RC. This caused a total reduction of boats fishing for lobster in Jardines de la Reina of a bit less than a third. The consequence was a 50% decline of catch in NRW, RW and RC and a similar catch in the other two zones after the Marine Reserve was implemented (Figure 2).

Private Fishing Boat Activity

From 1989 to 1996 an average of one private boat operated in each zone of Jardines de la Reina. Each boat performed an average of 12 journeys per year, catching around 10 boxes (500 kg) of fish per journey for all the zones except for the NRW, where they catch some five boxes (250 kg). One fifth of that catch corresponded to mutton snapper, cubera snapper, and black grouper and a tenth to dog snapper, jacks, Nassau grouper and hogfish. Two thirds of the catch were made inside what would later be the Marine Reserve (Figure 2).

Since 1997 fishing effort inside the Marine Reserve changed. Surveillance exercised by Azulmar and the corresponding control bodies from the Ministries of Fisheries; Interior and Science, Technology and Environment caused a decrease of a third of the fishing effort in RE (eight journeys), a half in RW (six journeys) and of two-thirds in RC (four journeys), staying similar in NRW and NRE for a general decrease of about a third. Catch for each species declined in that same proportion because the catch species composition has not varied. Catch inside the Marine Reserve declined from two-thirds to a half with regard to the whole area of Jardines de la Reina. As this type of fishing is prohibited in the Marine Reserve it can be classified as poaching (Figure 2).

TOTAL CATCH

Gathering all this information together, it is evident that before the Marine Reserve, catch was very similar in all zones of Jardines de la Reina except for the NRW, an zone regarded as “poor” in abundance for these species by all fishermen (fin, lobster and private boats, Figures 2 and 3).

Since the establishment of the Marine Reserve, catch changed in connection with variation of fishing effort. Declines are drastic for RW and RC (around two-thirds with regard to the previous period) and smaller (40%) in the

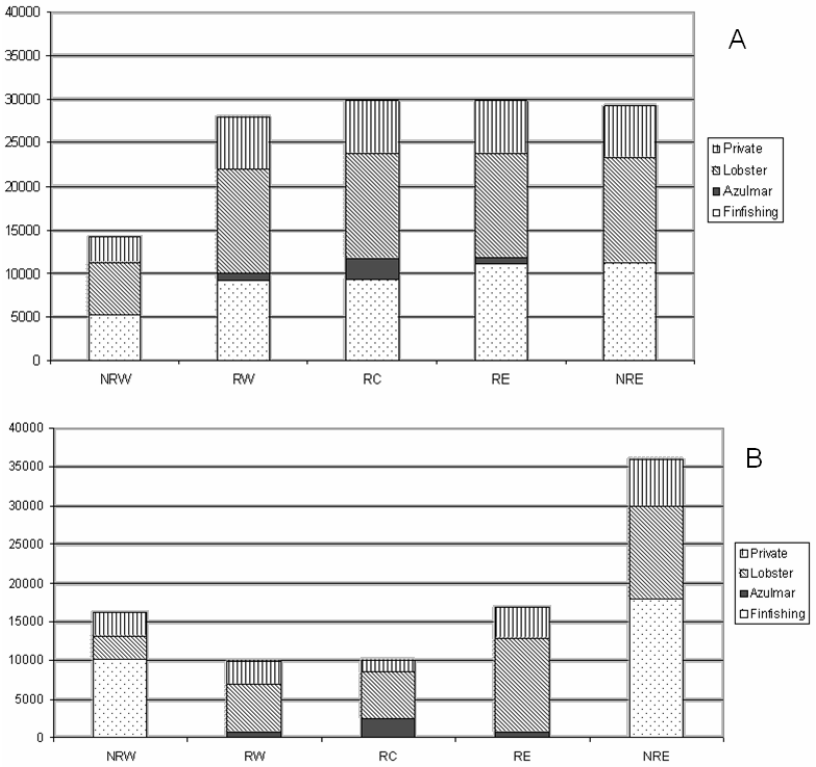

Figure 2. Catch by users. A: before Marine Reserve. B: after Marine Reserve. X axis are zones and Y axis are catch in kilograms.

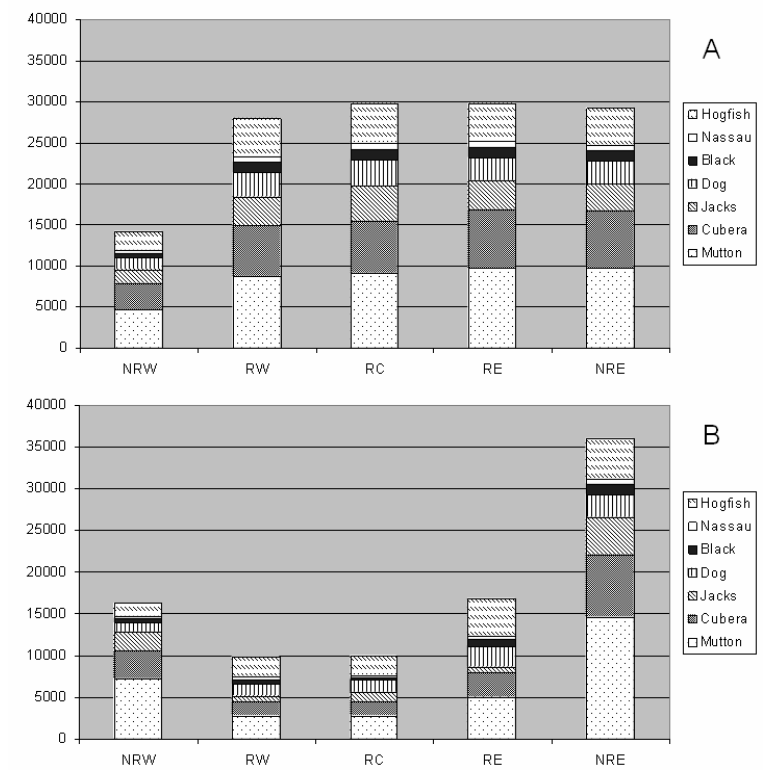

Figure 3. Catch by species. A: before Marine Reserve. B: after Marine Reserve. X axis are zones and Y axis are catch in kilograms.

RE. The total catch in NRW did not increase as much (around 15%) as in the NRE (around 25%). In general, fishing effort and catch declined by a third (Figures 2 and 3). Catch levels inside the Reserve are still high (almost 37 tons out of more than 87 ton catch before the Marine Reserve for a 60% decrease).

Relationship Between Catch and Visual Census Estimates of Abundance

The results of visual censuses show a clear trend to greater abundance of target species in zones inside the Marine Reserve. For the analysis of the relationship between counts and fishing, the data of the censuses were averaged by zones taking into account the five samplings (Table 3) and correlated with the average total catch between 1997 and 2006. The trend line presents a negative slope with a 0.757 square R, which means that as catch increases, abundance declines and vice versa and that the relationship is significant (Figure 4 A). This regression is strengthened when graphs refer just to zones outside of the Marine Reserve (NRE and NRW) with 0.900 square R, that is to say abundance is smaller in the most fished sites (Figure 4 B).

DISCUSSION

The use of fishing gears like corrals and fishing concentrated on the spawning seasons make catch volumes high even with little effort and therefore the effect on abundance of fishing resources is considerable. This statement endorses the negative relationship found between catch and abundance for all the zones of Jardines de la Reina. This coincides with what other authors have obtained in the Philippines (Alcala *et al*. 2005 and previous works in Apo and Sumilon), Seichelles (Jennings *et al*. 1996) and theoretical analysis predictions (Polacek 1990, Carr and Reed 1993, Rowley 1994, Nowlis and Roberts 1997, Halpern 2003).

Increase of effort on finfish in the NRW and NRE since the establishment of the Marine Reserve justifies increase of catch of NRE but not that of NRW. This can be due to the fact that the NRW was underexploited and therefore catch per unit of effort is now bigger than in the NRE. It could also be due to an increase of the fishing effort directed to snappers and jacks but this cannot be quantitatively elucidated. Another possible explanation is that for both zones fishermen state that "fish leave the

Table 3. Average abundances (± standard error) per species obtained from visual censuses.

Census	NRW	RW	RC	RE	NRE
Mutton snapper	23.4±4.66	47.8±14.26	31.8±8.95	27.8±10.41	12.0±2.23
Cubera snapper	24.8±11.23	54.0±14.97	61.0±21.15	48.4±16.66	13.4±3.19
Jacks	23.4±5.83	36.8±10.11	23.8±8.72	39.8±6.54	12.8±6.91
Dog snapper	53.4±13.66	68.4±17.40	65.8±11.12	32.8±7.99	20.8±10.27
Black grouper	18.4±4.96	19.0±2.04	27.8±8.84	12.4±2.42	8.4±4.17
Nassau grouper	38.4±7.03	40.0±13.84	51.4±17.91	33.4±6.88	19.0±6.81
Hogfish	168.4±25.02	202.4±30.75	238.4±48.66	116.0±18.81	113.0±20.82

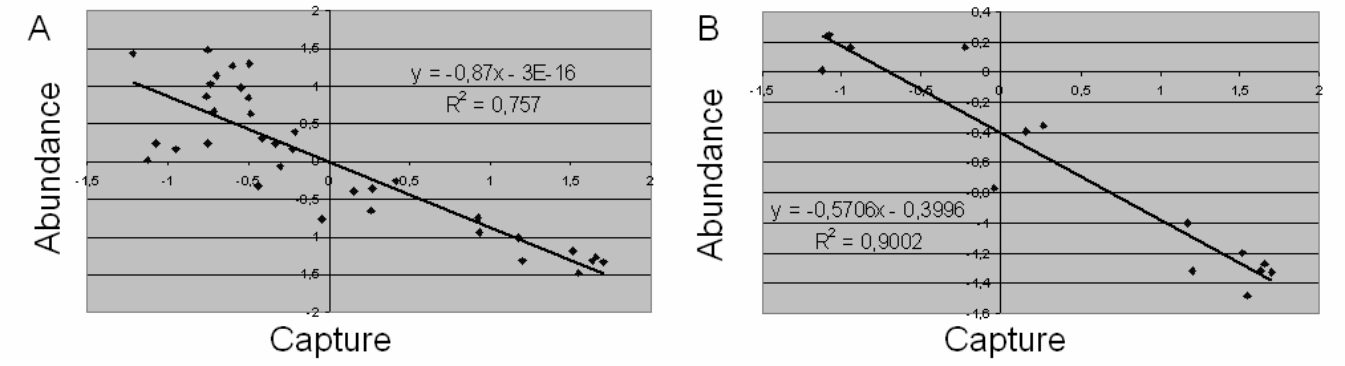

Figure 4. Regressions between abundance estimated by visual censuses and catch. Graph A includes data of all zones and Graph B only not protected zones.

reserve and for that reason they now catch more fish outside than before". There is scientific evidence of the effect of spillover of mature fish from the Marine Reserve of Jardines de la Reina, particularly in the west boundary (Pina-Amargós *et al*. In preparation). Research on this topic was done, however, at a smaller scale and results have to be taken very warily in regard of the entire marine reserve. Any of these processes or an unknown combination of them could be happening in this case. The analysis of the total catch, that is to say, fin, lobster, private boats and Azulmar, clearly reveals that, since the establishment of the Marine Reserve, catch changed in connection with the variation of the fishing effort. This displacement of the effort since the creation of a marine reserve has been discussed in the literature (Alcala *et al*., 2005) as one of its possible negative effects, because the effort is added to the existing one out the reserve, increasing the likelihood of overfishing, although in this case there is no evidence that this is happening.

None of the consulted studies done in areas fished

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