<u>FISHERIES CO-MANAGEMENT: EVALUATION AND LONG-TERM OUTCOMES IN TÁRCOLES, COSTA RICA</u>

by

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A Dissertation
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DEDICATION

To my wife Jessica, who fills me with unbreakable love.

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I would like to thank my loving wife, Jessica, who always provides a foundation and helped make this possible. I am indebted to the fishers of the Tárcoles community who welcomed me during five site visits beginning in 2012. The Costa Rican Government office of Fishery Statistics, particularly Licenciado Miguel Durán Delgado merits recognition for providing the necessary data. I would also like to acknowledge the NGO community of Costa Rica, particularly CoopeSolidar R.L., Conservation International and Pretroma, whom I learned from and who challenged me. My committee; Drs. Kennedy, de Mutsert, Christen, and Storr provided a diversity of thought and guided me. The Department of Environmental Science and Policy provided much-appreciated travel funding that ensured successful completion of my research. My employer funded my academic endeavors and also accommodated my research travel. Finally, thanks go out to the Founder's Hall facility management team for providing a clean, and well-equipped library and computer lab in which to work.

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ABSTRACT

FISHERIES CO-MANAGEMENT: EVALUATION AND LONG-TERM OUTCOMES IN TÁRCOLES, COSTA RICA

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Fisheries stakeholders have identified the need to implement fisheries management approaches that ensure sustainable practices while addressing the economic interests of fishers. Co-management of fisheries resources, where communities collaborate with government regulators to develop fishery policy, has gained traction in Costa Rica. The "Area Marina de Pesca Responsable de Tárcoles" ("Tárcoles Responsible Fishing Marine Area" or RFMA) is an example were the Tárcoles artisanal fishing cooperative, CoopeTárcoles R.L., has developed and implemented a regulatory structure using the co-management model. This dissertation evaluates the short-term outcomes and long-term implications of the RFMA using Ecopath with Ecosim (EwE). This EwE analysis represents the first multi-species, time-dynamic model of the Gulf of Nicoya (GoN). Results of this analysis can inform CoopeTárcoles R.L. and the conservation community of those factors which may contribute to the success of the Tárcoles RFMA. Lessons and

insights gained from researching the Tárcoles RFMA can also supplement management efforts for other RFMAs established in Costa Rica.

CHAPTER 1. FISHERIES CO-MANAGEMENT IN COSTA RICA

Fishing activities have altered and degraded the marine ecosystems through both direct and indirect effects. Traditional regulatory approaches (e.g., gear regulations, area closures, etc.) enforced by central governments to prevent this degradation have been perceived as unsuccessful in terms of fisheries management and conservation outcomes (Agrawal and Gibson, 1999; Alpízar, 2006). Unsuccessful systems have generally involved attempts at top-down control with poor ability to monitor and implement regulations (Hilborn et al., 2004) due to limited management capacity, inadequate funding, and lack of expertise (Guarderas et al., 2008).

The Gulf of Nicoya (GoN) of Costa Rica extends from a mangrove fringed shallow estuary to an open oceanic bay greater than 100 m. in depth and represents the center of the Costa Rican shrimp and finfish fishery (Wolff, 2006). By law, GoN fishery planning and management is the responsibility of the Costa Rican Institute of Fisheries and Aquaculture (Instituto Costarricense de Pesca y Acuacultura (INCOPESCA)) (Herrera-Ulloa et al., 2011). However, INCOPESCA faces a high demand for its services and is constrained by limited funding and staff. Further, competing economic and governmental priorities have marginalized the effectiveness of INCOPESCA (Alpízar, 2006). INCOPESCA has therefore not been able to either prevent the overexploitation of fish stocks, or significantly increase productivity and income for most fishers (Cornick et al., 2014). This situation has led to a call for the development of alternative regulatory structures such as “co-management” of fisheries resources.

Policy Framework

Costa Rican fisheries managers and stakeholders have identified the need to implement sustainable practices while addressing the economic interests of resource users. Advances in scientific knowledge of marine ecosystems as well as the incorporation of socioeconomic theory have helped evolve fishery management approaches. Regulatory approaches span a spectrum from total closure to open access. Each approach yields varying outcomes in terms of environmental sustainability and socio-economic impacts. The various approaches also introduce management challenges associated with the stochastic nature of fishery resources and resource-user response.

Spatial Closure

In Costa Rica, 17.5% of the territorial waters and 0.9% of the Exclusive Economic Zone is protected as a National Park, Wildlife Reserve, Absolute Natural Reserve, Wetland or Biological Reserve (Alvarado et al., 2012) (Figure 1). These reserves can reduce the impact of fishing on an ecosystem’s structure, as well as yield increased biomass, biodiversity, organism size and organism density (Halpern, 2003). There have been calls for much wider use of reserves to address the need for ecosystem-based management (Beddington et al., 2007; Hilborn et al., 2004). However, for fisheries that target highly mobile single species with little or no by-catch or habitat impact, marine reserves provide few benefits compared to conventional fishery management tools (*ibid*).

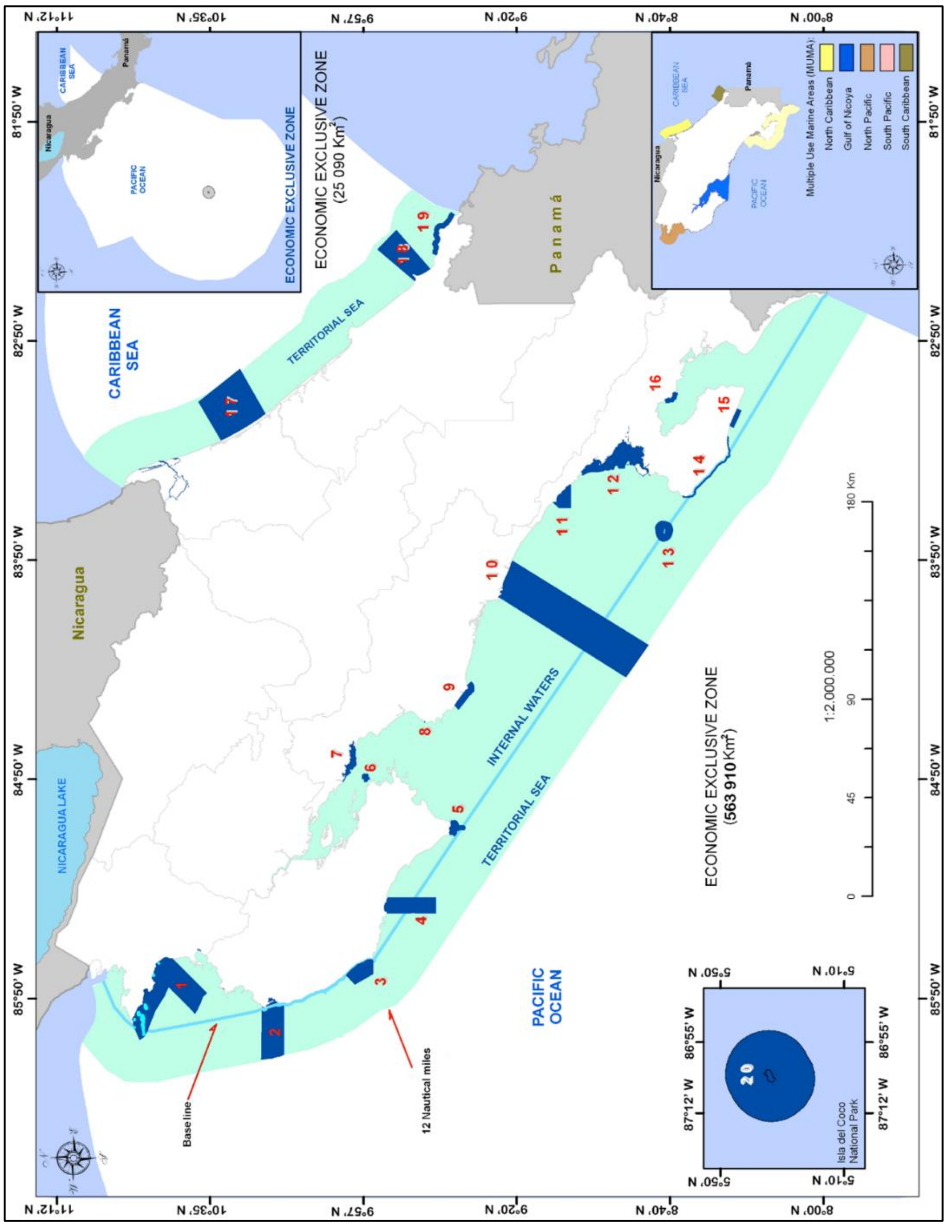

Figure 1 Spatial Closures in Costa Rica (Alpízar et. al, 2012).

(1) Santa Rosa National Park (NP), (2) Marino Las Baulas NP, (3) Ostional Wildlife Reserve (WLR), (4) Camaronal WLR, (5): Cabo Blanco Absolute Natural Reserve (ANR), (6) Isla San Lucas WLR, (7) Puntarenas Estuary and Mangroves Wetland (W), (8) Marino Playa Blanca W, (9) Playa Hermosa WLR, (10) Manuel Antonio NP, (11) Marino Ballena NP, (12) Manglar Térraba-Sierpe W, (13) Isla del Caño Biological Reserve (BR), (14) Corcovado NP, (15) Rió Oro WLR, (16) Piedras Blancas NP, (17) Tortuguero NP, (18) Cahuita NP, (19) Gandoca-Manzanillo WLR, (20) Coco Island NP

Indeed, previous empirical analyses have concluded that the density of harvested fish species inside some marine reserves increased compared with unprotected areas. This included increased mean size and abundance (Boersma and Parrish, 1999; Claudet et al., 2008; Myers et al., 2011). In analyzing long-term changes in key populations within temperate and tropical no-take marine reserve locations and reference (fished) areas, Babcock et al. (2010) found that populations of directly exploited species increased over time in reserves; first appearing within five years on average (5.13 ± 1.9 years). This finding indicates that the initial effects of protection occurred quickly. Empirical evidence collected by Myers et al. (2011) suggests that most measures of fish abundance, species richness, and diversity were greater in 2006 (after 11 years of protection) compared to 1995 (1 year after reserve designation) in the Playa Blanca Marine Reserve in the GoN.

Results used to characterize optimal reserve design assume export of dispersing larvae beyond reserve boundaries. This assumption is often made despite limited knowledge of the spatial details of this process (Gaines et al., 2010). There is growing empirical evidence for larval export and its potential benefits to conservation and fisheries, but the results are species-specific and difficult to quantify accurately (*ibid*).

The prohibition of fishing in a reserve removes an enclosed stock biomass from harvester access and forces fishers to either reduce overall effort, or intensify fishing elsewhere (Smith and Wilen, 2003). This resource area closure will have complicated spatial and temporal effects, both in the short run and in the long run (*ibid*). For example, the closing of areas (with the total level of fishing effort kept constant) will create a reduction of profits for fishing fleets when closure causes a shift of fishing effort towards more offshore areas (Russo et al., 2014) due to a likely increase of variable costs and opportunity cost associated with increased time at sea.

In the redistribution of effort to adjacent areas, the lowest capacity vessel fleet may give preference to more inshore than offshore areas (Dowling et al., 2012) presumably due to vessel capability to maintain a crew, safety considerations, cost considerations or inadequate infrastructure for maintaining catch inventory for a prolonged trip. Therefore, evaluating the potential effectiveness of alternative spatial management options requires an ability to estimate the effects on fleet behavior (*ibid*).

In the absence of empirical information and carefully controlled experiments, most of the current understanding comes from mathematical and simulation models (Wilen et al., 2002). A seminal theoretical paper on this topic was produced by Sanchiricho and Wilen (1999). Sanchirico and Wilen formulated a patch system by introducing patch-specific effort taxes and patch-specific landings taxes within a model that incorporated both inter-temporal dynamics and spatial movement. They allowed for different types of dispersal, including source-sink and density-dependence. Using this approach they found that, under open access, most reserve scenarios produced a biological benefit. They also noted that very few combinations of biological and economic parameters gave rise to both a harvest increase and a biological benefit. In particular, they found that harvest increases were likely only when the designated reserve patch had been severely overexploited in the pre-reserve setting. In the case of taxation strategies, Moeller and Newbert (2013) predicted that the imposition of a non-spatial tax reduced effort throughout the habitat because harvesters experienced an additional cost per unit effort. The areas that were not fished increased in size because a higher stock density was required to support any fishing effort under these increased costs. Ultimately, the tax-induced effort reductions resulted in higher stock densities throughout the habitat.

Prior to 1999, Sumaila (1998) simulated a no-take zone following Beverton-Holt recruitment function and found economic rent was maximized for large Marine Protected Areas (MPAs). Also in 1998, Hannesson formulated a Continuous Time Model to consider a fish stock exhibiting the logistic law of growth to evaluate open access outcomes outside a no-take zone. This study concluded that marine reserves increased fishing costs and shortened fishery seasons, but incorporated less generality in the biological and economic models than Sanchirico and Wilen. The work of Sanchiricho and Wilen (1999) was also preceded by Holland and Brazee (1996) who simulated an open access area outside no-take zone using a detailed age-structured two-patch population model. They depicted biological mechanisms, including density-dependent stock/recruitment relationships in both the reserve and open area, migration of adults according to a density-dependent mechanism, and uniform larval dispersal. They concluded that fishers did not seek to reduce risk by choosing areas where revenue rates were less variable.

Sanchirico and Wilen (2001a) expanded on the earlier work by evaluating a license system outside a no-take zone. They found that license prices would rise until equal to expected production rent, concluding that license prices could serve as indicators of the economic benefit of an MPA to the fishery. Also in 2001, Sanchirico and Wilen (2001b) simulated an open access area outside a no-take zone using a bio-economic model that combined a meta-population model and dispersal with a behaviorally based, spatially explicit harvesting. In this analysis, they concluded that total catch would increase only under certain economic and biological conditions.

Using a two-agent model for the assessment of MPA performance, Sumaila (2002) simulated an open access area outside a no-take zone. The simulation found that when participants in a fishery cooperated, joint management induced better resource rebuilding and higher discounted profits. Anderson (2002) followed Hannesson (1998) and Sanchirico and Wilen (2001b) by simulating effort as a function of profitability which was, in part, determined by the existence of reserves. The model considered density but used absolute stock size as the state variable. The paper extended Hannesson’s analysis by deriving sustainable catch and revenue curves. Results of this analysis suggested marine reserve policy will achieve a lower equilibrium harvest level, but will not result in an overcapitalized fleet or shortened fishing season.

Hannesson (2002) modeled an open access area outside a no-take zone using a variant of the spatial model developed by Sanchirico and Wilen (1999). This model incorporated two patches where there was mutual in-migration and out-migration. The model assumed the growth of the two sub-populations was governed by the logistic equation. This analysis concluded that the MPA increased biomass while catch decreased. Smith and Wilen (2003) evaluated open "urchin harvest patches" with closure of an individual source patch. The spatial and dynamic model was described as a true bio-economic model in that it integrated a population model of sea urchins with a behavioral model of the harvesting sector and generated joint bio-economic equilibrium. They found that reserves can produce harvest gains in an age-structured model but only when the biomass is severely overexploited. They also concluded that even when steady state harvests are increased with a spatial closure, the discounted returns are often negative. This was a result of slow biological recovery relative to the discount rate. These results were congruent with Sanchirico and Wilen (1999), who concluded that easily exploited patches were most likely to be the best sites to produce both harvest and reproductive gains.

More recently, Dowling et al. (2012) modeled key characteristics of a long-line fishery. These characteristics included fluctuating catchability due to (i) the migration of the target species, (ii) prices influenced by supply in the market and (iii) individual quotas on effort. Results showed fishing effort was redistributed in part to areas that had not been previously exploited in the absence of the closure. Moeller and Newbert (2013) reviewed the open-access case for stock whose population density changed as a result of local population growth, diffusion, and harvesting. They concluded that habitat quality degraded under unrestricted effort, reducing the local population density. This also produced a reduction in fishing effort density.

Russo et al. (2014) simulated different management scenarios including spatial closures. They incorporated spatial models of fishing effort, environmental characteristics and distribution of demersal resources, as well as an Artificial Neural Network of the relationships among these aspects. This model was used to predict resources abundance using a deterministic module that analyzed the size structure of catches and the associated revenues (the module was dependent on different spatially-based management scenarios). Russo et al. found, among other conclusions, that a partial improvement in resource conditions can be achieved by means of nursery closures, even if the overall fishing effort in the area remained stable.

As these simulations suggest, MPAs are promoted as a useful management tool for living marine resources (Russ et al., 2004). Thus, a critically important factor in developing a spatial management plan for any marine zone with an active fishing industry is a clear understanding of the dynamics of fishing effort, in particular addressing the question of how fishing effort will be redistributed in response to a spatial closure (Wilen, 2004; Dowling et al., 2012). Different spatial management measures create different incentives, resulting in different responses by fishers that often have unintended consequences (Fulton et al. 2011; Dowling et al., 2012). These responses and consequences necessitates rigorous bio-economic modeling of management scenarios (van Putten et al., 2011).

Although there may be general conclusions drawn regarding likely fisher response to spatial management policies, simplified assumptions about effort distribution and its determinants are likely to confuse the debate about marine policy instruments (Smith and Wilen, 2003). For example, Holland and Sutinen (1999) found that accounting for individual heterogeneity greatly improved the ability to predict the distribution of fishing effort. Heterogeneity in the attractiveness of different fishing locations to different fishers is not limited to cost due to proximity of the areas. Holland and Sutinen's empirical work with large trawlers in New England suggested that fishers' experience with particular areas and fisheries also impacted their expected revenues. They noted habits may have led fishers to maintain traditional fishing patterns despite potential gains that might be derived from changing these patterns. For longer trips which last over a week, a skipper may also fish a number of different locations (Holland and Sutinen, 1999) in a manner that is not based on cost avoidance.

The discount rate is also an essential determinant of whether reserves generate net economic benefits (Smith and Wilen, 2003). Reserves may decrease harvests initially and then increase harvests as spillovers begin to emerge after a period of stock recovery. This discount rate may vary from fisher to fisher, dependent on near-term economic goals as well as general uncertainty because of the stochastic nature of fisheries. Put under pressure by declining catches or weak market prices, the typical fisherman's response may be to retreat to alternative means of employment altogether, as was found by Holm (1995) in Norwegian fisheries. That said, fishers do make decisions ranging from long-term entry/exit decisions to daily or even hourly decisions about where and how to fish that are influenced by regulations, technology, and expectations about prices, costs, and abundance (Wilen et al., 2002).

If a fishery management strategy includes a single reserve that provides a refuge that supports elevated biomass densities in surrounding areas through adult spillover and larval subsidies, evidence indicates that adult spillover and larval subsidies may benefit fished areas outside MPAs (Hamilton et al., 2010). The leakage of ‘surplus’ adults across reserve boundaries may create a sustainable supply of fishable individuals (Polachek, 1990). This would cause fishing effort to concentrate on the reserve edges, where fishers ‘‘fish the line’’ (Kellner et al. 2007; Moeller and Newbert, 2013). For example, Goni et al. (2006) showed the cumulative distribution of fishing effort was concentrated within one km of the Columbretes Islands Marine Reserve boundary due to spillover of spiny lobsters

(*Palinurus elephas*). Similarly, Kelner et al. (2007) concluded the temporal and spatial patterns of California sheephead (*Semicossyphus pulcher*) densities outside a reserve suggested that fishing the line was occurring. This occurred adjacent to a no-take marine-life refuge on Santa Catalina Island, California.

Property Rights

The initial approach to fisheries management involved little control over the level of fishing effort. Per Lauck et al. (1998), opening the entire population to exploitation exposes it to the risk of depletion. As a result, the open access of fisheries resources created an overly capitalized fishery industry and resulted in overexploitation of fisheries resources. The concern of over-fishing created incentive for stakeholders to develop policy approaches that prevented continued deterioration of fisheries resources.

The initial step to eliminating the open access and over-fishing was development and assignment of property rights. As described by Caddy and Cochrane (2001) at the international level, some countries unilaterally extended their jurisdiction to 200 miles beginning in 1975. This practice was formalized in 1982 when UNCLOS III included the provision of an exclusive economic zone (EEZ). This provision of the Law of the Sea entered into force in November 1994, but its provisions dealing with fisheries had become international customary law since 1982. By defining the autonomous territory of nations, the EEZ allowed for the identification of authorized resource users. It also allowed governing countries to set controls on the fishing methods to be employed in their waters, authorized fisher entrance, set total allowable catch quantities, and delineate closed areas.

The same "open-access" principles apply within an EEZ. Where central governments have limited resources to establish and implement fishery regulations, property rights can promote the sustainable exploitation of fishery resources. With no regulation and no assigned property ownership, the equilibrium level of effort in the fishery will be bioeconomic equilibrium (Figure 2) where total revenue equals total cost. Effort beyond bioeconomic equilibrium would be an irrational choice given that fisher profits would be negative.

The hypothesized "Maximum Profit" effort level (E1) is also associated with a more ecologically sustainable effort given that effort level E1 allows for the biomass of target (and non-target) species to increase. However, empirical evidence suggests that fishers will not stop increasing their effort when the rents are maximized. Rather, effort increases to point E3, resulting in Hardin's (1968) proverbial "Tragedy of the Commons". Libecap (2009) described this "tragedy" as occurring in four main stages; (1) open access creates exploitation of the resource for resource rents, (2) resource exploitation creates externalities affecting each competitor, (3) anticipation of externality impact promotes additional exploitation of the resource, and (4) in latter stages, over-exploitation is supported by the irrational application of labor and capital inputs (beyond E3). This situation was noted to have occurred in Costa Rica in 1988 when the estimated annual rents were negative for the Costa Rican fishery (de Camino et al., 1991).

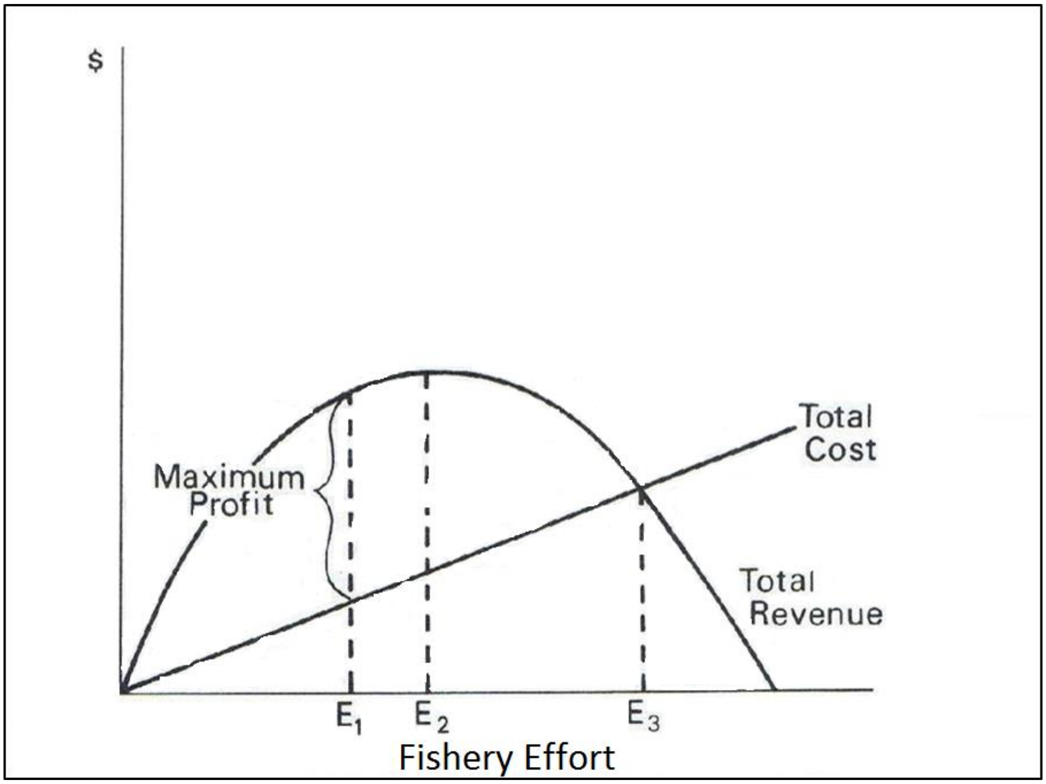

Figure 2 Fishery Cost-Revenue Curve (from Stevenson, 2005). Effort level E1 designates Maximum Profit effort, effort level E2 designates Maximum Sustainable Yield Effort, and effort level E3 designates bioeconomic equilibrium

Effort level E2 corresponds to the Maximum Sustainable Yield (MSY) of the fishery, beyond which it is anticipated stock will begin to be depleted. Note that the MSY approach is largely species-based and has been shown to have limited accuracy. Traditional calculations of MSY did not consider the interconnectedness of marine ecosystems, the stochastic nature of marine habitats, or the potential effect of environmental shocks to a fish population. Although fisheries scientists are now well aware that individual fisheries populations interact in systems where predator–prey relationships are also important, the dominance of single-species MSY management approaches persists (Wilen et al., 2012).

Per Costa Rican law, the ocean and its resources are a public good (The Nature Conservancy, 2011). This prevents implementation of ownership mechanisms based on exclusive access to a location (e.g. Territorial User Rights Fisheries (TURFs)). Methods of allocating property rights, in lieu of legal ownership of an area, include issuance of Permits as well as the provision of Individual Quotas and Individual Transferable Quotas. This creates ownership of the "Right to Fish". Theoretically, the changes in incentives created by giving fishers secure access to the resource should be immediate because fishers no longer race each other to capture a share of the resource and instead focus on maximizing the value of catch on a long term basis (Wilen et al., 2012).

Permits take the form of entrance permits to a specific region for a specific duration. The benefits of this approach include the ability to regulate access to fishing areas, which is a pre-requisite to preventing the "Tragedy of the Commons". This approach however increases the management cost for implementing regulatory policy given that a regulatory organization will be required to administer the permit program and implement a compliance monitoring scheme. This approach will also do little to prevent harvesting beyond sustainable levels given that some individuals will discount future benefits at varying rates. Thus, high discounting will promote unsustainable catch rates in the near term and low discounting will promote conservation.

An improvement on individual entrance permits is the application of the individual quota. Under this regulatory scheme, an individual or firm is allocated an approved catch level of a species for a defined duration. This approach allows for the control of not only the entrants, but also the total catch to be allowed (presumably based on the MSY evaluation). However, provisioning these rights to multiple users, each of whom manages his own activities in a marine ecosystem, does not prevent externalities. Individual quotas can affect the harvests of others, with examples being the dragging of gear over productive habitat that supports other species, or the taking of too many fish that provide food for other users' species of interest (Wilen et al., 2012). The introduction of a quota on catch or effort also means that the decision to fish depends not only on the relative catch rates in that time period, but also on the opportunity cost of using the quota now rather than later. Fisher decisions need to be made not just on spatial allocation of effort but also when effort is to be applied. This introduces the possibility of not fishing as being an optimal decision during some time periods (Dowling et al, 2012).

Another difficulty in implementing individual quotas is the equitable allocation of quotas. Quotas are sold, auctioned, issued via lottery, or are based on historical use and tenure. Each of these approaches raises issues of fairness to new entrants (in the case of tenure-based quota issuing), or places potential entrants at a disadvantage if they do not possess the financial resources to compete at auction or purchase quotas. In the case of a quota lottery, there is a possibility that stakeholders who have historically relied on the fishery resource, and whose cultural identity is legitimately linked to the fishery, to be omitted from the activity.

Similar to a simple permit program, the quota approach increases the fishery management cost given. A regulatory organization will be required to administer the quota system and implement a compliance monitoring system to prevent the exceedance of the approved catch quantity. Furthermore, prohibiting landings of some protected species or sizes may simply force dumping (Hilborn et al., 2004).

An extension of the individual quota is the transferable quota methodology. The types of ITQs that have been implemented include individual fishing quotas (IFQs) that assign quotas with individuals and individual vessel quotas (IVQs) that assign quotas to vessels (Chu, 2009). Under an ITQ program, fishers are expected to favor management actions that protect and enhance fish populations because the value of a quota share increases as stocks become more abundant (Beddington et al., 2007).

However, the ITQ system also poses the risk of unsustainable practices. Per Wilen et al., (2012) any spatially undifferentiated ITQ system that allows fishers to fish over any subpopulation invites misallocation of effort over space, with too much near ports and less conducted in distant areas. Alternatively, different subpopulations may have different productivity. In these cases undifferentiated ITQs incentivize overexploitation of the most productive and under-exploitation of less productive patches. Per Chu (2009), ITQ programs in one fishery may also have little effect on stock biomass for highly migratory species because other parties (e.g. neighboring communities, parties to international agreements) may not effectively control for compliance. A reasonably well-designed ITQ system focused at the target species level may also fail to provide incentives to protect valuable habitat or to avoid unwanted ecosystem effects such as incidental catch of small fish, unmarketable fish, mammals, and other non-target organisms (Wilen et al., 2012).

Similar to standard permits and quotas, compliance monitoring is also required to prevent or reduce quota exceedance where landings are greater than the approved catch quantities. These problems have been successfully countered by the use of observers, which are used extensively in the U.S. Pacific fisheries, Iceland, Australia, and New Zealand (Chu, 2009). Observer cost has caused New Zealand and Iceland to have some of the highest costs of management per fishing vessel (Beddington et al., 2007).

Co-management of Common Pool Resources

Co-management, or the joint management of the commons, is almost solely associated with common pool resources (Plummer and Fitzgibbon, 2004) and often formulated in terms of some arrangement of power sharing between the governing body and a community of resource users (Carlsson and Berkes, 2005). Proponents of co-management argue that the empowerment of resource users is the best approach to strengthen public participation and improve management effectiveness (Alpízar, 2006). Through consultations and negotiations, stakeholders develop a formal agreement on their respective roles, responsibilities and rights with regard to resource management (Pomeroy, 1997). Proponents suggest co-management will promote sustainable use of marine resources because community participation and control over decision-making is seen as important in securing support for conservation (Ostrom, 1990; Jentoft et al., 1998; Pretty, 2003; Alpízar, 2006; Grafton, 2005; Campbell et al., 2007; Cavalcanti et al., 2013). Co-management is also seen as a method to ensure the local customs, cultures and the livelihoods of coastal communities are protected (CoopeSolidar R.L., 2008b) in a sustainable form.

Ostrom (2011) identified characteristics of resources and resource settings that may lead self-organized resource users to initiate this process. These include (1) the size of the resource system, (2) the productivity of system, (3) the predictability of system dynamics, (4) the mobility of the resource, (5) the number of users, (6) respected leadership, (7) accepted norms and social capital, (8) knowledge of the socio-ecological system, (9) importance of resource to users, and (10) collective-choice rules.

There are documented cases where groups have organized to monitor community members' resource use, allocate use rights among members, and adjust aggregate utilization levels to maintain sustainable use of the resources (Feeny et al., 1990). A successful example of long-standing fishery co-management was identified along the Coromandel Coast of New Zealand, where Bavink (2001) documented successful bans of gear thought to be destructive to the ecosystem. The Seri people, located in the northern section of the Gulf of California, have been able to sustain relatively constant rates of fishing effort over time using a co-management approach (Basurto, 2005). In this community, the involvement of the Mexican government is limited to certification of Seri government elections. Along the east coast of India, the Chilka have implemented a complex system of spatial and temporal fishery regulations amongst themselves with each fishing group's access determined on the basis of the species they catch (Sekhar, 2004).

Co-management of common pool resources can be categorized by varying degrees of central government involvement which Sen and Nielse (1996) group as "Cooperative", "Advisory" and "Informative". A "Cooperative" arrangement is described as a setting where rules and regulations are developed and implemented via collaborative consultation between a central government and local groups. An "Advisory" arrangement occurs when the local community develops Common Pool Resource (CPR) management rules, advises a government of said rules and receives approval of the CPR management rules from the government. An “Informative” arrangement is the laissez faire model where government allows CPR management processes to be entirely driven at the local level. Common to all three categories is the recognized role of local groups to develop and implement CPR management rules.

A critique of co-management approaches in Costa Rica suggests that a laissez faire approach will disregard the state’s MPA management experience by giving the government only a small role (or no role at all) in resource management (Alpízar, 2006). Opponents of co-management further argue that impacts on coastal zone environments can be the result of influences outside the coastal area and that site-specific management approaches may be unsuitable to address the effect of these influences (Lal and Holland, 2011). The problem of "free-riding" is also assumed to remain with co-management because it is still in the interest of the individual fishers or other resource users to defect, or break agreed upon rules (Jentoft et al., 1998). “Free-Riding” can potentially undermine co-management efforts and lead to over-exploitation. Defection is more likely to occur where there is a weak (or nonexistent) system for monitoring compliance and/or the probability of receiving a deterring sanction is low.

The community-driven development and implementation of co-management structures to effectively address collective action problems may occur in the absence of formal policy structures or structures that fail to meet community goals. The utility of this type of collective action arises in the pursuit of self-interests in settings where the individual can achieve improved outcomes through collaboration and coordination with other individuals who share the same interest (Olson, 2002). In these settings, individuals will voluntarily organize themselves to gain the collective benefits (Ostrom, 2000). Ostrom's research has identified key elements of long-enduring, successful collective action regimes for common pool resource management. These include:

1. Clearly defined boundaries – Individuals and households who have rights to withdraw resource units from the common pool resource must be clearly defined as must the boundaries of the common pool resources itself.

2. Congruence between appropriation and provision rules and local conditions - Appropriation rules restricting time, place, technology, and/or quantity of resource units are related to local conditions and to provisions rules requiring labor, material and money.

3. Collective-choice arrangements – Most individuals affected by the operational rules can participate in modifying the operational rules.

4. Monitoring – Monitors who actively audit common pool resource conditions and appropriator behavior are accountable to the appropriators or are the appropriators.

5. Graduated Sanctions – Appropriators who violate operational rules are likely to be assessed graduated sanctions (depending on the seriousness and the context of the offense) by other appropriators, by officials accountable to these appropriators, or by both.

6. Conflict resolution mechanisms – Appropriators and their officials have rapid access to low-cost local arenas to resolve conflicts among appropriators or between appropriators and officials.

7. Minimal recognition to organize – The rights of appropriators to devise their own institutions are not challenged by external government authorities.

8. Nested enterprises – Appropriation, provision, monitoring, enforcement, conflict resolution, and governance are organized in multiple layers of nested enterprises.

Research on common pool resource management has demonstrated that social and cultural control mechanisms are often effective in regulating access to, and extraction from, common-pool resources and reducing the probability of resource collapse (Prakash, 2011). This social control has been shown to occur when dominant coalitions of users expect benefits from creating and implementing their own rules (as well as modifying them over time) that exceed the immediate and long-term expected costs (Poteete et al., 2010). Beyond the management of resources, individuals have also been shown to cooperate in order to gain trade benefits or to provide mutual protection against risk (Ostrom, 2000) by breaking away from established routines in a form of social innovation.

The resulting rule structure may be based on endogenously developed systems of customs and taboos, which control behavior within the community (Burton, 2003). However, in settings where evolved norms are not always sufficient to prevent nonconformance, participants must deliberately devise rules, create and finance formal monitoring arrangements, and establish sanctions for nonconformance (Ostrom et al., 1999).

The early stages of collective action require a critical mass of actors whose contributions mobilize the action(s) (Simpson et al., 2012). Cohesive social networks with high communication rates and strong group identities such as the Tárcoles fishing community can increase the diffusion of innovative processes, which can promote cooperation (Granovetter, 2005). This cooperation can accelerate the aggregation of individuals into critical mass. Strong group identity is so profound in achieving this critical mass that it can influence rates of cooperation even in the absence of strong communication (Kollock, 1998). That said, one of the most robust findings in the literature is the positive effects of communication on rates of cooperation. Across a wide variety of studies, when individuals are given the chance to talk with each other, cooperation increases significantly (*ibid*).

As described by Ostrom (1965), the role of community leaders as social entrepreneurs is also an important aspect of social mobilization. The effectiveness of social entrepreneurs as leaders is gauged by how capable they are of strengthening people's ties with their group and influencing the willingness of members to cooperate (De Cremer and Van Vugt, 2002). The primary task of a leader is to initiate and maintain contributions to the collective goal rather than reactively waiting for others to define what is appropriate behavior in the situation (Simpson et al., 2012). Note however, not all innovations arise from the social inner circle or from a social entrepreneur with deep social ties within the community. Granovetter (2005) suggests the socially marginal individuals may at times be best placed to break away from established practices. This can occur because these individuals are not involved in dense, cohesive social networks of strong ties that create a high level of consensus on current practices. Therefore, a social entrepreneur may not be the initial source of an entrepreneurial concept. In Tárcoles the outsider role was filled by CoopeSolidar R.L., which is a non-profit organization that aligned with the fishing cooperative to champion improved approaches for the management of fisheries.

For successful collective action, communities must also overcome free-rider problems by its members by directly punishing 'anti-social' actions of others (Bowles and Gintis, 2002). Therefore, communities must devise rules to implement collective action (Ostrom, 2007) encourages contributions and discourages free riding (Willer, 2009). Agreeing on a common set of rules may be difficult because stakeholders must accept that the rules are fair (Thompson, 2000). Simpson et al. (2012) suggest that in cases of disagreement about a given course of action or rule for the group, higher-status actors are likely to exercise influence over the choices and opinions of other group members and are themselves less likely to be influenced by others' choices or opinions.

Prior to 2008, there was no legal authority or precedent for the establishment of co-managed marine protected areas in Costa Rica. This hampered the Tárcoles community's initial attempt at CPR management in 2007 (Fargnier et al., 2014). To address this regulatory gap, the Costa Rican Institute of Fisheries and Aquaculture (Instituto Costarricense de Pesca y Acuacultura (INCOPESCA)) established a coalition including representatives of INCOPESCA, representatives of MINEA (Energy and Environment Ministry), CoopeSolidar R.L., CoopeTárcoles R.L., and other non-government organizations (NGOs). The charter of this working group was to develop a methodology for the establishment of "Responsible Fishing Marine Areas" (RFMAs) in Costa Rica (CoopeSolidar R.L., 2008b; Fargier et al., 2014). The resulting regulation was approved by INCOPESCA on April 4, 2008 (AJDIP 138-2008). Within this regulatory environment CoopeTárcoles R.L. and CoopeSolidar R.L. re-initiated the campaign to establish the "Area Marina de Pesca Responsable de Tárcoles" in the GoN (CoopeSolidar R.L., 2008a).

In accordance with AJDIP 138-2008, the declaration of an RFMA is initiated through a petition by a community or organized group of fishers. The process of creating an RFMA requires the petitioners to submit:

- The objectives of the organization as well as the background of the petitioning group or organization. The background data should include an overview of the organization, year of foundation, and a list of stakeholders who perform activities dependent on the proposed RFMA. Details on the petitioning individuals should also include identification number, vessel name, registration number, and fishing license information

- A biological evaluation and/or historical information to demonstrate the biological importance of the proposed RFMA

- An analysis of the importance of the fisheries resource to affected stakeholders. This analysis should include fishing interests, social-cultural aspects and ecological factors that support the creation of the RFMA and its regulatory mechanisms

- A baseline socio-economic status of the affected members of the organization concerned along with a socio-economic impact analysis

- A map that indicates the geographical coordinates of the proposed area formatted in accordance with the National Geographic Institute of Costa Rica standards

- A Management Plan listing the proposed zoning for areas designated for fishing and areas of partial or total closure. This Plan should also include detail on the types of fishing (commercial, sports, tourism, etc.) to be permitted, proposed quantity of quotas (if any), the number and type of fishing gear allowed, and allowable sizes of landings or any other relevant information.

The Costa Rican government subsequently sanctioned seven areas as "Responsible Fishing Marine Areas" beginning with the islands of Chira and Palito (AJDIP 315-2009), the second in Golfo Dulce (AJDIP 191-2010), and the third adjacent to Tárcoles which was sanctioned by INCOPESCA in July, 2011 (AJDIP 193-2011). More recently in 2012, three additional RFMAs have been sanctioned by the Costa Rican government in Nispero (AJDIP 160-2012), Palito Montero (AJDIP 154-2012), and Isla Caballo (AJDIP 169-2012). The seventh RFMA was sanctioned in San Juanillo February 15, 2013 (AJDIP 068-2013). The Nature Conservancy (2011) suggests the current number of RFMAs is limited by INCOPESCA's capacity to evaluate, implement and manage these areas given that there is interest in sustainable fishing to protect livelihoods in many coastal localities.

Discussion and Conclusions

INCOPESCA has been seen as incapable of developing and implementing fishery regulations to promote sustainability. That said, there are several policy approaches that can be implemented to manage fisheries with the goal of improved livelihoods for fishers and sustained ecological improvement. Doing so will require new levels of funding, a revised organizational structure, and an overall shift in the INCOPESCA operational approach from one that is seen as promoting the semi-industrial fleet to the detriment of the GoN ecosystem and its dependent artisanal fishers. A new operational approach would objectively promote sustainable science-based fishing policy that incorporates input from all fisher sectors, the scientific community, and the environmental NGOs in Costa Rica.

In developing policy approaches and fishery regulations, stakeholders must consider the impacts to fishers as well as ecosystem sustainability. Thus, a well-designed fishery regulation will be based on a multi-disciplined evaluation that includes economic analysis and ecological analysis of local conditions – with consideration of the broader ecological and economic inter-dependencies. An additional variable to consider is the interaction of fisheries policy with broader market conditions and economic variables. Variables such as fuel prices, demand for fishery products, and the availability of alternative employment opportunities must be included in the development of fishery policy.

No-take reserves have the potential to improve fishery ecosystems by eliminating anthropogenic pressure. Allowing for biomass recovery will theoretically yield benefits for fishers. The length of time for benefits to manifest is case dependent, and in some cases may extend beyond time periods that fishers are willing to support. This willingness to support is influenced by the discounting of future benefits.

The perceived ineffectiveness of INCOPESCA to regulate fishery fleets caused the fishing communities to initiate bottom-up Common Pool Resource management approaches. There is a significant body of theoretical work describing the necessary conditions for development and successful implementation of CPR management regimes. Development of the GoN RFMA co-management regimes has approximated these conditions. By applying the "blueprint for success", the fishing communities may see successful outcomes for the local fishers. This has hastened the recognition of co-management regimes in the GoN and there is now much interest in co-management of fisheries in Costa Rica. It is anticipated local fisher knowledge will yield regulations that incorporate "hands-on" experience with ecological dynamics. Additionally, local involvement in rule-making is seen as key to promoting compliance with resulting regulations given the community played a role in the development of rules.

In the absence of empirical evidence, advocacy for or against co-management as an appropriate fisheries management approach in Costa Rica is not convincing. The Costa Rican government has implemented successful co-management regimes as in the case of legal harvesting of marine turtle eggs in Ostional, Costa Rica (Campbell, 1998; Campbell et al, 2007). Costa Rican ecotourism has also exhibited sustainable practices when strong community interaction, open communication, participation, distributive justice and tolerance are present (Matarrita-Cascante et al., 2010). An example of successful outcomes for co-management of nearshore fisheries, however, is not available because co-management is in the early stages of implementation in Costa Rica fishery management.

CHAPTER 2. TÁRCOLES FISHERIES CO-MANAGEMENT

Tárcoles, Garabito, Costa Rica is located on the mainland coast of the GoN where the Tárcoles River empties into the Gulf. The Tárcoles community is composed of approximately 4,315 members and possesses an artisanal fishing tradition which spans fifty years (CoopeSolidar R.L., 2008a). Approximately 50% of the population currently depends directly or indirectly on artisanal fishing within the GoN (CoopeSolidar R.L, 2008a). Like many coastal fishers, the artisanal fishers of Tárcoles are facing the effects of fishery overexploitation (Wolff et al., 2006) making it difficult to sustain fishing livelihoods and artisanal fishing cultures.

Artisanal fishing for commercial sale was not common until the late 1970's when entrepreneurs from surrounding areas visited Tárcoles and created a demand for fish catch. Local fishermen using wooden boats, paddles and candlelight were not required to travel far to obtain substantial catches. A majority of the fish catch was sold to the middlemen who would, in turn, sell the catch to local hotels, wholesalers and retailers at higher rates. The local community found itself in a disadvantaged bargaining position during these transactions not only due lack of organization, but also due to the lack of production and inventory control infrastructure (e.g. lack of ice, no central processing area, etc.).

Outside information and the resulting community learning played an important role in eliminating this disadvantage. The initial influx of new ideas came in the early 1980's when a professor from San Jose by the name of Doña Olga Bolaños and her husband bought a vacation lodge in Tárcoles and became the acquaintances of a local fishers. Doña Olga

Bolaños found middlemen would sell the catch in San Jose and would return with payment a week later. Given this had resulted in non-payments on several occasions (when payments were received they provided disproportionately low profits to the fishermen), she began tutoring locals on the utility of forming a cooperative and eliminating the middleman. Armed with this new knowledge, locals sought to organize the community and remove the middleman so that fish catch could be sold at a higher profit margin. The improved organization buoyed the local fishing community to form a cooperative in 1985, known as CoopeTárcoles R.L. The original membership of approximately twelve members soon found improved profit margins through direct sales to retailers, wholesalers, and private consumers. Membership in the cooperative provided other benefits to the associates such as fuel loans, fishing bait loans and ice loans for fishing activity (which were paid back after the catch had sold), and assistance with the sale of catch at a competitive price. This cooperative has now evolved to a small scale processing facility equipped with an ice plant, a receiving area, a management office, a fuel storage tank with a fueling pump and a shipping program that allows for the shipment of product and receipt of necessary materials. Much of this infrastructure has been acquired through assistance from the Costa Rican government and international organizations which the cooperative played a major role in facilitating.

Technological advances were introduced in the late 1980's in the form of motors and the use of fishing nets. The initial motor operated "panga" in Tárcoles belonged to a banker from San Jose by the name of Carlos Alvarado. Mr. Alvarado had a vacation lodge in Tárcoles and would contract locals to captain the motorized "panga" during his fishing expeditions. Upon learning of the advantages of motorized “pangas”, and having saved funds from the elimination of the middleman, locals managed to purchase motors. This began a local mechanical revolution with all of the CoopeTárcoles R.L. associates eventually purchasing motors.

A second technological step was taken five years after CoopeTárcoles R.L. was formed when they began gillnet fishing with three-inch netting. Prior to using nets, the local fishermen had only used long-lines for capturing pelagic fish species. The new fishing technique expanded the productivity of the fishermen’s activities and netting currently makes up approximately fifty-seven percent of the fishing effort (CoopeTárcoles R.L., 2010).

Given Costa Rica’s accumulated experience in natural resource and fisheries management, Tárcoles fishermen took steps to improve fisheries management. This management evolution was initiated in 2001 with the integration of technical and organizational assistance from CoopeSolidar R.L., a non-profit non-governmental organization whose emphasis is the protection of environmental resources through integration, and protection of local communities.

An initial product of this collaboration was the implementation of a local regulatory structure through the enactment of a Code of Responsible Fishing in 2004. This applied to all members of CoopeTárcoles R.L. This document laid out the pledge to bring the cooperative’s activities in line with regulatory requirements and best practices. Norms such as those listed in the Code of Responsible Fishing are established as means of reducing externalities, and their benefits are captured by the local community (Coleman, 1988). The benefits envisioned by CoopeTárcoles R.L. in establishing these norms were (i) the longevity of marine resources and (ii) sustained economic security for artisanal fishermen.

Following the enactment of the Code of Responsible Fishing, CoopeTárcoles R.L. began a data collection campaign to collect information such as fishing effort, fishing location, fishing technique, species caught, and fishing location. This data collection process, which was supported by Conservation International, has now evolved to a robust fisheries management resource that provides time-series information (from 2006 to the present) regarding landings of fish species in the area adjacent to Tárcoles.

The next phase of improved management involved the development of the RFMA by the local community. The Costa Rican government officially recognized the Tárcoles RFMA July, 2011 (AJDIP 193-2011) after three years of negotiations. The protracted negotiations, primarily concerned with the elimination of trawling within the proposed RFMA, resulted in the approval being delayed. As a result, it was the third RFMA approved in spite of it being the first application submitted. The resulting RFMA (Figure 3) applies to the fishing areas seen by local fishers as the "Tárcoles Community Region". Per CoopeTárcoles R.L. (2010), CoopeTárcoles R.L. fishers expend approximately half of their effort within this area (Zone 1 - Zone 6).

Tárcoles RFMA Design and Implementation

The Tárcoles RFMA does not meet the literal definition of a traditional Marine Protected Area (Alvarado et al., 2012). However, the combination of controls intended to improve biomass has effectively created a management strategy meeting the classification of Marine Protected Areas in Costa Rica (Decreto Ejecutivo 34433). Namely;

> "An area that ensures the maintenance, integrity and viability of natural ecosystems as a priority, benefiting the communities through a sustainable use of the resources, characterized by its low impact according to technical criteria".

The officially recognized Tárcoles RFMA was formulated to incorporate the eight principles of enduring Common Pool Resource Management regimes identified by Ostrom (1990). Expanding on Ostrom's first principle, effective CPR regulations must include a well-delineated group of users, well-defined physical parameters, and explicit or implicit well-understood rules that exist among users regarding their rights and their duties to one another about resource extraction (Stevenson's, 1991). Accordingly, clearly defined boundaries are a requisite to obtain approval for the designation of the RFMA. The defined boundary coordinates correspond to the area adjacent to the Tárcoles community (Figure 3) with an area of approximately 108 km^2. Approved users are any permit-holding fishers who choose to enter the RFMA fishing zones and are practicing approved fishing techniques for that zone.

Figure 3 Tárcoles Responsible Fishing Marine Area with numbered Zones (adapted from Consorcio PorLaMar R.L. 2012)

Ostrom's "Congruence between appropriation and provision rules and local conditions" element and the "Collective-choice arrangements" element are met by the participatory nature of RFMA design. The effort involved representatives from the local and surrounding communities, independent fishers, CoopeTárcoles R.L. members, as well as representatives of the Semi-Industrial (trawler) fleet. This resulted in a rule structure that was congruent with local conditions (Figure 4) given the rules were developed as a collective choice. This approach was necessary given that attempts to impose regulations that are contrary to the economic interests of the fishery community will most likely fail (Browman et al., 2004). Social-cultural aspects are important as well given that artisanal fishing is not only a source of income, but also a way of life that has molded individuals and communities (CoopeSolidar R.L., 2008b).

In the case of Tárcoles, a collaborative approach was vital given the finalized design would, in effect, introduce a "trawl ban", a "gillnet ban", and a "longline ban" in different zones. This would be augmented by a "total ban" within one kilometer of the river mouths of the Río Tárcoles and Río Jesús María. The resulting rule structure was based on local understanding of the ecosystem within the RFMA, thus ensuring the rules developed for management of the common-pool resource were appropriate for the specific location. This also helped to ensure rules were understood to promote the long-term viability of fish stocks. The elimination of trawling was seen as key to increasing shrimp biomass in the area, which Wolff (2006) predicted would lead to an increase in the biomass of higher-trophic levels. Therefore the collection of rules can be seen as an economically rational choice given the anticipated increase of biomass would increase catch and income.

The resulting strategy of gear regulation is applied to the six distinct zones as listed in Table 1 (INCOPESCA, 2011). Local fishers gauge the 15 meter (m.) isobath using the "quince brazos" (fifteen arm-spans) technique to verify the appropriate depth has been reached. In September, 2013 the MV Undersea Hunter deployed marker buoys to identify the outer boundary of the RFMA. This activity was funded by Conservation International and was a collaborative effort that included INCOPESCA and the local fishing community. The five buoys placed in the region were intended to ensure fishers from outside the Tárcoles region were made aware of the RFMA boundary in order to prevent the use of unapproved gear.

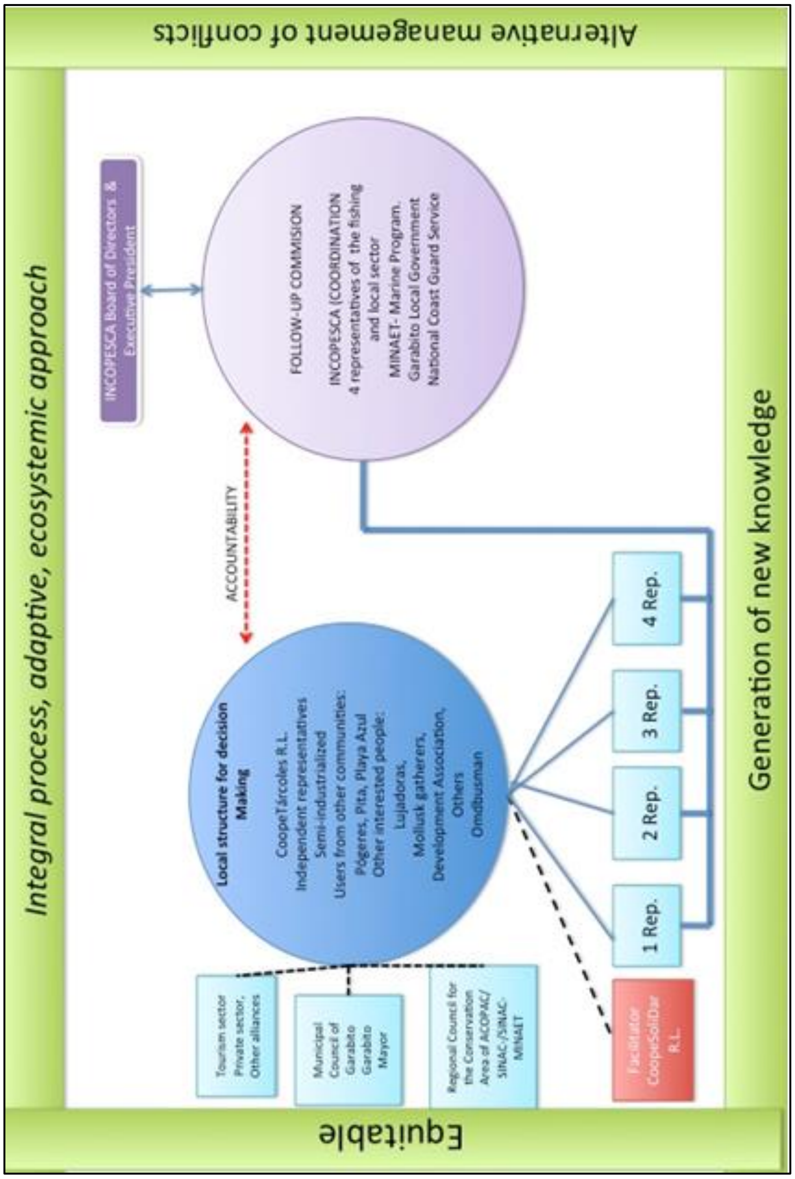

Figure 4 Governance model for the marine area of responsible fishing in Tárcoles, Costa Rica (CoopeSolidar R.L.)

Table 1. Tárcoles RFMA Rule Structure.

Applicable to Zone (Y)						Restriction
1	**2**	**3**	**4**	**5**	**6**	
y	y	y	y	y	y	Fishing is allowed only with hand line from the coast to the 15 m. isobaths.
y	y	y	y	y		In the area after the 15 m. isobath and up to three nautical miles from the coast, the use of net of mesh size 3.0 inches or greater is allowed, and after one year will be evaluated in order to analyze the possibility to increase the mesh size to 4.5 inches.
	y	y	y			In the area after the 15 m. isobath and up to three nautical miles from the coast, allows fishing with hand line and line of 3000 meters (1200 circle hooks or less) with circle hook size 6.
Y						Longline with 500 hooks (size 6) and hand line with hook size 6 is allowed in the remainder of the Zone.
	y	y				No fishing is allowed for any kind of method within a 1 kilometer radius from the mouth of the Rio Grande de Tárcoles.
			y			No fishing is allowed for any kind of method within a 1 kilometer radius from the mouth of the Río Jesús María.
y			y			Basket with opening to allow only capture the individuals of authorized size.
				y	y	Raya only allowed as bycatch.
y						Diving is not allowed because of harm to the health of fishers, nor is the gaff hook allowed because it is not selective to catch size.

Monitoring and Sanctions

"Monitoring" and "Graduated Sanctions" can be difficult to implement on a peer-to-peer basis given the potential for conflict and retaliation within the Tárcoles fisher community (Personal Observation, 2015). In spite of this challenge, the Tárcoles RFMA application submitted to INCOPESCA listed the CoopeTárcoles R.L. cooperative as a focal group in the development and implementation of monitoring and sanctioning protocols (CoopeSolidar R.L. 2010). Specifically, CoopeTárcoles R.L., CoopeSolidar R.L., INCOPESCA, and MINAET intended to carry out the following actions within five months of the implementation of the Tárcoles RFMA:

1. Conduct training sessions for artisanal fishers on the process to file criminal charges
2. Strengthen the CoopeTárcoles R.L. ability of detecting possible offenses subject to criminal charges
3. File criminal charges for violation of the regulations in force
4. Publicly disclose sanctions for infractions in the RFMA

The Costa Rican Coast Guard, which is the agency responsible for monitoring compliance and enforcing fishing regulations within the GoN, was anticipated to also take a primary role in monitoring and sanctioning of non-compliance within the Tárcoles RFMA. INCOPESCA was not anticipated to take a major role monitoring compliance and enforcing fishing regulations given INCOPESCA's fourteen inspectors are primarily focused on enforcing on-shore regulations in eight primary ports (Cormick et al., 2014).

“Conflict Resolution Mechanisms” were designed into the continued management process (Figure 4). Under this system, the collaborating groups met periodically to discuss the status of the RFMA, communicate concerns, and work towards resolution with CoopeSolidar R.L. serving as moderator (Figure 5). Note however, any revisions to the regulatory scheme would be processed through the nested structure for final approval by INCOPESCA. Although this final approval at the federal level would essentially override local autonomy, formal approval would also support implementation of conflict-resolving rules. By legitimizing regulatory updates, the legitimacy of co-management regulations would not be questioned.

Figure 5 Tárcoles RFMA Stakeholder Meeting

In accordance with Ostrom (1990), central governments should respect the rights of community members to devise rules and implement regulations at the local level. With the 2008 AJDIP/138 accord, the Costa Rican government officially recognized these rights, allowing communities to organize and develop RFMA proposals for government review and approval. This was a significant improvement in recognition of local rights given artisanal fishers, by far the largest contingent of the Nicoya fishing fleet, were seldom represented on the INCOPESCA board (Cornick et al., 2014).

Given the multitude of stakeholders and the role of the Costa Rican government, development and implementation of the Tárcoles RFMA was a "Nested Enterprise" endeavor. As seen in Figure 4, the primary working group at the local level was designed to collaborate within the framework of a nested structure. This included coordination with and review by the local government, the Regional Council for the Conservation Area of ACOPAC, the National System of Conservation Areas (SINAC) and the Ministry of Environment, Energy and Telecommunications (MINAET). As part of a nested structure, four representatives of the local community would take part in the continuing commission appointed by the Executive Presidency of INCOPESCA and INCOPESCA retained ultimate authority. This nested review and approval process was the mechanism to adjust Tárcoles RFMA regulations as stakeholders developed new insights and increased their understanding of ecological and social dynamics.

Evaluating Outcomes

In evaluating the performance of a protected area such as an RFMA, an important variable is whether biomass has increased to desired levels (Palsson, 2002). Beyond biomass, the efficient utilization of resources associated with fishery production (such as labor, capital, etc.) is necessary to maximize the social benefits of the fishing industry

(Sharma and Leung, 1999). Economic benefits are expected if a persistent reserve area is a source of biomass to neighboring fished areas (Gaines et al., 2010). Empirical evidence does indicate that adult spillover and larval subsidies may benefit fished areas outside MPAs (Hamilton et al., 2010) when spill-over of 'surplus' adults across reserve boundaries create a sustainable supply of fishable individuals (Polachek, 1990). Individual reserves can also enhance population growth outside their borders when enhanced larval production from a reserve seeds larger populations in fished areas (Gaines et al., 2010). However, spillover and recruitment effects are likely to require long periods of time to fully develop (McClanahan and Mangi 2000; Jennings 2001, Russ 2002; Russ et al., 2003). Investigating spillover of tropical reef fish from a reserve over decadal time scales, Roberts et al. (2001) showed that export of fish to hook-and-line fisheries outside the Merritt Island no-take reserve took between nine and thirty-one years to begin to develop for three species of long-lived reef fish. Evaluating five marine reserves in coastal waters of New Zealand, Australia, California, and the Philippines, as well as aggregate data from a group of reserves in Kenyan coastal waters, Babcock et al., (2010) found the average time for indirect effects to first appear was more than thirteen years and sometimes much longer.

Effect on Landings

Sampling analysis of the Tárcoles RFMA in 2012 and 2013 suggested the expected increase in landings of commercially important species had not materialized for the local fishers. The analysis was conducted within the 15 m. isobath using the trawl net fleet with mesh sizes of 3, 3.5, 5 and 7 (inches). This information was compared to data gathered from 2005-2010 (with exception of 2009) to identify an effect on landings. Given the number of samples per month was not consistent throughout the sampling years, the yearly comparison could not identify an effect on total landings on a yearly basis. These data did, however, provide a basis for comparing catch per effort by dividing the total landings by the number of surveys (Table 2).

The resulting evaluation suggested the catch rate remained stable or decreased within the Tárcoles RFMA. As described by INCOPESCA (2013), this is an important finding given the area had been under protection for two years (beginning in 2011), and it was anticipated capture rates would increase for all species groups in the area. With respect to shrimp, the 2013 INCOPESCA analysis noted the low quantities of landings made this species group unimportant to the artisanal fishers.

Table 2 Total Landings per Gillnet Effort (kg.) (INCOPESCA Data)

Group	2005	2006	2008	2010	2012	2013	Average per Group
Scomberomorus sierra	4.88	13.18	61.1	19.38	3.75	1.5	17.3
Lutjanus guttatus	12.9	13.19	15.52	11.61	15.36	13.53	13.68
Centropomus robalito	17.12	5.24	15.73	18.01	6.09	4.46	11.11
Micopogonias altipinnis	12.49	5.47	6.48	28.21	8.66	1.86	10.53
Cynoscion albus	6.31	2.65	8.04	17.48	8.9	7.08	8.41
Cynoscion squamipinnis	3.87	5.62	6.62	5.42	3.16	1.84	4.42
Cynoscion phoxocephalus	1.6	3.79	5.03	6.9	3.39	0.93	3.6
Average	8.45	7.82	25.24	15.44	8.43	4.69	11.68

This analysis contradicted a previous evaluation conducted by local stakeholders between February and July, 2012. Following an equivalent sampling methodology using gillnet fishers, CoopeTárcoles R.L. and CoopeSolidar R.L. concluded that, although information was gathered only for the first half of 2012, the results already showed higher or similar landings than previous years. Therefore CoopeTárcoles R.L. and CoopeSolidar R.L. concluded the Tárcoles RFMA had a positive impact on the species groups analyzed and suggested the Tárcoles RFMA rule structure would allow for the sustainable management of the fishery adjacent to Tárcoles.

Non-parametric testing of landings data supports the INCOPESCA conclusion of "No Effect" resulting from the Tárcoles RFMA within the first two full years of application. To carry out this analysis, the annual landings data for each reported group were compared using the test-for-trend developed by Cuzick (1985). By using the total landings reported (Appendix Figure 46 – Figure 60; Appendix Table 37 – Table 42) this comparison extended the pool of fisherman activity to include all fishing techniques and independent fishers. Therefore this analysis provides an insight to the overall impact of the Tárcoles RFMA. Landings reported for years 2008-2010 represented the pre-RFMA baseline and 2012-2013 landings represented the post-RFMA effects. Landings for 2011 were not included in the analysis because the Tárcoles RFMA was initiated in August of 2011, causing landings for 2011 to be affected by the baseline treatment as well the RFMA implementation. Each reported group was tested with results failing to reject the null hypothesis for all groups, suggesting "No Trend" (α = 0.05) (Table 3).

Table 3 Cuzick (1985) Test for Trend Results

Group Name	INCOPESCA Grouping	Test Statistic (Z)	Prob > |z|
Croaker	Agria Cola	1.73	0.083
Tuna	Atun	-1.29	0.197
Mollusks	Bivalvos	-0.82	0.414
Grouper	Cabrilla	-1.73	0.083
Squid	Calamar	-1.78	0.076
White Shrimp	Camaron Blanco	0.58	0.564
Titi Shrimp	Camaron Titi	-0.58	0.564
Crab	Cangrejos	-0.58	0.564
Shark	Cazon	0	1
Low Value Group	Chatarra	1.15	0.248
Classified	Clasificado	-0.58	0.564
Mahi-Mahi	Dorado	1.73	0.083
Sea Bass	Filet	-0.89	0.374
Pacific Lobster	Langosta Pacifico	0.58	0.564
Marlin	Marlin	--	--
Snapper	Pargo	-1.73	0.083
Primary Large *(Croaker and Snook Weight > 4 kilograms)*	Primera Grande	1.73	0.083
Primary Small *(Croaker and Snook Weight < 4 kilograms)*	Primera Pequena	1.15	0.248
Octopus	Pulpo	-1.29	0.197
Sardine	Sardina	-1.73	0.083

Evaluating Human Dimensions

Without attention to the underlying socioeconomic issues, science-based reserve development will be significantly constrained, and is unlikely to serve social needs effectively (Sale et al., 2005). Thus, when expanding the scope of analysis from that of the ecosystem to an evaluation that includes the dependent fishery, one must evaluate the impact to resource users to assess the success or failure of an RFMA. However, a gap remains in economic evaluation of RFMAs. The implementation of RFMAs in Costa Rica has outpaced the collection of economic data associated with the restructured regulatory regimes. Evaluation of the Tárcoles RFMA is further challenged by constraints to academic research and technical investigation established at the local level. The willingness to collaborate with investigators is constrained by a perceived history of little-to-no benefit for local fishers (Personal Observation). Namely, the artisanal fishers feel they have not gained significant benefits from assisting in sampling or other study support activities. Where the cooperative has agreed to collaborate with investigators, the terms of the collaboration have in some cases caused the study to become invalid (Marín Cabrera, 2012). In all cases, there is a requirement for internal review and approval of final drafts. This includes declaration of intellectual property rights for any products (Consorcio PorlaMar R.L., 2012). There have also been restrictions placed on the sharing of study results with the broader academic and policy analysis communities ((Consorcio PorlaMar R.L., 2012; Personal Observation), and a fee placed on collected data (Conservation International, Personal Communication). This has distanced the Tárcoles community from collaboration with well-established conservation groups in Costa Rica such as Conservation International and PRETOMA. That said, CoopeSolidar R.L. has been successful in coordinating a stream of undergraduate and graduate students from abroad into the community for educational purposes (Personal Observation). Resulting analyses, however, are not made available for critical review or reference (Personal Observation). This augments the data gap for conducting objective economic analysis of coastal zone management in Costa Rica.

Tárcoles RFMA Compliance

For local fishing communities to support co-management regimes, some clear evidence of local fishery benefits is essential. When short-term costs have increased due to increased travel distances beyond protected areas (such as the distance required for the Tárcoles RFMA) leaders will have to sustain stakeholder confidence in the management effort. Within this context, Tárcoles RFMA proponents are facing an increasing challenge to secure continued support for the RFMA and will likely need to continue this campaign for the foreseeable future. This is because Tárcoles regional landings data have not shown an increase. This has created a situation where fishers are losing faith in the co-management approach and local fishers are now questioning the effectiveness of the RFMA (Personal Observation).

With exception of a handful of RFMA proponents, the general practice is to disregard the RFMA requirements in the interest of short-term returns (Personal Observation). This non-compliance within the RFMA aligns with the general trend in Costa Rica fisheries where the main source of profits results from overexploitation and the use of illegal gear (Cornick et al., 2014). There is no deterrent to this non-compliance within the local community. The planned compliance monitoring and sanctioning system has not materialized because peer-to-peer regulation can lead to conflict. This has caused the local fishers to avoid non-compliance reporting (Personal Observation). There is however, no apparent issue in reporting the non-compliance of the trawler fleet to either INCOPESCA or the Costa Rican Coast Guard (Personal Observation). Two factors that may promote reporting of trawler non-compliance are lower risks of retaliation and a clear distinction between the fleet members. The trawler fleet is based in Puntarenas and there is no connection to the local community given trawler crews are made up of "outsiders" from different areas of Costa Rica. There is also lower probability of confrontation with trawler fleet crews given these individuals do not dock in the Tárcoles region. This results in low probability of direct interaction between fleet groups. In this sense, the Tárcoles RFMA has been successful in that formal restrictions on trawling were codified by INCOPESCA and trawler non-compliance is reported.

Discussion and Conclusions

Analysis of Tárcoles RFMA landings was based on a combination of INCOPESCA landings data, INCOPESCA sampling analysis (Alpízar, 2013), and CoopeTárcoles R.L. sampling analysis (CoopeTárcoles R.L., 2012). The project proponents, CoopeTárcoles R.L. and CoopeSolidar R.L., suggest the RFMA exhibited a biomass increase within less than a year of implementation. A notable improvement within such a short duration would likely be a product of the stochastic nature of fishery ecosystem rather than an RFMA accelerated effect. This stochasticity may have manifested in the subsequent analysis conducted by INCOPESCA a year later, which yielded conclusions opposite to the Cooperative's. The present study analyzed the larger data set that included all area fishermen from 2008 to 2013. Analysis of this information using the Cuzick (1985) non-parametric test for trend suggested no change in landings due to implementation of the RFMA. One gap in this trend analysis is the lack of information regarding the activity level. If post-RFMA activity was lower the test would not account for increased CPUE and would potentially yield erroneous results. However, a more likely scenario would be increased fisher activity in the region due to anticipated increased landings.

The development and implementation of the Tárcoles RFMA was, in fact, a significant accomplishment. The community exhibited a progressive CPR approach for protecting the resources on which they are dependent. The level of local engagement was an improvement from INCOPESCA's historical approach of under-representing the artisanal fleet. The zone-based regulatory structure was based on local fisher knowledge. There is legitimate value in this type of local ecological knowledge. However, because fisheries are complex systems that are affected by external variables, local fishers could have improved the design of the RFMA by collaborating with the broader scientific community. By not accounting for the inter-species dynamics, project proponents failed to identify realistic outcomes. An objective analysis of landings data suggests the anticipated short-term benefits did not materialize and there has been no spill-over effect.

Beyond the ecological aspects of the RFMA, the socio-economic benefits have also failed to meet anticipated results. Continued poverty is anticipated under the current structure given there is no evidence the zone-based management increased biomass within the RFMA. A lack of compliance also suggests Tárcoles RFMA proponents planned for an unrealistic and optimistic acceptance of the RFMA regulation. The lack of effective monitoring or a legitimate risk of sanctioning has created an open-access type resource. Without a community norm-driven compliance program, the proverbial tragedy of the commons is anticipated to occur.

CHAPTER 3. ECOSYSTEM MODELING

When changes in species richness or changes in community structure and function have only been superficially explored, the long-term effects of marine reserves need to be monitored to concretely assess their effectiveness (Boersma and Parrish, 1999). Given the ecological complexities and trophic interactions, it may take decades to observe and validate the full implications because many of the trophic processes operate on these time scales. The multitude of links and processes that make an ecosystem may augment the ultimate effects of anthropogenic actions because of inevitable non-linearities (Babcock et al., 2010).

Ecosystem models are a tool to aid in the understanding of the potential long-term outcomes (Fulton et al. 2003). The advantage of this modeling approach is that a large quantity of data can be integrated to give a holistic description of an entire system, in which the important biota and the biomass fluxes can be presented. This allows for evaluating the impact of fisheries, while considering trophic interactions as well as environmental impact related to system productivity (Wolff, 2006).

One function of fisheries models, whether single or multispecies, is to help inform decision-makers of the consequences of possible fishing activities (Fulton et al. 2003; Dorn et al., 2003). The predictive capability allows fishers, scientists, managers and policy makers to explore the ecological, and economic benefits of different conservation and harvest strategies (Christensen, 2008). Robust models can simulate the effects of changes in policies and the economic environment on behavior and welfare. Lack of data, complex interdependencies and the stochasticity of variables must be addressed with reasonable and plausible assumptions. The challenge, therefore, is to define an optimal model that minimizes complexity and uncertainty to produce valid and robust predictions. Too much complexity may lead to too much uncertainty of predictions, while too little detail results in models that cannot produce realistic behaviors (Fulton et al. 2003).

Methods

Ecopath with Ecosim

Modeling packages such as Ecopath with Ecosim (EwE) allow "what if" analysis of different scenarios at varying temporal and spatial scales (Christensen, 2008). Ecopath bases the parameterization on an assumption of mass balance and Ecosim incorporates biomass dynamics using coupled differential equations (see Christensen and Walters (2004) for mathematical framework). Examples where the utility of the EwE modeling approach was employed include the Bettie et al. (2002) evaluation of strategies available to regulators in the North Sea to find a compromise that maximized the benefits to both the fleets and the biomass pools; the Arreguín-Sánchez et al. (2004) evaluation of management scenarios for artisanal fisheries in Baja California; the Heymans (2004) investigation of fisheries policies for the Northern Bengula ecosystem; the Chen et al. (2009) evaluation of the impact of the current trawl closure which produced improved alternatives for the Beibu Gulf; the Walters et al. (2008) investigation of the impact of shrimp trawler removal in the Gulf of Mexico; and the Salomon et al. (2002) investigation of ecological consequences and socioeconomic implications of fisheries policy within the proposed Gwaii Hanaas National Marine Conservation Area.

The Ecopath model's basic data requirements (biomass estimates, ecotrophic efficiencies, consumption estimates, and diet composition) are relatively simple and generally available in the literature (Christensen et al., 2005). Because the GoN is among the best-studied tropical ecosystems (Vargas, 1995), this ecological information can be combined with INCOPESCA fleet landings and activity data to carry out the Ecosim dynamic analysis and estimate the long-term outcomes of fishery management alternatives.

EwE with Ecospace

Ecospace analysis allows for spatial analysis of zones and sections within the study area to identify site-specific effects (see Christensen and Walters (2004) for mathematical framework). This spatio-temporal analysis of the ecosystem can be used as policy exploration tool (Le Quesne et al., 2007). Using Ecospace, Varkey et al. (2012) evaluated three types of fishing restrictions employed in the Raja Ampat MPAs and concluded that functional groups with low dispersal rates responded most to protection from MPAs (with the caveat that there is significant uncertainty regarding the dispersal behavior of fish species). This study concluded that rapid rebuilding of reef fish populations requires no-take areas. Dichmont et al. (2013) evaluated the MPA designs for the Australian Northern Prawn Fishery based on competing objectives. The authors suggested a total closure scenario for 26% of the trawl area performed no better than a base case with respect to biomass of functional groups or indirect impacts due to bycatch. Using Ecospace to assess the effects of an MPA system proposal in northern Chile, Ramirez et al. (2015) concluded the interaction of MPA size, location and the dispersal rate of EwE groups will play a significant role in spillover effects and will subsequently impact fishery income. The authors also concluded the MPA system analyzed had positive effects in terms of biomass increases, but had negative effects to fisher profits resulting from displacement.

Similar analyses can be performed for the Tárcoles RFMA, where the impacts of gear restrictions for each zone can be estimated. The Tárcoles RFMA was designed, based largely on the local understanding of ecological dynamics of the area, to increase biomass within the RFMA and supplement the adjacent region through a spillover effect. The Ecospace analysis can be used to evaluate this assumption and predict the long-term outcomes.

Wolff Nicoya Model

Analyzing the Tárcoles RFMA using an Ecopath with Ecosim (EwE) model provides the capability of estimating long-term outcomes for the regulatory regime. Wolff et al. (1998) developed an Ecopath model of the GoN to analyze the multi-species interactions in addition to the impacts of fishery landings. The Wolff model was composed of twenty-one groups (Table 4) representing the spectrum of biodiversity within the GoN. These groupings were based primarily on data reported during two comprehensive biomass surveys carried out in the GoN. Namely, the 1979 US RV Skimmer that yielded the first quantitative data on the biotic structure for the GoN. The second source of data was the 1994 RV Victor Hensen sampling effort. This effort further provided data on the structure and dynamics of bentho-demersal fish and invertebrate assemblages as well as infauna (*ibid*). Data collected represented a depth gradient from shallow waters (20m) near the mangrove edge to the adjacent and deeper fishing grounds (>200 m) (*ibid*). Note however, the "Wolff Model" did not include a group for Large Pelagics (Dorado).

Wolff et al. (1998) based group parameters on available information on biomass, catches, P/B ratios, consumption rates (Q/B), as well as growth and mortality rates for the species of the GoN. The information was assembled from landing statistics, the modeling team's research data and available literature. Note however, the model did not account for fishery discards.

Table 4 Wolff et al. (1998) GoN Ecopath Model Groups with Ecopath parameters

Group Number	Group Name	Trophic Level (TL)	Biomass (B), tons per km^2	Production to Biomass Ratio (P/B)	Consumption to Biomass Ratio (Q/B)	Ecotrophic Efficiency (EE)
1	Phytoplankton	1	6	180	-	658
2	Microphytobenthos	1	0.5	120	-	934
3	Mangroves	1	100	0.22	-	447
4	Zooplankton	2.05	4	40	160	0.5
5	Shrimps	2.53	1.5	6	28	0.931
6	Squids	3.54	0.4	40610	32	0.914
7	Small Pelagics	2.42	2.6	5.5	28	0.923
8	Carangids	3.63	0.5	0.8	7.3	0.943
9	Small Demersals	3.03	1.3	2.3	12	0.932
10	Flatfish	3.08	0.78	1.8	7.5	0.939
11	Catfish	3.5	0.5	0.9	4	0.92
12	Snappers and Grunts	3.67	0.4	0.95	4.3	0.962
13	Lizardfish	3.64	0.19	1	7	0.981
14	Sciaenids and Lutjanids	3.62	0.3	0.6	4	0.963
15	Rays and Sharks	3.9	0.09	0.6	2.8	0.954
16	Morays and eels	3.84	0.16	0.75	3.6	0.992
17	Endobenthos	2.1	0.35	30	150	0.994
18	Epibenthos	2.01	12	4	25	0.448
19	Predatory crabs	3.05	0.5	2	11	0.904
20	Sea/shore birds	3.35	0.05	0.15	65	0
21	Detritus	1	0	0	0	0.336

Wolff et al. (1998) published the results of the Ecopath model for the GoN in which they concluded (among other key findings); (i) shrimp occupy a central position in the food web as food source for many fish groups and overexploitation of white shrimp (*Penaeusvannamei*) seems to have severely affected the food web of the whole system, (ii) for their wide-scale distribution and specific trophic niche (converter of the system's rich detritus source), it is improbable that other species can compensate the central role of shrimp, and the decline of many commercially important populations of shrimp feeding species seems a logical consequence of this overexploitation, and (iii) the drastic decline in the fishery catches observed over the last decades not only reflect overfishing of some resources but rather a general destabilization of the entire ecosystem. Wolff et al. (1998) estimated the mean trophic level of the Golfo de Nicoya fishery to be 4.06 associated with an annual catch of $3.38 gm^{-2}$. This model of the GoN suggested that sustainable levels of higher catches seemed attainable only after a several year period of strong reduction in fishing effort to allow shrimps and fish resources to re-attain the large stock sizes of the late 1970s (Wolff, 2006). This model, however, did not introduce the Ecosim (time-dynamic simulation) or Ecospace (spatial simulation) utilities of the modeling software.

GoN Model 1999-2007

Based on the Wolff et al. (1998) model of the GoN, the RFMA EwE model was developed to carry out an analysis of the present-day status and potential outcomes of the Tárcoles RFMA. Given the Tárcoles RFMA model begins in 2008, the RFMA model required reconciliation with the 1998 Wolff baseline. This reconciliation was necessary given the biomass for the EwE groups may have been reduced due to continuing fishing pressure from 1999-2007. A second factor requiring consideration was the scale at which the Wolff Model analyzed the GoN. The Tárcoles RFMA is approximately 108 km^2 while the GoN is approximately 1530 km^2 in total area.

To accomplish this reconciliation, an intermediate EwE model was developed for the GoN. This gulf wide model incorporated trawling and artisanal activity, including catch - and in the case of trawling, bycatch and discards. The intermediate model was programmed to address the noted gaps in the 1998 Wolff model. The updated model included a Large Pelagic group (Dorado), was updated to include trawler discards, and introduced the Ecosim functionality of the modeling software. This required the development of a diet matrix for Dorado, the calculation of bycatch and bycatch discard quantities, as well as estimates of trawler and artisanal fleet activity.

Trawler Activity

Trawling commenced in Costa Rica in 1952 and in 1960 the trawling fleet in Costa Rica was made up of six vessels. That number increased to 35 by 1980 and to 70 by 1989 (Alvarez and Ross, 2010). This fleet has declined to 23 boats currently operating on a part-time basis (Cornick et. al, 2014). There are three trawler fleets active in Costa Riva. Each fleet can be characterized by the depth of trawl activity and the target species. Fleet 1 trawls areas within the GoN to a maximum depth of 50 meters and targets white shrimp (*Litopenaeus occidentalis, Litopenaeus stylirostris, Litopenaeus vannamei*), and titi shrimp (*Xiphopenaeus riverti*). Fleet 2, which trawls both within and beyond the GoN, is characterized as focusing on depths between 35 meters and 120 meters, with a target of crystal shrimp (*Penaeus brevirostri*) and yellow leg shrimp (*Penaeus californiensis*). Fleet 3 focuses exclusively outside the GoN at depths between 120 meters and 1,000 meters. Fleet 3 targets kolibri shrimp (*Solenocera agassizii*) at the 120 meter range while bigheaded shrimp (*Heterocarpus vicarious*) and camellón shrimp (*Heterocarpus affinis*) are targeted at depths between 350 meters and 1,000 meters. Note, Fleet 1 is a key fleet for the Tárcoles community given the area trawled by this fleet (depth less than 50 meters) and the target shrimp species correspond with the area and species found within the Tárcoles RFMA. Hence, this trawler fleet in Costa Rica is an integral driver of ecosystem dynamics within the Tárcoles RFMA. Table 5 lists the number of trawl days per year from 1994-2005 and Table 6 lists the monthly quantity of active trawlers from 2003-2013 (INCOPESCA Data).

Table 5 Total Trawl Activity per Year (days) by Fleet Type (Araya et. al, 2007)

Year	FLEET 1	FLEET 2	FLEET 3	Total
1994	3239	5265	5677	14181
1995	6070	2865	6166	15101
1996	7635	2406	5277	15318
1997	9121	2906	3718	15745
1998	9156	3264	2904	15324
1999	8090	4249	3372	15711
2000	7838	4044	3989	15871
2001	6162	5225	2860	14247
2002	6897	4277	2903	14077
2003	3752	3784	4274	11810
2004	2345	2918	4967	10230
2005	3635	2317	5075	11027

Table 6 Quantity of Active Trawlers per Month - All Fleets (INCOPESCA Data)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2003	48	43	45	43	49	41	40	45	41	45	42	46
2004	44	39	33	28	36	39	36	42	33	39	35	39
2005	47	46	43	47	39	42	40	38	38	38	36	31
2006	42	40	41	38	39	39	37	33	31	40	33	40
2007	35	35	41	38	35	42	36	43	40	35	31	36
2008	31	35	33	34	37	38	32	29	24	26	31	30
2009	23	30	33	30	27	29	28	19	28	29	30	28
2010	29	31	26	27	29	21	23	26	24	25	21	27
2011	27	18	24	18	23	20	26	22	21	26	24	26
2012	30	29	31	32	31	25	28	25	27	26	27	25
2013	24	24	26	27	29	22	26	28	25	26	27	26

Shrimp fisheries in Costa Rica have been characterized by a progressive move to deeper waters as stocks become overexploited and depleted (Alvarez and Ross, 2010). Analysis of monthly activity data shows a decrease in Fleet 1 (Figure 6) and Fleet 2 (Figure 7) activity between 1994 and 2005 while Fleet 3 exhibited an increase in activity during the same time period (Figure 8). This is congruent with a pattern of fishers shifting away from depleted fishery to new, deeper waters that may yield higher catch rates associated with less depleted species and stocks as described by Cornick et al. (2014).

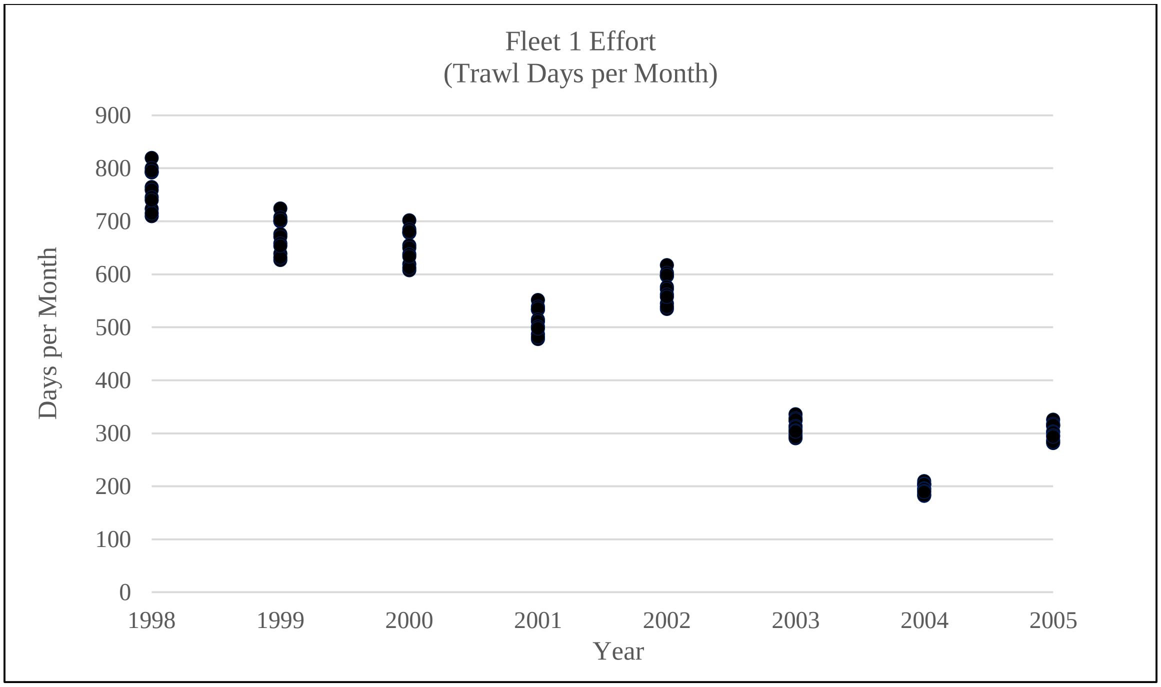

Figure 6 Fleet 1 Activity Profile (1998-2005), Total Days per Month

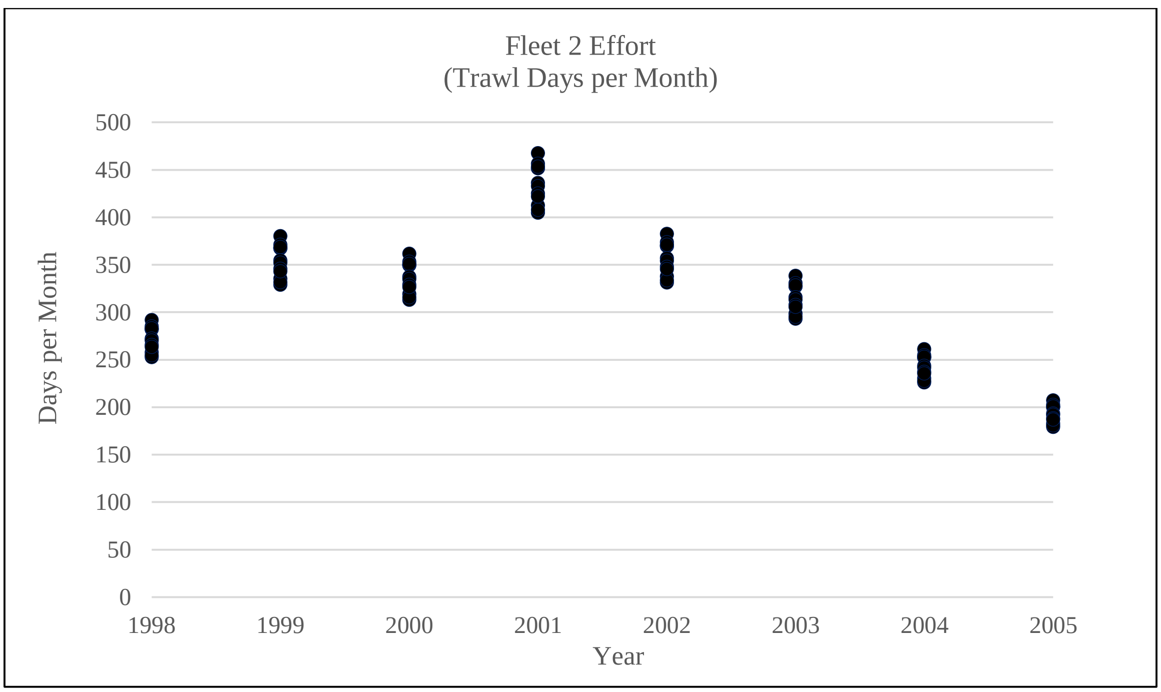

Figure 7 Fleet 2 Activity Profile (1998-2005), Total Days per Month

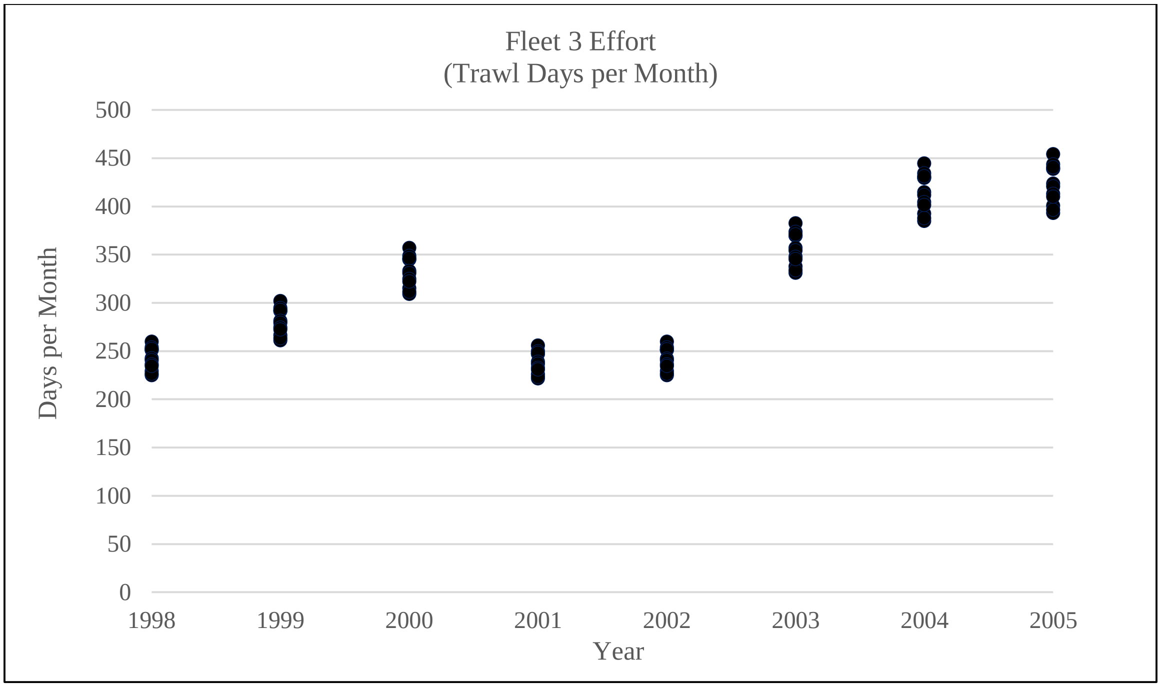

Figure 8 Fleet 3 Activity Profile (1998-2005), Total Days per Month

The monthly activity data was entered into the EwE GoN model for 1999 to 2005. Note however, because no data was available for trawling effort beyond 2005, the monthly activity data for 2006 and beyond was estimated using a regression model.

Regression Analysis

A regression analysis was carried to analyze the effect of selected independent variables on the total trawling activity. This type of reduced-form analysis can be used to investigate a "treatment" by linking the dependent variable solely to exogenous variables. A proper analysis will be designed to prevent the exogenous variables from influence through multicollinearity. One advantage of reduced-form models is that it is easier to understand what source of variation explains the dependent variable (Timmins and Schlenker, 2009). In a fisheries context, reduced form analysis can be performed using basic statistical techniques such as generalized linear model regression analysis with Total Trawl Activity (in Days per month) as the dependent variable. Feedback loops are difficult, if not impossible, to implement in a reduced-form setting (*ibid*).

Beyond seasonal effects, other factors can play a role on the amount of trawler activity taking place on a monthly basis. These may include the price of oil, availability of a support workforce, effects of significant weather events and competing economic interests. Therefore, the variables included in the regression analysis were Sea Surface Temperature Anomalies (SSTANOM), oil price in terms of USD per barrel (OILP), monthly economic growth in Costa Rica (EconG), the monthly unemployment rate for Costa Rican Males (Munemp), and the month (1 – 12). No data manipulation or transformation was required given all independent variables exhibited frequency distributions that approximated normal distributions (with exception of the Month variable).

Sea Surface Temperature (SST)

According to ISO 8402:1995/BS 4778, maritime risk assessment is defined as: "The process whereby decisions are made to accept a known or assessed risk and/or the implementation of actions to reduce the consequences or probability of occurrence." When significant weather events will create a risk to crew and equipment, it is anticipated trawler activity will be reduced based on skipper risk assessment. Therefore, SST anomaly was selected as a dependent variable to analyze the effect, if any, of weather events such as intense rains resulting from significant SST anomalies as seen with El Nino event of 1997-

1998. SST data was acquired from NOAA Oceanic Niño Index (ONI) in Niño region 3.4. (Available at http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ensoyears.shtml)

Oil Price

The price of oil can have a significant effect on the trawler industry in that this sector requires significant fuel expense when compared to other fishing techniques. According to Mestre and Ortega (2012), Costa Rican trawlers consume approximately 23% of fuel used in the fishery sector while only making up approximately 4% of the sector. This is primarily due to an estimated consumption of 156 liters of fuel for each trawl effort (Mestre and Ortega, 2012). Note, Baloaños (2005) estimated the average length of a trawl effort to be 23 days with a range between 15 and 30 days, generating an average revenue of $311.21 usd per day.

Comparing Trawler activity from 1994-2005 to the price of crude oil (in US $), a price point of approximately $40 USD per barrel of crude oil is associated with increased activity for all three types of trawling (Figure 9, Figure 10, Figure 11). The data for Oil Prices (Crude Oil (petroleum), US "real" dollars per barrel) was accessed from U.S. Energy Information Association data.

(Available at http://www.eia.gov/petroleum/data.cfm#prices).

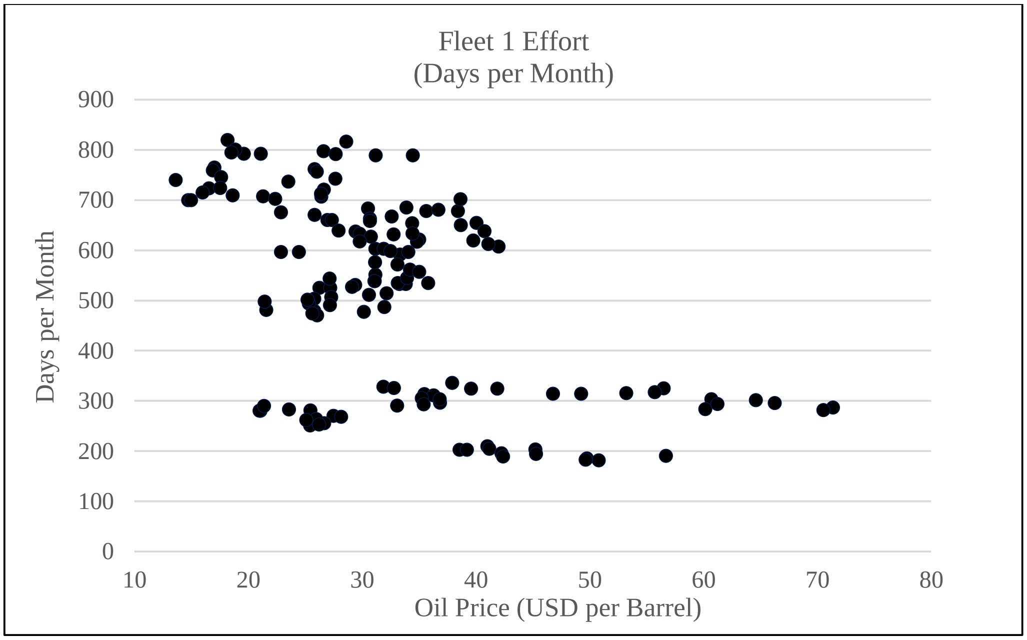

Figure 9 Fleet 1 Activity (in Days per Month) vs Crude Oil Price (USD per Barrel)

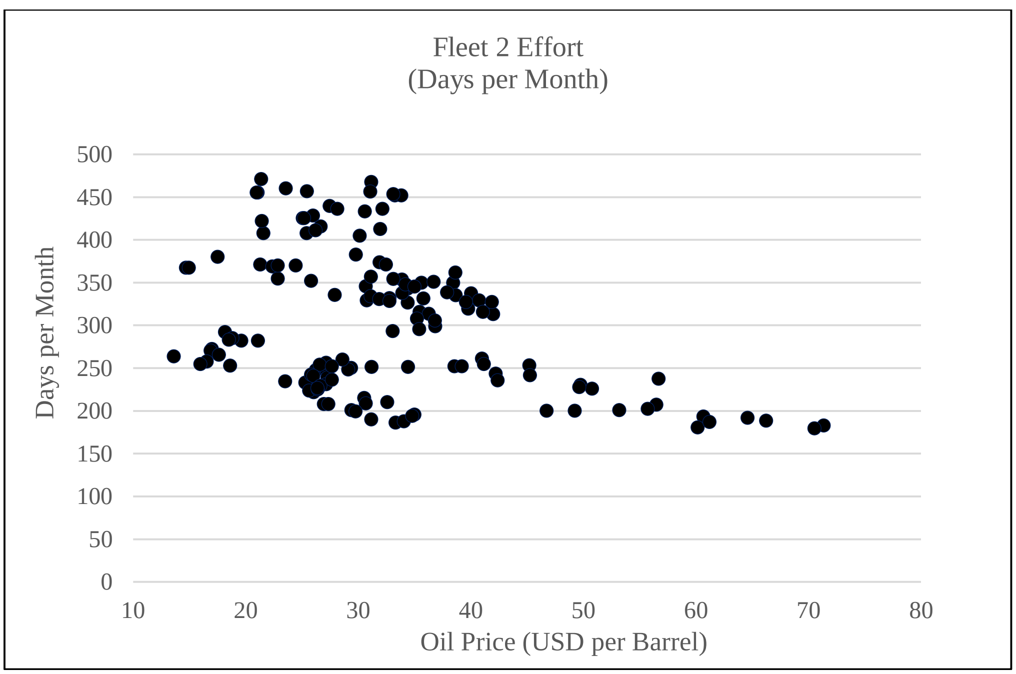

Figure 10 Fleet 2 Activity (in Days per Month) vs Crude Oil Price (USD per Barrel)

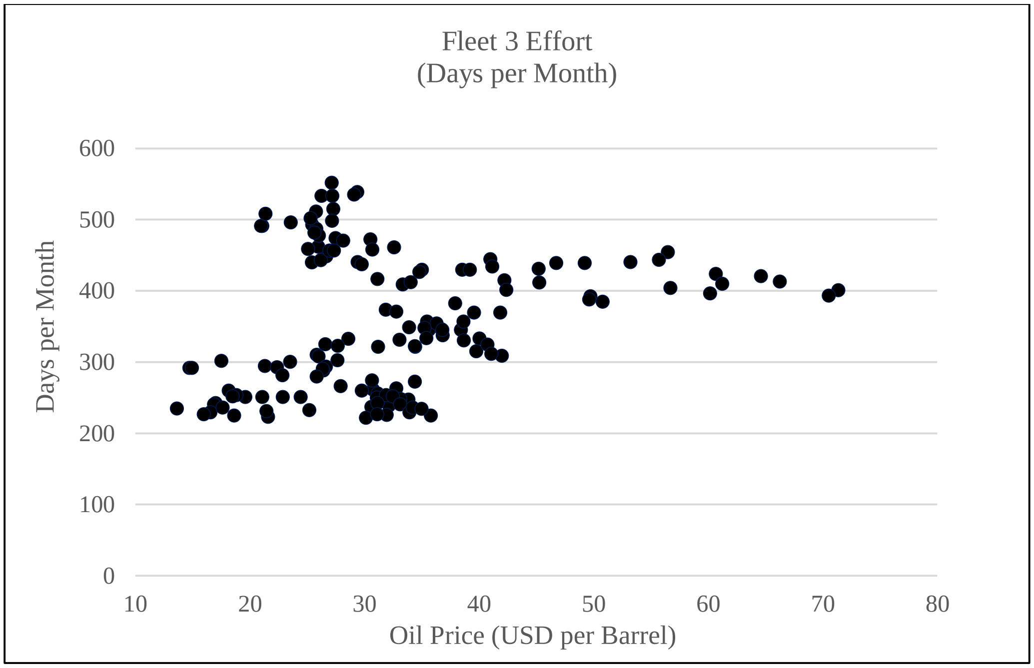

Figure 11 Fleet 3 Activity (in Days per Month) vs Crude Oil Price (USD per Barrel)

Economic Growth

Gross Domestic Product was selected as an independent variable in order to identify a connection between the broader Costa Rican economy and the trawler industry. Trawling activity was estimated to make up only 0.5% of the Costa Rica GDP in 2007 (Alvarez and Salazar, 2010). Increased trawler activity will, in theory, increase output which in turn will contribute to an increase in GDP. However, due to the overexploited status of the GoN fishery, trawling may not yield sufficient returns to attract new investment and increased activity. This can occur when effort cost exceeds revenue. Economic Growth data (the rate of change of real GDP) was derived from World Bank Data.

(Available at http://www.theglobaleconomy.com/Costa-Rica/Economic_growth/)

Male Unemployment

Male unemployment was selected as an explanatory variable of trawler activity given that trawling requires higher levels of labor when compared to other fishing sectors in Costa Rica. Trawling currently provides direct employment to approximately 830 people (divided between crew members, owners, net repair, processors, marketers and exporters). This is estimated to generate indirect economic benefits for 4150 people. Thus the total number of individuals employed by the trawling fleet is estimated to be 4980 (FAO, 2015). Data for the Costa Rican male unemployment rate (% male 15 years old and greater) was derived from United Nations datasets.

(Available at https://www.quandl.com/data/UGEN/UNEM_CRI-Unemployment-Rates-Costa-Rica)

Month

The variable "Month" was selected to account for temporal trends within each year. Beyond SST anomalies, it is anticipated that trawler activity is affected by seasonal variables such as anticipated fish migration patterns. Additionally, trawler activity may be impacted by known or perceived reproduction and growth patterns of target species, given that shrimp stocks exhibit strong seasonality (Tabasco-Blanco and Chavez, 2006).

Regression Results

The regression analysis shows that 67% of the variance for the dependent variable (number of days trawled per month) can be explained by the selected independent variables ($R^2 = 0.67$) and coefficients (β) for all selected independent variables were statistically significant ($\alpha < 0.05$) (Table 7).

Table 7 Regression Analysis Results
Sea Surface Temperature Anomaly (SSTANOM), Real Price per Barrel of Crude Oil (REALP), Economic Growth (EconG), Male Unemployment (Munemp), Calendar Month (Month), and Regression Equation Constant (Const)

Variable	β	SE	95% CI for β
SSTANOM	-37.06*	10.32	-57.482, -16.641
REALP	-8.68*	0.81	-10.289, -7.075
EconG	-13.77*	3.55	-20.805, -6.741
Munemp	-63.86*	15.24	-93.995, -33.727
Month	-10.04*	2.47	-14.927, -5.152
Const	1894.46*	75.90	1744.384, 2044.54

*$p \leq .05$

Analysis of regression residuals versus fitted values showed no pattern present and a Breusch-Pagan/Cook-Weisberg test for constant variance of fitted values indicated heteroskedasticity was not present (χ^2 = 0.00, p = 0.9541). Variance Inflation Factor test values were below 1.19 for all independent variables (mean = 1.09) suggesting multicollinearity is not present.

The regression suggests SST anomalies affect trawler activity, where a unit increase in SST (in degrees Celsius) will decrease Trawler activity by a factor of 37.06. This suggests that severe weather events may influence skipper decisions. Oil prices also show a statistically significant effect on trawler activity where a unit increase (in USD) will reduce trawler activity by a factor of 8.68. Therefore, higher fuel costs will reduce the profit levels to a point where trawling is no longer a rent-generating activity. Economic growth (in terms of GDP % increase) is also strongly correlated to trawling activity, where increased GDP reduces trawler activity by a factor of 13.77. This suggests that, not only is trawling not associated with economic growth in Costa Rica, but that economic activity outside the trawling fleet may attract investment and effort away from the trawling industry. Similarly, an increase in male unemployment will reduce the level of trawling activity by a factor of 63.86. This suggests that the general unemployment rate may follow the pattern of trawler employment, where both rise and fall concurrently. This may also suggest that a surplus in labor may not affect the decision to trawl, or that there is a shortage of labor for the trawling fleet. The Month variable is also statistically significant, likely due to the seasonality of shrimp stocks. The coefficient of -10.04 suggests that trawling activity is higher in the early months of the year.

Estimated Trawl Activity

This regression was used to estimate the monthly trawling activity for the EwE model beyond 2005 using Equation 1. These resulting estimates are listed in Table 8.

Eq 1: $\text{Trawler Days} = 1894.46 + {}^{-}37.06(\text{SSTANOM } y,m) + {}^{-}8.68(\text{REALP } y,m) + {}^{-}13.77\ (\text{EconG } y,m) + {}^{-}63.86(\text{Munemp } y,m) + {}^{-}10.04(\text{Month})$

Where: y = year, m = month

Table 8 Trawler Activity Estimate (2006-2007).
Sea Surface Temperature Anomaly (SSTANOM), Real Price per Barrel of Crude Oil (REALP), Economic Growth (EconG), Male Unemployment (Munemp), Calendar Month (Month)

Year	Month	REALP	SST ANNO	EconG	Munemp	Trawler Activity (Days)
2006	1	66.83	-0.7	8.78	4.4	927.70
	2	63.15	-0.6	8.78	4.4	945.92
	3	66.05	-0.4	8.78	4.4	903.27
	4	74.16	-0.2	8.78	4.4	815.42
	5	76.29	0	8.78	4.4	779.52
	6	75.39	0.1	8.78	4.4	773.57
	7	79.92	0.2	8.78	4.4	720.51
	8	77.76	0.3	8.78	4.4	725.47
	9	67.37	0.5	8.78	4.4	798.22
	10	62.25	0.8	8.78	4.4	821.53
	11	62.22	0.9	8.78	4.4	808.05
	12	64.55	1	8.78	4.4	774.09
2007	1	58.11	0.7	7.94	3.2	1039.74
	2	62.79	0.3	7.94	3.2	1003.89
	3	65.42	0	7.94	3.2	982.17
	4	70.02	-0.1	7.94	3.2	935.90
	5	71.00	-0.2	7.94	3.2	921.05
	6	75.08	-0.2	7.94	3.2	875.57
	7	81.28	-0.3	7.94	3.2	815.43
	8	78.42	-0.6	7.94	3.2	841.36
	9	82.73	-0.8	7.94	3.2	801.29
	10	89.62	-1.1	7.94	3.2	742.51
	11	96.75	-1.2	7.94	3.2	674.28
	12	93.85	-1.3	7.94	3.2	693.09

Trawler Shrimp Landings

Trujillo et al. (2012) suggest shrimp trawling has been the most significant source of fishing mortality in Costa Rica's marine ecosystem. Shrimp landings from nearshore waters have significantly declined, such that only tití shrimp are still commercially viable. In the case of deep-water shrimp, landings of approximately 220 tons per year of each of the three species were recorded in the mid-2000s. Since then, *H. affinis* catch has dropped dramatically, such that there are no landings on record since 2006. On the other hand, landings of *H. vicarius* and *S. agassizii* are relatively stable or slightly increasing

(Wehrtmann and Nielsen-Muñoz, 2009). This re-focus on more abundant species has not prevented a continued reduction in landings. INCOPESCA records suggest the total Trawl landings decreased by 39% from 2003 to 2013 (Figure 12).

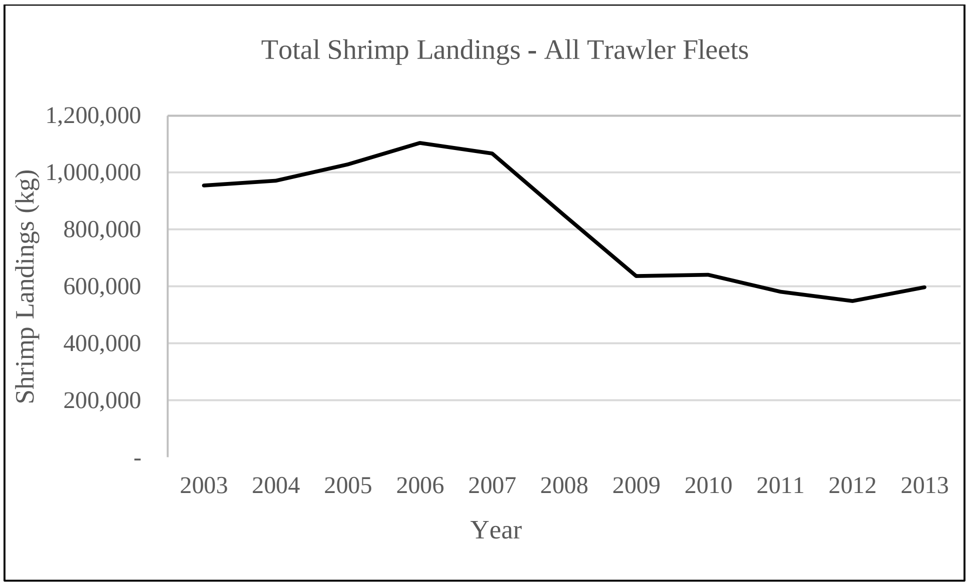

Figure 12 Annual Shrimp Landings by Year (2003-2013) in kilograms

This trend is consistent with a fishery that has been affected by continued overfishing, where the target group is not capable of reproducing at rates that will compensate for the biomass that is extracted on a yearly basis. Total trawler shrimp landings for the GoN EwE model were estimated directly from INCOPESCA Department of Fishery Statistics data from 2003 to 2007 and included all reported shrimp species landings given these are representative of Gulf-wide trawling activity.

Trawler Bycatch and Discards

Virtually all fisheries in the world target more than one species or affect secondary species (Botsford et al., 1997). Chronic disturbance from fishing activity, such as incidental catch or damage to the ecosystem substrate, may reduce the complexity of such habitats thereby reducing the suitability of the area for species of commercial importance (Cohen et al., 2013). Shrimp trawling, especially in the tropical shrimp trawl fisheries, is a very specialized activity producing large amounts of bycatch that is either discarded or partially kept on board (Gillet, 2008). Bycatch may impact community structure if trawling directly removes or reduces the populations representing specific trophic levels of the community and by the provision of additional food or nutrients in the form of discards (Blaber et al. 2000).

Within the shrimp fishery, shrimp trawl fisheries have the most bycatch of any of the Costa Rican fisheries sectors (Kelleher, 2005). The ratio of by-catch to target resources in tropical and subtropical shrimp fisheries often varies between 1:5 and 1:10 (Arana et al., 2013). A 1987 survey conducted by the INCOPESCA regional office in Puntarenas determined that the total shrimp to bycatch ratio was between 1:7.7 and 1:9 (Gutierrez, 1990). However, more recent field studies suggest shrimp to bycatch ratios as high as 1:48 (Porras and Sanabria, 2013). Porras and Sanabria (2013) noted bycatch to be significantly higher when targeting white shrimp (*Litopenaeus occidentalis, L.stylirostris, L.vannamei*) and titi shrimp (*Xiphopenaeus riverti*) (1:48). Bycatch ratios also varied significantly by region, with the highest rate occurring in the zone between Punta Judas and Quepos, in comparison to the outer zone of the GoN. This combination resulted in an overall average shrimp to bycatch ration of 1:25 (FAO, 2015).

Reductions in the total biomass of target fish and bycatch could be expected to affect predators, prey, competitors of a target species, and overall seafloor community structure (NRC, 2002). Using the EwE modeling tool, Gribble (2003) estimated decreasing shrimp biomass due to an increase in biomass of higher trophic levels if bycatch was reduced. Criales-Hernandez et al. (2006) showed increased biomass of middle to low trophic level consumers as a result of reduced bycatch, but estimated no negative effect on shrimp biomass. Thus, bycatch is one of the most pressing and controversial aspects of shrimp trawling (Gillet, 2008) and must be included in a multi-species model when trawling is a component within the fishery.

A more sustainable method is one which reduces or eliminates these externalities. This prevents by-catch of non-target species, is selective to prevent catch of juvenile members of the ecosystem, or does not cause damage to the underlying ecosystem to ensure baseline biodiversity is maintained. These methods are case dependent and will vary with the types of ecosystems and species characteristics. A range of technological solutions have been proposed including Turtle Exclusion Devices (TEDs) and By-catch Reduction Devices (BRDs). An emerging approach being implemented by the European Union requires that no by-catch be discarded and all catch be landed. Although this has the potential to increase incentives to implement more selective fishing technologies, the elimination of biomass may have significant impacts to trophic interactions due to reduced detritus when bycatch is not capped by quotas. In stricter policy applications to eliminate negative impacts of trawling, entire trawling fleets have been banned.

Shrimp trawling contributes to the highest level of discard/catch ratios of any fishery (Kumar and Deepthi, 2006), with tropical shallow-water shrimp fisheries accounting for 70 percent of the total estimated discards. Almost all of these tropical shallow-water fisheries target penaeid shrimp and have an average discard rate of 55.8% (Gillet, 2008). Alverson et al. (1994) estimated a shrimp catch to discard ratio of 1:10.3, resulting in a biomass discard rate of over 91 percent. In Costa Rica, Porras Porras and Sanabria (2013) estimated a shrimp catch to discard ratio of 1:22 (95%). However the shrimp catch to discard ratio increased to 1:42 (98%) when white shrimp (*Litopenaeus occidentalis, L.stylirostris, L.vannamei*) was the target species.

Factors identified by Kumar and Deepthi (2006) that contribute to the discarding of bycatch included; little or no commercial value for the bycatch, the cost involved in landing fish, storage, and processing (icing), and storage capacity limitations in trawlers given the trawlers refrigerator is used almost exclusively for target species.

Bycatch that is discarded has potential impacts to the ecosystem, primarily because discards returned to the sea dead (or dying) are exploited by multiple species across trophic levels (NRC, 2002) as a form of anthropogenic food subsidies. Fondo et al. (2015) suggested that an abrupt ban on discards by requiring all bycatch to be landed can have a negative impact on the scavenger species and could potentially destabilize the affected ecosystem.

The GoN EwE trawler bycatch landings for non-shrimp groups were calculated from INCOPESCA Department of Fishery Statistics data from 2003 and 2007 (Table 9). INCOPESCA trawler landings data from 2003 to 2013 includes information on shrimp landings as well as the total bycatch landed. This allowed for a robust analysis of the bycatch element to be carried out in the multi-species model (see Appendix Table 26 – Table 36 for detail).

Table 9 Retained Trawler Bycatch (kg), Costa Rica 2003-2007. INCOPESCA Data

Year	Snappers and Grunts	Dorado	Rays and Sharks	Large Sciaenids	Small Demersals	Small Pelagics
2003	23.74	37	6083.55	82257.95	303262.16	35213.5
2004	25	0	3482.39	80934.64	297428.71	67883.8
2005	66	158	2,552.90	106,160.52	333,051.29	98,643.80
2006	0	0	1,887.21	97,658.34	356,651.05	165,931.00
2007	765.5	0	2,213.80	48,089.33	432,459.51	57,431.51

There is no detailed data for total discards associated with trawling in Costa Rica. Therefore an estimate was calculated (Table 10) using a discard rate of 1:22, as was reported by Porras Porras and Sanabria (2013). More specifically, FAO (2015) estimated a bycatch landing to discard ratio of 1:3 for non-target species. Taken together, these ratios suggest that a bycatch landing to bycatch discard ratio of 3:22 is reasonable. This 3:22 ratio, or a factor of 7.33, was therefore applied to estimate trawler catch discard of the EwE groups.

Table 10 Estimated Discarded Trawler Bycatch (kg per km^2 per year), 2008-2013

Year	Dorado	Rays & Sharks	Snappers and Grunts	Large Sciaenids	Small Demersals	Small Pelagics
2008	0.00394	0.23088	0	2.2262	2.0596	0
2009	0.06732	0.20188	0.002	1.5851	1.8524	0.0297
2010	0.01543	0.06627	0.0008	0.8969	1.9961	0.1188
2011	0	0.05221	0	1.0336	3.2941	0
2012	0.0018	0.02823	0.0004	1.5616	5.9523	0.1688

2013	0	0.01148	0	1.2362	1.7369	0.3466

Artisanal Fleet Activity

The artisanal fleet activity is composed of gillnet, longline, as well as pole and other manual techniques. In 2012, an estimated 2,600 artisanal fishers were active in the GoN (Marín Cabrera, 2012). This fleet is characterized by small boats that use outboard 25 horse power engines and operate as far as three miles from the coast on single-day trips (Herrera-Ulloa et al., 2011). Gillnet fishing is the most productive (in terms of total catch) artisanal fishery in the GoN. The average annual catch of gillnet activity is 73% of total artisanal landings, with longline fishing landings making up 21% of artisanal landings (Araya et al. 2007). Total length of gillnets can range between 400 and 500 meters and is 1.5 meters wide (Carvajal, 2013). The mesh sizes range between 2 inches and 7 inches (Gillet, 2008; Personal Observation) with average catch size increasing by mesh size. Marín Alpízar (2013) found the average weight for gillnet catch to be 2.5 kg for 3.5 inch gillnet, 3.5 kg for 5 inch gillnet, and 7 inch gillnet yielding an average catch weight of 16.2 kg. Target species of gillnet activity include shrimps (*Litopenaeus stylirostris* or *L. occidentalis*), croacker (*Cynocsion sp*.), snook (*Centropomus sp.),* snapper (*Lutjanus sp*.), black tuna (*Euthynnus lineatus*), and mackerel (*Scombridae*) (Herrera-Ulloa et al., 2011).

Crew sizes of two are generally the norm for small scale gillnet and midwater longline activities. Crew sizes can increase to four when Snapper (*Lutjanus sp*.) and grouper (*Serranidae)* are targeted using bottom longline (Herrera-Ulloa et al., 2011), which are also associated with longer distances to the outer regions of the GoN (Araya et al., 2007).

A graphical representation of the gillnet activity (Figure 13) suggests a downward trend in total gillnet effort. Unlike trawling, the artisanal fishers cannot expand activities significantly beyond the three-mile distance due to limited equipment and resources. This suggests attrition of gillnet fishing labor or increased idle time due to reduced activity. Note, idle time may not be associated linearly with reduced income given the Catch per Unit Effort has increased from 1.4 kg/day in 1998 to 2.0 kg/day in 2005 (Araya et al., 2007). INCOPESCA data on Malla activity from 1994-2005 (Araya et al., 2007) was utilized for estimating annual activity in the EwE model (Table 11).

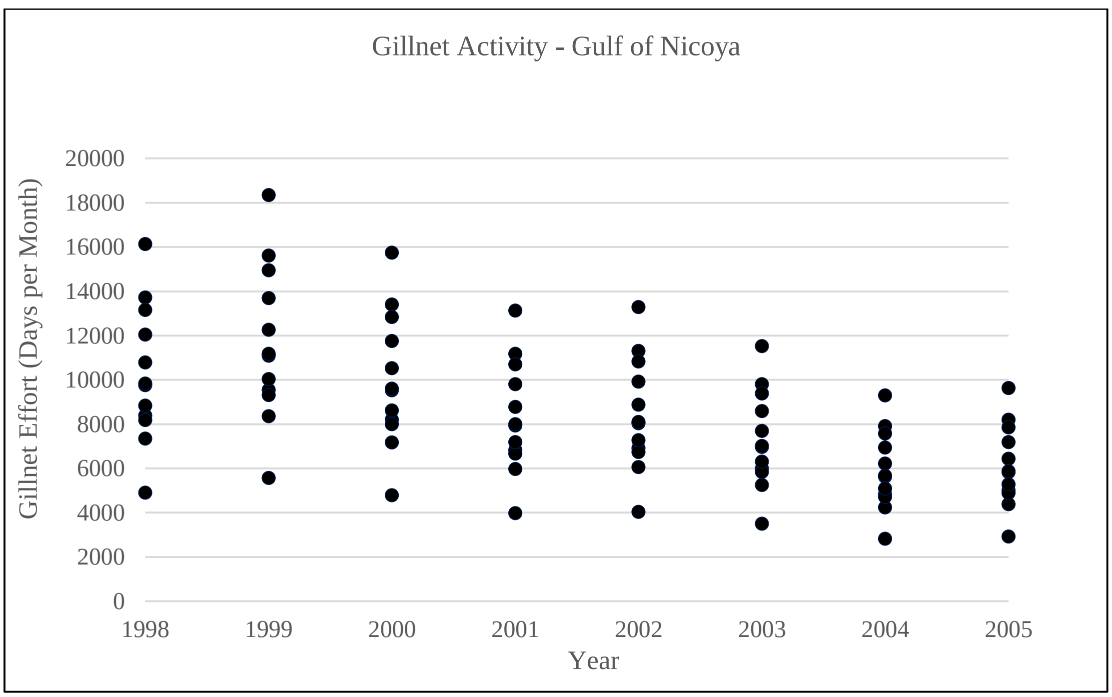

Figure 13 Gillnet Activity Profile (1998-2005), Total Days per Month

Table 11 Total Gillnet Activity per Year (days) Upper GoN (Araya et. al, 2007)

Year	Total Days
1994	72456
1995	83130
1996	90328
1997	91486
1998	123058
1999	139940
2000	120144
2001	100148
2002	101404
2003	87856
2004	70924
2005	73480

Given the EwE model update required information from 1999 through 2007, an attempt was made to identify causal factors for calculation of estimated gillnet activity for 2006-2007. Note however, this regression calculation yielded statistically insignificant coefficients. In order to address the data gap, the information from the Tárcoles community was utilized as a proxy for Nicoya-level artisanal activity for 2006 and 2007.

Artisanal Fleet Landings

The artisanal fleet landings were estimated using information from INCOPESCA for the Tárcoles Region. Per CoopeTárcoles R.L. (2010), CoopeTárcoles R.L. fishers spend approximately 52% of fishing time within what is termed as the "Tárcoles Community Region" that corresponds to the RFMA. The artisanal fishing community reports that cooperative members will spend approximately 11% of the total time fishing as far south as Esterillos, Parrita, and Quepos and approximately 10% of the total fishing time as far north as Los Negros and Tambor (CoopeTárcoles R.L., 2010). It is assumed non-Cooperative fishers, or “independents”, follow a similar pattern given there are no restrictions on fishing activity locations making areas exclusive to CoopeTárcoles R.L. members. More specifically, CoopeTárcoles R.L. cooperative members do not possess ownership rights nor are they allocated additional access to fishing locations.

Independent fishers are able to submit landings to the CoopeTárcoles R.L. collection site, however most independents elect to submit landings to other repositories in the region. These adjacent repositories include Barracuda, Marilyn, Pescaderia JJ, El Refugio, and Recibidor La Pista offices (INCOPESCA Data). Information reported for the Tárcoles region by artisanal fleets is listed in Table 12 (see Appendix Table 37 – Table 43 for detail). Given these landings were submitted for the Tárcoles region, the total area of activity was estimated to be 216 km^2, which is approximately twice the area of the RFMA. Note, there is no information regarding discards for the artisanal fleet. However, it is unlikely there is a significant amount of discard associated with this sector given the more selective nature of the materials and methods used. In addition to this, no (or low) value catch is oftentimes used as a bait for the longline fishery or for pole fishing, either while lines and gillnets soak, or for tourist fishery excursions (Personal Observation).

Table 12 Total Annual Catch (kg.) – Tárcoles Region (INCOPESCA Data).

Group Name	2008	2009	2010	2011	2012	2013
Croaker	6100.4	13850.08	8514.8	21503.2	18283.44	21253.48
Tuna	0	5569.2	15720.8	8548.4	0	0
Mollusks	0	0	33	0	0	0
Grouper	9096.8	18726.6	7555.2	7987.6	5775.2	4953.6
Squid	106.8	1499.2	52	924	0	0
White Shrimp	2089.84	1910.31	783.6	2647.8	1621.6	2281.64
Titi Shrimp	1408.2	863.6	48	622	488.8	520.4
Crab	495.8	225	0	0	128	108.8
Shark	5952.8	7808.12	4809.2	6947.28	5108	7388
Low Value Group	43287.33	59411.64	35814.4	61450.24	89174.4	50805.4
Classified	13829.92	33306.48	43990.6	37022.04	28079.04	32350.48
Crustaceans	0	0	0	72	0	0
Mahi-Mahi	6965.2	29042	5095.2	22055.6	35209.4	35162.8
Sea Bass	127.6	8.4	0	0	0	4
Pacific Lobster	1468.9	631.84	179.2	1207.2	1367	1450.4
Marlin	0	0	0	80	0	0
Snapper	887.6	9248.8	6554	1680	0	188.8
Primary Large (Croaker and Snook Weight > 4 kilograms)	7782.6	7442.6	16143.44	8055.6	16405.6	17436.4
Primary Small (Croaker and Snook Weight < 4 kilograms)	47843.5	81642.16	69028.6	79976.64	99196.44	73613.84
Octopus	14	4	0	0	0	0
Sardine	1009	425.6	692.8	1344.8	40	248

The Role of Dorado (*Coryphaena hippurus*)

Dorado (*Coryphaena hippurus*), also referred to as "Mahi-Mahi" or "Dolphin Fish" (Figure 14), are abundant, wide-ranging, epipelagic predators in tropical and subtropical ocean waters warmer than 20^{o} C (Palko et al., 1982; Gibbs and Collette, 1959). Distribution of Dorado in the GoN is concentrated in the lower section of the gulf where the gulf bathymetry exhibits a drop to 200 meters. However this species is highly migratory and is therefore also found in the RFMA Tárcoles region where artisanal fishers report periodic landings (Figure 15), primarily from longline activity (BIOMARCC, 2013).

Figure 14 Dorado (from Fishbase, R. Winterbottom photo (1994))

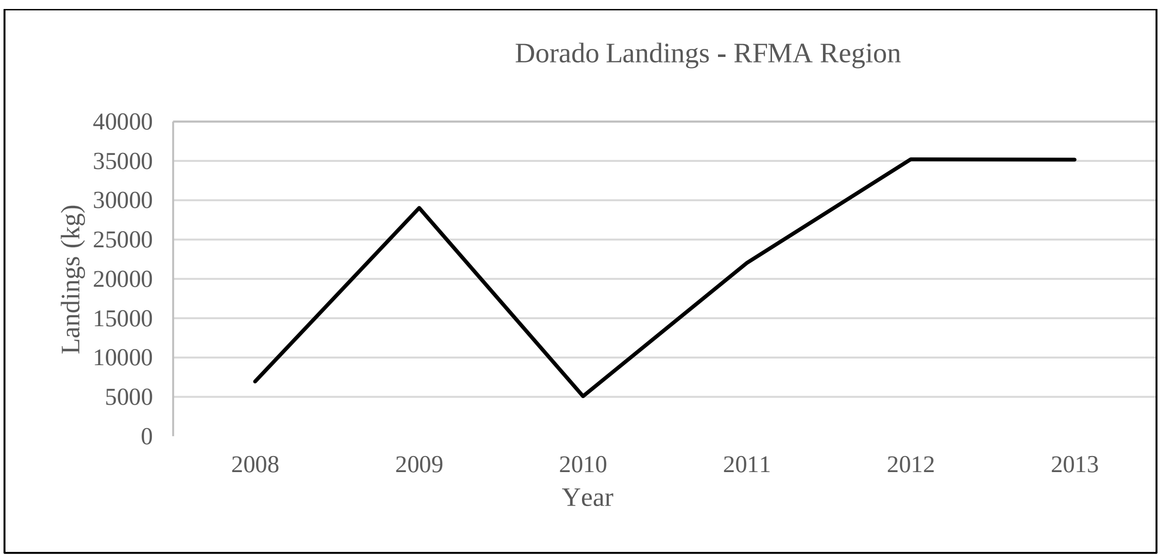

Figure 15 Dorado (*Coryphaena hippurus*), Total Annual Catch – Tárcoles Region (INCOPESCA Data)

A review of the literature shows wide variation in the Consumption to Biomass (Q/B) ratio applied to Dorado for analyzing trophic interactions. Galvan-Pina and

Arreguin-Sanchez (2008) estimated Q/B = 4.05 for the Central Pacific Coast of Mexico while Ferriss and Essington (2014) suggest Q/B = 26.86 in a large scale analysis of the Pacific Ocean encompassing the Central North Pacific and the Eastern Tropical Pacific. This range narrows for analyses conducted within the Eastern Tropical Pacific Ocean with Torres-Rojas et al. (2014) estimating Q/B = 21.9 and Cisneros-Montemayor estimating Q/B = 20.39 in the Baja California region. Olson and Watters (2003a) estimated Q/B = 15.6 in an initial study of the Eastern Tropical Pacific Ocean but increased this value in subsequent studies of the same region to Q/B = 21.9 (Olson and Watters (2003b); Watters et al. (2003)).

Based on the occurrence of items such as sargassum, sea fans, corals, plastics and pieces of wood in the stomachs of Dorado, Varghese et al. (2013) suggest an opportunistic and voracious feeding nature. This opportunistic predation behavior tends to be influenced by multiple factors including spatial stratification by size to avoid cannibalism (Torres-Rojas et al. (2014)). The non-selective predation results in prey composed of a wide variety of fish and invertebrates (Oxenford and Hunte, 1999).

Olson and Galván-Magaña (2002) found flying fish (*Exocoetidae*) and epipelagic cephalopods to be dominant in the diet of Dorado in the Eastern Pacific Ocean. Allain (2003) also suggests Dorado feeds on epipelagic preys such as puffer fish (*Tetraodontidae*), trigger fish (*Balistidae*), flying fish (*Exocoetidae*) and pelagic juveniles of reef-lagoon fish such as blowfish (*Diodontidae*), filefish (*Monacanthidae*), butterflyfish (*Chaetodontidae*), and surgeonfish (*Acanthuridae*). Torres-Rojas et al. (2014), in analyzing Dorado diet composition in waters south of the Baja California, found the main prey species were red crab (*Pleuroncodes planipes*) and jumbo squid (*Dosidicus gigas*). They noted, however, that Dorado smaller than 65 cm fed mainly on Pacific sardine (*Sardinops sagax caeruleus*). Oxenford and Hunte (1999) also noted slight diet variation by size in the Caribbean, with small Dorado eating fewer flyingfish and more squid than larger sized Dorado. They also noted feeding variation by sex with males taking proportionally more of the active, fast swimming species such as flyingfish, squid and Dorado (via cannibalism) than females. Cannibalism was also documented within the Eastern tropical Pacific Ocean by Moteki et al. (2001), noting Dorado present in 10.5% of stomachs examined.

These studies suggest Dorado are an important component of the food web. High energy requirements imply that predators like Dorado can account for important amounts of production removed from an ecosystem (Essington et al., 2002). In reviewing INCOPESCA catch data for the GoN, there is a potential cascade effect between an influx of Dorado with a notable drop of lower trophic level species biomass (as gauged by total catch) in 2002 and 2003 (Figure 16). This is then followed by what seems to be an unstable ecosystem when compared to previous years, suggesting a trophic analysis of the GoN must include a large pelagic group that includes Dorado effects.

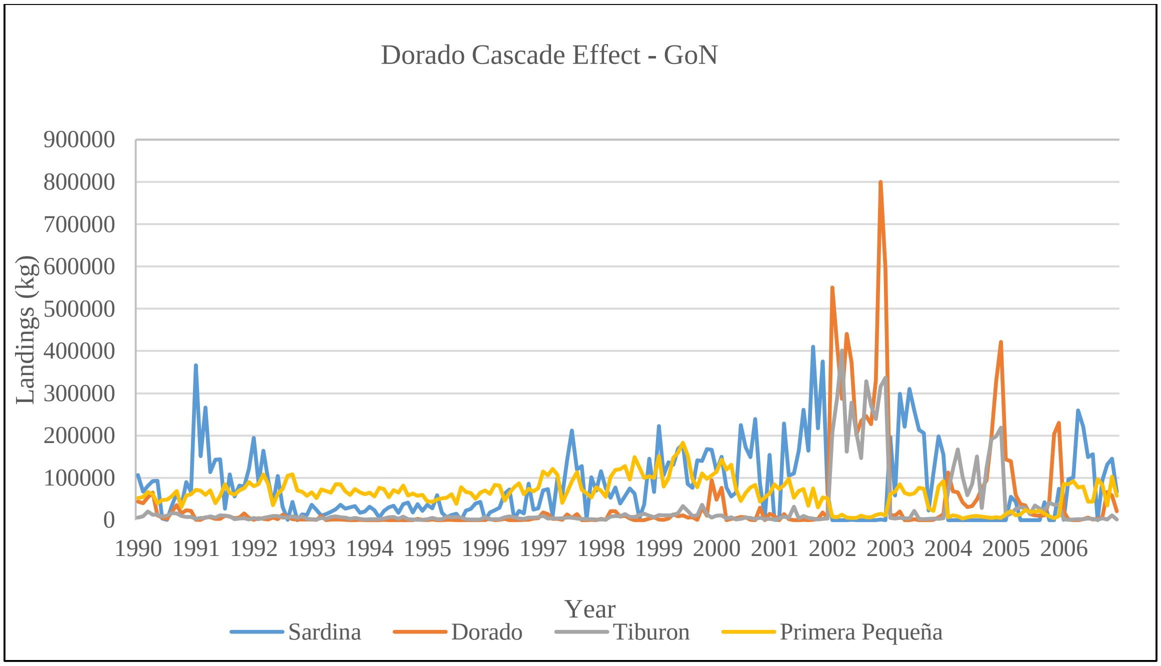

Figure 16 Potential Cascade effect of Dorado with a significant drop of lower trophic level species biomass (INCOPESCA Data)

Estimating Dorado Diet

There is no standard diet matrix established for Dorado in the EwE modeling literature for the Eastern Tropical Pacific Ocean (Table 13). This is due to opportunistic predation where location-dependent species incidence and biomass levels will influence diet. Although there are site-specific effects that influence diet composition, a comprehensive analysis conducted by Torre-Rojas et al. (2014) suggests that a plausible diet matrix for Dorado should reflect the spectrum of biodiversity in the region of study coupled with selectivity, or preference, for specific groups.

Table 13 Dorado Diet Composition for Selected Models

Author	Group Name	Predation Proportion for Dorado
Cox et al. 2002	Dorado	0.01
	Small scombrids	0.19
	Flying squid	0.05
	Squids	0.05
	Flying fishes	0.4
	Mesopelagic fish	0.01
	Epipelagic fish	0.15
	Epipelagic micronekton	0.1
	Mesopelagic micronekton	0.05
Cisneros-Montemayor et al. (2012)	Yellowfin tuna	0.002
	Dorado	0.017
	Small scombrids	0.126
	Misc. piscivores	0.047
	Squids	0.103
	Flying fish	0.31
	Small pelagic fish	0.176
	Mesopelagic fish	0.092
	Zooplankton	0.126
Chan 2014	Juvenile Skipjack	0.002
	Epipelagic Fishes	0.875
	Invertebrates	0.06
	Epipelagic Molluscs	0.02
	Mesopelagic Fishes	0.008
	Mesopelagic Molluscs	0.03
	Detritus	0.005
Olson and Watters 2003a	Auxis spp	0.035
	Small yellowfin	0.015
	Small dorado	0.018
	Small wahoo	0.049
	Flyingfishes	0.546
	Misc. epipelagic	0.064
	Misc. mesopelagic	0.146
	Cephalopods	0.094
	Crabs	0.013
	Mesozooplankton	0.015
	Microzooplankton	0.005
Olson and Watters 2003b	Auxis spp	0.035
	Bluefin Tuna	0.001
	Small yellowfin	0.014
	Small dorado	0.018
	Flyingfishes	0.551
	Misc. piscivores	0.049
	Misc. epipelagic	0.064

Misc. mesopelagic	0.146
Cephalopods	0.107
Crabs	0.015

Given the lack of stomach content data for Dorado in the GoN, INCOPESCA catch data from 1990 to 2006 was used to calculate a pairwise correlation between Dorado and other key groups for which data is collected. The resulting correlation coefficients (Table 14) were the basis to estimate an effect of increased Dorado predation on GoN fishery.

Table 14 Pairwise Correlation of Total Catch for Selected Groups. Note Groups are labeled per INCOPESCA naming convention

Category	Correlation Coefficient
Primary Large	-0.4309
Primary Small	-0.4724
Classified	-0.4019
Low Value Group	-0.3293
Croaker	-0.4738
Grouper	0.3128
Rose Snapper	0.5953
White Marlin	0.5295
Pink Marlin	0.6951
Treacher	0.169
Sea Bass	0.6721
Sword Fish	0.6788
Sardine	-0.26
Total Shark	0.8547
Total Shrimp	-0.2826
Total Lobster	0.2395
Squid	0.4672
Total “All Others”	0.8041

Given an increase in total Dorado catch can be associated with increased Dorado biomass (where fishers technical efficiency is constant), it is reasonable to inference

Dorado prey group catch in a specific period will decrease when Dorado biomass is high per the trophic cascade seen in Figure 16. This effect would apply to species listed in Table 14 where correlations are negative (significant at $\alpha < 0.01$). This includes the “Primary Large” group (r=-0.4309), “Primary Small” group (r = -0.4724), the “Classified” group (r = -0.4019), the “Low Value” group (r = -0.3293), the “Croaker” group (r = -0.4738), the “Sardine” group (r = -0.2600), and the “Total Shrimp” group (r = -0.2826). See Appendix Table 43 for listing of species included in the INCOPESCA grouping convention.

The resulting estimate of EwE diet composition for Dorado was based on the level of correlation and the comprehensive stomach content review documented by Torre-Rojas et al. (2014) factoring for the opportunistic predatory nature of Dorado. EwE Group 4 (Snappers and Grunts) which corresponds to Classified, and Group 6 (Carangids) which is included in Low Value Catch, were assigned a prey ratio of 0.215. EwE Group 14 (Shrimp) corresponding to Total Shrimp, and EwE Group 15 (small pelagics) corresponding to Sardine, were assigned a prey ratio of 0.15. The balance of the diet ratio was applied the remaining fish groups including Group 5 (lizardfish), Group 9 (catfish), and Group 11 (flatfish) due to the opportunistic predatory behavior of Dorado. Group 12 (predatory crabs) and Group 13 (small demersals), were assigned the balance with an elevated factor congruent with Torre-Rojas et al. (2014).

Using the Wolff (1998) model as the foundation for the updated GoN EwE model, the resulting EwE Diet Matrix (Table 15) was constructed to include the Dorado group to represent Dorado.

Table 15 GoN EwE Model Diet Matrix

	Prey \ predator	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	Large Pelagics	0	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	Rays and Sharks	0	0	0.02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	Morays and eels	0	0.03	0.02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	snappers and grunts	0.215	0.03	0.05	0	0.05	0	0.05	0	0	0	0	0	0	0	0	0	0	0
5	Lizardfish	0.02	0.02	0.04	0.02	0	0	0.02	0	0	0	0	0	0	0	0	0	0	0
6	carangids	0.215	0.02	0	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	Large Scianids	0.05	0.05	0.05	0	0	0	0.01	0	0	0	0	0	0	0	0	0	0	0
8	squids	0.05	0	0.05	0.05	0	0.2	0.05	0.1	0.1	0.05	0	0	0.03	0	0	0	0	0
9	catfish	0.02	0.1	0.05	0	0	0	0.05	0	0	0	0	0	0	0	0	0	0	0
10	Sea/shore birds	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	flatfish	0.02	0.08	0.08	0.05	0.05	0	0.1	0	0	0	0	0	0.05	0	0	0	0	0
12	Predatory crabs	0.06	0.15	0.1	0.05	0.1	0.05	0.05	0	0	0.04	0.02	0	0	0	0	0	0	0
13	small demersals	0.05	0.16	0.14	0.15	0.2	0.02	0.1	0	0.2	0	0	0.1	0	0	0	0	0	0
14	shrimps	0.15	0.05	0.05	0.1	0.2	0.06	0.05	0.2	0.1	0.06	0.2	0.15	0.12	0	0	0	0	0
15	small pelagics	0.15	0.1	0.05	0.18	0.2	0.5	0.1	0.65	0.2	0.45	0.05	0	0	0	0	0	0	0
16	Endobenthos	0	0	0	0.05	0	0	0	0	0	0.1	0.05	0.1	0.05	0.15	0	0.04	0	0
17	zooplankton	0	0	0	0.05	0	0.12	0.07	0.05	0	0	0	0	0.1	0.25	0.4	0.05	0.05	0.01
18	Epibenthos	0	0.2	0.3	0.2	0.2	0.05	0.35	0	0.4	0.3	0.6	0.5	0.5	0.1	0	0	0	0
19	phytoplankton	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.6	0.14	0.75	0.6
20	microphytobenthos	0	0	0	0	0	0	0	0	0	0	0	0	0.09	0.1	0	0.1	0	0.15
21	mangroves	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0
22	Detritus	0	0	0	0	0	0	0	0	0	0	0.08	0.15	0.05	0.4	0	0.67	0.2	0.24

Consumption of Dorado was added to Group 2 (Rays and Sharks) at a proportion of 0.01 which is within the range in the literature evaluating this region. Cisneros-Montemayor et al. (2012) estimate Dorado proportion of Shark diet to be 0.026 for Large Sharks and 0.012 for Small Sharks in Baja California; Cox et al. (2002) estimate the proportion of Dorado for Large Sharks to be 0.05 and 0.02 for Brown Sharks in the Central Pacific Ocean; and Olson and Waters (2003a) assign no predation of Dorado to Sharks in the Eastern Tropical Pacific Ocean.

GoN EwE Model Biomass

With exception of Sea/Shore birds and detritus, the EwE software was used to calculate the Biomass in the habitat area based on the Ecotrophic Efficiencies (EE), Production to Biomass (P/B) ratios, and consumption to biomass (Q/B) ratios listed in the original Wolff model. Detritus was assigned a biomass estimate of 100 tons/km^2 while sea/shore birds' biomass was kept constant to the Wolff model. The EE for Dorado was estimated at 0.25, similar to Olson and Watters (2003a) and Watters et al. (2003) (Table 16).

Table 16 Updated GoN Ecopath Model Groups with Ecopath Parameters

Group Number	Group Name	Trophic Level (TL)	Biomass (B), tons per km^2	Production to Biomass Ratio (P/B)	Consumption to Biomass Ratio (Q/B)	Ecotrophic Efficiency (EE)
1	Dorado*	4.209[1]	0.397[1]	1.200[3]	21.900[3]	0.250[3]
2	Rays and Sharks	3.903[1]	0.169[1]	0.600[2]	2.800[2]	0.950[2]
3	Morays and Eels	3.843[1]	0.078[1]	0.750[2]	3.600[2]	0.990[2]
4	Snappers and Grunts	3.671[1]	6.002[1]	0.950[2]	4.300[2]	0.960[2]
5	Lizardfish	3.640[1]	1.152[1]	1.000[2]	7.000[2]	0.980[2]
6	Carangids	3.629[1]	6.096[1]	0.800[2]	7.300[2]	0.940[2]
7	Large Sciaenids	3.623[1]	4.634[1]	0.600[2]	4.000[2]	0.960[2]
8	Squids	3.536[1]	3.425[1]	8.300[2]	32.000[2]	0.910[2]
9	Catfish	3.501[1]	1.554[1]	0.900[2]	4.000[2]	0.920[2]
10	Sea/shore Birds	3.353[1]	0.050[2]	0.150[2]	65.000[2]	0.000[2]
11	Flatfish	3.078[1]	4.789[1]	1.800[2]	7.500[2]	0.940[2]
12	Predatory crabs	3.047[1]	3.789[1]	2.000[2]	11.000[2]	0.900[2]
13	Small Demersals	3.029[1]	6.877[1]	2.300[2]	12.000[2]	0.930[2]
14	Shrimps	2.529[1]	10.293[1]	6.000[2]	28.000[2]	0.930[2]
15	Small Pelagics	2.421[1]	21.546[1]	5.500[2]	28.000[2]	0.920[2]
16	Endobenthos	2.096[1]	2.321[1]	30.000[2]	150.000[2]	0.990[2]
17	Zooplankton	2.053[1]	30.935[1]	40.000[2]	160.000[2]	0.500[2]
18	Epibenthos	2.011[1]	74.473[1]	4.000[2]	25.000[2]	0.450[2]
19	Phytoplankton	1.000[1]	44.108[1]	180.000[2]	0.000[2]	0.660[2]
20	Microphytobenthos	1.000[1]	3.139[1]	120.000[2]	0.000[2]	0.930[2]
21	Mangroves	1.000[1]	165972[4]	0.220[2]	0.000[2]	0.001[2]
22	Detritus	1.000[1]	100.000[5]	0.000[2]	0.000[2]	0.285[2]

[1] Calculated by Ecopath

[2] From Wolff et al. (1998)
[3] From Olson and Watters, 2003b
[4] From Hutchison et al. (2014) and Sifuentes (2012)
[5] De Mutsert (Personal Communication, 2015)
* Group added to Wolff et al. (1998) Ecopath Model

The updated biomass estimates were higher that published by Wolff et al. (1998) primarily because of the idealized construction of GoN fishery (i.e. no trawler discards) assumed in the Wolff Model. With exception of morays and eels, the updated model calculated higher estimates of biomass in the habitat area for all groups (Figure 17), the scale of which is plausible given the ecosystem is impacted by an estimated trawler discard ratio of 1:22. Following Hutchison et al. (2014), the estimated biomass of the 17,417 ha mangrove coverage estimated by Sifuentes (2012) was calculated to be 165,972 tons/km^2, which applies to approximately 3% coverage of the GoN EwE model area (Figure 18).

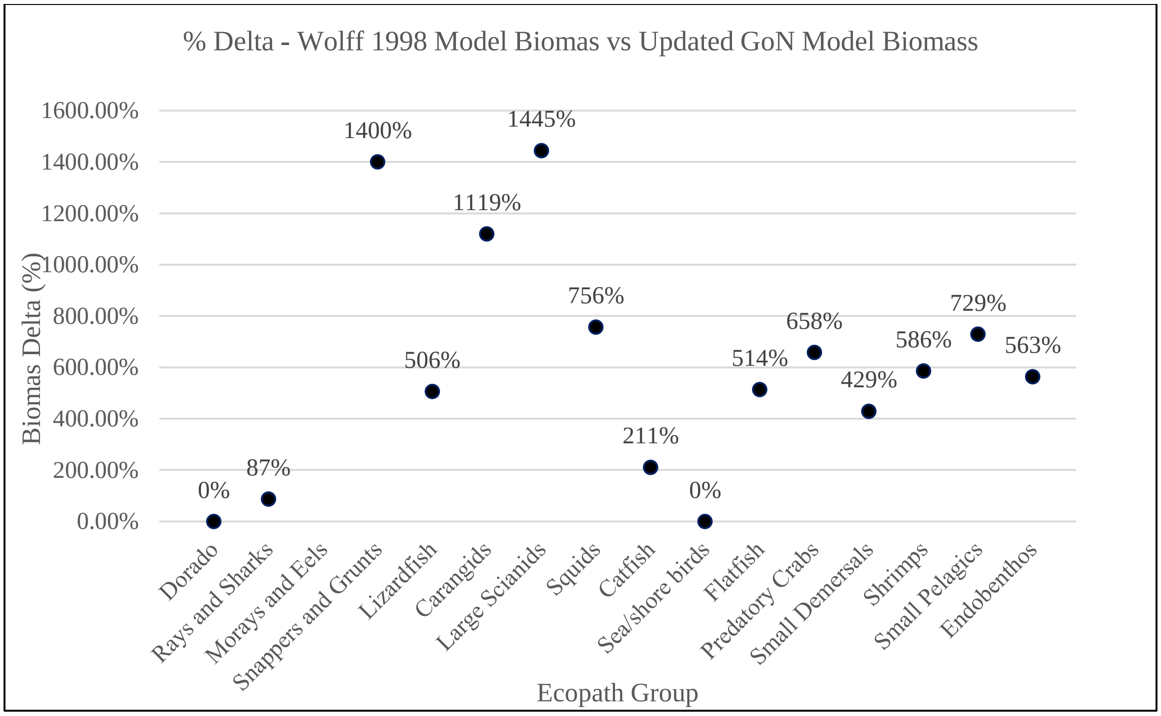

Figure 17 Wolff 1998 Model Biomas vs Updated GoN Model Biomass. A comparison of Dorado is not applicable.

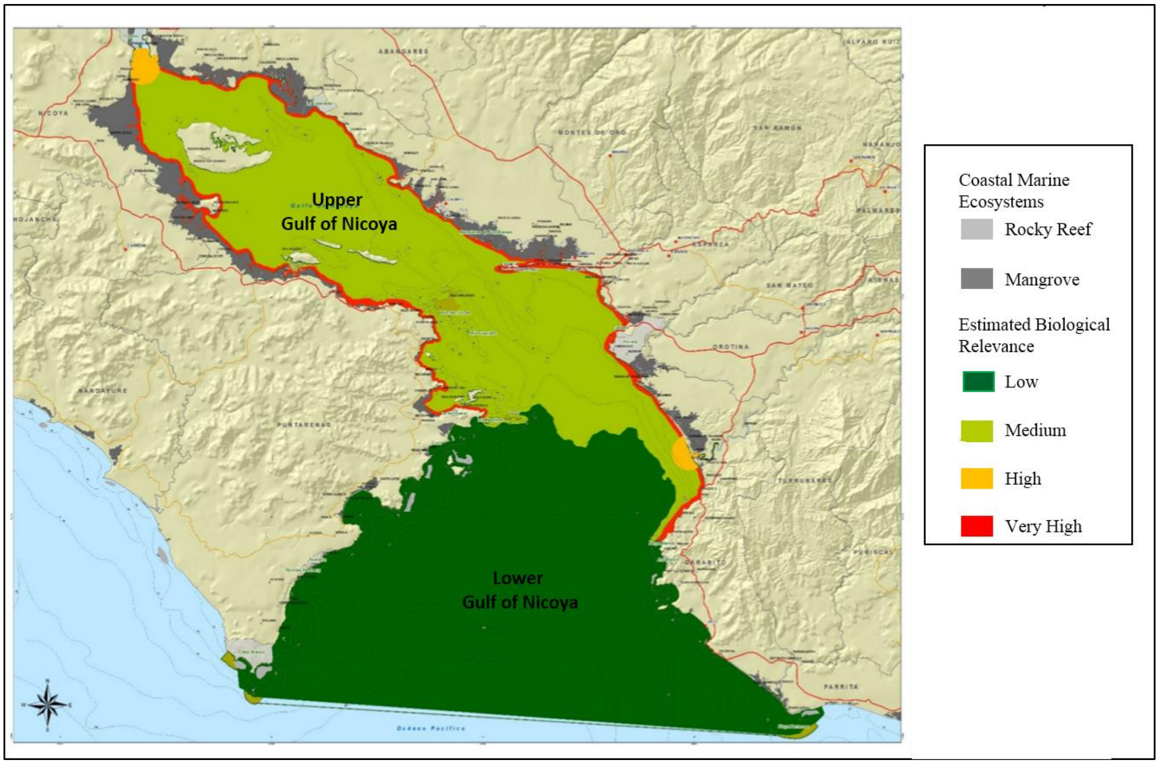

Figure 18 GoN Estimated Relative Biological Importance – Mangrove Cover Shaded Grey (Adapted from EPYPSA-MARVIVA, 2014)

The increase in trawler catch and discards resulted in the increase in the model value for total catch to 12.01 tons•km^{-2} per year representing a significantly higher rate than the 3.38 tons•km^{-2} estimated in 1998. The estimated 12.01 tons•km^{-2} is both reasonable and plausible given the average for yearly GoN landings from 1999 to 2007 was 4.34 tons•km^{-2}, which did not include discards. The 4.34 tons•km^{-2} listed in the INCOPESCA landings report is also within 3% of the updated model's 4.356 tons•km^{-2} estimate for landings which are a combination of artisanal (1.092 tons•km^{-2}) and trawler (3.264 tons•km^{-2}) landings (Table 17).

Table 17 GoN EwE Model – Landings by Fleet (tons per km^2 per year)

Group Name	Artisanal	Semi-Ind	Total
Dorado	0.1136	0.0001	0.1137
Rays and Sharks	0.0323	0.007	0.0393
Morays and Eels	0.0052	0.00394	0.00914
Snappers and Grunts	0.1765	0.2495	0.426
Lizardfish	0.0088	0.00468	0.01348
Carangids	0.0231	0.01232	0.03542
Large Sciaenids	0.5223	0.1794	0.7017
Squids	0.0022	0.00985	0.01205
Catfish	0.0231	0.01232	0.03542
Flatfish	0.036	0.01922	0.05522
Predatory crabs	0.0009	0.01232	0.01322
Small Demersals	0.106	0.0501	0.1561
Shrimps	0.013	2.2155	2.2285
Small Pelagics	0.0286	0.1838	0.2124
Endobenthos	0	0.00862	0.00862
Epibenthos	0	0.29562	0.29562
Sum	1.0916	3.26429	4.35589

The updated mean trophic level (TL) of the GoN fishery landings was estimated to be 2.902. This TL is represented by the small demersals group (Figure 19) however the composite mean TL is composed of all landed groups. The updated estimate of mean TL for catch across the GoN is more plausible than the 1998 estimate of 4.06 that concluded the primary landing was composed of Rays and Sharks. The suggestion that Rays and Sharks comprise the majority of landings contradicts the Wolff et al. (1998) suggestion that reduced shrimp biomass had impacted the higher trophic species biomass.

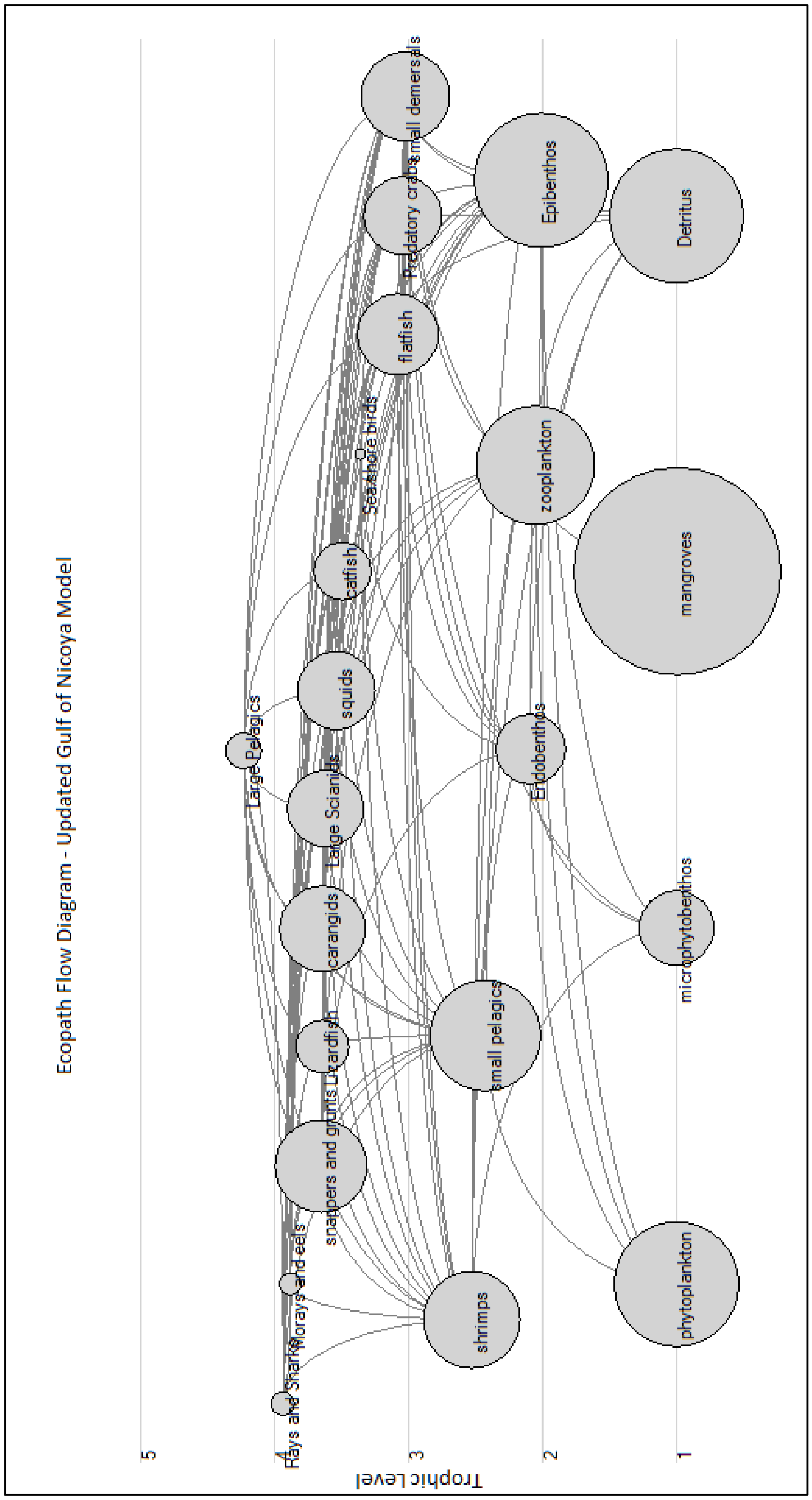

Figure 19 GoN Ecopath Flow Diagram. Size of dot represents scale of biomass for listed group, relative to other model groups in model region

Similar to the original model, the updated model also identified the shrimp group as a potential keystone species based on relative total impact. Other groups such as Small Demersals, Large Sciaenids, Epibenthos, and Phytoplankton were also calculated to have a high effect on the ecosystem (Table 18). Keystone species were determined based on Relative Total Impact, or overall effect on the multi-trophic model. Ecospace calculates Relative Total Impact values for each group, with values ranging from 0 to 1. Values closer to 1 indicate a higher impact of the corresponding group and are therefore identified as playing a keystone role.

Keystone Index #1 is an alternative method for identifying a keystone role of a functional group. This is calculated per Libralato et al. (2006), with values closer to or larger than 0 identifying keystone functional groups. Using this methodology, large negative values identify low keystones (see Libralato et al. (2006) for mathematical framework). Keystone Index #2, also known "Community Importance" index (Power et al., 1996) identifies those functional groups that would cause a community characteristic to be reduced if deleted from the system. Groups with a larger values would cause larger impacts if eliminated (see Power et al. (1996) for mathematical framework).

In contrast to the description of mangroves in the 1998 model that suggests "enormous importance for the biomass distribution and energy flow pattern within the estuary", mangroves were not estimated to be an important trophic link in terms of relative total impact.

Table 18 EwE Keystoneness – Selected Groups

Group name	Keystone index #1	Keystone index #2	Relative total impact
Shrimps	-0.1	4.108	0.766
Large Sciaenids	-0.131	4.424	0.713
Small Demersals	0.0158	4.399	1
Epibenthos	-0.0687	3.28	0.823
Phytoplankton	-0.105	3.471	0.757

GoN Ecosim Model Results

The GoN EwE model was run from January 1999 through December 2007 to analyze the dynamic response of the GoN ecosystem to annual fishing pressure (see Trawler Activity and Artisanal Fleet Activity sections for description of fishing pressure estimates; Trawler Landings (to include bycatch) and Artisanal Landings sections for description of landings estimates, and Trawler Discards section for description of discards estimate). Figure 20 displays the relative biomass effect for the EwE model groups. Note, this update required a single adjustment to achieve a balanced model. Immigration of the Morays and Eels group at a rate of 0.003 t/km^2/year was added to balance the model. This biomass immigration value was developed using an iterative approach to arrive at the minimum value to achieve model balance.

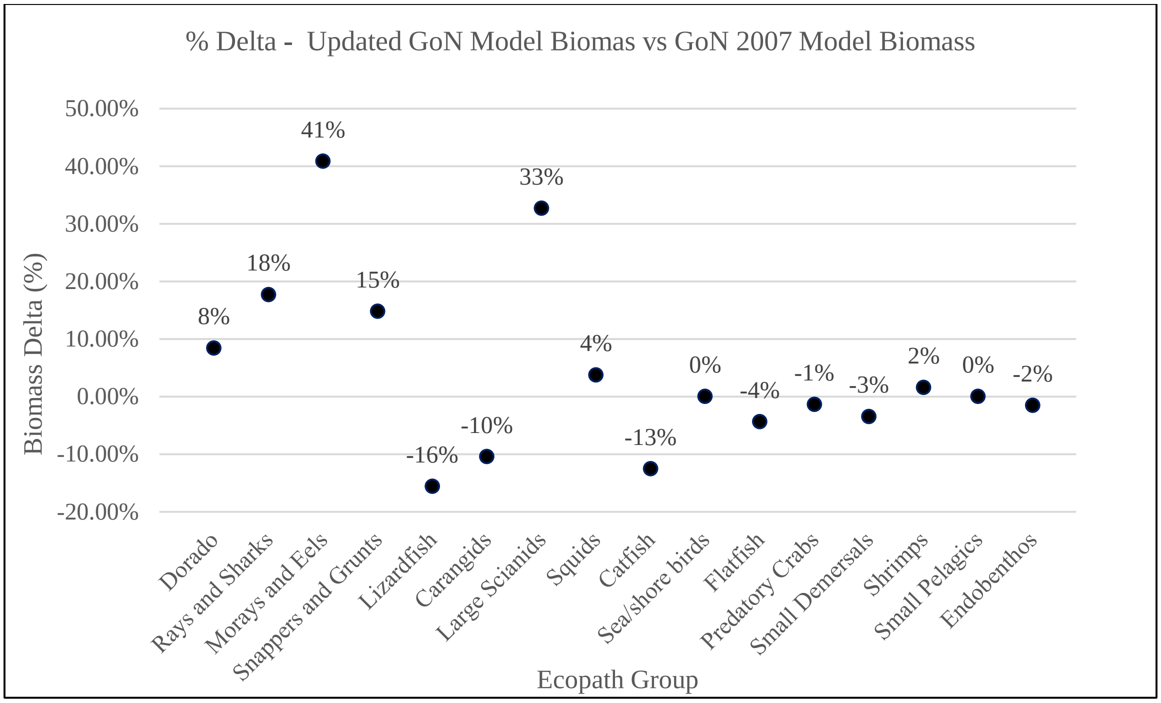

Figure 20 GoN 1998 Model Biomas vs GoN 2007 Model Biomass

Compared to 1999, the resulting model suggests the annual catch would decrease from 12.012 tons•km^{-2} in 1999 to 8.585 tons•km^{-2} in 2007 with discards included (Figure 21) and the mean trophic level of the catch would increase from 2.902 to 2.99. The decrease in landings is associated with decreased trawler activity. The biomass for species that contribute to the Chatarra group which is a low market value stock; namely Catfish, Lizardfish, and Flatfish, would experience a relative decrease. This is due to increased predation from higher trophic level groups, which increase in biomass due to reduced competition with trawlers and direct impact from trawlers via bycatch. This increase is anticipated to occur for Dorado, Rays and Shark as well as Morays and Eels which are higher trophic level groups. Appendix A Figure 61 through Figure 74 display the group specific Ecosim output for the time-dynamic simulation run (1998 - 2007).

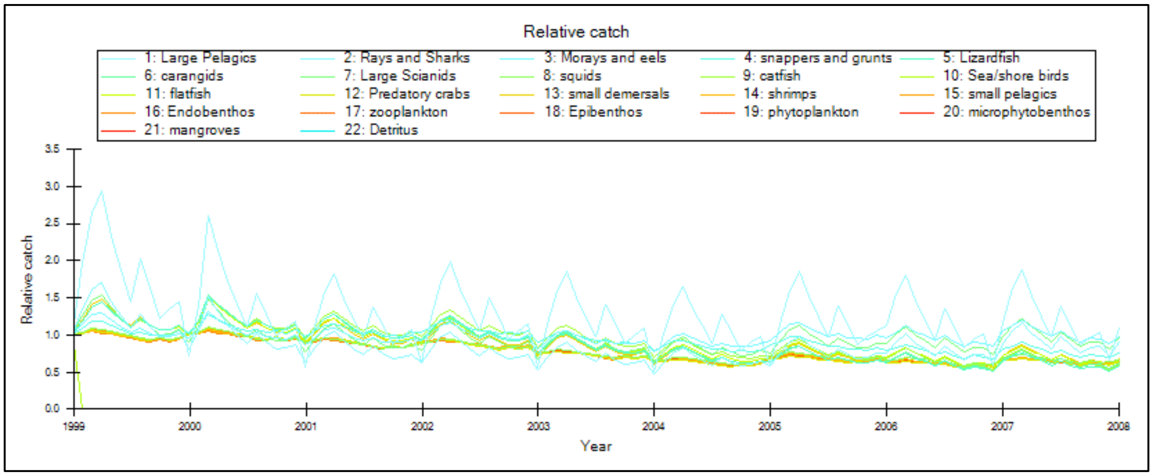

Figure 21 Relative Catch – All EwE Groups (Ecosim Output)

Discussion and Conclusions

Wolff et al. (1998) developed an Ecopath model for the GoN based on a comprehensive review of available information. This information included data collected by the modeling team members as well as information available in the literature. The resulting model provides an idealized framework of GoN multi-species dynamics by approximating a steady-state mass balance with little disturbance on the system.

Adding information on fishery landings, bycatch and discards, fishery activity, and a large pelagic group (Dorado) allows for a more robust analysis of the GoN. The updated model suggests the total biomass in the GoN is significantly higher than was originally estimated by Wolff et al. (1998). Of the four above-listed elements added to the GoN model, the primary gap in the Wolf Model was not accounting for bycatch and discards in the mass balance. Adding this information to the 1998 framework did not result in a balance model. More specifically, the Wolff Model biomass entries would require the EE for multiple groups to be greater than 1.0. This would be necessary to accommodate bycatch (and discards) as well as base model inter-group dynamics. This technical gap was addressed by allowing EwE to calculate an estimated biomass. Although not ideal, this approach is reasonable in cases where biomass surveys are not available (Christensen et al., 2005).

The addition of the Dorado group was necessary to account for the role of large pelagic predators in the GoN. A review of INCOPESCA landings data shows an influx of Dorado in 2002 may have created a trophic cascade effect, further highlighting the importance of incorporating this model group in the analysis. INCOPESCA data provided landings totals for Dorado during the analysis period, however species specific information (EE, Q/B, P/B, B) was not available for the GoN. This data gap was addressed by developing a profile of Dorado using data available in the literature. To ensure a plausible profile of Dorado was developed, efforts were made to limit the literature referenced to studies conducted in the Eastern Tropical Pacific Ocean.

The updated model was run from 1999 to 2007 using an estimated fishery activity profile for 2006 and 2007. Results of the Ecosim analysis suggest landings decreased during the time period (Figure 21) primarily due to decrease trawler activity. Trawler activity decreased, in part, due to an increase in crude oil prices given fuel prices are primary factor driving Trawler Fleet activity.

Highly mechanized fleets such as trawling are influenced by fuel prices where increasing fuel costs lower profitability and reduce incentive to trawl. Data analysis suggests that a price above $40 USD per barrel of crude oil will eliminate a large portion of the trawling effort in Costa Rica. To counter increased fuel costs, Costa Rican regulation (AJDI 15-2010) calls for the provision of fuel subsidies to permitted fishery fleets. This benefit is intended to provide fuel at competitive international-level prices. Sumaila et al. (2008) estimated the Costa Rican fishery fuel subsidy at 0.18 USD per liter (in year 2000 dollars), totaling to an annual estimate of ten million dollars for all fleets. In 2008, this would have reduced the cost for a liter of diesel by 16% (from $1.10 to $0.92 per liter). Herrera-Ulloa et al. (2011) identify this type of subsidy as a contributing factor to the current state of over-capitalized fishery fleets. This in turn, promotes the over-exploitation of fishery resources by increasing the profitability of unsustainable activity. In the absence of subsidies, total cost increases which then drives effort towards levels that reduce impact to environmental resources.

Incorporating economic variables such a fuel prices (as a driver of trawl activity) in the dynamic input of an Ecosim model connects the ecosystem analysis to market forces. This combination of ecological and economic factors is necessary for the analysis of fishery policy because financial interests are the key driver of fleet activity. Linking the ecosystem model to economic factors and including fishery landings, bycatch and discards, fishery activity, and a large pelagic group (Dorado) now allows for robust fishery policy analysis in the GoN.

CHAPTER 4. TÁRCOLES EWE MODEL

The EwE modeling software was used to evaluate the long-term implications of the Tárcoles RFMA. This analysis was augmented with the Ecospace application to simulate spatial-temporal outcomes. The 2007 GoN EwE model diet matrix served as the basis for the EwE analysis of the Tárcoles RFMA. In this manner the 1999-2007 GoN EwE model reconciled the updated 1998 Ecopath model with the Tárcoles EwE model start of January 2008. Note, EwE calculated the estimates for the Tárcoles EwE model biomass in the habitat area based on the EE, Q/B, and C/B ratios from Wolff et al. (1998) for all groups with exception of Dorado, Detritis, Mangroves, and Sea/shore Birds (Table 19).

Table 19 Tárcoles RFMA Ecopath Model Groups with Ecopath Parameters

Group Number	Group Name	Trophic Level (TL)	Biomass (B), tons per km^2	Production to Biomass Ratio (P/B)	Consumption to Biomass Ratio (Q/B)	Ecotrophic Efficiency (EE)
1	Dorado*	4.225[1]	0.409[1]	1.353[3]	21.422[3]	0.226[3]
2	Rays and Sharks	3.934[1]	0.178[1]	0.565[2]	3.061[2]	0.825[2]
3	Morays and Eels	3.883[1]	0.145[1]	0.649[2]	3.858[2]	0.924[2]
4	Snappers and Grunts	3.648[1]	10.010[1]	0.959[2]	4.199[2]	0.962[2]
5	Lizardfish	3.644[1]	1.212[1]	0.978[2]	6.790[2]	0.996[2]
6	Carangids	3.637[1]	6.974[1]	0.828[2]	7.530[2]	0.914[2]
7	Large Sciaenids	3.626[1]	4.511[1]	0.559[2]	4.389[2]	0.839[2]
8	Squids	3.540[1]	4.564[1]	8.165[2]	32.161[2]	0.911[2]
9	Catfish	3.499[1]	1.499[1]	0.844[2]	3.788[2]	0.904[2]
10	Sea/shore Birds	3.355[1]	0.050	0.154[2]	64.926[2]	0.000[2]
11	Flatfish	3.080[1]	5.851[1]	1.718[2]	7.386[2]	0.940[2]
12	Predatory crabs	3.043[1]	4.647[1]	1.956[2]	10.974[2]	0.895[2]
13	Small Demersals	3.029[1]	8.443[1]	2.259[2]	12.258[2]	0.934[2]
14	Shrimps	2.528[1]	13.190[1]	5.734[2]	28.164[2]	0.950[2]
15	Small Pelagics	2.421[1]	28.124[1]	5.252[2]	27.994[2]	0.935[2]
16	Endobenthos	2.096[1]	2.987[1]	29.187[2]	147.033[2]	0.998[2]
17	Zooplankton	2.053[1]	40.614[1]	39.697[2]	158.957[2]	0.498[2]
18	Epibenthos	2.011[1]	95.552[1]	3.869[2]	25.045[2]	0.452[2]

19	Phytoplankton	1.000[1]	57.271[1]	180.060[2]	0.000[2]	0.661[2]
20	Microphytobenthos	1.000[1]	4.062[1]	117.927[2]	0.000[2]	0.934[2]
21	Mangroves	1.000[1]	4979.000[1]	0.214[2]	0.000[2]	0.001[2]
22	Detritus	1.000[1]	100.000[5]	19.006[2]	0.000[2]	0.297[2]

[1] Calculated by Ecopath
[2] From Wolff et al. (1998)
[3] From Olson and Watters, 2003
[4] From Hutchison et al. (2014) and Sifuentes (2012)
[5] De Mutsert (Personal Communication, 2015)
* Group added to Wolff et al. (1998) Ecopath Model

Estimated Trawl Activity

The Tárcoles EwE model was programmed to only include Fleet 1 activity due to the fleet's targeting of shallow water shrimp. Fleet 1 limits activity to areas within an isobath of 50 meters and targets white Shrimp (*Litopenaeus occidentalis*, *L.stylirostris*, *L.vannamei*), and titi Shrimp (*Xiphopenaeus riverti*) which corresponds to shrimp species found in the Tárcoles RFMA. Therefore, the total area trawled for the Tárcoles EwE model was reduced to 500 km^2 assuming approximately one-third of the GoN is at or less than 50 meters depth.

The revised trawl area was not applied to non-shrimp groups given these groups' landings were impacted by all trawler sub-fleets (Fleet 1, Fleet 2, and Fleet 3). Therefore the total annual catch was divided by 1000 km^2 which was equivalent to the estimate used for the GoN EwE model. The regression analysis conducted to estimate the Trawler activity for 2006 and 2007 as part of the GoN EwE model was extended to estimate the level of trawler activity from 2008 – 2013 and develop the Fleet 1 activity profile (Figure 22).

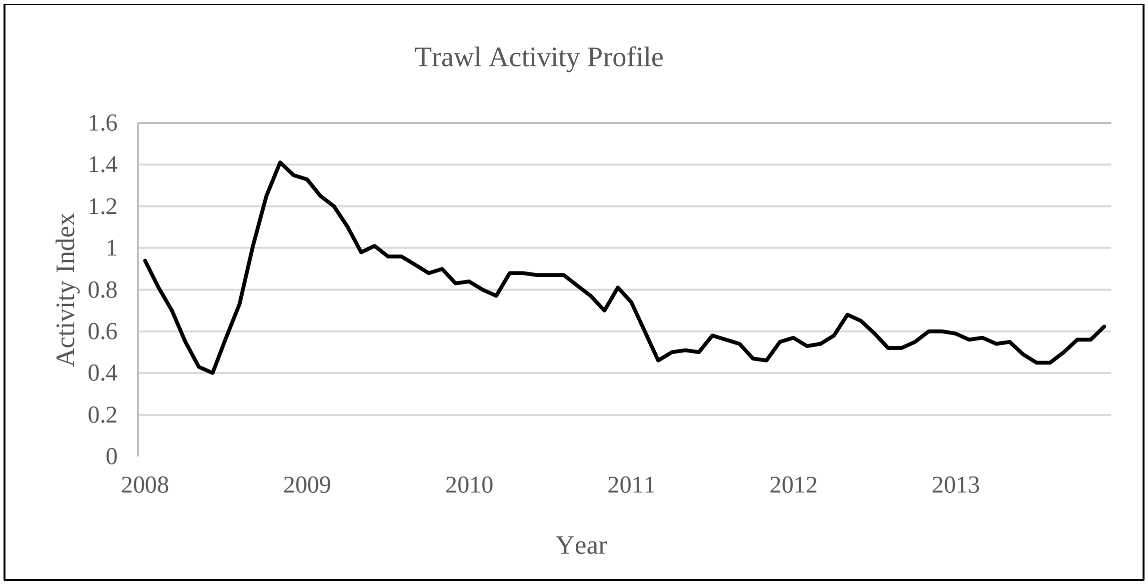

Figure 22 Shrimp Trawler Activity Profile

Trawler Shrimp Landings

Total trawler shrimp landings (Table 20) where taken directly from INCOPESCA Department of Fishery Statistics data from 2008 to 2013. Only landings for the white shrimp species (*Litopenaeus occidentalis, L. stylirostris*, *L. vannamei*), and titi shrimp (*Xiphopenaeus riverti*) were included in the analysis, given these are the shrimp species found within the study area isobath of less than 50 meters.

The trawler bycatch landings for non-shrimp groups were calculated from INCOPESCA Department of Fishery Statistics data from 2008 and 2013 using the methodology followed for the GoN EwE model. Namely, actual reported landings from 2008 to 2013 were the basis for the estimated landings of the EwE model groups (Table 20).

Table 20 Trawler Landings (tons per km ^{2} per year)

Group name	Trawler Landings
Dorado	0.0007
Rays and Sharks	0.0045
Morays and Eels	0.0039
Snappers and Grunts	0.5871
Lizardfish	0.0047
Carangids	0.0124
Large Sciaenids	0.0647
Squids	0.0099
Catfish	0.0124
Flatfish	0.0194
Predatory crabs	0.0124
Small Demersals	0.0897
Shrimps	0.1911
Small Pelagics	0.005
Endobenthos	0.0087
Epibenthos	0.2992
Sum	1.3263

Similar to the GoN EwE model, Trawler discards were estimated using a factor of 1:22 and the FAO (2015) estimated shrimp catch to bycatch landing ratio of 1:3. Taken together, these ratios suggest a bycatch landing to bycatch discard ratio of 3:22, which was applied to the trawler catch of the EwE groups (Table 21).

Table 21 Estimated Trawler Discards (tons per km ^{2} per year)

Group name	Trawler Discards
Dorado	0.00489
Rays and Sharks	0.03268
Morays and Eels	0.02913
Snappers and Grunts	4.2856
Lizardfish	0.03459
Carangids	0.09103
Large Sciaenids	0.47228
Squids	0.07283
Catfish	0.09103
Flatfish	0.14201

Predatory crabs	0.09103
Small Demersals	0.65478
Small Pelagics	0.03673
Endobenthos	0.06372
Epibenthos	2.18482
Sum	8.28716

Artisanal Fleet Activity

The artisanal fleet activity was estimated using information from CoopeTárcoles R.L. The fishing cooperative has recorded the total number of hours fished by cooperative members from 2006 to the present. This information detailing the level of effort for each type of gear utilized by the fishers was provided for analysis purposes, in accordance with the cooperative's data publication policy. Gear types listed include Gillnet 3 in., Gillnet 5 in., Gillnet 7 in., Longline, and Scuba. This information was used to develop a monthly activity profile for each gear type, with each gear type designated as a model fleet in the Tárcoles EwE model (Figure 23 – Figure 27). This monthly profile was then applied to the Tárcoles EwE model for years 2008-2010. Artisanal fisher activity for 2011-2013 was estimated to be equivalent to the 2008-2010 profile given the lack of more recent information. This is a reasonable estimate given the artisanal fishers that submit information are long-term members of the cooperative with few opportunities for alternative employment (Proyecto Golfos, 2012). Another segment of the artisanal fishing fleet includes the "independents" that choose not to join the cooperative and also do not submit information to the data collection effort. Therefore, a constant effort profile was estimated for this group given the absence of data.

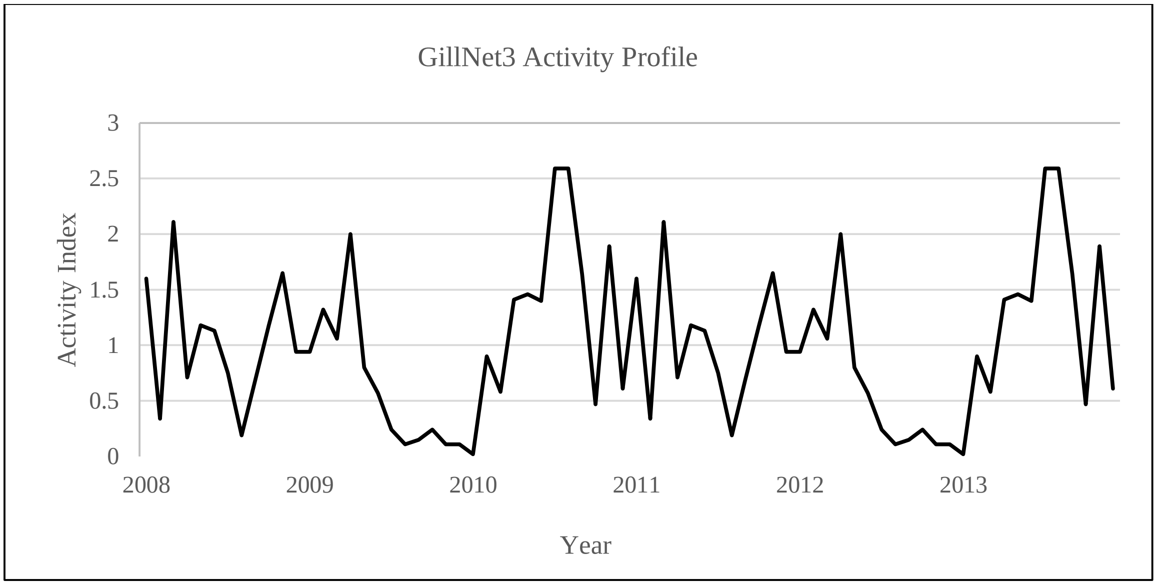

Figure 23 Gillnet 3 Activity Profile

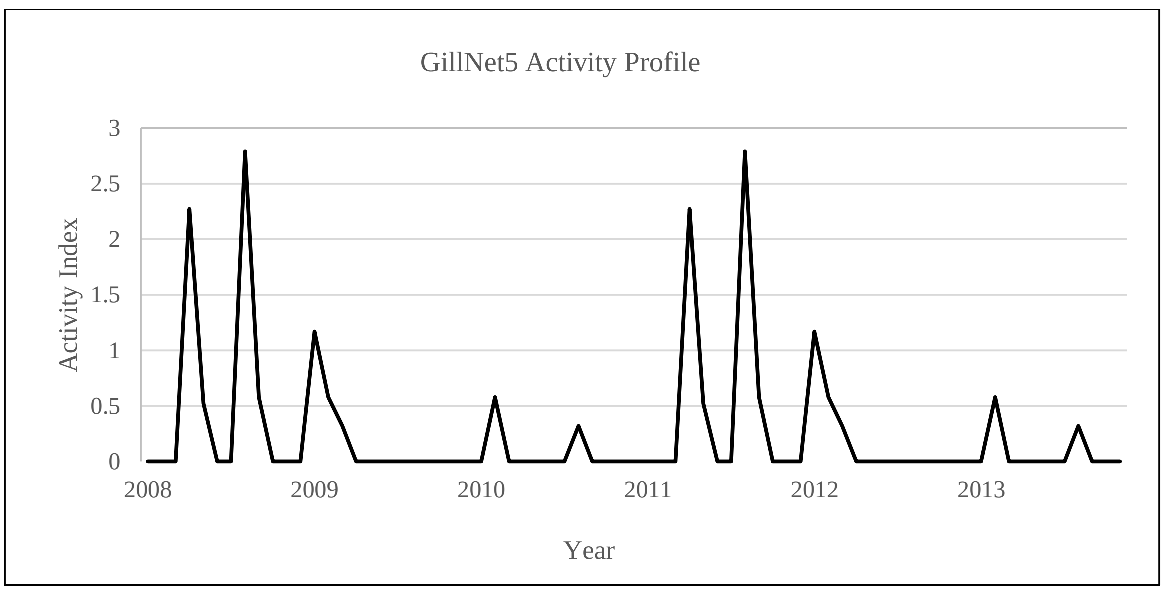

Figure 24 Gillnet 5 Activity Profile

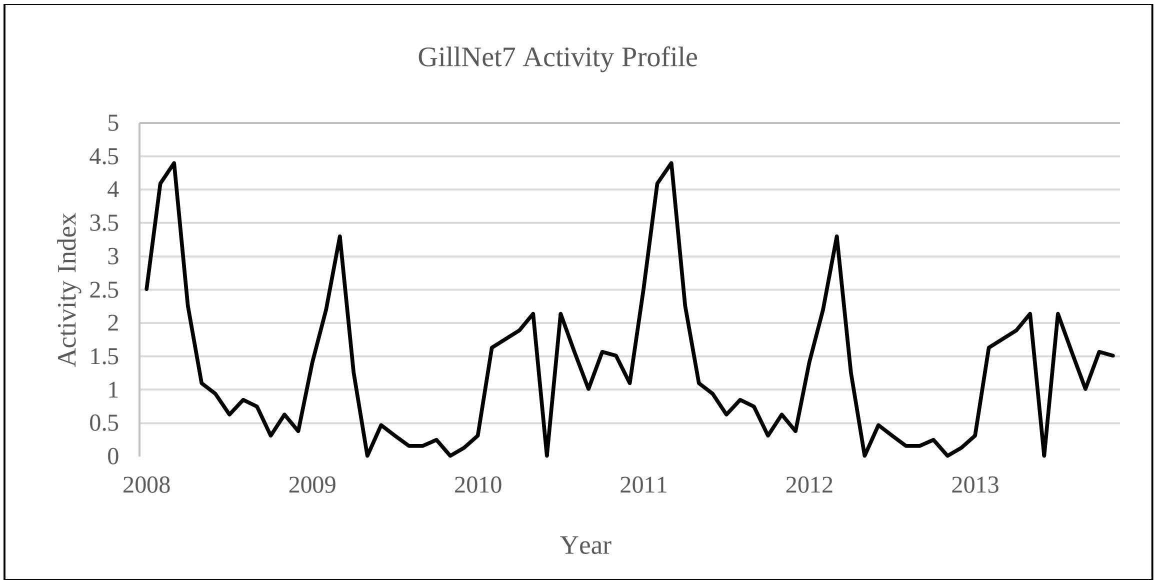

Figure 25 Gillnet 7 Activity Profile

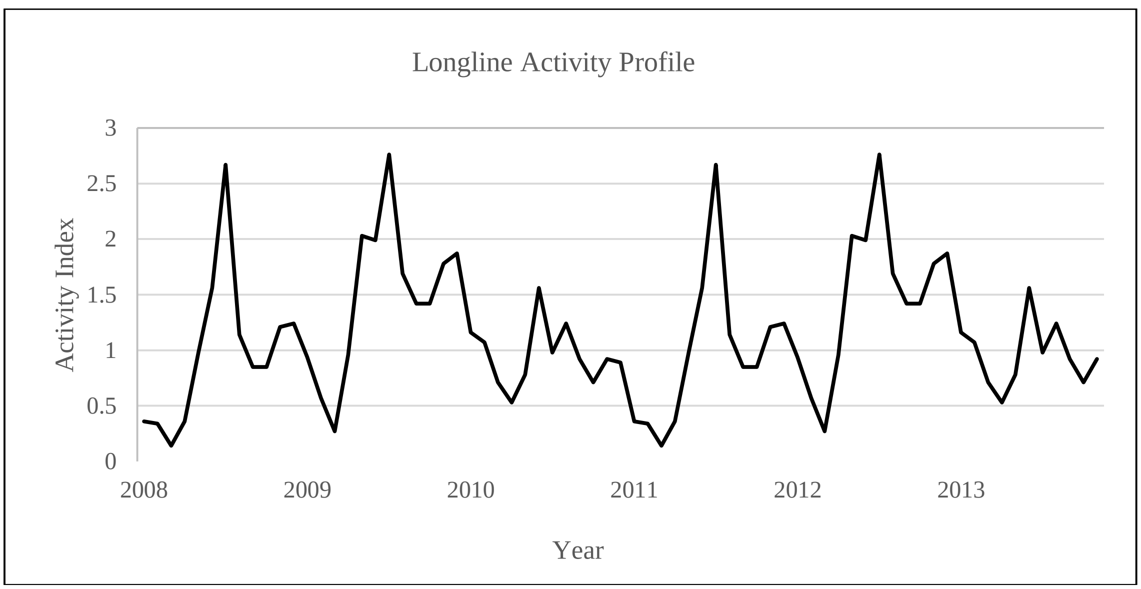

Figure 26 Long Line Activity Profile

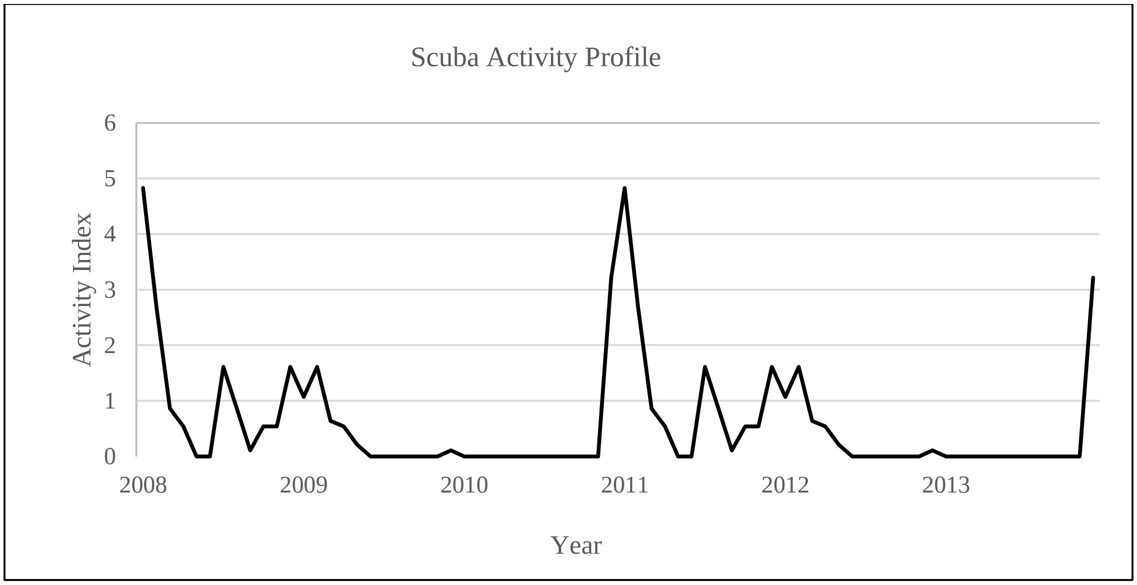

Figure 27 Scuba Fishers Activity Profile

Artisanal Fleet Landings

Artisanal fleet landings for the Tárcoles region were collected from the INCOPESCA Department of Fishery Statistics. This information included data on the CoopeTárcoles R.L. fisher landing as well as landings submitted to the adjacent collection centers not associated with CoopeTárcoles R.L. from 2008 to 2013. This provided a robust data set with which to calculate the annual landings per model group in the Tárcoles RFMA region. The assumption that landings received in local depositories represent catches within, or in close proximity, to the Tárcoles RFMA is reasonable given artisanal fleet pangas lack storage capacity and the purchase of more than the minimal ice required may affect already-low profits (Personal Observation). Therefore it is assumed landings are deposited in close proximity to fishing activity to prevent spoilage. CoopeTárcoles R.L. data was also used to divide landings for each EwE model group per fishing fleet (Gillnet

3 in., Gillnet 5 in., Gillnet 7 in., Longline, and Scuba) (Table 20). Independent landings data was analyzed from 2008-2013 to estimate the total catch associated with this fleet compared to the fishing cooperative members. This analysis suggests independent fishers contribute an additional 25% to total landings across all groups. This suggests the CoopeTárcoles R.L. fishers are significantly more efficient than independent fishers or that fishing activity in the study region is dominated by CoopeTárcoles R.L. fishers.

Table 22 Artisanal Fleet Landings by Group (tons per km^2 per year)

Group name	GillNet3	GillNet5	GillNet7	LLine	Scuba	Independent
Dorado	0	0	0	0.0909	0	0.0227
Rays and Sharks	0	0	0.0259	0	0	0.0065
Morays and Eels	0	0	0.0036	0.0006	0	0.001
Snappers and Grunts	0.0431	0.0161	0.0047	0.0772	0	0.0353
Lizardfish	0.0063	0.0007	0	0	0	0.0018
Carangids	0.0166	0.0018	0	0	0	0.0046
Large Sciaenids	0.0942	0.0026	0.119	0.202	0	0.1045
Squids	0.0016	0.0002	0	0	0	0.0004
Catfish	0.0166	0.0018	0	0	0	0.0046
Sea/shore birds	0	0	0	0	0	0
Flatfish	0.026	0.0028	0	0	0	0.0072
Predatory crabs	0	0	0	0	0.0009	0.0002
Small Demersals	0.0488	0.0053	0	0.0307	0	0.0212
Shrimps	0.0104	0	0	0	0	0.0026
Small Pelagics	0.0207	0.0023	0	0	0	0.0057
Sum	0.2843	0.0336	0.1532	0.4014	0.0009	0.2183

Tárcoles EwE Model Biomass

Where reliable biomass estimates are not available, Ecopath's biomass estimating function can be used to calculate Group biomass estimates. With exception of Sea/Shore birds and detritus, the EwE software was used to calculate the biomass in the habitat area based on the Ecotrophic Efficiencies (EE), Production to Biomass (P/B) ratios, and consumption to biomass (Q/B) ratios listed in the original Wolff model. Detritus was assigned a biomass estimate of 100 tons/km^2 while sea/shore bird biomass was kept constant with the Wolff model. The EE for Dorado was estimated at 0.25, similar to Olson and Watters (2003b) and Watters et al. (2003). These parameters are equivalent to the Gul-wide parameters, which is a plausible modeling approach given the 108 km^2 RFMA region is entirely within the GoN.

Comparison of the estimated biomass suggests that biomass is higher for all modeled groups within the Tárcoles RFMA (Figure 28), with exception of Dorado, Rays and Sharks, and Large Sciaenids. The increased productivity in this area is consistent with the area's designation as a "Biologically Important" region (EPYPSA-Marviva, 2014). The Tárcoles EwE model suggests the catch rate per square kilometer within the study area is 10.71 tons•km^{-2}. This is approximately equivalent to the estimated gulf-wide catch rate of 11.13 tons•km^{-2}.

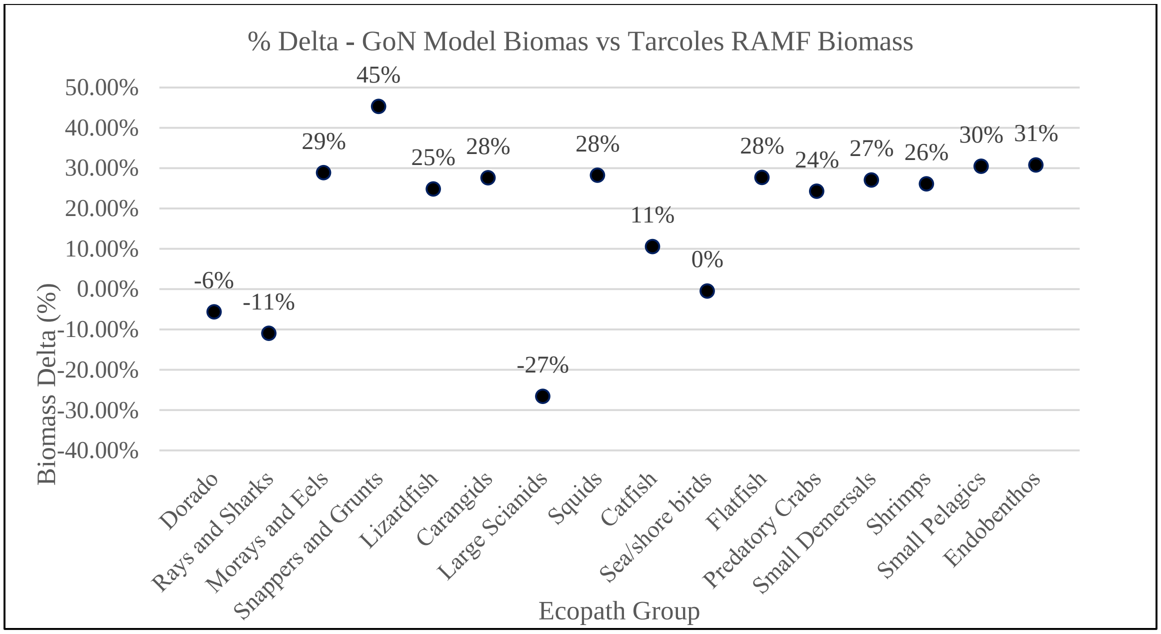

Figure 28 Biomass Estimate – Tárcoles RFMA Model (2007 GoN vs 2008 Tárcoles RFMA)

Tárcoles Ecospace Model

The potential effect of the spatial regulatory structure within the Tárcoles RFMA was analyzed using the Ecospace application of EwE. In accordance with Alpízar (2011) it is anticipated the sediment and nutrients exiting the river mouths of the Rio Tárcoles River and the Rio Santa Maria make the Tárcoles RFMA a biologically important region. Whelan (1989) suggested the Rio Tárcoles was injecting a significant nutrient load to the GoN from domestic waste, agricultural run-off, and industrial outfalls discharged into the river. The nutrient load coupled with mangroves within the area would serve as an ideal location to promote biomass growth across ecosystem groups (Alpízar, 2011). Wolf and Taylor (2011) reiterated the anticipated importance of mangroves within the GoN, suggesting the daily detritus exports from mangrove structures feed the centrally located trophic groups such as the Shrimp group. Manson et al. (2005) suggest a mangrove nutrient effect may be less a function of mangroves biomass but also associated with epiphytes, phytoplankton, and bethnic microalgae. They further suggest the function as shelter from predation and a benign environment may also contribute to a hypothesized mangrove effect. The shelter effect is a function of the complexity of the mangrove structure which prevents the entrance of large piscivorous fish. Turbidity within mangroves is also suggested as a predation-inhibiting factor (*ibid*). In line with these assumptions, Aburto-Oropez et al. (2008) reported increased landings associated with the total area of mangroves within the Gulf of Mexico from 2001 to 2005. However, this analysis did not evaluate adjacent, non-mangrove regions for control purposes.

CoopeTárcoles R.L. (2010) landings data from 2006 to 2010 were used to evaluate the potential of a mangrove effect in the RFMA region, which is lined with approximately 589 hectares of mangroves (Figure 18). Comparing catch per unit effort within the RFMA and beyond the RFMA using the Student T-test did show a statistically significant difference in means ($p = 0.05$), however the CPUE beyond the RFMA (5.11 kg/hr) was greater than the CPUE within the RFMA (3.24 kg/hr) (Table 23). Thus a mangrove effect in the Tárcoles region cannot be confirmed. Possible explanations for this divergence from the expected results may be related to skipper skill, with new fishers tending to stay closer to shore while more experienced and efficient fishers may choose to go farther. Other potential causes may also be an increased catch rate of smaller weight individuals closer to the mangrove structures. Alternatively, mangroves could be reducing CPUE because fishes are protected from fishing activity (de Mutsert, Personal Communication, 2016). However, without additional data, the causal factors for increased CPUE further from the mangrove structures cannot be identified. Therefore, only a moderate mangrove habitat preference of lower-trophic groups was included in the Ecopath model structure.

Table 23 CPUE Comparison - Tárcoles RFMA

Year	CPUE Within RFMA (kg/hr)	CPUE Beyond RFMA (kg/hr)
2006	4.63	7.22
2007	3.47	6.44
2008	2.67	2.54
2009	2.84	5.05
2010	2.57	4.31
Avg	3.24	5.11

Ecospace Map

The Ecospace map was constructed based on the Tárcoles RFMA Zone structure. The estimated 118 km^2 RFMA map was constructed with 19 rows and 35 columns and a cell length of 1 km (Figure 29). The north-westernmost coordinate lies at 9° latitude, -85° longitude. Note, the fifteen-meter isobath was not drawn into the Ecospace model due to the relative alignment with the western boundary of Zones 1-4. Each Zone was drawn as an individual MPA in the Ecospace Map. These MPAs were nested within the RFMA habitat. Two additional habitats termed "Rio" were drawn to include the 1 km regions where all fishing is banned at the river mouths of the Rio Tárcoles River and the Rio Santa Maria. The habitat "Fuera" represents the eastern section of the region, which is the open GoN beyond the Tárcoles RFMA while the eastern boundary is the shoreline. 3% mangrove coverage of was added to the RFMA region to simulate the possible role of mangrove as a protective zone for lower-trophic groups in the model. However given the lack of statistically significant impact to CPUE this effect was estimated to moderately drive model dynamics.

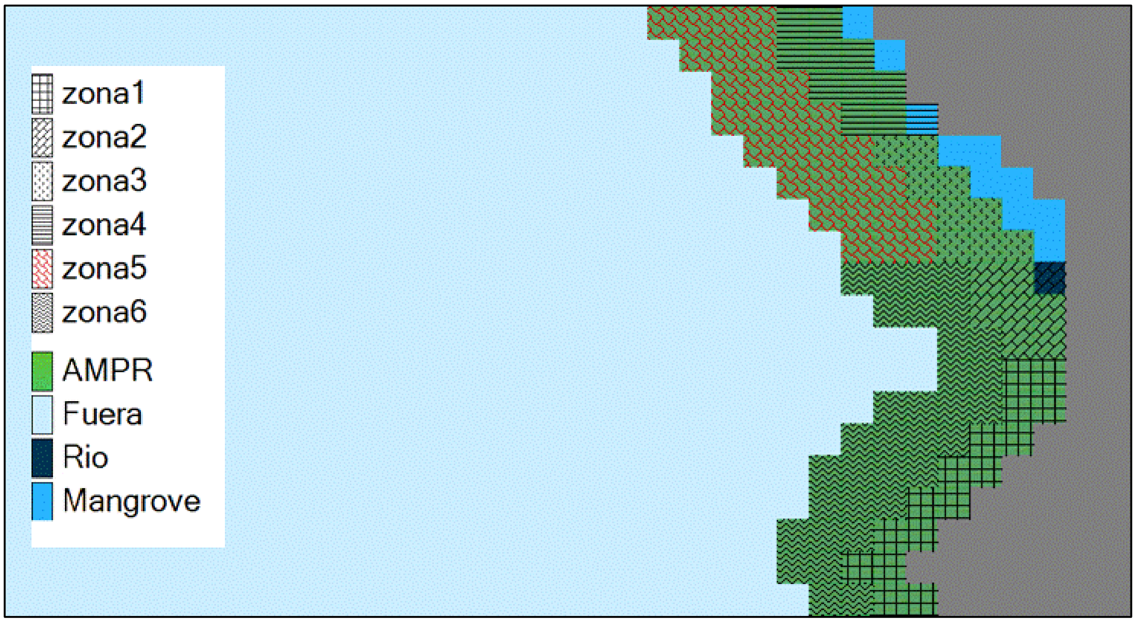

Figure 29 Ecospace Map – Tárcoles RFMA

The Ecospace fishery was defined per Tárcoles EwE fleet definitions (Gillnet 3 in., Gillnet 5 in., Gillnet 7 in., Longline, and Scuba, Independent, and Semi-industrial) with the fishery fleet activity applied in accordance with the Tárcoles RFMA regulations. All Fleets were assumed to be active beyond the Tárcoles RFMA in the region designated as "Fuera". This assumed compliance with regulatory requirements by all cooperative members, independent fishers as well as the trawl fleet.

Tárcoles Model Results

The Tárcoles EwE model was run from 2008 to 2013, corresponding to the available data for trawler landings and artisanal landings in the Tárcoles region. This model was calibrated using landings data for selected groups (Figure 30).

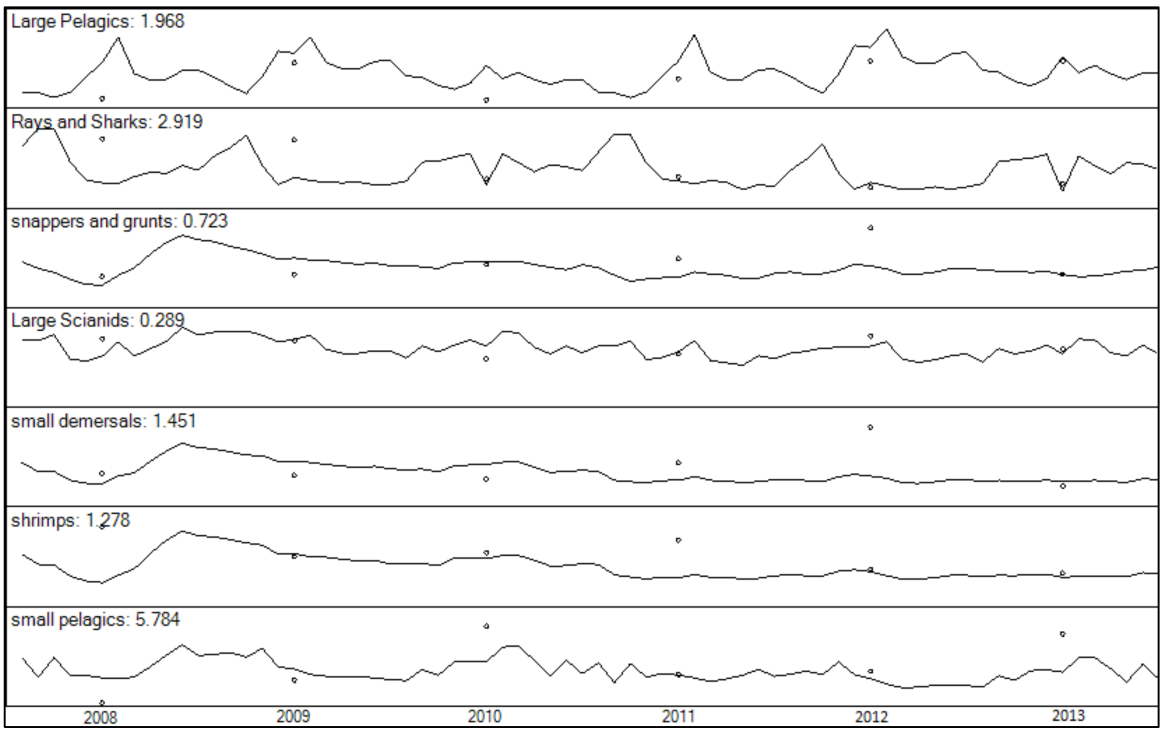

Figure 30 Tárcoles RFMA Ecosim Model Calibration (2008-2013). Contribution to Sum of Squares listed.

This analysis suggests there is no significant impact on relative biomass for lower trophic level groups from the establishment of the Tárcoles RFMA (Figure 31). The model further suggests there is an increase in biomass for higher trophic level groups due to reduced trawl activity. This is coupled with a constant landings profile for all the modeled groups (Figure 32) with exception of the Malla 3 Fleet (Gillnet size 3 in.). Ecosim output suggests the Malla 3 fleet is estimated to increase landings by 30% - primarily composed of Chatarra-type landings with low economic value (e.g. Lizardfish, Catfish, and Flatfish). Rays and Sharks group biomass is estimated to increase by approximately 13% due to the reduction of trawl activity. The model also suggests the biomass for the Morays and Eels group, the Dorado group, as well as the Snappers and Grunts group will increase due to increased availability of prey. This suggests the increase in prey overrides the impact of shark predation on these groups. The biomass of the Large Sciaenids group, which accounts for the more valuable landings (e.g. Croaker and Snook) is also estimated to increase by approximately 12%.

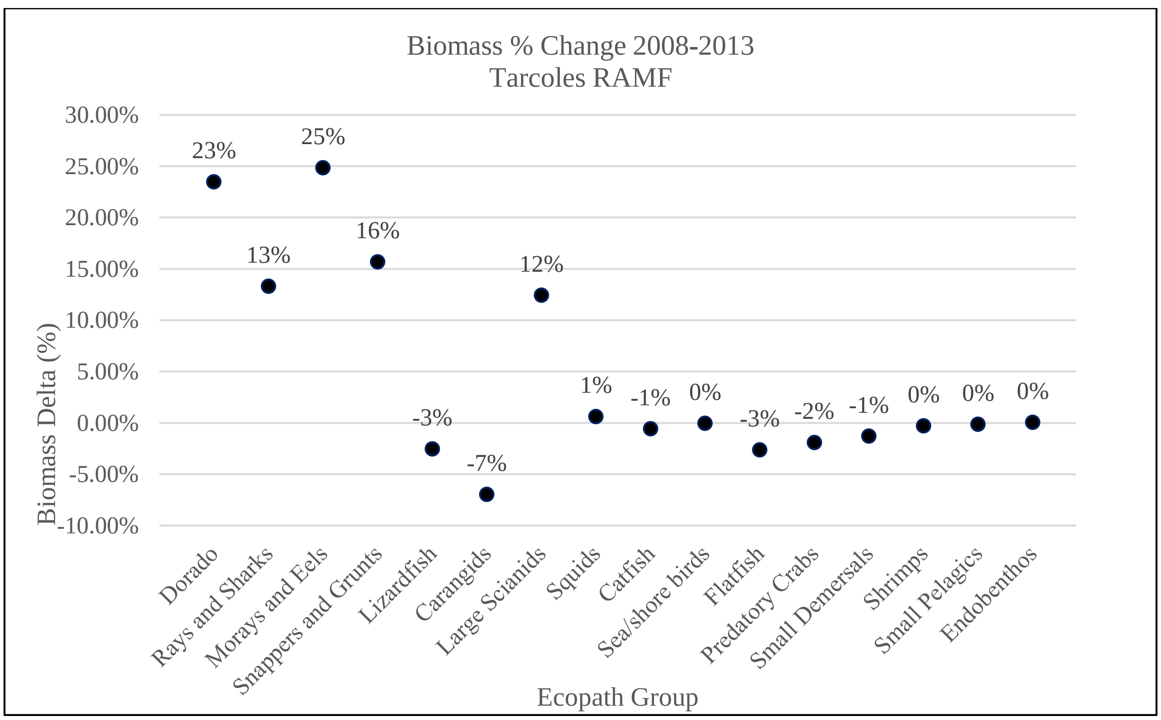

Figure 31 Relative Biomass (2008 vs 2013)– All Groups within Tárcoles RFMA

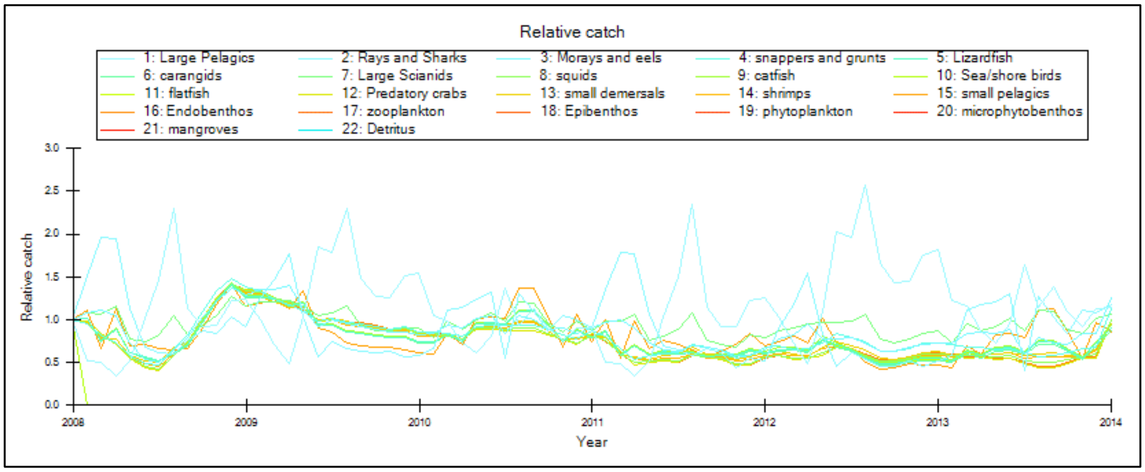

Figure 32 Relative Catch – All Groups (Ecosim Output)

The Ecospace analysis also suggests no impact on biomass for any modeled group within the RFMA due to the implementation of the RFMA structure (Figure 33). The lack of biomass variation between the RFMA regions suggests there is no impact from the control of the artisanal fleet activity within the different Zones. The Ecospace analysis also suggests a biomass accumulation of lower-trophic groups within the mangrove region, however there is no anticipated gradient of spillover when analyzed on a log scale (Ecospace default). This is congruent with the anticipated mangrove effect that has not promoted increased biomass in the adjacent region. Figures 75 through Figure 88 (Appendix A) display the group specific estimates for the time-dynamic simulation from 2008 to 2013.

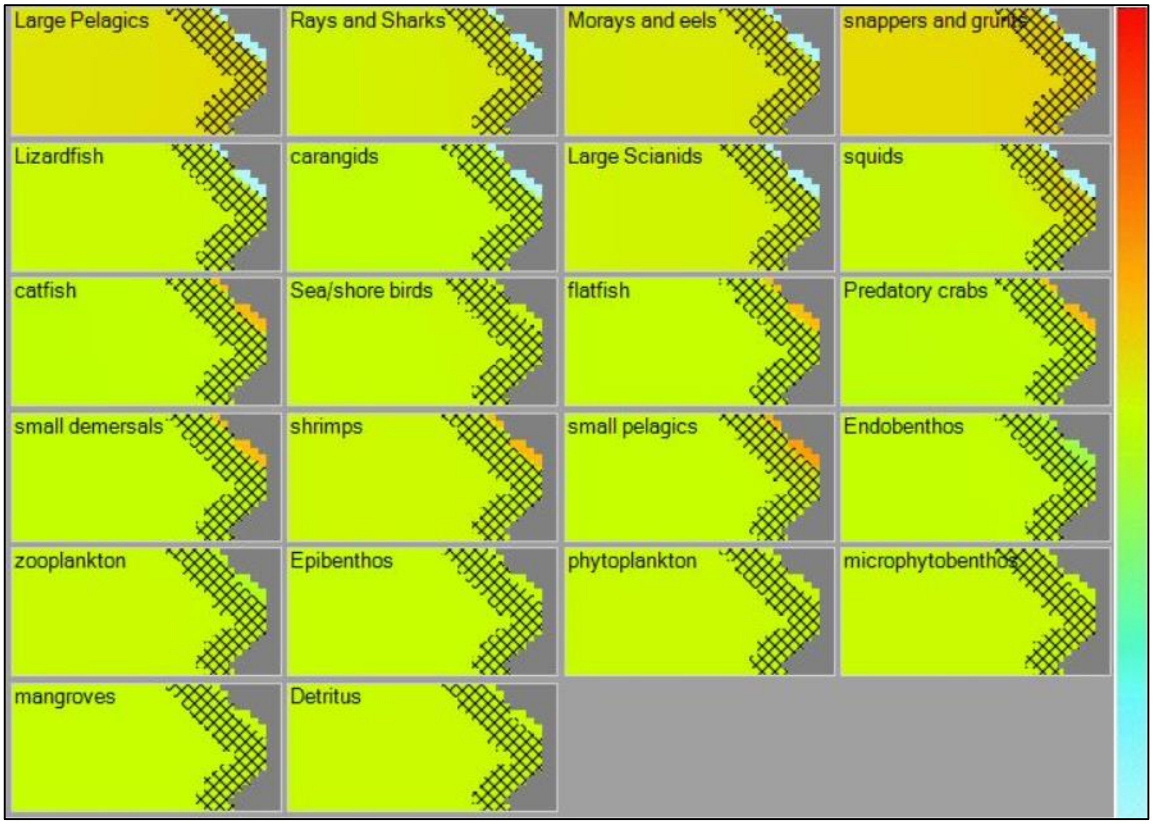

Figure 33 Tárcoles RFMA Biomass change by Region from 2008 to 2013 (Ecospace Output) +10 increase (Log Scale) is denoted by Red on spectrum. -10 decrease (Log Scale) is denoted by Blue on spectrum. Large Pelagic represents Dorado.

Discussion and Conclusions

The Tárcoles EwE model was developed to evaluate the Tárcoles RFMA on a long-term basis. Using the updated GoN EwE model as the baseline, the model was updated to incorporate detailed artisanal fleet information collected by the CoopeTárcoles R.L. fishermen from 2006 to 2010. Conservation International assisted the fishing cooperative in establishing this data collection process to record fisher activity information as well as landings data. This information includes data on total time spent in the RFMA zones by each of the artisanal fleets (Gillnet 3, Gillnet 5, Gillnet 7, Longline, and Scuba) and associated landings. This information was used to develop detailed fleet activity profiles for the Tárcoles RFMA. In this manner, local ecological knowledge was incorporated in the technical analysis and model development. CoopeTárcoles R.L. data was supplemented by INCOPESCA data for artisanal landings from 2008 to 2013. INCOPESCA data included information for all landings within the RFMA region which eliminated the data gap for independent fisher data. This data was also used to calibrate the Tárcoles EwE model.

Trawler activity was estimated using a regression analysis that identified fuel prices as a key variable (see Chapter 3) and landings for trawlers were based on the two shrimp species that are targeted in the RFMA region (white shrimp (*Litopenaeus occidentalis*, *L. stylirostris*, *L. vannamei*), and titi shrimp (*Xiphopenaeus riverti*)).

Geographically, the baseline GoN model represents a much larger area than the Tárcoles RFMA model. Therefore the model area for the Tárcoles RFMA was reduced from the 1,510 km^2 of the GoN to 216 km^2. Geographic detail was incorporated in the Ecospace module of the EwE software. This detail included the mangrove coverage adjacent to RFMA Zone 3 and Zone 4. Each RFMA zone was as added as a region in the Ecospace map which allowed for modeling of fishery fleet activity within each region.

Similar to the GoN EwE model, the Tárcoles EwE Model biomass was calculated by Ecopath. The resulting biomass estimates suggest the Tárcoles RFMA region contains higher biomass of lower trophic groups and lower biomass of higher trophic groups (compared to the GoN biomass estimates). This is consistent with the area's designation as a "Biologically Important" region within the GoN (EPYPSA-Marviva, 2014).

Ecosim analysis from 2008 to 2013 estimates an increase in higher-trophic groups associated with decreased trawler activity. This effect is a result of reduced trawler pressure on lower-trophic groups which increases prey availability for the higher-trophic groups. As with the GoN model, reduced trawl activity is primarily a result of increasing fuel prices.

Ecospace output for the model period does not allow for high-resolution analysis given the default log-scale heat map. The heat map does not suggest an increase or decrease in biomass in the fished areas nor does it identify any difference between RFMA zones. The heat map does identify a biomass increase within the mangrove region for lower-trophic groups. The opposite effect is noted for higher-trophic groups due to the inability of larger piscivores to physically enter or maneuver within the complex mangrove root structure.

The combination of locally collected information and INCOPESCA data has contributed to the construction of a robust model. This model can now provide a reasonable and plausible approximation of the Tárcoles RFMA that incorporates local ecological knowledge and economic drivers. Linking the ecosystem model to economic factors and including fishery landings, bycatch and discards, fishery activity, and a large pelagic group (Dorado) now allows for robust and comprehensive fishery policy analysis of the Tárcoles RFMA.

CHAPTER 5. TÁRCOLES RFMA POLICY ALTERNATIVES

Introduction

Environmental Policy development and analysis must incorporate both ecological and socio-economic factors. This allows for multiple, sometimes competing, priorities to be weighed and considered in the identification of an optimal policy approach. To analyze impacts of varying policy approaches within the RFMA, the calibrated EwE model was run from 2008 to 2017 for different trawl pressure scenarios. This was carried out by revising the model input for Trawl Fleet effort data. Ecospace evaluation was also carried out for each policy scenario to evaluate the impact of the spatial controls and to identify any variation in biomass between the Tárcoles RFMA and the region beyond the RFMA. A ”no fuel subsidy” scenario was analyzed to evaluate the potential impact of eliminating subsides for the trawler fleet. The elimination of controls on artisanal activity within the 15 m. isobath was also evaluated for all scenarios.

The policy alternatives were analyzed by employing a derivative of the evaluation fields developed by Alder et al. (2002) and general principles for the robust governance of environmental resources (Ostrom, 1990; Dietz et al., 2003). This combination resulted in a set of socio-economic and ecological variables to gauge policy alternatives for the Tárcoles RFMA. These "outcome" criteria or “indicators of success” are congruent with Ostrom's (2009) second level variables for analyzing socio-ecological systems.

Methods

A ten-year analysis was conducted assuming Trawler Fleet 1 activity was sustained at the August, 2011 level. The output of this scenario was used as the baseline for evaluating the policy outcomes involving increased and decreased trawl effort (Figure 34). To estimate the potential impact of increased trawling activity, the calibrated EwE model simulated the RFMA fishery assuming a fifty percent increase in trawling activity. Note this fifty percent increase, based on the August, 2011 level, is still approximately 100 Trawl Effort Days (monthly) below the simulation starting effort of January, 2008. To further estimate the potential impact of increased trawling activity, the calibrated EwE model simulated the RFMA fishery assuming a 100 percent increase in trawling activity from the August, 2011 baseline of 474 trawl days. This would result in an estimated 948 trawl days, which is a 17% decrease from the maximum calculated trawl effort from 2008 to 2013 (1151 trawl days). This maximum was estimated to have occurred in December, 2008 primarily driven by reduced fuel costs. To estimate the potential impact of eliminated subsidies, the calibrated EwE model simulated the RFMA fishery assuming a 20% increase in crude oil prices. This assumes Costa Rican diesel prices are linearly related to global crude oil prices. The increased price was applied to the regression analysis discussed in Chapter 3 to estimate the number of trawl effort days. Regression analysis output suggests this would result in an average reduction of 268 trawl effort days per month. This represents a 43% reduction from the August, 2011 baseline of 474 trawl effort days. The total elimination of trawling effort and a 50% trawl reduction scenario were also included in the policy analysis.

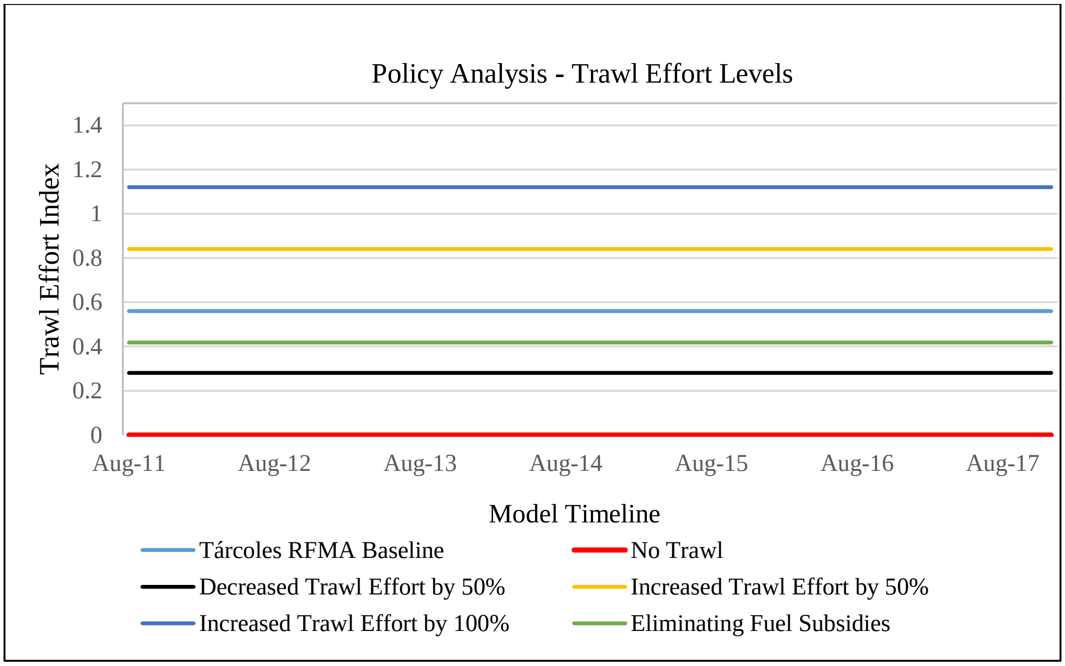

Figure 34 Trawl Effort for Policy Alternatives

Policy alternatives were evaluated using five evaluation fields, or variables, to identify the policy that promotes long-term fishery sustainability and improves economic outcomes. These variables included (i) Use of Sustainable Methods, (ii) Centrally Sanctioned Stakeholder Empowerment, (iii) Robust Self-regulating Regimes, (iv) Positive Socio-economic Outcomes, and (v) Fisheries Conservation. EwE with Ecospace output was incorporated into the Five-Element Rubric to identify the optimal approach.

Sustainable Methods – Marín et al. (2007) suggested an trawl effort reduction of 23%, which is a reduction of ten trawlers from the 2005 fleet of 41 (based on Shaefer model) and a 46% reduction, corresponding to elimination of 19 trawlers from the fleet (based on Fox model) to achieve a maximum sustainable yield. Similarly, Alvarez and Ross (2010) suggested a reduction in trawl fleet by 12 vessels would be in alignment with a sustainable trawling activity level. Given the impact of trawling on the GoN ecosystem, the rubric was based on the relative amount of trawl effort when compared to the baseline. (Reduced trawl effort by 100% (+2), Reduced trawl effort by 50% (+1), Equivalent trawl effort (0), Increased trawl effort by 50%(-1), Increased trawl effort by 100% (-2)).

Centrally Sanctioned – Central governments must sanction the co-management program and must empower stakeholders to develop and implement regulations at the local level (Ostrom, 1990). These are not only success criteria for co-management regimes, but may also be prerequisites in areas where the legitimacy of co-management regulation is questioned and the authority of local stakeholders is challenged. The assumption is all policy approaches and resulting regulations will be approved by INCOPESCA, therefore all alternatives were applied an equivalent positive rating (+1).

Self-regulation – An effective co-management regime must have well-understood regulations and well-delineated boundaries for approved fishing activities. A successful co-management regime must therefore exhibit well-understood regulations, well-defined boundaries, effective governance through equitable representation of stakeholders in rule development and revision, effective compliance monitoring, and graduated sanctioning. The “Self-regulation” rubric was based on the policy’s promotion of (i) monitoring at the local level, and (ii) follow-on sanctioning by the authority having jurisdiction. Ratings ranged from -1 to +1 (Local monitoring with resulting sanctions (+1), Local monitoring without sanctions (0), No local monitoring (-1)).

Socio-economic Outcomes – The establishment of co-management regimes must result in the protection of local customs, cultures and livelihoods as well as protection or improvement of economic returns. Socio-economic conditions under traditional regulatory approaches can serve as a baseline to gauge the success of co-management regimes. Increased incomes and positive community perceptions reflect successful outcomes. The Socio-Economic evaluation rubric was based on the net number of fleets affected positively. More specifically, the number of fleets whose landings value increase by more than 10% was compared to the number of fleets whose landings value decreased by more than 10%.

Fishery Conservation – Few efforts have addressed the lack of systematic data collection and integrated information on small-scale fisheries (Salas et al., 2007). This information is necessary for monitoring the state of fishery stocks (CoopeTárcoles R.L., 2010) and the impact of RFMAs. A robust co-management program must have an established methodology for the accurate collection and analysis of fishing activity and fish catch. In order for co-management of fisheries to be shown as superior to traditional regulatory schemes, the data collected should reflect a coastal ecosystem in relative long-term stability and increased biomass, with consideration for the stochastic nature of marine ecosystems and the transitory nature of marine species. The Fishery Conservation rubric was based on the net number Ecopath groups affected positively. More specifically, the number of Ecopath groups with biomass increases of more than 10% was compared to the number of Ecopath groups with biomass decreases of more than 10%.

Results

Tárcoles RFMA Simulation – 10 Years

Figure 35 illustrates the anticipated impact to biomass from constant trawling effort (August, 2011 baseline). Under this scenario, the biomass for most lower-trophic groups remains relatively constant while biomass for higher-trophic groups increases when compared to 2008 levels. Biomass of the Rays and Sharks group is estimated to increase by 30%, Dorado biomass increases by 25% and biomass for the Morays and Eels group increases by approximately 19%. Note, this analysis suggests shrimp biomass will not increase.

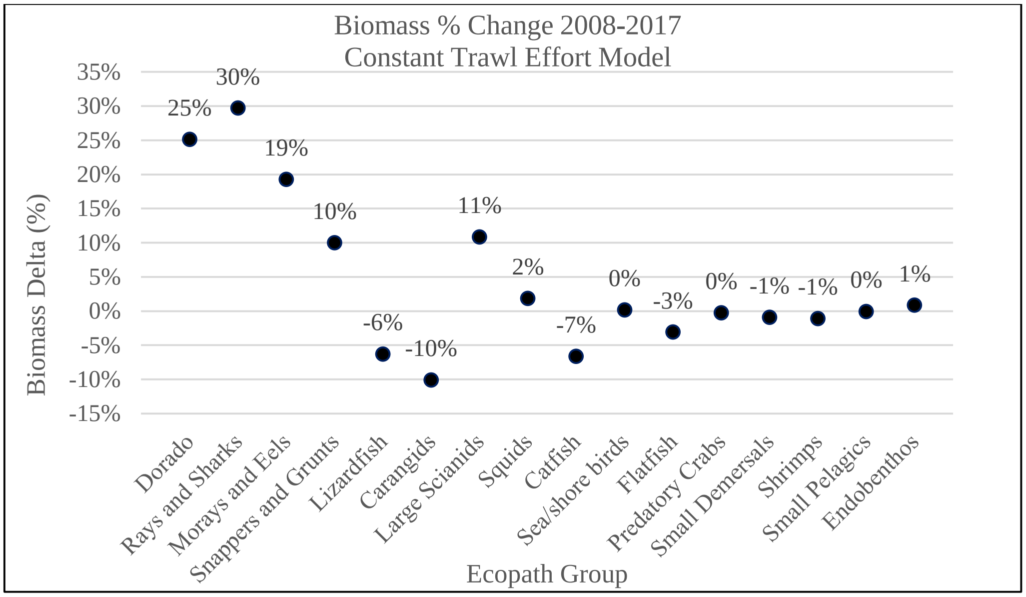

Figure 35 Biomass Change 2008 vs 2017 - Constant Trawl Effort Model

Assuming constant technical efficiency of fishing fleets, the model suggests landings would increase for only the Longline and Gillnet 7 artisanal fleets, which capitalize on the larger, higher-trophic groups. This outcome suggests fishers livelihoods would be expected to remain relatively constant for a majority of the fishers, which in the context of the present state would be continued poverty. This result is not congruent with the original goals of the Tárcoles RFMA which intended to improve livelihood of the artisanal fishers in the Tárcoles region and improve the fishery ecosystem. This would then create a situation where the community would begin to lose confidence in the conservation effort - leading to an increased likelihood of breaking from a compliance agreement. Although no data is available to validate this outcome due to the difficulty in obtaining insight from community members, social media postings and personal observations suggest a local frustration with a lack of benefits from the RFMA effort in Tárcoles, Costa Rica, with only the key project proponents communicating positive outcomes.

Impact of Zoning

For most modeled groups, Ecospace analysis of the Constant-Trawl effort scenario suggests biomass is constant across all RFMA zones for the higher trophic groups. Biomass for lower-trophic groups that benefit from mangrove coverage is anticipated to increase moderately in Zone 2, Zone 3, and Zone 4. The Ecospace analysis further suggests there is no differentiation between the biomass in the RFMA and the region beyond the RFMA due to a spillover effect. The scenario where zoning restrictions are eliminated for the Artisanal Fleets results in an equivalent outcome to the zoned restriction model. This suggests the zone structure of the RFMA is not contributing to the biomass increase and results in equivalent outcomes as the non-zoned structure (see Appendix Figure 89 - Figure 102 for detailed graphical representation of the results).

No Trawl with Constant Artisanal Effort Simulation – 10 Years

EwE output for this scenario was compared with the constant-trawl scenario to evaluate the impact of the policy. The EwE model suggests that eliminating trawl pressure entirely from the modeled area will increase biomass for several model groups. The most notable increase occurs with the Rays and Sharks group (Figure 36) with an estimated increase of 89%. This suggests a positive impact to the shark group biomass is inversely related to the level of trawling. Given trawling does not land significant levels of shark biomass, the effect is primarily a result of increased prey availability for sharks rather than any direct effect on the Rays and Sharks group.

The EwE model suggests a slight reduction of shrimp biomass despite the elimination of trawler activity within the 50 meter isobath. This counterintuitive outcome results from the replacement of trawl pressure on shrimp with the predation pressure of the higher trophic-level groups. Thus any anticipated increase of shrimp, which is a high value product, may not be realized. However the increased biomass of other valuable groups, namely the Large Sciaenids group that includes croaker and snook, would yield financial benefits for artisanal fleets (Figure 36). This policy would therefore meet the intent of the RFMA proposal to improve artisanal fisher livelihoods (Figure 37). According to the EwE with Ecopath analysis, this outcome would be due to a complete trawler elimination and not due to the complex six-zone regularity structure.

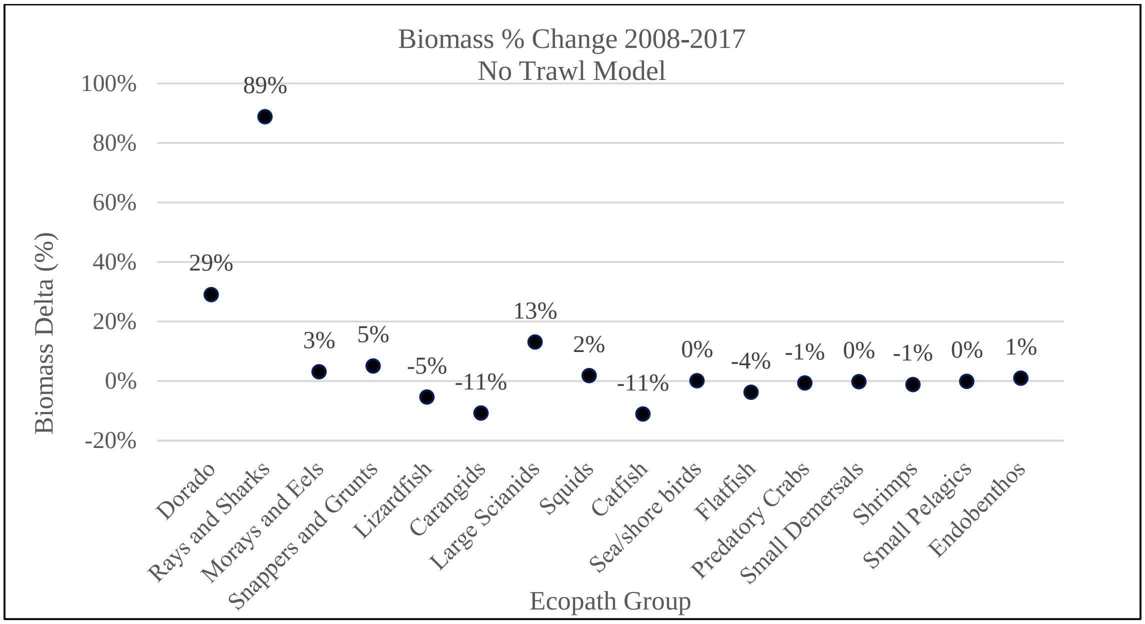

Figure 36 Biomass Impact of No Trawl Effort (2008 vs 2017).

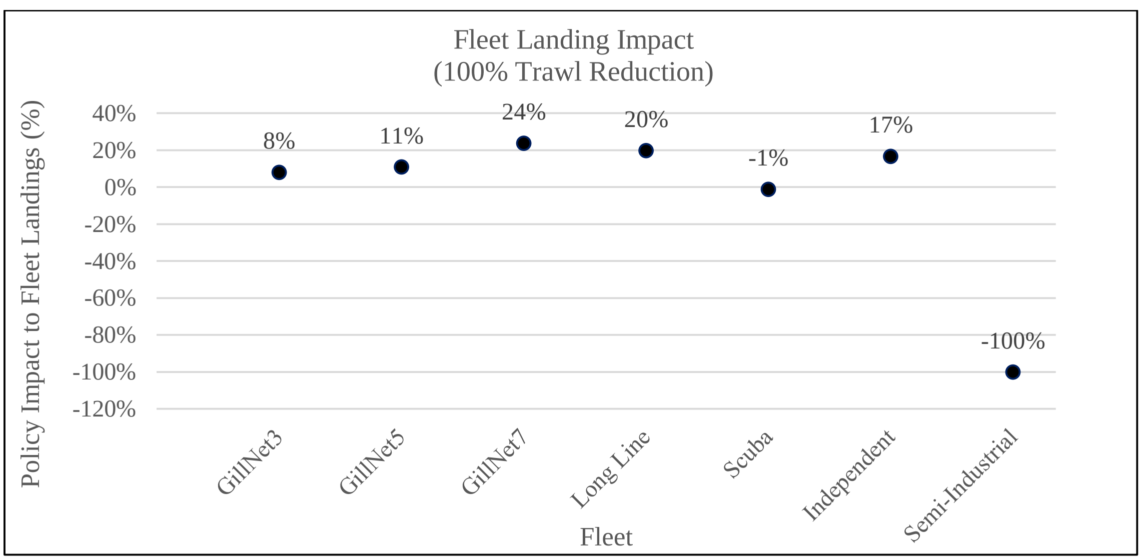

Figure 37 Fleet Landings Impact of No Trawl Effort (2008 vs 2017).

Reduced Trawl Effort (-50%) with Constant Artisanal Effort Simulation – 10 Years

Comparing a "Half-Trawl" scenario with the constant-trawl scenario suggests that reducing trawl pressure by 50% from within the 50 meter isobath will increase biomass for several model groups (Figure 38). Similar to the no-trawl simulation, the Rays and Sharks group exhibits the largest increase in biomass (38%). As with the "no trawl' scenario, the positive impact to the shark group biomass is a result of increased prey availability rather than any direct trawling effect on the Rays and Sharks group. The counterintuitive result of low levels of shrimp biomass is due to the replacement of anthropogenic pressure on shrimp with predation pressure.

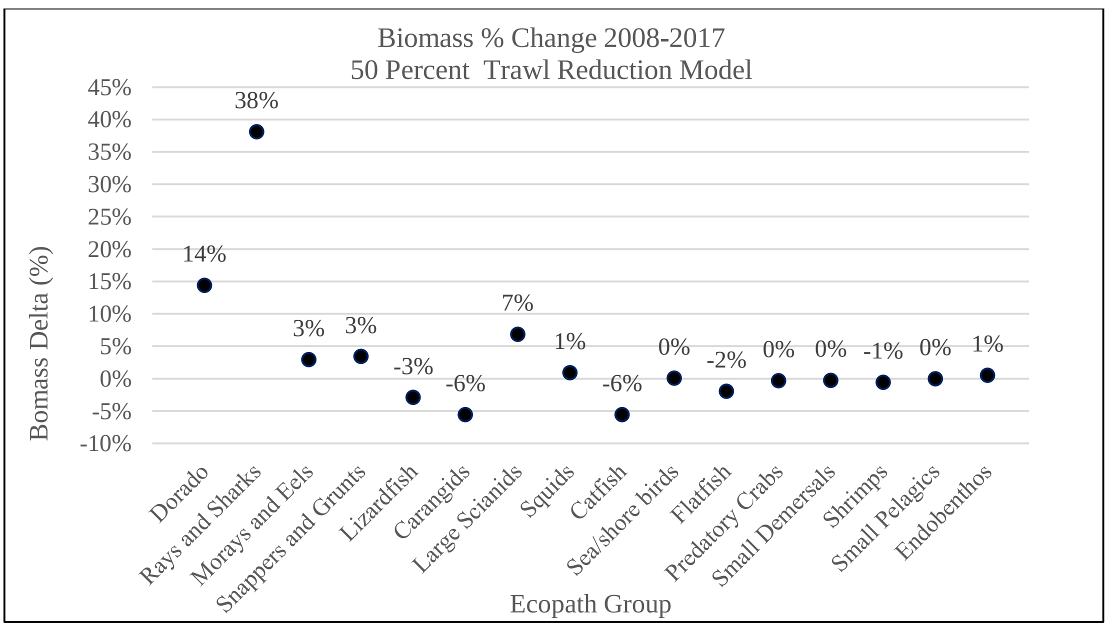

Figure 38 Biomass Effect 2008-2017. Reduced Trawl Effort (-50%) Policy Model

The Ecospace analysis of landings suggests a modestly improved economic condition for artisanal fishers coupled by a reduction of landings for the trawl fleet (Figure 39). By improving biomass of two higher trophic groups, improving artisanal fishers livelihoods, and still allowing for the trawl fleet to operate, this scenario represents a policy approach that reconciles ecological goals and economic interests of the fishery fleets - where there is still interest in maintaining a functioning trawl fleet.

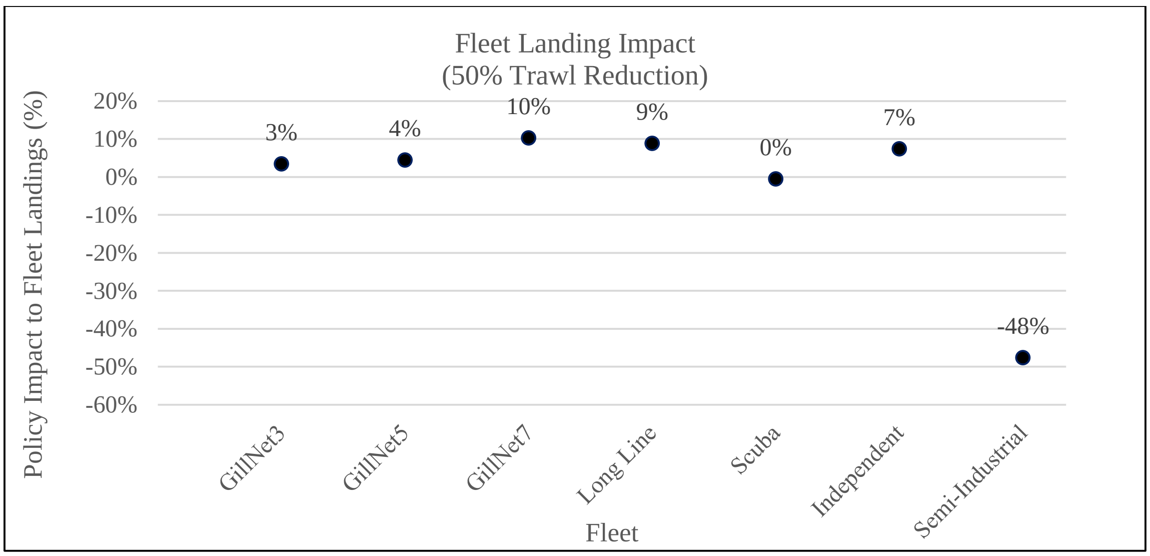

Figure 39 Fleet Landings Effect of Reduced Trawl Effort (-50%)

Increased Trawl Effort (+50%) Simulation – 10 Years

EwE output for the Fifty-Percent increase scenario was compared with the constant-trawl scenario to evaluate the impact of the policy. The simulation results suggest that increasing trawl pressure by fifty percent of the August, 2011 baseline will result in an increase of biomass for the Low Value group (Lizardfish, Catfish and Carangids), however this increase is modest (Figure 40). As with the previous simulations, the counterintuitive, non-response of shrimp biomass to increased trawling is due to shrimp biomass already being at depleted levels under the baseline scenario.

This simulation suggests the income levels of artisanal fishers will be impacted negatively (Figure 41). With respect to the fishery cost-revenue curve, this estimated result suggests a Fifty-Percent Trawl increase may shift the effort to where economic losses are incurred by the fishery fleet.

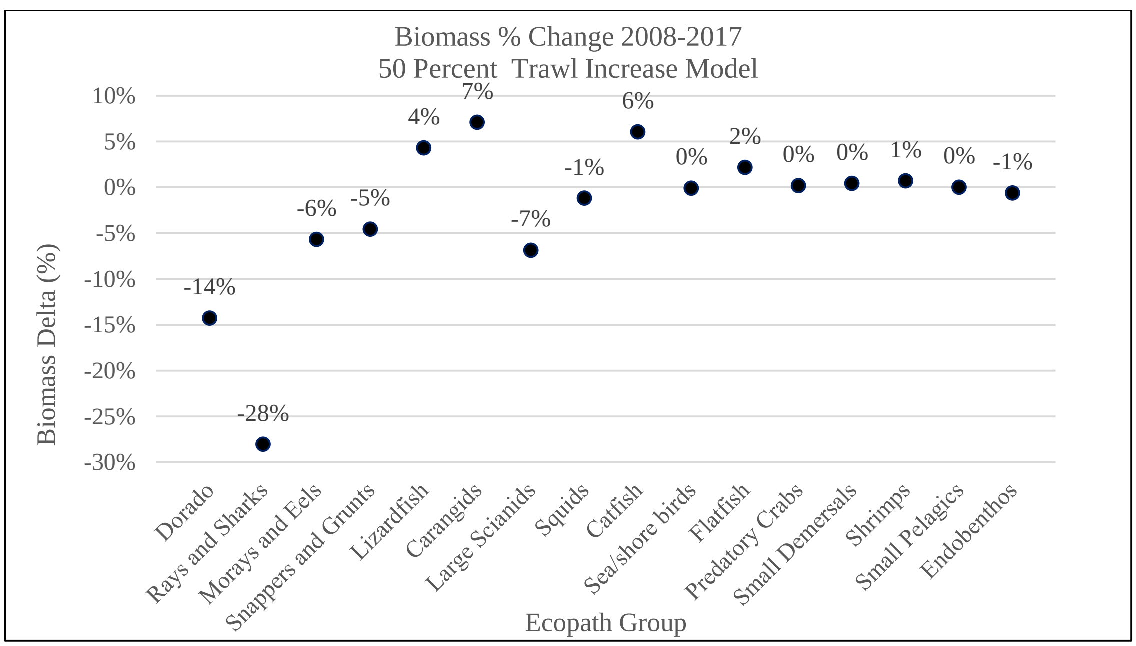

Figure 40 Biomass % Change 2008-2017 with Increased Trawl Effort (+50%)

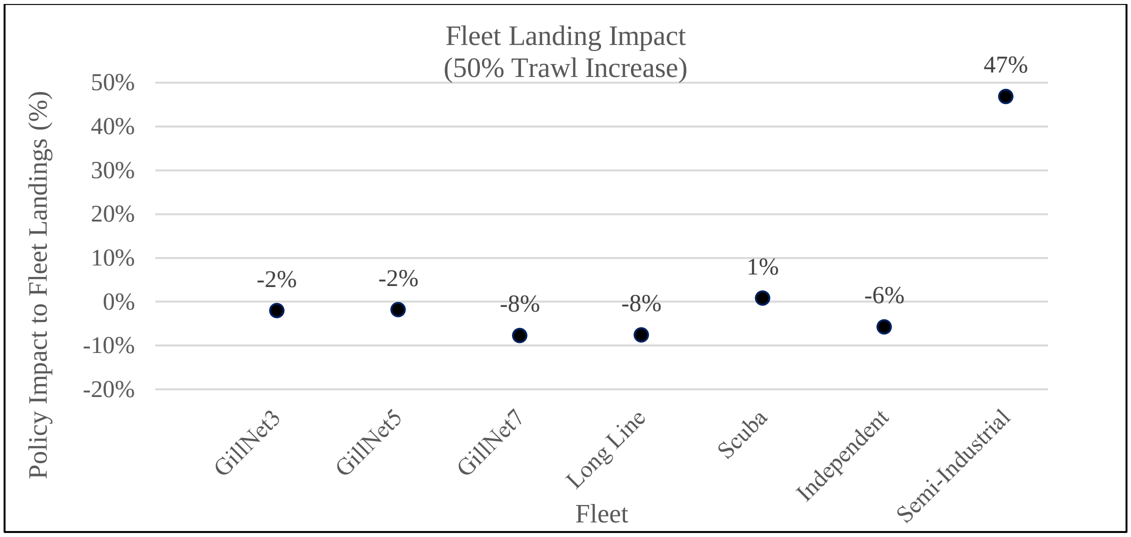

Figure 41 Fleet Landings Effect of Increased Trawl Effort (+50%)

Increased Trawl Effort (+100%) Simulation – 10 Years

EwE output for the 100% Increase scenario was compared with the constant-trawl scenario to evaluate the impact of the policy. The simulation results suggest that increasing trawl pressure by one-hundred percent of the August, 2011 baseline will lead to reduced biomass for the high value groups of interest to the artisanal fleets. This includes Large Sciaenids that decrease by 14% (Figure 42). As with the previous simulations, the counterintuitive response of shrimp biomass to increased trawling is due to the already depleted shrimp group. The model suggests the Rays and Sharks group and the Dorado group would also exhibit a decline in biomass, primarily due to reduced prey levels within the 50 meter isobath. In this scenario, the biomass of the Low Value group (Lizardfish, Carangids, and Catfish) is predicted to increase, primarily due to decreased predation from the higher-trophic groups. No response is estimated to occur within the lower-trophic level groups.

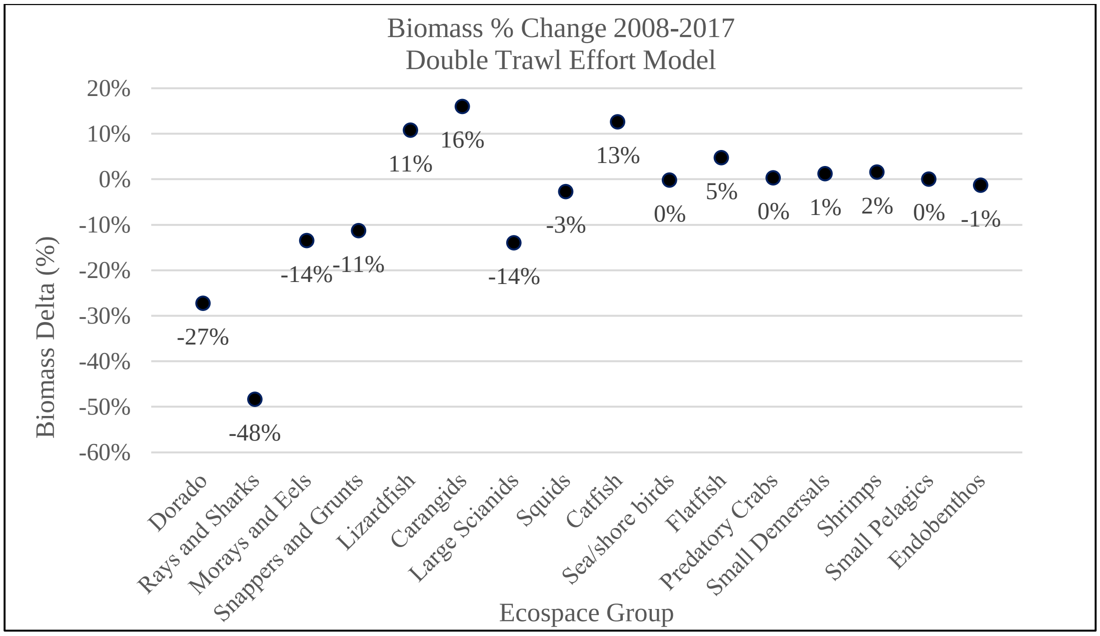

Figure 42 Biomass % Change 2008-2017, Increased Trawl Effort (+100%)

Ecospace landings analysis suggests the doubling of trawl effort would increase trawl fleet landings by a disproportionate amount (88%) (Figure 43). The increased landings are expected to negatively effect artisanal fleet landings. Ecospace estimates suggest artisanal landings will decrease with the exception of the Scuba Fleet.

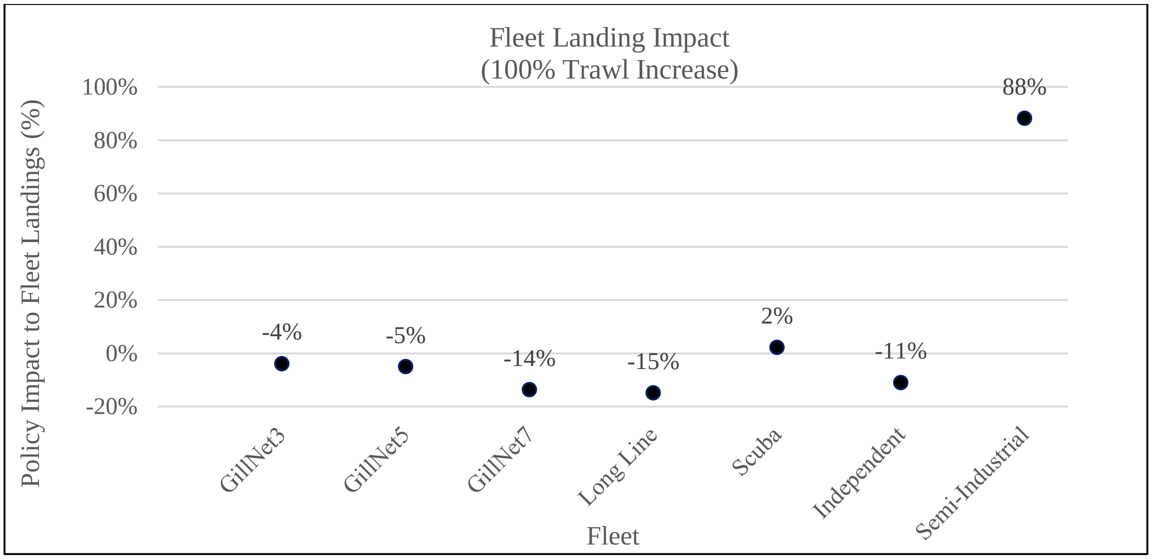

Figure 43 Fleet Landings Effect of Increased Trawl Effort (+100%)

Eliminating Fuel Subsidies

The EwE subsidy elimination model yields estimates congruent with the 50% reduction simulation (Figure 44). Two higher-trophic groups showed an increase when compared to the baseline scenario while lower-trophic groups remained constant. The Rays and Sharks group showed the highest increase (21%) due to increased prey availability. Fleet landings increased for Gillnet 7 and Longline fleets due to the increased presence of larger piscivores in the Tárcoles RFMA. Trawler Fleet landings are estimated to be reduced by 26% due to lower activity levels (Figure 45).

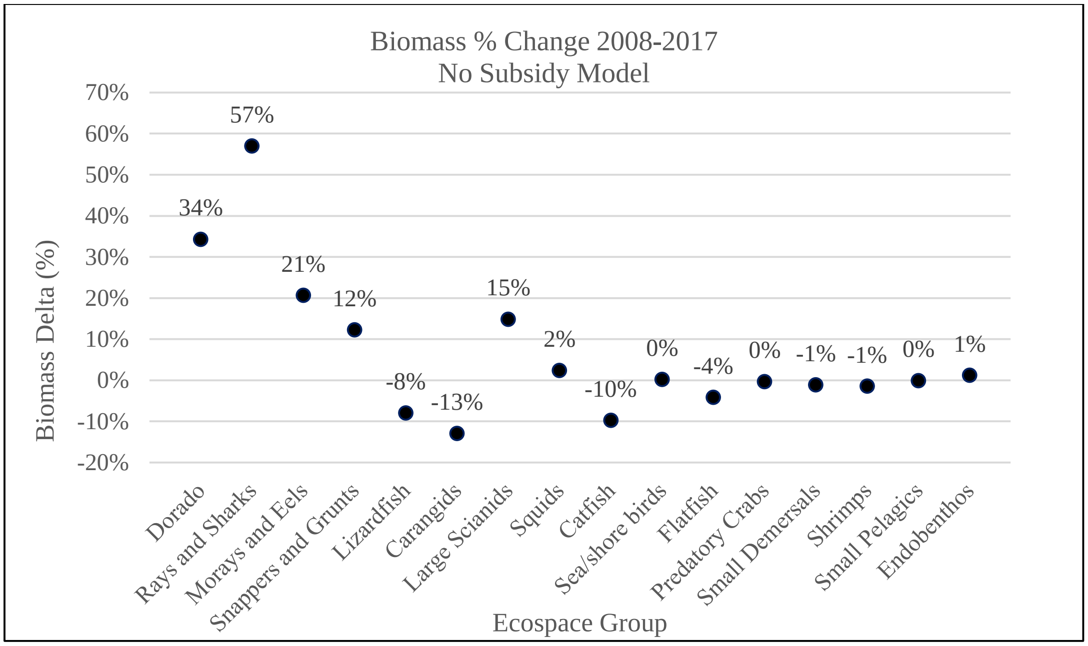

Figure 44 Biomass % Change 2008-2017. Eliminated Fuel Subsidy Model

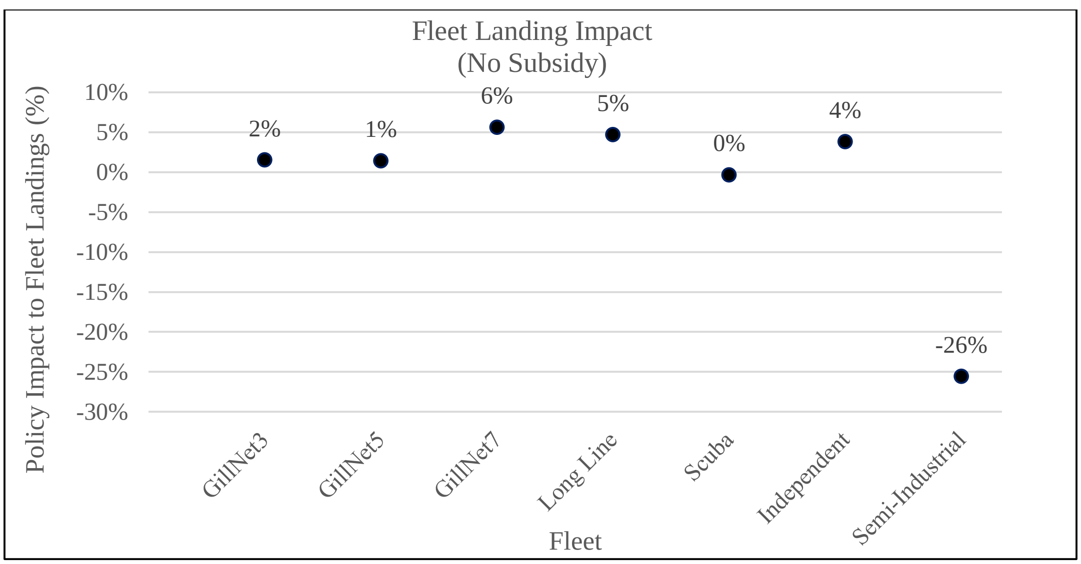

Figure 45 Fleet Landings Effect of Eliminated Fuel Subsidy

Analysis of zoning impact resulted in similar estimates for all policy scenarios. For most modeled groups, Ecospace analysis suggests biomass is constant across al RFMA zones for the higher trophic groups. Biomass for lower-trophic groups that benefit from mangrove coverage is anticipated to increase moderately in Zone 2, Zone 3, and Zone 4. The Ecospace analysis further suggests there is no differentiation between the biomass in the RFMA and the region beyond the RFMA due to a spillover effect. The scenario where zoning restrictions are eliminated for the Artisanal Fleets results in an equivalent outcome to the zoned restriction model. This suggests the zone structure of the RFMA is not contributing to a biomass increase and results in equivalent outcomes as the non-zoned structure (see Appendix Figure 103 - Figure 172 for detailed graphical representation of the results).

Ecospace analysis was extended to include the landings value of different fleets based on current market price. A gap remains, however, in economic evaluation of Costa Rican fisheries. There is a paucity of economic analysis within the significant effort to document and analyze the coastal zone management of Costa Rica. As a result, there is no analysis of the value of fisheries which evaluates variables such as fishery product demand or elasticity of said demand. A robust analysis of fishery costs (opportunity cost, fuel cost, bait cost, vessel cost, ice cost, labor cost) for semi-industrial fleets and artisanal fishers is also lacking. Monserrat and Ortega (2012) did provide a description of costs associated with fishing effort in Costa Rica, but did not extend the analysis to include the selling price of catch in order to evaluate profit nor do they evaluate technical efficiency. More recently, Babue et al. (2012) attempted to analyze the socioeconomic status of artisanal fishers of

Palito and Montero, however the lack of data and significant assumptions reduced the validity of the economic evaluation. Table 24 lists the estimated landings value for different fleets under each policy alternative (based on current market price). This output suggests complete elimination of trawlers from within the 50 meter isobath will yield significant economic benefits to the artisanal fishermen in the GoN.

Table 24 Landings Value* response to Trawl Policy (Ecospace Estimate)

Fleet name	50% Trawl Reduction	100% Elimination	50% Increase	100% Increase	No Subsidy
GillNet3	6%	14%	-4%	-7%	3%
GillNet5	6%	15%	-3%	-7%	2%
GillNet7	9%	20%	-7%	-11%	5%
Long Line	9%	21%	-8%	-14%	5%
Scuba	-1%	-2%	1%	3%	0%
Independent	8%	19%	-6%	-12%	4%
Semi-Industrial	-32%	--	31%	57%	-17%

*Price data available at https://www.incopesca.go.cr/mercado/mercado_nacional.html

Discussion and Conclusions

The present study evaluates multiple levels of trawler activity using a simple, yet multi-faceted rubric to identify a policy that promotes long-term fishery sustainability and improves economic outcomes for the largest number of fishers. The analysis suggests the "No Trawl Scenario with no Artisanal Zone Restriction" policy is the best regulatory alternative for the Tárcoles RFMA (Table 25). Complete elimination of trawling activity from within the 50 meter isobath would prevent bycatch (and discards) of non-target species. This regulatory structure would promote self-regulation and sanctioning by relegating trawl activity to those areas well beyond the Tárcoles RFMA. In previous cases of non-compliance, trawlers have argued they had unknowingly drifted into the Tárcoles RFMA or argued the GPS units used by monitors had not been calibrated (Personal Observation). With a total ban, a sanction would more likely be applied to non-compliant trawler given there would be no approved trawling in the region and previous defenses would be inadequate. This policy approach will also eliminate the need for peer-to-peer compliance monitoring. With respect to Socio-Economic factors, the “No Trawl Scenario with no Artisanal Zone Restriction” scenario will result in increased revenue for all artisanal fleets but eliminates trawler fleet revenue. This scenario promotes fisheries conservation as shown in Figure 36, where the biomass of higher-trophic species increases, also yielding a more biodiverse ecosystem.

This policy would require the Trawling Fleet crews to either obtain alternative employment or transition to an artisanal fleet. Trawlers may also choose to continue trawling beyond the 50 meter isobath under this policy alternative. This would require longer trips leading to increased operating costs. However, Baloaños (2005) noted three trawlers that illegally transitioned from near-shore activity to targeting camellón shrimp (*Heterocarpus affinis*) at depths between 350 meters and 1,000 meters showed the highest operating revenue of sixteen sampled vessels. This suggests the increased costs associated with longer distances may be associated with improved revenue as trawlers transition out of the 50 meter isobath. The profitability of extended trawl trips may increase further if no investment is necessary to upgrade vessels and fixed costs are constant.

Table 25 Policy Alternative Evaluation

Policy Alternatives	Sustainable Methods	Centrally Sanctioned	Self-regulation	Socio-economic Factors	Fishery Conservation	Total Score
No Trawl Scenario	2	1	0	4	2	9
No Trawl Scenario with no Artisanal Restriction	2	1	1	4	2	10
50% Trawl Reduction	1	1	0	-1	1	2
50% Trawl Reduction with no Artisanal Restriction	1	1	0	-1	1	2
50% Trawl Increase	-1	1	0	1	-2	-1
50% Trawl Increase with no Artisanal Restriction	-1	1	0	1	-2	-1
100% Trawl Increase	-2	1	0	-2	-2	-5
100% Trawl Increase with no Artisanal Restriction	-2	1	0	-2	-2	-5
No Fuel Subsidy	0	1	0	-1	1	1

This analysis suggests the 100% trawl increase scenario is the worst alternative primarily due to the reduction in both biomass and loss of revenue for the collective fleets. Eliminating subsidies for the trawl fleet would reduce trawl effort and would yield increased revenue for the artisanal fleets. Note however, this approach would fail to implement regulatory controls, creating no barrier to increased trawl effort when fuel prices decrease.

The resulting biomass estimates for the different scenarios also suggest the market process may have defined the level of effort of the combined fleets in the region – coalescing at the point where total revenue is in equilibrium with total cost. Further economic analysis is necessary to identify if the effort level is based on the "maximum profit" level or if the fishers have progressed towards Hardin's (1968) "Tragedy of the Commons". However, the increased biomass estimates from the long-term analysis suggests the 2008 level of effort is at the bio-economic equilibrium. Namely, the reduced Fleet 1 trawl effort from 2008 to 2013 allowed the ecosystem to recover from overharvesting resulting in increased biomass for higher-trophic species.

Thus the fishers, in a non-technical and heuristic manner, may have identified the collective level of effort beyond which it is not rational to invest time and effort into fishing. This would be at the equilibrium level of effort where total revenue equals total cost. Noting that sustainable yield occurs at lower effort levels where the revenue per effort begins to decrease, an RFMA design that maintains the baseline level of effort at the equilibrium level would be equivalent to the "do-nothing" alternative. This approach, although associated with limited potential benefits, may have promoted acceptance of the RFMA framework given the policy would not be associated with a significant revision to total effort.

CHAPTER 6. GENERAL DISCUSSION AND CONCLUSIONS

Co-management of fisheries has gained interest in Costa Rica. This approach is seen as an improvement from traditional regulatory approaches that have failed to prevent over-harvesting of fishery resources. In addition to the anticipated ecosystem improvements (e.g. increased biomass, increased biodiversity), co-management also allows for local representation in policy development.

There is significant ongoing debate regarding the effectiveness of the Tárcoles RFMA in providing benefits to the local fishers. The discussion has been elevated to the national level with the president of Costa Rica, Luis Guillermo Solís Rivera, taking the position that efforts such as the Tárcoles RFMA allow for the continued trawler fleet activity while also providing benefits for Artisanal Fishers. The idealized outcome that proponents are communicating suggests the Tárcoles RFMA has (i) allowed for continued trawl fleet effort and the associated employment, (ii) ensured the continued practice of artisanal fishing with landings that support local livelihoods and the protection of local customs, and (iii) has allowed the ecosystem to recover from historical over-harvesting.

The creation of the Tárcoles RFMA as described by Alpízar (2012) is indeed a positive example of the progressive management of fishery resources in a manner that includes stakeholder input. Cornic et al. (2014) describe role of the local community in the creation of the Tárcoles RFMA as a significant improvement from the historical underrepresentation of the artisanal fleets of Costa Rica. Procedurally, the co-management process in Costa Rica approximates Ostrom's principles of enduring common pool resource management structures. It would be reasonable, therefore, to classify the Tárcoles RFMA as a successful co-management approach to fisheries regulation. However, in order for co-management of fisheries to be shown as superior to traditional regulatory schemes, landings data should also suggest increased fisher revenue.

The stochastic and complex nature of fishery ecosystems may cause potential improvements from the Tárcoles RFMA to materialize at temporal scales that extend beyond stakeholder expectations. It is also possible that anticipated outcomes may not appear (e.g. no increase in shrimp biomass with elimination of trawlers). INCOPESCA data suggests this to be the case for the Tárcoles RFMA, where improvements did not materialize within the first two years. This perceived delay may lead to decreased cooperation at the local level where fishers see no benefit from continued adherence to rules. Noncompliance may therefore result if there is a weak monitoring and sanctioning function.

A corollary to the Ostrom *"Eight Principles"* is therefore necessary in settings involving significant uncertainty such as stochastic and complex fishery ecosystems. Namely, proponents must account for and communicate the uncertainty associated with anticipated outcomes. Collaboration and planning for CPR management structures must be conducted such that stakeholders understand and accept the stochasticity of variables and the probabilistic nature of potential outcomes – as opposed to securing agreement based on deterministic predictions. This more complex analysis can be performed by engaging the scientific community in RFMA design.

There are multiple resources that can contribute scientific rigor to RFMA designs in Costa Rica. This would take the form of collaboration with the scientific community and Costa Rican NGOs. However, collaboration between these groups and the Tárcoles community has been difficult to carry out (present study included). Local representatives have placed significant constraints on outside evaluators due to a history of "being taken advantage of" (Personal Observation).

In the absence of local cooperation, INCOPESCA landings data for the two main fishery fleets (artisanal fishers and shrimp trawler fleets) were obtained to develop a multispecies model of the GoN. This allowed for evaluation of the long-term implications of the Tárcoles RFMA. To accomplish this, a published Ecopath model (Wolff et al., 1998) of the GoN was upgraded to a time-dynamic Ecopath with Ecosim model. The upgraded model addressed three significant gaps in the 1998 GoN model. These included (i) accounting for trawler landings and discards, (ii) accounting for the activity of fishery fleets, and (iii) the addition of a "Dorado" group. The resulting GoN model is the first analysis of the GoN using a time-dynamic multi-species model. This GoN model served as the basis for Tárcoles RFMA EwE with Ecospace model. EwE modeling of GoN fishery activity was based on available data. Where data was absent, reasonable and plausible estimates were developed. That said, improvements to the modeling effort can be realized with increased data availability. Uncertainty would be reduced with updated sampling of the GoN to verify species presence and the associated biomass. Sampling for stomach content will improve accuracy of diet matrices. Updated fleet activity data and landings per fleet will increase the validity of Ecosim simulations. Fishers cost data will also improve the analysis of competing policy alternatives.

The analysis of the Tárcoles RFMA suggests the co-management based policy has been and will be ineffective. Model results also suggest the RFMA zoning strategy yields no anticipated benefit. The effectiveness of the six-zone structure is also reduced by the lack of compliance monitoring or sanctions. The absence of barriers-to-entry make the area further susceptible to non-compliance. Simplified zoning will eliminate non-compliance and may reduce conflict within the community regarding zoning structure, which was evident during the negotiation process in Tárcoles. Under the nested enterprise, the local community would be required to propose the no-zone restriction approach to INCOPESCA for official approval.

Per the EwE model and Ecospace analysis, a revised regulatory structure should eliminate trawler fleet activity from within the 50 meter isobath to increase fish biomass and increase revenue for artisanal fishers. The analysis also concludes that shrimp trawler activity is affected by fuel prices, where a price above $40 USD per barrel of crude oil reduces trawl activity. It is therefore likely the increased fuel costs experienced in 2011 hastened the adoption of the Tárcoles RFMA by INCOPESCA's pro-trawler governing body, given the trawler activity would not be impacted (i.e. the do-nothing alternative). This occurred in spite of fuel subsidies which, if eliminated, would drive a 42% reduction in trawl effort. That said, fuel prices alone cannot control trawl effort at levels that promote fishery recovery because these costs fluctuate and trawler fleets will choose to operate if fuel prices fall significantly.

The EwE model suggests the elimination (or reduction) of trawler activity will have an indirect benefit to Rays and Sharks due to increased availability of prey. This, in turn, increase Rays and Sharks biomass and will allow the Costa Rican government to meet the goals of CITES - where shark species have been designated for prioritized protection. Costa Rica is party to the United Nations Environmental Program Convention on the Conservation of Migratory Species of Wild Animals and ratified the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) in 1975. However in February, 2016 the president of Costa Rica, Luis Guillermo Solís, was awarded the Shark Enemy of the Year Award due to a series of policy decisions perceived to be detrimental to shark species in Costa Rican waters. Given that Costa Rica hosted Sharks MOS2 (Second Meeting of the Signatories to the Memorandum of Understanding on the Conservation of Migratory Sharks) in February, 2016, there is significant pressure on the Costa Rican government from both within Costa Rica and from the international community for policy approaches that protect shark species.

Eliminating the trawler fleet through regulation will be a challenging endeavor given the structure of INCOPESCA. The semi-industrial fleet has had significant influence on Costa Rican fishery policy. Of the eleven-member INCOPESCA committee that defines fishery policy in Costa Rica, seven are representatives of the fishing industry with direct financial interests in trawling activity. Any significant reduction of trawling will occur only after a revamping of the INCOPESCA structure. A legislative bill proposed by the previous administration intended to address said structure of the INCOPESCA governing body, which is mandated by Article 7 of Costa Rica Law 7384. However the proposed bill has yet to be considered. If successfully passed and reduced industry influence allows for reduction or elimination of trawler fleets, the updated policy will also require increased resources to develop and implement a compliance monitoring regime.

The EwE models described here represent the first multi-species, time-dynamic, models of the GoN. Results of this analysis can inform CoopeTárcoles R.L. and the conservation community of those factors that may contribute to the success of the Tárcoles RFMA. Given the Tárcoles RFMA is the largest and most complex RFMA in the GoN, lessons and insights gained from researching this RFMA can supplement management efforts for other RFMAs established in Costa Rica.

APPENDIX

Table 26 GoN – Shrimp Trawler Landings – 2003

Cantidad barcos/mes.	48	43	45	43	49	41	40	45	41	45	42	46	44
CONCEPTO	**ENE**	**FEB**	**MAR**	**ABR**	**MAY**	**JUN**	**JUL**	**AGO**	**SET**	**OCT**	**NOV**	**DIC**	**TOTAL**
PRIMERA GDE.	-	62.00	30.60	9.00	-	-	109.00	-	-	4.00	15.50	-	230.10
PRIMERA PEQ.	8,948.41	6,153.30	6,523.84	3,922.85	5,944.30	11,273.80	4,422.95	7,108.09	8,127.09	4,817.60	6,505.82	8,279.80	82,027.85
CLASIFICADO	10,676.18	8,691.59	6,609.00	3,228.69	9,962.30	5,551.70	6,523.71	6,422.60	6,679.49	9,747.32	8,148.30	7,904.95	90,145.83
CHATARRA	17,301.01	25,938.11	18,032.30	11,274.37	22,016.65	16,724.20	15,501.70	19,789.00	14,131.49	17,184.60	19,332.80	15,644.70	212,870.93
AGRIA COLA	201.00	391.00	278.20	311.60	336.70	23.75	27.00	194.00	138.50	-	99.60	61.00	2,062.35
CABRILLA	408.40	42.50	167.30	87.20	3,053.44	982.50	801.40	954.00	137.60	166.40	259.60	123.30	7,183.64
PARGO	-	-	-	-	-	-	-	-	-	-	-	-	-
PARGO SEDA	10.74	-	-	-	13.00	-	-	-	-	-	-	-	23.74
DORADO	30.00	-	7.30	-	-	-	-	-	-	-	-	-	37.30
MARLIN	-	-	-	-	-	-	-	-	-	-	-	-	-
MARLIN BLCO.	-	-	-	-	-	-	-	-	-	-	-	-	-
MARLIN ROS.	-	-	-	-	-	-	-	-	-	-	-	-	-
PEZ VELA	-	-	-	-	-	-	-	-	-	-	-	-	-
PEZ ESPADA	-	-	-	-	-	-	-	-	-	-	-	-	-
WAHOO	-	-	-	-	-	-	-	-	-	-	-	-	-
TOT PESC EVIS (1)	37,575.74	41,278.50	31,648.54	18,833.71	41,326.39	34,555.95	27,385.76	34,467.69	29,214.17	31,919.92	34,361.62	32,013.75	394,581.74
SARDINA													-
ATUN	24.00	-	90.30	63.20	-	-	-	36.00	35,000.00	-	-	-	35,213.50
BALLYHOO	-	-	-	-	-	-	-	-	-	-	-	-	-
TOT PELAGICOS (2)	24.00	-	90.30	63.20	-	-	-	36.00	35,000.00	-	-	-	35,213.50
CAZON	97.70	177.90	492.50	258.65	1,018.30	537.50	1,063.30	592.00	517.40	463.80	273.10	500.20	5,992.35
POSTA	31.00	-	60.20	-	-	-	-	-	-	-	-	-	91.20
MACO	-	-	-	-	-	-	-	-	-	-	-	-	-
TREACHER	-	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL TIBURON (3)	128.70	177.90	552.70	258.65	1,018.30	537.50	1,063.30	592.00	517.40	463.80	273.10	500.20	6,083.55
A. PESCADOS (1+2+3)	**37,728.44**	**41,456.40**	**32,291.54**	**19,155.56**	**42,344.69**	**35,093.45**	**28,449.06**	**35,095.69**	**64,731.57**	**32,383.72**	**34,634.72**	**32,513.95**	**435,878.79**
CAMARON BLCO.	11,275.00	9,268.20	5,031.10	2,668.80	3,261.40	4,460.40	3,602.60	2,215.80	1,409.40	2,961.20	4,302.30	4,066.40	54,522.60
CAMARON CAFE	124.00	39.20	58.80	112.60	21.00	-	11.50	7.00	110.50	56.20	39.00	-	579.80
CAMARON ROSADO	9,237.10	11,784.70	15,726.20	8,329.90	18,260.30	9,232.10	11,347.80	14,937.80	9,871.20	16,596.80	12,661.10	9,034.00	147,019.00
CAMARON FIDEL	9,395.60	4,180.60	6,377.50	4,565.00	11,528.90	6,861.40	8,989.10	17,577.20	8,657.70	12,971.40	14,067.70	24,955.20	130,127.30
CAMARON CAMELLO	17,626.50	18,222.00	44,586.10	22,493.70	21,739.10	17,872.20	25,801.50	52,088.80	25,948.60	32,310.60	49,489.90	16,908.40	345,087.40
CAMARON REAL	8,331.60	-	3,168.10	18,708.10	33,518.10	26,733.80	28,388.50	27,647.30	27,276.30	33,525.20	8,465.00	6,408.00	222,170.00
CAMARON TITI	390.70	1,147.60	1,724.30	2,287.50	2,185.70	3,026.50	7,146.00	7,218.00	4,104.70	7,463.80	13,662.50	4,528.10	54,885.40
TOT CAMARON (4)	56,380.50	44,642.30	76,672.10	59,165.60	90,514.50	68,186.40	85,287.00	121,691.90	77,378.40	105,885.20	102,687.50	65,900.10	954,391.50
LANG PACIFICA (CTE)	-	2.80	5.00	-	-	-	-	-	-	1.50	-	-	9.30
LANG CARIBE	-	-	-	-	-	-	-	-	-	-	-	-	-
TOT LANGOSTA (5)	-	2.80	5.00	-	-	-	-	-	-	1.50	-	-	9.30
CALAMAR	-	-	-	18.00	-	-	105.00	72.00	-	-	11.40	-	206.40
PULPO	-	-	-	-	-	-	-	-	-	-	-	-	-
BIVALVOS	-	-	-	-	-	-	-	-	-	-	-	-	-
CAMBUTE	-	-	-	-	-	-	39.00	-	-	-	-	-	39.00
TOT MOLUSCOS (6)*	-	-	-	18.00	-	-	144.00	72.00	-	-	11.40	-	245.40
B. TOT MARISCOS (4+5+6)	**56,380.50**	**44,645.10**	**76,677.10**	**59,183.60**	**90,514.50**	**68,186.40**	**85,431.00**	**121,763.90**	**77,378.40**	**105,886.70**	**102,698.90**	**65,900.10**	**954,646.20**
ALETA TIBURON	-	-	-	-	-	-	-	-	-	-	-	-	-
FILET	-	-	-	-	-	-	-	-	-	-	-	-	-
BUCHE	-	-	-	-	-	9.47	-	-	-	-	-	-	9.47
CANGREJO	-	-	-	16.50	-	83.00	43.00	-	-	-	26.50	-	169.00
C. TOT OTROS (7)	-	-	-	16.50	-	92.47	43.00	-	-	-	26.50	-	178.47
D. TORTUGA (8)	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
GRAN TOTAL (ó A+B+C+D)	**94,108.94**	**86,101.50**	**108,968.64**	**78,355.66**	**132,859.19**	**103,372.32**	**113,923.06**	**156,859.59**	**142,109.97**	**138,270.42**	**137,360.12**	**98,414.05**	**1,390,703.46**

Table 27 GoN – Shrimp Trawler Landings – 2004

PESCA TOTAL SEGÚN CLASIFICACION COMERCIAL POR MESES COSTA RICA: LITORAL PACIFICO - FLOTA SEMI - INDUSTRIAL - 2004													PROMEDIO
Cantidad barcos/mes.	44	39	33	28	36	39	36	42	33	39	35	39	37
CONCEPTO	ENE	FEB	MAR	ABR	MAY	JUN	JUL	AGO	SET	OCT	NOV	DIC	TOTAL
PRIMERA GDE.	15.60	26.50	43.00	-	11.10	269.00	-	-	-	-	3.50	-	368.70
PRIMERA PEQ.	8,534.60	8,412.70	7,742.00	3,540.10	5,200.40	5,367.90	11,300.90	12,925.46	1,830.90	3,181.43	4,702.20	7,827.35	80,565.94
CLASIFICADO	11,086.80	4,895.00	6,440.20	3,469.50	7,275.69	7,140.39	6,129.40	13,182.50	8,148.30	5,645.90	5,478.74	9,023.39	87,915.81
CHATARRA	16,449.35	19,773.56	29,526.60	11,639.66	16,053.20	11,818.50	17,223.70	25,041.77	9,579.40	10,830.85	17,778.30	23,578.51	209,293.40
AGRIA COLA	68.00	-	482.30	-	592.00	-	194.00	-	-	-	-	76.00	1,412.30
CABRILLA	254.30	225.50	445.70	163.95	970.01	950.90	691.10	562.25	37.80	180.50	21.50	65.50	4,569.01
PARGO	-	-	-	-	-	-	-	-	-	-	-	-	-
PARGO SEDA	25.00	-	-	-	-	-	-	-	-	-	-	-	25.00
DORADO	-	-	-	-	-	-	-	-	-	-	-	-	-
MARLIN	-	-	-	-	-	-	-	-	-	-	-	-	-
MARLIN BLCO.	-	-	-	-	-	-	-	-	-	-	-	-	-
MARLIN ROS.	-	-	-	-	-	-	-	-	-	-	-	-	-
PEZ VELA	-	-	-	-	-	-	-	-	-	-	-	-	-
PEZ ESPADA	-	-	-	-	-	-	-	-	-	-	-	-	-
WAHOO	-	-	-	-	-	-	-	-	-	-	-	-	-
TOT PESC EVIS (1)	36,433.65	33,333.26	44,679.80	18,813.21	30,102.40	25,546.69	35,539.10	51,711.98	19,596.40	19,838.68	27,984.24	40,570.75	384,150.16
SARDINA													-
ATUN	-	-	-	7,580.00	13,401.00	21,540.00	-	23,065.00	600.00	1,276.80	421.00	-	67,883.80
BALLYHOO	-	-	-	-	-	-	-	-	-	-	-	-	-
TOT PELAGICOS (2)	-	-	-	7,580.00	13,401.00	21,540.00	-	23,065.00	600.00	1,276.80	421.00	-	67,883.80
CAZON	338.80	131.50	487.20	165.60	447.51	154.90	544.30	124.30	160.09	290.39	98.50	539.30	3,482.39
POSTA	-	-	-	-	-	-	-	-	-	-	-	-	-
MACO	-	-	-	-	-	-	-	-	-	-	-	-	-
TREACHER	-	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL TIBURON (3)	338.80	131.50	487.20	165.60	447.51	154.90	544.30	124.30	160.09	290.39	98.50	539.30	3,482.39
A. PESCADOS (1+2+3)	**36,772.45**	**33,464.76**	**45,167.00**	**26,558.81**	**43,950.91**	**47,241.59**	**36,083.40**	**74,901.28**	**20,356.49**	**21,405.87**	**28,503.74**	**41,110.05**	**455,516.35**
CAMARON BLCO.	3,599.70	3,472.40	5,641.10	1,849.70	1,680.70	1,765.00	2,628.80	2,789.70	2,021.00	4,098.90	4,091.00	7,431.80	41,069.80
CAMARON CAFE	193.00	136.80	34.20	187.60	19.00	-	60.40	338.70	6.80	95.40	353.50	-	1,425.40
CAMARON ROSADO	12,178.00	14,973.60	15,064.00	5,372.40	17,274.30	21,247.00	15,203.10	20,491.00	7,828.20	8,865.50	6,533.50	17,436.90	162,467.50
CAMARON FIDEL	19,476.50	17,919.50	9,717.60	34,040.00	21,191.90	27,165.50	25,248.30	46,487.40	55,957.00	54,390.60	68,802.20	39,621.50	420,018.00
CAMARON CAMELLO	30,101.20	15,522.60	43,225.90	11,647.30	25,111.00	30,651.20	28,504.40	14,771.60	2,501.90	6,711.60	8,150.80	6,541.60	223,441.10
CAMARON REAL	15,093.60	7,168.60	6,364.40	1,239.20	14,134.70	11,451.20	4,797.70	6,621.20	-	13,433.10	-	3,720.70	84,024.40
CAMARON TITI	3,407.10	1,120.30	1,386.70	831.90	3,058.70	2,361.30	4,004.00	1,662.30	2,085.90	5,139.00	8,196.30	5,086.10	38,339.60
TOT CAMARON (4)	84,049.10	60,313.80	81,433.90	55,168.10	82,470.30	94,641.20	80,446.70	93,161.90	70,400.80	92,734.10	96,127.30	79,838.60	970,785.80
LANG PACIFICA (CTE)	-	-	-	-	-	-	-	-	-	-	-	-	-
LANG CARIBE	-	-	-	-	-	-	-	-	-	-	-	-	-
TOT LANGOSTA (5)	-	-	-	-	-	-	-	-	-	-	-	-	-
CALAMAR	-	-	-	-	73.00	21.50	14.00	-	-	-	39.00	72.00	219.50
PULPO	-	-	-	-	-	-	-	-	-	-	-	-	-
BIVALVOS	-	-	-	-	-	-	-	-	-	-	-	-	-
CAMBUTE	-	-	-	-	-	-	-	-	-	-	-	-	-
TOT MOLUSCOS (6)*	-	-	-	-	73.00	21.50	14.00	-	-	-	39.00	72.00	219.50
B. TOT MARISCOS (4+5+6)	**84,049.10**	**60,313.80**	**81,433.90**	**55,168.10**	**82,543.30**	**94,662.70**	**80,460.70**	**93,161.90**	**70,400.80**	**92,734.10**	**96,166.30**	**79,910.60**	**971,005.30**
ALETA TIBURON	-	-	-	-	-	-	-	-	-	-	-	-	-
FILET	-	-	-	-	-	-	-	-	-	-	-	-	-
BUCHE	-	-	-	-	-	-	-	-	-	-	-	-	-
CANGREJO	-	-	-	-	-	-	-	-	-	-	-	13.00	13.00
C. TOT OTROS (7)	-	-	-	-	-	-	-	-	-	-	-	13.00	13.00
D. TORTUGA (8)	**-**												**-**
GRAN TOTAL (ó A+B+C+D)	**120,821.55**	**93,778.56**	**126,600.90**	**81,726.91**	**126,494.21**	**141,904.29**	**116,544.10**	**168,063.18**	**90,757.29**	**114,139.97**	**124,670.04**	**121,033.65**	**1,426,534.65**

Table 28 GoN – Shrimp Trawler Landings – 2005

PESCA TOTAL SEGÚN CLASIFICACION COMERCIAL POR MESES													
COSTA RICA: LITORAL PACIFICO - FLOTA SEMI - INDUSTRIAL - 2005													PROMEDIO
Cantidad barcos/mes.	**47**	**46**	**43**	**47**	**39**	**42**	**40**	**38**	**38**	**38**	**36**	**31**	**40**
CONCEPTO	**ENE**	**FEB**	**MAR**	**ABR**	**MAY**	**JUN**	**JUL**	**AGO**	**SET**	**OCT**	**NOV**	**DIC**	**TOTAL**
PRIMERA GDE.	11.00	48.00	24.30	15.40	127.50	44.60	104.10	109.00	7.00	21.00	11.50	-	523.40
PRIMERA PEQ.	6,650.30	16,878.30	9,003.82	11,003.95	11,935.37	10,485.59	8,379.20	6,885.60	7,434.60	4,638.80	5,689.10	6,652.49	105,637.12
CLASIFICADO	11,305.05	12,570.70	8,981.01	11,813.63	7,578.29	11,848.40	7,216.40	9,364.11	9,128.30	7,946.07	6,923.20	5,327.60	110,002.76
CHATARRA	17,134.95	22,674.42	24,472.76	23,615.46	19,062.32	19,293.30	13,964.30	14,575.05	17,475.40	14,440.36	14,040.10	21,749.01	222,497.43
AGRIA COLA	-	-	290.00	-	19.00	82.00	468.50	43.00	-	241.40	-	-	1,143.90
CABRILLA	-	80.60	86.80	794.85	539.50	448.90	637.80	224.70	34.10	168.50	81.50	71.00	3,168.25
PARGO	-	-	-	-	-	-	-	-	-	-	-	-	-
PARGO SEDA	64.50	1.50	-	-	-	-	-	-	-	-	-	-	66.00
DORADO	-	-	-	-	-	-	132.00	26.00	-	-	-	-	158.00
MARLIN	-	-	-	-	-	-	-	-	-	-	-	-	-
MARLIN BLCO.	-	-	-	-	-	-	-	-	-	-	-	-	-
MARLIN ROS.	-	-	-	-	-	-	-	-	-	-	-	-	-
PEZ VELA	-	-	-	-	-	-	-	-	-	-	-	-	-
PEZ ESPADA	-	-	-	-	-	-	-	-	-	-	-	-	-
WAHOO	-	-	-	-	-	-	-	-	-	-	-	-	-
TOT PESC EVIS (1)	35,165.80	52,253.52	42,858.69	47,243.29	39,261.98	42,202.79	30,902.30	31,227.46	34,079.40	27,456.13	26,745.40	33,800.10	443,196.86
SARDINA													-
ATUN	2,779.10	1,251.70	545.00	7,580.00	4,003.00	22,814.00	8,960.00	18,050.00	8,050.00	-	10,711.00	13,900.00	98,643.80
BALLYHOO	-	-	-	-	-	-	-	-	-	-	-	-	-
TOT PELAGICOS (2)	2,779.10	1,251.70	545.00	7,580.00	4,003.00	22,814.00	8,960.00	18,050.00	8,050.00	-	10,711.00	13,900.00	98,643.80
CAZON	219.00	54.60	46.99	410.50	286.40	315.70	304.70	184.10	63.90	356.00	41.00	158.00	2,440.89
POSTA	-	-	-	-	112.01	-	-	-	-	-	-	-	112.01
MACO	-	-	-	-	-	-	-	-	-	-	-	-	-
TREACHER	-	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL TIBURON (3)	219.00	54.60	46.99	410.50	398.41	315.70	304.70	184.10	63.90	356.00	41.00	158.00	2,552.90
A. PESCADOS (1+2+3)	**38,163.90**	**53,559.82**	**43,450.68**	**55,233.79**	**43,663.39**	**65,332.49**	**40,167.00**	**49,461.56**	**42,193.30**	**27,812.13**	**37,497.40**	**47,858.10**	**544,393.56**
CAMARON BLCO.	4,579.10	3,760.40	4,827.90	3,645.80	3,824.80	4,912.90	9,492.30	23,665.10	16,366.10	8,701.40	9,804.30	9,262.20	102,842.30
CAMARON CAFE	122.10	1,368.90	767.30	210.20	377.40	152.40	-	733.90	132.30	242.80	36.10	554.60	4,698.00
CAMARON ROSADO	19,474.80	11,984.00	11,161.90	12,669.20	11,652.40	17,859.50	9,968.40	7,284.40	10,134.60	12,467.20	13,729.00	18,476.20	156,861.60
CAMARON FIDEL	54,610.60	55,597.90	25,449.60	55,052.20	52,070.80	75,216.00	76,216.40	37,447.20	41,609.30	50,900.60	28,081.00	24,639.00	576,890.60
CAMARON CAMELLO	2,788.40	6,954.70	10,916.50	19,969.60	7,071.30	2,000.40	2,699.10	3,526.20	834.90	12,321.00	2,619.70	9,610.30	81,312.10
CAMARON REAL	6,381.00	9,437.90	10,639.10	7,275.60	5,323.20	1,821.60	-	-	-	554.00	1,870.00	-	43,302.40
CAMARON TITI	2,245.40	977.40	3,977.20	2,072.60	2,101.40	3,224.10	3,479.10	2,418.20	3,834.70	6,328.50	15,984.80	16,563.80	63,207.20
TOT CAMARON (4)	90,201.40	90,081.20	67,739.50	100,895.20	82,421.30	105,186.90	101,855.30	75,075.00	72,911.90	91,515.50	72,124.90	79,106.10	1,029,114.20
LANG PACIFICA (CTE)	-	9.40	-	3.00	7.00	4.00	-	7.00	-	-	-	-	30.40
LANG CARIBE	-	-	-	-	-	-	-	-	-	-	-	-	-
TOT LANGOSTA (5)	-	9.40	-	3.00	7.00	4.00	-	7.00	-	-	-	-	30.40
CALAMAR	-	-	-	102.00	45.00	22.00	-	308.50	-	-	-	-	477.50
PULPO	-	-	-	-	61.00	-	-	-	-	-	-	-	61.00
BIVALVOS	-	-	-	-	-	-	-	-	-	-	-	-	-
CAMBUTE	-	12.60	-	-	-	-	-	-	-	-	-	-	12.60
TOT MOLUSCOS (6)*	-	12.60	-	102.00	106.00	22.00	-	308.50	-	-	-	-	551.10
B. TOT MARISCOS (4+5+6)	**90,201.40**	**90,103.20**	**67,739.50**	**101,000.20**	**82,534.30**	**105,212.90**	**101,855.30**	**75,390.50**	**72,911.90**	**91,515.50**	**72,124.90**	**79,106.10**	**1,029,695.70**
ALETA TIBURON	-	-	-	-	-	-	-	-	-	-	-	-	-
FILET	-	25.50	-	-	-	-	-	-	-	-	-	-	25.50
BUCHE	-	-	-	-	-	-	-	-	-	-	-	-	-
CANGREJO	-	106.00	-	-	22.00	-	-	40.00	28.00	80.00	-	-	276.00
C. TOT OTROS (7)	-	131.50	-	-	22.00	-	-	40.00	28.00	80.00	-	-	301.50
D. TORTUGA (8)	-												-
GRAN TOTAL (õ A+B+C+D)	**128,365.30**	**143,794.52**	**111,190.18**	**156,233.99**	**126,219.69**	**170,545.39**	**142,022.30**	**124,892.06**	**115,133.20**	**119,407.63**	**109,622.30**	**126,964.20**	**1,574,390.76**

Table 29 GoN – Shrimp Trawler Landings – 2006

PESCA TOTAL SEGÚN CLASIFICACION COMERCIAL POR MESES													
COSTA RICA: LITORAL PACIFICO - FLOTA SEMI - INDUSTRIAL - 2006													PROMEDIO
Cantidad barcos/mes.	42	40	41	38	39	39	37	33	31	40	33	40	38
CONCEPTO	ENE	FEB	MAR	ABR	MAY	JUN	JUL	AGO	SET	OCT	NOV	DIC	TOTAL
PRIMERA GDE.	-	-	57.00	11.90	31.50	67.00	142.70	51.50	6.00	-	-	-	367.60
PRIMERA PEQ.	7,461.32	9,477.70	7,158.75	6,709.40	5,955.70	5,176.20	10,242.70	11,759.70	8,067.59	11,353.78	5,889.90	8,038.00	97,290.74
CLASIFICADO	7,478.00	11,054.90	11,232.00	7,688.61	9,669.91	18,452.60	10,049.80	8,527.90	7,446.40	7,466.30	6,521.21	11,282.41	116,870.04
CHATARRA	18,612.40	25,919.95	22,780.90	18,227.61	18,064.31	17,057.00	20,310.30	26,917.76	11,044.40	18,891.12	17,541.16	24,095.60	239,462.51
AGRIA COLA	-	-	-	-	-	-	-	-	-	41.00	-	-	41.00
CABRILLA	172.50	484.69	1,767.20	945.70	793.20	2,411.70	1,254.00	2,899.90	2,199.10	518.00	148.70	1,086.70	14,681.39
PARGO	-	-	-	-	-	-	-	-	-	-	-	-	-
PARGO SEDA	-	-	-	-	-	-	-	-	-	-	-	-	-
DORADO	-	-	-	-	-	-	-	-	-	-	-	-	-
MARLIN	-	-	-	-	-	-	-	-	-	-	-	-	-
MARLIN BLCO.	-	-	-	-	-	-	-	-	-	-	-	-	-
MARLIN ROS.	-	-	-	-	-	-	-	-	-	-	-	-	-
PEZ VELA	-	-	-	-	-	-	-	-	-	-	-	-	-
PEZ ESPADA	-	-	-	-	-	-	-	-	-	-	-	-	-
WAHOO	-	-	-	-	-	-	-	-	-	-	-	-	-
TOT PESC EVIS (1)	33,724.22	46,937.24	42,995.85	33,583.22	34,514.62	43,164.50	41,999.50	50,156.76	28,763.49	38,270.20	30,100.97	44,502.71	468,713.28
SARDINA													-
ATUN	20,500.00	-	-	-	46,308.00	26,896.00	15,593.00	-	16,591.00	40,043.00	-	-	165,931.00
BALLYHOO	-	-	-	-	-	-	-	-	-	-	-	-	-
TOT PELAGICOS (2)	20,500.00	-	-	-	46,308.00	26,896.00	15,593.00	-	16,591.00	40,043.00	-	-	165,931.00
CAZON	41.00	5.80	169.40	76.60	221.60	301.00	179.20	96.20	29.10	381.41	158.00	227.90	1,887.21
POSTA	-	-	-	-	-	-	-	-	-	-	-	-	-
MACO	-	-	-	-	-	-	-	-	-	-	-	-	-
TREACHER	-	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL TIBURON (3)	41.00	5.80	169.40	76.60	221.60	301.00	179.20	96.20	29.10	381.41	158.00	227.90	1,887.21
A. PESCADOS (1+2+3)	**54,265.22**	**46,943.04**	**43,165.25**	**33,659.82**	**81,044.22**	**70,361.50**	**57,771.70**	**50,252.96**	**45,383.59**	**78,694.61**	**30,258.97**	**44,730.61**	**636,531.49**
CAMARON BLCO.	10,819.40	12,155.40	14,851.60	5,795.40	3,674.10	3,044.40	8,998.30	14,520.50	6,769.10	7,340.40	4,386.60	6,453.50	98,808.70
CAMARON CAFE	225.60	50.90	975.80	153.90	46.00	18.90	-	55.00	-	-	-	-	1,526.10
CAMARON ROSADO	30,266.70	19,849.90	26,323.60	19,821.30	30,162.80	35,263.50	18,786.90	20,034.80	25,575.70	32,923.90	17,227.60	22,643.60	298,880.30
CAMARON FIDEL	25,642.60	22,809.40	39,197.20	41,509.30	45,081.20	36,656.60	29,330.70	36,354.10	41,243.80	55,524.70	37,582.70	49,039.60	459,971.90
CAMARON CAMELLO	10,739.80	2,317.40	27,020.80	14,859.20	19,698.40	28,088.80	36,488.30	1,626.30	2,930.80	9,393.70	29,471.10	28,846.50	211,481.10
CAMARON REAL	-	-	-	-	-	-	-	-	-	-	-	-	-
CAMARON TITI	3,059.40	1,368.50	2,230.70	1,318.20	1,752.10	3,228.20	6,039.10	4,528.70	1,117.90	2,021.70	3,455.70	2,960.20	33,080.40
TOT CAMARON (4)	80,753.50	58,551.50	110,599.70	83,457.30	100,414.60	106,300.40	99,643.30	77,119.40	77,637.30	107,204.40	92,123.70	109,943.40	1,103,748.50
LANG PACIFICA (CTE)	-	-	51.51	-	-	114.00	-	11.00	-	-	-	-	176.51
LANG CARIBE	-	-	-	-	-	-	-	-	-	-	-	-	-
TOT LANGOSTA (5)	-	-	51.51	-	-	114.00	-	11.00	-	-	-	-	176.51
CALAMAR	30.00	-	-	-	-	-	224.00	52.00	-	-	-	12.50	318.50
PULPO	-	-	-	-	-	-	-	-	-	-	-	-	-
BIVALVOS	-	-	-	-	-	-	-	-	-	-	-	-	-
CAMBUTE	-	-	-	-	-	-	-	-	-	-	-	-	-
TOT MOLUSCOS (6)*	30.00	-	-	-	-	-	224.00	52.00	-	-	-	12.50	318.50
B. TOT MARISCOS (4+5+6)	**80,783.50**	**58,551.50**	**110,651.21**	**83,457.30**	**100,414.60**	**106,414.40**	**99,867.30**	**77,182.40**	**77,637.30**	**107,204.40**	**92,123.70**	**109,955.90**	**1,104,243.51**
ALETA TIBURON	-	-	-	-	-	-	-	-	-	-	-	-	-
FILET	-	-	-	-	-	-	-	-	-	-	-	-	-
BUCHE	-	-	-	-	-	-	-	-	-	-	-	-	-
CANGREJO	-	-	-	13.00	-	-	54.00	-	-	-	11.50	-	78.50
C. TOT OTROS (7)	-	-	-	13.00	-	-	54.00	-	-	-	11.50	-	78.50
D. TORTUGA (8)	-												-
GRAN TOTAL (õ A+B+C+D)	**135,048.72**	**105,494.54**	**153,816.46**	**117,130.12**	**181,458.82**	**176,775.90**	**157,693.00**	**127,435.36**	**123,020.89**	**185,899.01**	**122,394.17**	**154,686.51**	**1,740,853.50**

Table 30 GoN – Shrimp Trawler Landings – 2007

PESCA TOTAL SEGÚN CLASIFICACION COMERCIAL POR MESES													
COSTA RICA: LITORAL PACIFICO - FLOTA SEMI - INDUSTRIAL - 2007													PROMEDIO
Cantidad barcos/mes.	35	35	41	38	35	42	36	43	40	35	31	36	37
CONCEPTO	ENE	FEB	MAR	ABR	MAY	JUN	JUL	AGO	SET	OCT	NOV	DIC	TOTAL
PRIMERA GDE.	80.42	528.00	-	35.50	13.50	46.20	29.00	40.20	57.00	12.70	-	53.50	896.02
PRIMERA PEQ.	14,233.71	13,976.30	3,344.10	627.90	1,218.70	2,145.10	2,903.60	3,471.10	1,644.50	792.30	836.50	1,999.50	47,193.31
CLASIFICADO	10,648.10	17,156.80	18,396.99	20,712.70	18,801.79	19,660.90	15,055.12	13,273.50	9,238.72	9,586.15	7,802.61	11,059.00	171,392.38
CHATARRA	26,581.60	23,595.80	24,242.59	19,915.00	17,608.40	22,453.00	25,143.30	24,505.00	15,507.04	21,184.50	17,101.40	21,814.50	259,652.13
AGRIA COLA	75.75	-	-	-	-	187.00	48.00	-	-	-	-	-	310.75
CABRILLA	814.10	561.50	855.90	2,428.00	813.20	1,108.10	1,102.40	670.70	734.20	805.40	812.60	1,503.45	12,209.55
PARGO	-	-	-	-	-	-	-	-	-	-	-	-	-
PARGO SEDA	59.00	-	-	-	-	-	-	-	-	-	706.50	-	765.50
DORADO	-	-	-	-	-	-	-	-	-	-	-	-	-
MARLIN	-	-	-	-	-	-	-	-	-	-	-	-	-
MARLIN BLCO.	-	-	-	-	-	-	-	-	-	-	-	-	-
MARLIN ROS.	-	-	-	-	-	-	-	-	-	-	-	-	-
PEZ VELA	-	-	-	-	-	-	-	-	-	-	-	-	-
PEZ ESPADA	-	-	-	-	-	-	-	-	-	-	-	-	-
WAHOO	-	-	-	-	-	-	-	-	-	-	-	-	-
TOT PESC EVIS (1)	52,492.68	55,818.40	46,839.58	43,719.10	38,455.59	45,600.30	44,281.42	41,960.50	27,181.46	32,381.05	27,259.61	36,429.95	492,419.64
SARDINA													-
ATUN	12,452.00	6,821.00	1,971.00	987.00	15,081.00	5,345.75	7,567.76	2,176.00	2,971.00	2,059.00	-	-	57,431.51
BALLYHOO	-	-	-	-	-	-	-	-	-	-	-	-	-
TOT PELAGICOS (2)	12,452.00	6,821.00	1,971.00	987.00	15,081.00	5,345.75	7,567.76	2,176.00	2,971.00	2,059.00	-	-	57,431.51
CAZON	279.70	161.50	288.00	115.90	326.50	312.80	252.20	124.40	13.50	108.20	48.70	27.40	2,058.80
POSTA	-	-	-	-	-	95.00	-	60.00	-	-	-	-	155.00
MACO	-	-	-	-	-	-	-	-	-	-	-	-	-
TREACHER	-	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL TIBURON (3)	279.70	161.50	288.00	115.90	326.50	407.80	252.20	184.40	13.50	108.20	48.70	27.40	2,213.80
A. PESCADOS (1+2+3)	**65,224.38**	**62,800.90**	**49,098.58**	**44,822.00**	**53,863.09**	**51,353.85**	**52,101.38**	**44,320.90**	**30,165.96**	**34,548.25**	**27,308.31**	**36,457.35**	**552,064.95**
CAMARON BLCO.	3,007.60	2,674.20	2,857.50	3,402.00	2,519.30	3,448.00	9,439.50	18,318.70	12,445.80	9,832.00	6,608.20	7,718.10	82,270.90
CAMARON CAFE	463.50	334.80	28.00	8.00	202.90	22.00	33.20	11.90	-	-	813.60	-	1,917.90
CAMARON ROSADO	24,299.90	17,202.60	39,779.00	30,289.10	18,521.90	25,278.60	24,402.10	26,092.50	12,316.60	29,738.20	29,472.90	31,324.20	308,717.60
CAMARON FIDEL	32,079.80	28,390.70	27,484.70	35,751.70	40,423.90	50,367.30	45,516.90	29,091.00	42,023.80	29,110.30	24,053.30	32,446.40	416,739.80
CAMARON CAMELLO	5,887.80	6,066.70	3,358.00	3,306.20	724.80	1,574.00	4,165.20	5,470.70	14,658.50	2,516.00	5,550.20	7,569.40	60,847.50
CAMARON REAL	10,369.50	-	7,490.20	13,262.60	13,494.40	24,493.70	-	30,663.20	-	13,538.40	7,650.60	12,980.70	133,943.30
CAMARON TITI	1,575.60	367.70	999.50	1,382.40	3,113.50	3,766.60	7,057.30	6,201.70	5,674.50	9,735.50	10,392.90	12,324.90	62,592.10
TOT CAMARON (4)	77,683.70	55,036.70	81,996.90	87,402.00	79,000.70	108,950.20	90,614.20	115,849.70	87,119.20	94,470.40	84,541.70	104,363.70	1,067,029.10
LANG PACIFICA (CTE)	-	-	-	-	-	-	-	-	-	-	74.00	-	74.00
LANG CARIBE	-	-	-	-	-	-	-	-	-	-	-	-	-
TOT LANGOSTA (5)	-	-	-	-	-	-	-	-	-	-	74.00	-	74.00
CALAMAR	13.00	-	225.00	-	-	154.00	647.00	-	48.00	-	-	328.00	1,415.00
PULPO	-	-	-	-	-	-	-	-	-	-	-	-	-
BIVALVOS	-	-	-	-	-	-	-	-	-	-	-	-	-
CAMBUTE	-	-	-	-	-	-	-	-	-	-	-	-	-
TOT MOLUSCOS (6)*	13.00	-	225.00	-	-	154.00	647.00	-	48.00	-	-	328.00	1,415.00
B. TOT MARISCOS (4+5+6)	**77,696.70**	**55,036.70**	**82,221.90**	**87,402.00**	**79,000.70**	**109,104.20**	**91,261.20**	**115,849.70**	**87,167.20**	**94,470.40**	**84,615.70**	**104,691.70**	**1,068,518.10**
ALETA TIBURON	-	-	-	-	-	-	-	-	-	-	-	-	-
FILET	-	-	-	-	28.00	-	-	-	-	-	-	-	28.00
BUCHE	-	-	-	-	-	-	-	-	-	-	-	-	-
CANGREJO	100.00	-	98.00	-	-	-	-	-	23.00	-	-	-	221.00
C. TOT OTROS (7)	100.00	-	98.00	-	28.00	-	-	-	23.00	-	-	-	249.00
D. TORTUGA (8)	-						-	-					-
GRAN TOTAL (õ A+B+C+D)	**143,021.08**	**117,837.60**	**131,418.48**	**132,224.00**	**132,891.79**	**160,458.05**	**143,362.58**	**160,170.60**	**117,356.16**	**129,018.65**	**111,924.01**	**141,149.05**	**1,620,832.05**

Table 31 GoN – Shrimp Trawler Landings – 2008

PESCA TOTAL SEGÚN CLASIFICACION COMERCIAL POR MESES COSTA RICA: LITORAL PACIFICO - FLOTA SEMI - INDUSTRIAL - 2008													
Cantidad barcos/mes.	**31**	**35**	**33**	**34**	**37**	**38**	**32**	**29**	**24**	**26**	**31**	**30**	**32**
CONCEPTO	**ENE**	**FEB**	**MAR**	**ABR**	**MAY**	**JUN**	**JUL**	**AGO**	**SET**	**OCT**	**NOV**	**DIC**	**TOTAL**
PRIMERA GDE.	-	30.00	76.10	118.00	55.00	47.00	161.50	38.40	18.00	28.00	15.00	769.00	1,356.00
PRIMERA PEQ.	4,766.80	2,310.20	2,784.40	3,685.50	6,955.25	6,935.30	5,353.70	2,630.10	2,354.60	822.90	5,236.10	1,628.10	45,462.95
CLASIFICADO	14,699.30	15,553.10	13,823.30	22,603.20	22,999.50	20,269.20	10,638.50	10,761.40	9,289.70	6,893.90	15,629.00	13,038.80	176,198.90
CHATARRA	29,512.70	27,032.85	21,760.90	26,335.40	18,987.60	21,294.60	24,639.90	17,382.50	18,775.20	9,349.10	29,378.39	23,501.80	267,950.94
AGRIA COLA	-	-	-	-	-	-	-	-	-	-	100.00	137.60	237.60
CABRILLA	176.50	870.40	468.70	5,653.00	1,432.40	2,727.70	720.00	1,917.80	93.00	176.00	93.10	116.00	14,444.60
PARGO	-	-	-	-	-	-	-	-	-	-	-	-	-
PARGO SEDA	-	-	-	-	-	-	-	-	-	-	-	-	-
DORADO	-	-	83.00	-	-	-	-	-	-	-	-	-	83.00
MARLIN	-	-	-	-	-	-	-	-	-	-	-	-	-
MARLIN BLCO.	-	-	-	-	-	-	-	-	-	-	-	-	-
MARLIN ROS.	-	-	-	-	-	-	-	-	-	-	-	-	-
PEZ VELA	-	-	-	-	-	-	-	-	-	-	-	-	-
PEZ ESPADA	-	-	-	-	-	-	-	-	-	-	-	-	-
WAHOO	-	-	-	-	-	-	-	-	-	-	-	-	-
TOT PESC EVIS (1)	49,155.30	45,796.55	38,996.40	58,395.10	50,429.75	51,273.80	41,513.60	32,730.20	30,530.50	17,269.90	50,451.59	39,191.30	505,733.99
SARDINA													-
ATUN	-	-	-	-	-	-	-	-	-	-	-	-	-
BALLYHOO	-	-	-	-	-	-	-	-	-	-	-	-	-
TOT PELAGICOS (2)	-	-	-	-	-	-	-	-	-	-	-	-	-
CAZON	232.40	1,327.50	863.30	555.00	691.23	271.60	310.30	366.20	78.00	69.90	72.11	18.00	4,855.54
POSTA	-	-	-	-	-	-	-	-	-	-	-	-	-
MACO	-	-	-	-	-	-	-	-	-	-	-	-	-
TREACHER	-	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL TIBURON (3)	232.40	1,327.50	863.30	555.00	691.23	271.60	310.30	366.20	78.00	69.90	72.11	18.00	4,855.54
A. PESCADOS (1+2+3)	**49,387.70**	**47,124.05**	**39,859.70**	**58,950.10**	**51,120.98**	**51,545.40**	**41,823.90**	**33,096.40**	**30,608.50**	**17,339.80**	**50,523.70**	**39,209.30**	**510,589.53**
CAMARON BLCO.	9,289.80	12,467.70	6,170.40	6,741.20	3,605.90	3,947.80	4,951.30	3,388.10	5,671.10	2,778.50	9,398.20	7,535.10	75,945.10
CAMARON CAFE	725.70	750.80	410.70	157.90	165.30	25.20	2.00	-	-	14.00	140.00	20.40	2,412.00
CAMARON ROSADO	27,853.00	31,865.60	24,954.70	26,017.90	20,919.40	17,269.60	17,852.70	17,176.70	10,431.10	16,345.70	16,763.60	13,804.60	241,254.60
CAMARON FIDEL	14,152.40	9,937.40	21,392.00	10,464.70	37,217.00	44,671.70	35,083.70	23,500.70	25,216.60	17,064.10	16,037.90	13,647.40	268,385.60
CAMARON CAMELLO	4,110.30	3,284.30	3,127.60	2,659.00	2,100.00	2,290.80	997.90	1,082.50	2,508.60	5,340.00	1,540.80	1,965.10	31,006.90
CAMARON REAL	5,456.80	16,237.20	-	14,290.40	11,487.00	18,965.90	19,706.00	5,845.80	15,550.60	20,195.80	29,374.40	17,283.30	174,393.20
CAMARON TITI	3,575.20	1,911.70	2,461.70	3,930.80	3,617.90	3,876.90	3,479.70	5,002.50	4,149.00	3,647.00	12,121.40	8,997.70	56,771.50
TOT CAMARON (4)	65,163.20	76,454.70	58,517.10	64,261.90	79,112.50	91,047.90	82,073.30	55,996.30	63,527.00	65,385.10	85,376.30	63,253.60	850,168.90
LANG PACIFICA (CTE)	-	-	-	-	-	-	-	-	-	16.00	-	-	16.00
LANG CARIBE	-	-	-	-	-	-	-	-	-	-	-	-	-
TOT LANGOSTA (5)	-	-	-	-	-	-	-	-	-	16.00	-	-	16.00
CALAMAR	6.00	-	-	-	227.00	141.00	178.00	4.00	-	-	-	-	556.00
PULPO	-	-	-	-	-	-	-	-	-	-	-	-	-
BIVALVOS	-	-	-	-	-	-	-	-	-	-	-	-	-
CAMBUTE	-	-	-	-	-	-	-	-	-	-	-	-	-
TOT MOLUSCOS (6)*	6.00	-	-	-	227.00	141.00	178.00	4.00	-	-	-	-	556.00
B. TOT MARISCOS (4+5+6)	**65,169.20**	**76,454.70**	**58,517.10**	**64,261.90**	**79,339.50**	**91,188.90**	**82,251.30**	**56,000.30**	**63,527.00**	**65,401.10**	**85,376.30**	**63,253.60**	**850,740.90**
ALETA TIBURON	-	-	-	-	-	-	-	-	-	-	-	-	-
FILET	-	-	-	-	-	-	-	-	-	-	-	-	-
BUCHE	-	-	-	-	-	-	-	-	-	-	-	-	-
CANGREJO	14.00	-	17.50	38.00	-	-	-	-	-	-	-	-	69.50
C. TOT OTROS (7)	14.00	-	17.50	38.00	-	-	-	-	-	-	-	-	69.50
D. TORTUGA (8)	-												
GRAN TOTAL (ó A+B+C+D)	**114,570.90**	**123,578.75**	**98,394.30**	**123,250.00**	**130,460.48**	**142,734.30**	**124,075.20**	**89,096.70**	**94,135.50**	**82,740.90**	**135,900.00**	**102,462.90**	**1,361,399.93**

Table 32 GoN – Shrimp Trawler Landings – 2009

PESCA TOTAL SEGÚN CLASIFICACION COMERCIAL POR MESES COSTA RICA: LITORAL PACIFICO - FLOTA SEMI - INDUSTRIAL - 2009													
Cantidad barcos/mes.	**23**	**30**	**33**	**30**	**27**	**29**	**28**	**19**	**28**	**29**	**30**	**28**	**28**
CONCEPTO	**ENE**	**FEB**	**MAR**	**ABR**	**MAY**	**JUN**	**JUL**	**AGO**	**SET**	**OCT**	**NOV**	**DIC**	**TOTAL**
PRIMERA GDE.	-	-	47.50	4.40	65.20	36.50	-	29.50	25.00	34.50	129.80	394.00	766.40
PRIMERA PEQ.	1,336.60	531.80	1,056.60	2,190.40	540.80	1,940.80	3,143.40	3,380.70	7,482.30	3,675.50	3,471.30	3,819.50	32,569.70
CLASIFICADO	9,724.00	13,750.72	20,892.30	16,983.40	11,706.80	14,675.60	16,273.00	9,808.40	19,382.41	19,817.14	15,776.55	10,387.79	179,178.11
CHATARRA	19,489.90	15,370.60	16,397.70	20,434.40	16,986.00	20,987.30	19,838.40	13,003.70	21,140.61	25,035.10	27,666.99	20,478.10	236,828.80
AGRIA COLA	-	10.60	-	5.70	-	-	-	-	131.10	1,049.00	189.00	657.00	2,042.40
CABRILLA	106.40	427.71	6,073.70	1,481.50	1,100.00	1,085.30	569.30	39.00	469.29	130.10	297.00	138.00	11,917.30
PARGO	-	-	-	-	-	-	-	-	-	-	-	-	-
PARGO SEDA	-	-	-	42.50	-	-	-	-	-	-	-	-	42.50
DORADO	-	-	-	-	-	-	-	-	665.90	-	255.00	495.00	1,415.90
MARLIN	-	-	-	-	-	-	-	-	-	-	-	-	-
MARLIN BLCO.	-	-	-	-	-	-	-	-	-	-	-	-	-
MARLIN ROS.	-	-	-	-	-	-	-	-	-	-	-	-	-
PEZ VELA	-	-	-	-	-	-	-	-	-	-	-	-	-
PEZ ESPADA	-	-	-	-	-	-	-	-	-	-	-	-	-
WAHOO	-	-	-	-	-	-	-	-	-	-	-	-	-
TOT PESC EVIS (1)	30,656.90	30,091.43	44,467.80	41,142.30	30,398.80	38,725.50	39,824.10	26,261.30	49,296.61	49,741.34	47,785.64	36,369.39	464,761.11
SARDINA													-
ATUN	-	-	-	-	-	-	-	-	-	625.00	-	-	625.00
BALLYHOO	-	-	-	-	-	-	-	-	-	-	-	-	-
TOT PELAGICOS (2)	-	-	-	-	-	-	-	-	-	625.00	-	-	625.00
CAZON	157.40	565.30	222.10	391.00	248.60	200.00	35.00	1,432.50	231.51	542.00	152.20	68.00	4,245.61
POSTA	-	-	-	-	-	-	-	-	-	-	-	-	-
MACO	-	-	-	-	-	-	-	-	-	-	-	-	-
TREACHER	-	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL TIBURON (3)	157.40	565.30	222.10	391.00	248.60	200.00	35.00	1,432.50	231.51	542.00	152.20	68.00	4,245.61
A. PESCADOS (1+2+3)	**30,814.30**	**30,656.73**	**44,689.90**	**41,533.30**	**30,647.40**	**38,925.50**	**39,859.10**	**27,693.80**	**49,528.12**	**50,908.34**	**47,937.84**	**36,437.39**	**469,631.72**
CAMARON BLCO.	5,623.20	6,940.10	3,602.60	5,962.70	4,429.70	4,829.10	6,073.90	2,055.10	4,346.60	2,407.70	4,706.30	4,126.00	55,103.00
CAMARON CAFE	93.60	38.80	152.30	198.30	10,253.90	-	134.80	48.00	81.20	36.70	60.00	-	11,097.60
CAMARON ROSADO	9,062.40	33,968.40	34,192.50	22,237.60	12,152.00	10,910.30	20,233.90	15,003.60	21,975.20	22,672.10	22,786.00	18,663.80	243,857.80
CAMARON FIDEL	7,255.00	10,401.30	8,786.50	26,577.60	17,475.80	29,517.40	24,224.00	11,512.80	22,862.20	12,783.40	8,355.60	15,833.90	195,585.50
CAMARON CAMELLO	374.00	1,400.30	215.90	969.90	12,747.20	1,614.10	879.70	547.40	3,197.40	877.80	-	591.00	23,414.70
CAMARON REAL	13,700.90	2,517.60	6,862.40	7,193.90	3,011.50	12,624.50	13,809.90	-	7,889.00	3,040.20	7,188.30	2,999.10	80,837.30
CAMARON TITI	3,399.20	1,799.30	524.70	1,829.70	2,135.20	2,975.50	2,380.60	1,066.10	1,203.40	2,851.70	4,430.00	2,063.70	26,659.10
TOT CAMARON (4)	39,508.30	57,065.80	54,336.90	64,969.70	62,205.30	62,470.90	67,736.80	30,233.00	61,555.00	44,669.60	47,526.20	44,277.50	636,555.00
LANG PACIFICA (CTE)	-	-	-	-	-	-	21.00	14.00	-	-	5.00	-	40.00
LANG CARIBE	-	-	-	-	-	-	-	-	-	-	-	-	-
TOT LANGOSTA (5)	-	-	-	-	-	-	21.00	14.00	-	-	5.00	-	40.00
CALAMAR	-	-	-	-	-	-	44.00	54.00	-	-	14.00	-	112.00
PULPO	-	-	-	-	-	-	-	-	-	-	-	-	-
BIVALVOS	-	-	-	-	-	-	-	-	-	-	-	-	-
CAMBUTE	-	-	-	-	-	-	-	-	-	-	-	-	-
TOT MOLUSCOS (6)*	-	-	-	-	-	-	44.00	54.00	-	-	14.00	-	112.00
B. TOT MARISCOS (4+5+6)	**39,508.30**	**57,065.80**	**54,336.90**	**64,969.70**	**62,205.30**	**62,470.90**	**67,801.80**	**30,301.00**	**61,555.00**	**44,669.60**	**47,545.20**	**44,277.50**	**636,707.00**
ALETA TIBURON	-	-	-	-	-	-	-	-	-	-	-	-	-
FILET	-	-	-	-	-	-	-	-	-	-	-	-	-
BUCHE	-	-	-	-	-	-	-	-	-	-	-	-	-
CANGREJO	-	-	-	-	-	-	-	-	-	-	15.00	-	15.00
C. TOT OTROS (7)	-	-	-	-	-	-	-	-	-	-	15.00	-	15.00
D. TORTUGA (8)	-												-
GRAN TOTAL (õ A+B+C+D)	**70,322.60**	**87,722.53**	**99,026.80**	**106,503.00**	**92,852.70**	**101,396.40**	**107,660.90**	**57,994.80**	**111,083.12**	**95,577.94**	**95,498.04**	**80,714.89**	**1,106,353.72**

Table 33 GoN – Shrimp Trawler Landings - 2010

PESCA TOTAL SEGÚN CLASIFICACION COMERCIAL POR MESES													
COSTA RICA: LITORAL PACIFICO - FLOTA SEMI - INDUSTRIAL - 2010													PROMEDIO
Cantidad barcos/mes.	**29**	**31**	**26**	**27**	**29**	**21**	**23**	**26**	**24**	**25**	**21**	**27**	**26**
CONCEPTO	**ENE**	**FEB**	**MAR**	**ABR**	**MAY**	**JUN**	**JUL**	**AGO**	**SET**	**OCT**	**NOV**	**DIC**	**TOTAL**
PRIMERA GDE.	150.00	61.40	188.00	81.70	66.00	-	30.60	17.00	-	3.30	-	-	598.00
PRIMERA PEQ.	1,826.50	2,261.60	1,853.15	2,482.00	2,757.41	1,404.00	1,354.90	1,480.44	533.50	792.00	502.20	1,016.80	18,264.50
CLASIFICADO	17,822.50	21,239.15	19,359.85	15,746.90	22,827.00	14,635.80	11,058.90	13,337.00	9,835.90	13,357.00	40,814.40	35,602.40	235,636.80
CHATARRA	17,814.90	28,137.90	25,860.30	26,944.10	24,541.00	15,495.00	13,411.95	18,084.80	14,281.70	17,554.90	16,933.40	16,403.00	235,462.95
AGRIA COLA	484.00	1,857.30	511.10	334.40	511.30	120.80	229.50	440.00	22.30	86.34	87.10	-	4,684.14
CABRILLA	191.80	327.71	156.50	554.10	871.00	1,103.10	740.80	767.80	1,353.20	1,999.30	1,884.80	1,407.10	11,357.21
PARGO	-	-	-	-	-	-	-	-	-	-	-	-	-
PARGO SEDA	-	-	-	-	-	17.90	-	-	-	-	-	-	17.90
DORADO	300.00	24.50	-	-	-	-	-	-	-	-	-	-	324.50
MARLIN	-	-	-	-	-	-	-	-	-	-	-	-	-
MARLIN BLCO.	-	-	-	-	-	-	-	-	-	-	-	-	-
MARLIN ROS.	-	-	-	-	-	-	-	-	-	-	-	-	-
PEZ VELA	-	-	-	-	-	-	-	-	-	-	-	-	-
PEZ ESPADA	-	-	-	-	-	-	-	-	-	-	-	-	-
WAHOO	-	-	-	-	-	-	-	-	-	-	-	-	-
TOT PESC EVIS (1)	38,589.70	53,909.56	47,928.90	46,143.20	51,573.71	32,776.60	26,826.65	34,127.04	26,026.60	33,792.84	60,221.90	54,429.30	506,346.00
SARDINA													-
ATUN	-	-	-	-	-	-	2,500.00	-	-	-	-	-	2,500.00
BALLYHOO	-	-	-	-	-	-	-	-	-	-	-	-	-
TOT PELAGICOS (2)	-	-	-	-	-	-	2,500.00	-	-	-	-	-	2,500.00
CAZON	50.00	71.70	20.60	104.70	78.00	287.50	174.20	27.80	325.70	85.00	165.60	3.00	1,393.80
POSTA	-	-	-	-	-	-	-	-	-	-	-	-	-
MACO	-	-	-	-	-	-	-	-	-	-	-	-	-
TREACHER	-	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL TIBURON (3)	50.00	71.70	20.60	104.70	78.00	287.50	174.20	27.80	325.70	85.00	165.60	3.00	1,393.80
A. PESCADOS (1+2+3)	**38,639.70**	**53,981.26**	**47,949.50**	**46,247.90**	**51,651.71**	**33,064.10**	**29,500.85**	**34,154.84**	**26,352.30**	**33,877.84**	**60,387.50**	**54,432.30**	**510,239.80**
CAMARON BLCO.	2,219.60	2,615.70	4,025.00	4,122.10	5,076.10	3,518.00	2,363.70	6,007.30	6,508.40	7,990.90	4,164.10	10,737.80	59,348.70
CAMARON CAFE	23.00	501.40	154.10	328.10	441.20	9.30	57.50	20.40	375.80	694.00	92.70	428.40	3,125.90
CAMARON ROSADO	38,244.00	24,730.80	15,250.10	23,953.60	20,403.40	28,226.60	32,243.00	25,803.40	36,519.20	37,057.80	31,633.20	33,714.10	347,779.20
CAMARON FIDEL	16,051.50	18,963.60	13,165.10	19,653.00	17,166.50	5,355.10	5,978.10	1,333.30	6,153.90	4,253.60	2,835.10	2,130.70	113,039.50
CAMARON CAMELLO	930.50	6,451.60	5,248.10	6,910.60	7,949.60	806.10	404.80	2,666.70	608.00	12,662.90	3,293.40	454.70	48,387.00
CAMARON REAL	-	-	1,675.00	6,617.90	7,899.90	-	-	4,634.00	-	5,619.90	5,853.50	2,644.50	34,944.70
CAMARON TITI	720.90	945.50	940.50	1,026.50	1,363.90	896.30	1,442.00	3,952.10	6,111.60	4,523.90	5,192.00	6,690.40	33,805.60
TOT CAMARON (4)	58,189.50	54,208.60	40,457.90	62,611.80	60,300.60	38,811.40	42,489.10	44,417.20	56,276.90	72,803.00	53,064.00	56,800.60	640,430.60
LANG PACIFICA (CTE)	-	-	-	-	-	-	-	-	-	-	-	-	-
LANG CARIBE	-	-	-	-	-	-	-	-	-	-	-	-	-
TOT LANGOSTA (5)	-	-	-	-	-	-	-	-	-	-	-	-	-
CALAMAR	-	-	-	-	-	-	-	29.50	30.00	-	-	-	59.50
PULPO	-	-	-	-	-	-	-	-	-	-	-	-	-
BIVALVOS	-	-	-	-	-	-	-	-	-	-	-	-	-
CAMBUTE	-	-	-	-	-	-	-	9.00	-	-	-	-	9.00
TOT MOLUSCOS (6)*	-	-	-	-	-	-	-	38.50	30.00	-	-	-	68.50
B. TOT MARISCOS (4+5+6)	**58,189.50**	**54,208.60**	**40,457.90**	**62,611.80**	**60,300.60**	**38,811.40**	**42,489.10**	**44,455.70**	**56,306.90**	**72,803.00**	**53,064.00**	**56,800.60**	**640,499.10**
ALETA TIBURON	-	-	-	-	-	-	-	-	-	-	-	-	-
FILET	-	-	-	-	-	-	-	-	-	-	-	-	-
BUCHE	-	-	-	-	-	-	-	-	-	-	-	-	-
CANGREJO	-	-	-	-	-	-	-	39.00	-	-	-	-	39.00
C. TOT OTROS (7)	-	-	-	-	-	-	-	39.00	-	-	-	-	39.00
D. TORTUGA (8)	-												-
GRAN TOTAL (õ A+B+C+D)	**96,829.20**	**108,189.86**	**88,407.40**	**108,859.70**	**111,952.31**	**71,875.50**	**71,989.95**	**78,649.54**	**82,659.20**	**106,680.84**	**113,451.50**	**111,232.90**	**1,150,777.90**

Table 34 GoN – Shrimp Trawler Landings – 2011

PESCA TOTAL SEGÚN CLASIFICACION COMERCIAL POR MESES COSTA RICA: LITORAL PACIFICO - FLOTA SEMI - INDUSTRIAL 2011													
Cantidad barcos/mes.	27	18	24	18	23	20	26	22	21	26	24	26	22.9
CONCEPTO	**ENE**	**FEB**	**MAR**	**ABR**	**MAY**	**JUN**	**JUL**	**AGO**	**SEP**	**OCT**	**NOV**	**DIC**	**TOTAL**
PRIMERA GDE.	-	-	9.00	-	-	-	12.40	-	-	42.40	-	-	63.80
PRIMERA PEQ.	2,565.20	3,554.40	604.70	3,868.60	816.00	278.50	1,890.40	1,017.50	2,232.10	3,058.70	835.80	951.80	21,673.70
CLASIFICADO	40,590.60	75,058.66	45,181.40	18,706.20	15,541.01	13,307.68	19,932.15	14,375.40	11,253.70	14,878.20	9,374.05	33,005.10	311,204.15
CHATARRA	18,964.50	13,668.20	18,585.80	14,729.10	17,291.60	7,205.50	13,718.60	14,582.10	12,084.63	24,685.50	13,418.15	14,359.80	183,293.48
AGRIA COLA	-	-	3.00	-	-	-	-	23.00	-	-	-	-	26.00
CABRILLA	5,109.81	9,909.00	11,452.90	4,794.20	3,695.40	393.10	496.30	192.00	158.70	390.30	100.30	441.60	37,133.61
PARGO	-	-	-	-	-	-	-	-	-	-	-	-	-
PARGO SEDA	-	-	-	-	-	-	-	-	-	-	-	-	-
DORADO	-	-	-	-	-	-	-	-	-	-	-	-	-
MARLIN	-												-
MARLIN BLCO.	-												-
MARLIN ROS.	-												-
PEZ VELA	-												-
PEZ ESPADA	-												-
WAHOO	-												-
TOT PESC EVIS (1)	67,230.11	102,190.26	75,836.80	42,098.10	37,344.01	21,184.78	36,049.85	30,190.00	25,729.13	43,055.10	23,728.30	48,758.30	553,394.74
SARDINA													-
ATUN	-	-	-	-	-	-	-	-	-	-	-	-	-
BALLYHOO	-	-	-	-	-	-	-	-	-	-	-	-	-
TOT PELAGICOS (2)	-	-	-	-	-	-	-	-	-	-	-	-	-
CAZON	154.00	70.70	11.50	36.00	25.00	500.00	168.90	10.00	-	12.00	107.00	2.90	1,098.00
POSTA	-	-	-	-	-	-	-	-	-	-	-	-	-
MACO	-	-	-	-	-	-	-	-	-	-	-	-	-
TREACHER	-	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL TIBURON (3)	154.00	70.70	11.50	36.00	25.00	500.00	168.90	10.00	-	12.00	107.00	2.90	1,098.00
A. PESCADOS (1+2+3)	**67,384.11**	**102,260.96**	**75,848.30**	**42,134.10**	**37,369.01**	**21,684.78**	**36,218.75**	**30,200.00**	**25,729.13**	**43,067.10**	**23,835.30**	**48,761.20**	**554,492.74**
CAMARON BLCO.	8,010.70	7,672.00	6,389.90	4,962.40	2,937.90	988.80	3,486.10	5,160.50	4,254.80	5,976.20	6,388.90	11,271.30	67,499.50
CAMARON CAFE	570.00	-	-	-	21.60	54.50	-	96.00	2.00	141.00	339.20	-	1,224.30
CAMARON ROSADO	25,834.90	12,373.60	30,483.30	25,707.70	22,798.20	29,721.10	26,761.40	17,314.80	26,046.10	24,567.10	25,227.30	11,210.20	278,045.70
CAMARON FIDEL	3,390.90	387.10	2,992.90	5,630.10	16,984.80	4,961.70	14,068.40	3,778.40	3,859.50	4,141.20	7,209.20	2,619.40	70,023.60
CAMARON CAMELLO	-	-	-	-	287.70	185.40	221.90	-	115.00	365.50	1,351.20	-	2,526.70
CAMARON REAL	5,193.50	3,136.00	3,044.50	6,605.90	14,989.30	7,642.10	9,301.20	10,494.70	13,787.10	21,631.40	10,766.10	13,076.30	119,668.10
CAMARON TITI	4,395.50	3,247.80	4,007.90	1,979.30	2,196.90	531.20	3,313.70	4,523.00	1,485.20	3,458.70	6,656.80	6,460.40	42,256.40
TOT CAMARON (4)	47,395.50	26,816.50	46,918.50	44,885.40	60,216.40	44,084.80	57,152.70	41,367.40	49,549.70	60,281.10	57,938.70	44,637.60	581,244.30
LANG PACIFICA (CTE)	6.00	-	-	-	-	-	-	-	-	-	-	-	6.00
LANG CARIBE	-	-	-	-	-	-	-	-	-	-	-	-	-
TOT LANGOSTA (5)	6.00	-	-	-	-	-	-	-	-	-	-	-	6.00
CALAMAR	7.00	-	-	-	-	29.70	-	-	-	-	-	26.00	62.70
PULPO	-	-	-	-	-	-	-	-	-	-	-	-	-
BIVALVOS	-	-	-	-	-	-	-	-	-	-	-	-	-
CAMBUTE	-	-	-	-	-	-	-	-	-	-	-	-	-
OSTION VACA	-	-	-	-	-	-	-	-	-	-	-	-	-
TOT MOLUSCOS (6)*	7.00	-	-	-	-	29.70	-	-	-	-	-	26.00	62.70
B. TOT MARISCOS (4+5+6)	**47,408.50**	**26,816.50**	**46,918.50**	**44,885.40**	**60,216.40**	**44,114.50**	**57,152.70**	**41,367.40**	**49,549.70**	**60,281.10**	**57,938.70**	**44,663.60**	**581,313.00**
ALETA TIBURON	-	-	-	-	-	-	-	-	-	-	-	-	-
FILET	-	-	-	-	-	-	-	-	-	-	-	-	-
BUCHE	-	-	-	-	-	-	-	-	-	-	-	-	-
CANGREJO	-	-	-	-	-	-	-	-	-	-	-	-	-
C. TOT OTROS (7)	-	-	-	-	-	-	-	-	-	-	-	-	-
D. TORTUGA (8)	-	-	-	-	-	-	-	-	-	-	-	-	-
GRAN TOTAL (δ A+B+C+D)	**114,792.61**	**129,077.46**	**122,766.80**	**87,019.50**	**97,585.41**	**65,799.28**	**93,371.45**	**71,567.40**	**75,278.83**	**103,348.20**	**81,774.00**	**93,424.80**	**1,135,805.74**

Table 35 GoN – Shrimp Trawler Landings – 2012

PESCA TOTAL SEGÚN CLASIFICACION COMERCIAL POR MESES													
COSTA RICA: LITORAL PACIFICO - FLOTA SEMI - INDUSTRIAL - 2012													
Cantidad barcos/mes.	30	29	31	32	31	25	28	25	27	26	27	25	28.0
CONCEPTO	**ENE**	**FEB**	**MAR**	**ABR**	**MAY**	**JUN**	**JUL**	**AGO**	**SEP**	**OCT**	**NOV**	**DIC**	**TOTAL**
PRIMERA GDE.	-	-	-	-	-	37.00	-	36.40	116.00	7.50	2.70	10.00	209.60
PRIMERA PEQ.	418.40	966.30	1,289.20	2,046.50	3,371.10	3,818.61	5,537.20	3,388.00	2,063.10	4,074.20	3,057.10	2,603.40	32,633.11
CLASIFICADO	52,103.40	91,933.35	170,897.77	39,418.19	24,614.60	17,917.45	24,831.80	16,295.80	15,009.00	21,728.80	21,857.59	20,614.10	517,221.85
CHATARRA	20,030.80	18,074.00	21,466.75	19,926.20	20,626.70	17,815.71	19,842.60	19,051.30	18,789.00	21,880.60	25,078.10	21,409.80	243,991.56
AGRIA COLA	220.40	7.40	11.60	-	-	-	-	6.90	44.10	-	27.90	-	318.30
CABRILLA	3,373.90	18,009.04	35,377.35	12,874.70	1,183.40	695.70	402.30	997.80	432.90	480.50	472.10	1,400.80	75,700.49
PARGO	-	-	-	-	-	-	-	-	-	-	-	-	-
PARGO SEDA	-	-	10.00	-	-	-	-	-	-	-	-	-	10.00
DORADO	17.00	-	-	-	-	-	-	21.00	-	-	-	-	38.00
MARLIN	-	-	-	-	-	-	-	-	-	-	-	-	-
MARLIN BLCO.	-	-	-	-	-	-	-	-	-	-	-	-	-
MARLIN ROS.	-	-	-	-	-	-	-	-	-	-	-	-	-
PEZ VELA	-	-	-	-	-	-	-	-	-	-	-	-	-
PEZ ESPADA	-	-	-	-	-	-	-	-	-	-	-	-	-
WAHOO	-	-	-	-	-	-	-	-	-	-	-	-	-
TOT PESC EVIS (1)	76,163.90	128,990.09	229,052.67	74,265.59	49,795.80	40,284.47	50,613.90	39,797.20	36,454.10	48,171.60	50,495.49	46,038.10	870,122.91
SARDINA													-
ATUN	-	-	-	-	1,600.00	381.00	-	-	-	-	-	1,570.00	3,551.00
BALLYHOO	-	-	-	-	-	-	-	-	-	-	-	-	-
TOT PELAGICOS (2)	-	-	-	-	1,600.00	381.00	-	-	-	-	-	1,570.00	3,551.00
CAZON	89.20	14.10	107.90	159.60	25.60	80.50	59.80	14.00	43.00	-	-	-	593.70
POSTA	-	-	-	-	-	-	-	-	-	-	-	-	-
MACO	-	-	-	-	-	-	-	-	-	-	-	-	-
TREACHER	-	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL TIBURON (3)	89.20	14.10	107.90	159.60	25.60	80.50	59.80	14.00	43.00	-	-	-	593.70
A. PESCADOS (1+2+3)	**76,253.10**	**129,004.19**	**229,160.57**	**74,425.19**	**51,421.40**	**40,745.97**	**50,673.70**	**39,811.20**	**36,497.10**	**48,171.60**	**50,495.49**	**47,608.10**	**874,267.61**
CAMARON BLCO.	9,138.80	3,112.70	2,767.70	3,725.30	2,009.10	296.10	677.40	971.40	1,328.40	1,153.60	1,410.50	705.20	27,296.20
CAMARON CAFE	-	-	-	7.00	-	897.10	45.70	-	-	55.10	112.50	63.00	1,180.40
CAMARON ROSADO	29,282.50	24,350.00	14,950.00	19,820.50	15,178.30	21,185.60	26,087.10	20,073.70	21,636.70	21,617.90	22,564.80	28,782.40	265,529.50
CAMARON FIDEL	1,672.70	717.10	147.40	4,213.80	6,032.20	2,817.70	6,679.60	1,526.90	1,972.50	4,351.20	4,891.60	3,969.40	38,992.10
CAMARON CAMELLO	1,158.90	-	-	-	-	5,634.90	-	-	-	-	-	-	6,793.80
CAMARON REAL	10,456.80	11,375.60	17,129.00	5,764.50	13,177.80	13,413.00	14,907.50	14,099.60	22,956.40	26,328.70	16,412.70	9,000.10	175,021.70
CAMARON TITI	1,345.80	238.50	771.70	1,248.00	5,008.30	2,124.20	1,679.60	3,947.20	3,518.00	5,575.70	5,342.90	2,580.10	33,380.00
TOT CAMARON (4)	53,055.50	39,793.90	35,765.80	34,779.10	41,405.70	46,368.60	50,076.90	40,618.80	51,412.00	59,082.20	50,735.00	45,100.20	548,193.70
LANG PACIFICA (CTE)	-	-	-	-	-	-	-	-	-	-	-	-	-
LANG CARIBE	-	-	-	-	-	-	-	-	-	-	-	-	-
TOT LANGOSTA (5)	-	-	-	-	-	-	-	-	-	-	-	-	-
CALAMAR	-	-	-	-	216.00	115.00	178.00	215.00	53.00	35.00	7.00	33.00	852.00
PULPO	-	-	-	-	-	-	-	-	-	-	-	-	-
BIVALVOS	-	-	-	-	-	-	-	-	-	-	-	-	-
CAMBUTE	-	-	-	-	-	-	-	-	-	-	-	-	-
OSTION VACA													-
TOT MOLUSCOS (6)*	-	-	-	-	216.00	115.00	178.00	215.00	53.00	35.00	7.00	33.00	852.00
B. TOT MARISCOS (4+5+6)	**53,055.50**	**39,793.90**	**35,765.80**	**34,779.10**	**41,621.70**	**46,483.60**	**50,254.90**	**40,833.80**	**51,465.00**	**59,117.20**	**50,742.00**	**45,133.20**	**549,045.70**
ALETA TIBURON	-	-	-	-	-	-	-	-	-	-	-	-	-
FILET	-	-	-	-	-	-	-	-	-	-	-	-	-
BUCHE	-	-	-	-	-	-	35.00	-	-	-	-	-	35.00
CANGREJO	407.00	-	-	-	-	-	15.00	-	-	-	-	-	422.00
C. TOT OTROS (7)	407.00	-	-	-	-	-	50.00	-	-	-	-	-	457.00
D. TORTUGA (8)	-	-	-	-	-	-	-	-	-	-	-	-	-
GRAN TOTAL (õ A+B+C+D)	**129,715.60**	**168,798.09**	**264,926.37**	**109,204.29**	**93,043.10**	**87,229.57**	**100,978.60**	**80,645.00**	**87,962.10**	**107,288.80**	**101,237.49**	**92,741.30**	**1,423,770.31**

Table 36 GoN – Shrimp Trawler Landings – 2013

PESCA TOTAL SEGÚN CLASIFICACION COMERCIAL POR MESES													
COSTA RICA: LITORAL PACIFICO - FLOTA SEMI - INDUSTRIAL-2013													
Cantidad barcos/mes.	24	24	26	27	29	22	26	28	25	26	27	26	25.8
CONCEPTO	ENE	FEB	MAR	ABR	MAY	JUN	JUL	AGO	SEP	OCT	NOV	DIC	TOTAL
PRIMERA GDE.	-	-	5.00	25.50	6.00	-	23.00	-	-	-	25.60	-	85.10
PRIMERA PEQ.	3,231.99	2,150.80	1,409.10	2,760.20	3,426.30	1,704.60	1,309.30	3,121.00	1,010.20	426.80	4,185.40	1,177.90	25,913.59
CLASIFICADO	21,309.30	27,758.87	25,619.00	20,775.20	17,910.90	12,645.50	17,313.80	14,264.00	13,426.40	6,505.50	16,081.00	16,575.90	210,185.37
CHATARRA	23,343.41	24,121.40	25,861.60	20,560.60	22,577.50	12,148.90	13,321.60	16,781.20	12,449.00	11,283.40	24,027.30	15,553.80	222,029.71
AGRIA COLA	-	-	76.40	120.90	40.00	84.20	-	-	18.50	55.50	369.00	288.80	1,053.30
CABRILLA	277.20	169.39	1,627.50	2,172.10	1,043.80	782.80	998.80	332.00	59.30	42.20	334.50	595.00	8,434.59
PARGO	-	-	-	-	-	-	-	-	-	-	-	-	-
PARGO SEDA	-	-	-	-	-	-	-	-	-	-	-	-	-
DORADO	-	-	-	-	-	-	-	-	-	-	-	-	-
MARLIN	-	-	-	-	-	-	-	-	-	-	-	-	-
MARLIN BLCO.	-	-	-	-	-	-	-	-	-	-	-	-	-
MARLIN ROS.	-	-	-	-	-	-	-	-	-	-	-	-	-
PEZ VELA	-	-	-	-	-	-	-	-	-	-	-	-	-
PEZ ESPADA	-	-	-	-	-	-	-	-	-	-	-	-	-
WAHOO	-	-	-	-	-	-	-	-	-	-	-	-	-
TOT PESC EVIS (1)	48,161.90	54,200.46	54,598.60	46,414.50	45,004.50	27,366.00	32,966.50	34,498.20	26,963.40	18,313.40	45,022.80	34,191.40	467,701.66
SARDINA													-
ATUN	-	-	-	-	-	-	4,332.00	2,958.40	-	-	-	-	7,290.40
BALLYHOO	-	-	-	-	-	-	-	-	-	-	-	-	-
TOT PELAGICOS (2)	-	-	-	-	-	-	4,332.00	2,958.40	-	-	-	-	7,290.40
CAZON	-	13.80	-	14.30	16.40	85.10	-	112.00	-	-	-	-	241.60
POSTA	-	-	-	-	-	-	-	-	-	-	-	-	-
MACO	-	-	-	-	-	-	-	-	-	-	-	-	-
TREACHER	-	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL TIBURON (3)	-	13.80	-	14.30	16.40	85.10	-	112.00	-	-	-	-	241.60
A. PESCADOS (1+2+3)	**48,161.90**	**54,214.26**	**54,598.60**	**46,428.80**	**45,020.90**	**27,451.10**	**37,298.50**	**37,568.60**	**26,963.40**	**18,313.40**	**45,022.80**	**34,191.40**	**475,233.66**
CAMARON BLCO.	547.20	336.50	1,571.80	2,483.70	2,385.00	1,452.70	1,158.40	1,688.50	620.70	846.80	1,797.50	340.80	15,229.60
CAMARON CAFE	-	-	266.90	161.00	115.80	-	3.40	341.70	45.30	-	9.90	10.30	954.30
CAMARON ROSADO	20,778.70	23,884.90	26,454.00	17,873.90	24,055.40	20,441.60	39,676.10	22,020.00	30,818.60	26,442.60	24,482.30	22,141.30	299,069.40
CAMARON FIDEL	2,070.60	2,121.30	1,052.80	1,679.10	5,388.40	1,048.30	2,378.90	1,096.70	1,332.20	1,868.10	1,431.90	3,529.00	24,997.30
CAMARON CAMELLO	-	-	1,087.50	-	-	-	-	-	260.90	-	-	890.40	2,238.80
CAMARON REAL	11,387.70	6,515.60	5,573.80	36,767.70	26,431.70	18,166.70	14,964.10	26,453.20	34,311.00	15,231.50	9,566.80	10,181.40	215,551.20
CAMARON TITI	2,438.70	560.10	186.60	1,872.10	2,708.20	1,563.30	1,420.40	2,151.40	2,513.60	5,648.60	13,057.20	3,106.00	37,226.20
TOT CAMARON (4)	37,222.90	33,418.40	36,193.40	60,837.50	61,084.50	42,672.60	59,601.30	53,751.50	69,902.30	50,037.60	50,345.60	40,199.20	595,266.80
LANG PACIFICA (CTE)	-	-	-	1.50	-	-	-	-	-	-	-	-	1.50
LANG CARIBE	-	-	-	-	-	-	-	-	-	-	-	-	-
TOT LANGOSTA (5)	-	-	-	1.50	-	-	-	-	-	-	-	-	1.50
CALAMAR	-	-	123.00	-	331.00	219.39	801.00	47.50	89.00	321.00	-	-	1,931.89
PULPO	-	-	-	-	-	-	-	-	-	-	-	-	-
BIVALVOS	-	-	-	-	-	-	-	-	-	-	-	-	-
CAMBUTE	-	-	-	-	-	-	-	-	-	-	-	-	-
TOT MOLUSCOS (6)*	-	-	123.00	-	331.00	219.39	801.00	47.50	89.00	321.00	-	-	1,931.89
B. TOT MARISCOS (4+5+6)	**37,222.90**	**33,418.40**	**36,316.40**	**60,839.00**	**61,415.50**	**42,891.99**	**60,402.30**	**53,799.00**	**69,991.30**	**50,358.60**	**50,345.60**	**40,199.20**	**597,200.19**
ALETA TIBURON	-	-	-	-	-	-	-	-	-	-	-	-	-
FILET	-	-	-	-	-	-	-	-	-	22.00	-	-	22.00
BUCHE	-	-	-	-	-	25.07	-	-	-	-	-	-	25.07
CANGREJO	-	-	30.00	-	53.00	-	-	-	172.00	-	14.00	-	269.00
C. TOT OTROS (7)	-	-	30.00	-	53.00	25.07	-	-	172.00	22.00	14.00	-	316.07
D. TORTUGA (8)	-	-	-	-	-	-	-	-	-	-	-	-	-
GRAN TOTAL (ó A+B+C+D)	**85,384.80**	**87,632.66**	**90,945.00**	**107,267.80**	**106,489.40**	**70,368.16**	**97,700.80**	**91,367.60**	**97,126.70**	**68,694.00**	**95,382.40**	**74,390.60**	**1,072,749.92**

Table 37. Artisanal Landings Reported in the Tárcoles Region - 2008

PUESTO RECIBO	CLASE COMERCIAL	KILOS
COOPETARCOLES R.L.	AGRIA COLA	5,991.60
	CABRILLA	9,085.60
	CALAMAR	106.80
	CAMARON BLANCO	1,023.00
	CAMARON TITI	630.40
	CANGREJOS	114.40
	CAZON	5,525.40
	CHATARRA	40,002.20
	CLASIFICADO	11,130.40
	DORADO	6,897.20
	FILET	127.60
	LANGOSTA PACIFICO	1,315.80
	PARGO	396.40
	PRIMERA GRANDE	6,053.20
	PRIMERA PEQUEÑA	41,293.40
	PULPO	14.00
	SARDINA	387.20
MARILYN	CANGREJOS	1.40
	CAZON	403.80
	CHATARRA	283.25
	CLASIFICADO	546.20
	PARGO	10.00
	PRIMERA GRANDE	353.40
	PRIMERA PEQUEÑA	395.00
	SARDINA	156.80
PESCADERIA JJ	AGRIA COLA	108.80
	CABRILLA	11.20
	CAMARON BLANCO	1,065.64
	CAMARON TITI	777.80
	CANGREJOS	380.00
	CAZON	23.60
	CHATARRA	2,848.68
	CLASIFICADO	2,074.12
	DORADO	68.00
	LANGOSTA PACIFICO	153.10
	PARGO	464.00
	PARGO	10.40

	PRIMERA GRANDE	1,290.40
	PRIMERA PEQUEÑA	6,035.90
	SARDINA	465.00
RECIBIDOR LA PISTA	CAMARON BLANCO	1.20
	CHATARRA	153.20
	CLASIFICADO	79.20
	PARGO	6.80
	PRIMERA GRANDE	85.60
	PRIMERA PEQUEÑA	119.20

Table 38 Artisanal Landings Reported in the Tárcoles Region - 2009

PUESTO RECIBO	CLASE COMERCIAL	KILOS
BARRACUDA	AGRIA COLA	2,022.00
	CAZON	1,146.00
	CHATARRA	5,004.00
	CLASIFICADO	9,204.00
	DORADO	6,688.00
	PARGO	228.00
	PRIMERA GRANDE	1,405.20
	PRIMERA PEQUEÑA	9,906.00
COOPETARCOLES R.L.	AGRIA COLA	7,545.88
	ATUN	5,569.20
	CABRILLA	17,168.80
	CALAMAR	1,499.20
	CAMARON BLANCO	1,550.80
	CAMARON TITI	863.60
	CANGREJOS	205.60
	CAZON	6,432.80
	CHATARRA	49,366.84
	CLASIFICADO	17,359.20
	DORADO	17,602.00
	FILET	8.40
	LANGOSTA PACIFICO	631.84
	PARGO	8.80
	PRIMERA GRANDE	5,611.60
	PRIMERA PEQUEÑA	48,514.24
	PULPO	4.00

	SARDINA	384.40
EL REFUGIO	AGRIA COLA	3,084.00
	CHATARRA	240.00
	CLASIFICADO	4,060.00
	DORADO	4,752.00
	PARGO	9,012.00
	PRIMERA PEQUEÑA	17,281.60
MARILYN	AGRIA COLA	1,198.20
	CABRILLA	1,557.80
	CAMARON BLANCO	359.51
	CANGREJOS	19.40
	CAZON	229.32
	CHATARRA	4,800.80
	CLASIFICADO	2,683.28
	PRIMERA GRANDE	425.80
	PRIMERA PEQUEÑA	5,940.32
	SARDINA	41.20

Table 39 Artisanal Landings Reported in the Tárcoles Region - 2010

PUESTO RECIBO	CLASE COMERCIAL	KILOS
BARRACUDA	AGRIA COLA	2,160.00
	ATUN	12,864.00
	CAZON	1,102.00
	CHATARRA	5,524.00
	CLASIFICADO	18,366.00
	PARGO	1,402.00
	PRIMERA GRANDE	9,308.24
	PRIMERA PEQUEÑA	8,637.60
COOPETARCOLES R.L.	AGRIA COLA	4,975.60
	ATUN	2,856.80
	BIVALVOS	13.60
	CABRILLA	6,920.40
	CALAMAR	52.00
	CAMARON BLANCO	527.20
	CAZON	3,098.80
	CHATARRA	21,760.40
	CLASIFICADO	11,996.00

	DORADO	247.20
	LANGOSTA PACIFICO	179.20
	PRIMERA GRANDE	6,820.00
	PRIMERA PEQUEÑA	25,358.00
	SARDINA	202.00
EL REFUGIO	AGRIA COLA	232.00
	CHATARRA	880.00
	CLASIFICADO	4,992.00
	DORADO	4,848.00
	PARGO	5,152.00
	PRIMERA PEQUEÑA	9,906.40
MARILYN	AGRIA COLA	1,147.20
	BIVALVOS	19.40
	CABRILLA	634.80
	CAMARON BLANCO	256.40
	CAMARON TITI	48.00
	CAZON	608.40
	CHATARRA	7,650.00
	CLASIFICADO	8,636.60
	PRIMERA GRANDE	15.20
	PRIMERA PEQUEÑA	25,126.60
	SARDINA	490.80

Table 40 Artisanal Landings Reported in the Tárcoles Region - 2011

PUESTO RECIBIDO	CLASE COMERCIAL	KILOS
BARRACUDA	CHATARRA	6,742.00
	CLASIFICADO	7,116.00
	PRIMERA GRANDE	512.00
	PRIMERA PEQUEÑA	3,412.00
COOPETARCOLES R.L.	AGRIA COLA	20,319.20
	ATUN	3,372.40
	CABRILLA	7,967.20
	CALAMAR	924.00
	CAMARON BLANCO	2,450.40
	CAMARON TITI	622.00
	CAZON	6,580.88
	CHATARRA	47,795.64
	CLASIFICADO	22,558.04
	CRUSTACEOS	72.00
	DORADO	21,211.60
	LANGOSTA PACIFICO	1,207.20
	MARLIN	80.00
	PARGO SEDA	12.00
	PRIMERA GRANDE	7,421.60
	PRIMERA PEQUEÑA	63,288.64
	SARDINA	1,202.00
EL REFUGIO	CHATARRA	1,180.00
	CLASIFICADO	1,288.00
	DORADO	844.00
	PARGO	1,576.00
	PRIMERA PEQUEÑA	3,644.00
MARILYN	AGRIA COLA	1,184.00
	ATUN	5,176.00
	CABRILLA	20.40
	CAMARON BLANCO	197.40
	CAZON	366.40
	CHATARRA	5,732.60
	CLASIFICADO	6,060.00
	PARGO	92.00
	PRIMERA GRANDE	122.00
	PRIMERA PEQUEÑA	9,632.00
	SARDINA	142.80

Table 41 Artisanal Landings Reported in the Tárcoles Region - 2012

PUESTO	CLASE COMERCIAL	KILOS
BARRACUDA	AGRIA COLA	1,568.00
	CAZON	256.00
	CHATARRA	21,184.00
	CLASIFICADO	7,278.00
	PRIMERA GRANDE	2,628.00
	PRIMERA PEQUEÑA	9,264.00
COOPETARCOLES R.L.	AGRIA COLA	15,383.84
	CABRILLA	5,765.60
	CAMARON BLANCO	1,610.00
	CAMARON TITI	478.40
	CANGREJOS	128.00
	CAZON	4,394.40
	CHATARRA	60,882.00
	CLASIFICADO	15,596.64
	DORADO	33,357.00
	LANGOSTA PACIFICO	1,367.00
	PRIMERA GRANDE	12,305.20
	PRIMERA PEQUEÑA	77,913.80
MARILYN	AGRIA COLA	1,331.60
	CABRILLA	9.60
	CAMARON BLANCO	11.60
	CAMARON TITI	10.40
	CAZON	457.60
	CHATARRA	7,108.40
	CLASIFICADO	5,204.40
	DORADO	1,852.40
	PRIMERA GRANDE	1,472.40
	PRIMERA PEQUEÑA	12,018.64
	SARDINA	40.00

Table 42 Artisanal Landings Reported in the Tárcoles Region - 2013

PUESTO RECIBO	CLASE COMERCIAL	KILOS
BARRACUDA	AGRIA COLA	164.00
	CHATARRA	18,966.00
	CLASIFICADO	16,328.00
	PRIMERA GRANDE	1,152.00
	PRIMERA PEQUEÑA	6,542.00
COOPETARCOLES R.L.	AGRIA COLA	20,893.48
	CABRILLA	4,953.60
	CAMARON BLANCO	1,949.00
	CAMARON TITI	456.40
	CANGREJOS	75.60
	CAZON	7,333.20
	CHATARRA	27,885.00
	CLASIFICADO	13,448.80
	DORADO	35,162.80
	FILET	4.00
	LANGOSTA PACIFICO	1,356.80
	PRIMERA GRANDE	16,120.40
	PRIMERA PEQUEÑA	63,849.84
MARILYN	AGRIA COLA	196.00
	CAMARON BLANCO	332.64
	CAMARON TITI	64.00
	CANGREJOS	33.20
	CAZON	54.80
	CHATARRA	3,954.40
	CLASIFICADO	2,573.68
	LANGOSTA PACIFICO	93.60
	PARGO	188.80
	PRIMERA GRANDE	164.00
	PRIMERA PEQUEÑA	3,222.00
	SARDINA	248.00

Table 43 INCOPESCA Grouping Methodology

Group	Local Name	Scientific Name
PRIMERA GRANDE (Weight > 4 kilograms) *High Value Catch – Primarily Croaker and Snook*	Corvina Reina	*Cynoscion albus*
	Corvina Coliamarilla	*Cynoscion stolzmanni*
	Robalo	*Centropomus nigrescens*
PRIMERA PEQUENA (Weight < 4 kilograms) *High Value Catch – Primarily Croaker and Snook*	corvina aguada	*Cynoscion squamipinnis*
	corvina picuda	*Cynoscion phoxocephalus*
	corvina reina	*Cynoscion albus*
	corvina coliamarilla	*Cynoscion stolzmanni*
	Robalo	*Centropomus nigrescens*
	corvina guavina	*Nebris occidentalis*
	corvina zorra	*Menticirrhus nasus*
	corvina rayada	*Cynoscion reticulatus*
	mano de piedra	*Centropomus unionensis*
	Gualaje	*Centropomus robalito*
CLASIFICADO *Primarily Snappers*	Macarela	*Scomberomorus sierra*
	Berrugate	*Lobotes pacificus*
	pargo rojo	*Lutjanus colorado*
	pargo coliamarilla	*Lutjanus argentiventris*
	corvinas (weighing less than 400 grams)	*Cynoscion sp*
CHATARA *Low Market Value Catch*	Jurel	*Caranx hippos*
	jurel arenero	*Hemicaranx leucurus*
	Bonito	*Caranx caballus*
	Gallo	*Nematistius pectoralis*
	Pompano	*Trachinotus paitensis*
	Lisa	*Mugil curema*

	bobo blanco	*Polydactylus approximans*
	bobo Amarillo	*Polydactylus opercularis*
	Sierra	*Oligoplites sp*
	Palometa	*Selene sp.*
	Palmito	*Eucinostomas gracilis*
	Cotongo	*Anisotremus dovii*
	vieja ñata	*Anisotremus interruptus*
	vieja trompuda	*Pomadasys sp.*
	China	*Ophioscion sierus*
	Cinchada	*Paralonchurus dumerilii*
	Roncador	*Haemulon sp.*
	Catecismo	*Chaetodon humeralis*
	Hojarán	*Seriola sp*
	Ojona	*Isopisthus remifer*
	Chuerca	*Haemulon sp.*
	Gallina	*Elattarchus archidiun*
	Frijol	*Anisotremus pacifici*
	Salema	*Peprilus snydery*
	Lenguado	*Cyclopsetta querna*
	Platanillo	*Carans vinctus*
	jurel ojón	*Carans melanpyqus*
	pargo blanco	*Diapterus peruvianus*
	corvinas (weighing less than 200 grams)	*Cynoscion sp*
	other	
AGRIA COLA *Croaker*	agria cola	*Micropogonias altipinnis*
SARDINA *Sardine*	Sardine	*Opisthonema medirrastre* *Opisthonema libertate*
TOTAL CAMARON	camarón blanco	*Penaeus occidentalis*

Total Shrimp		*Penaeus stylirostris*
		Penaeus vannamei
	camarón café	*Penaeus californiensis*
	camarón Rosado	*Penaeus brevirostris*
	camarón fidel	*Solenocera agassizii*
	camarón camello corriente	*Heterocarpus vicarius*
	camello real	*Heterocarpus affinis*
	camarón cebra	*Trachypenaeus byrdii*
		Trachypenaeus facea
	camarón titi	*Protrachypene precipua*
		Xiphopenaeus rivetti

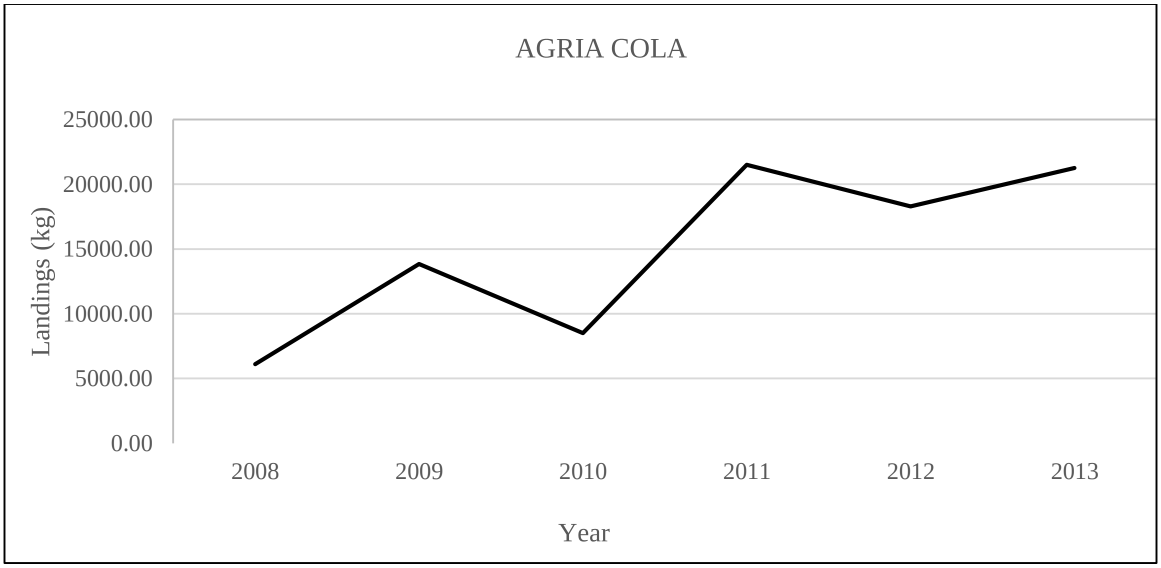

Figure 46 Yearly Artisanal Landings of AGRIA COLA – Tárcoles Region (INCOPESCA data)

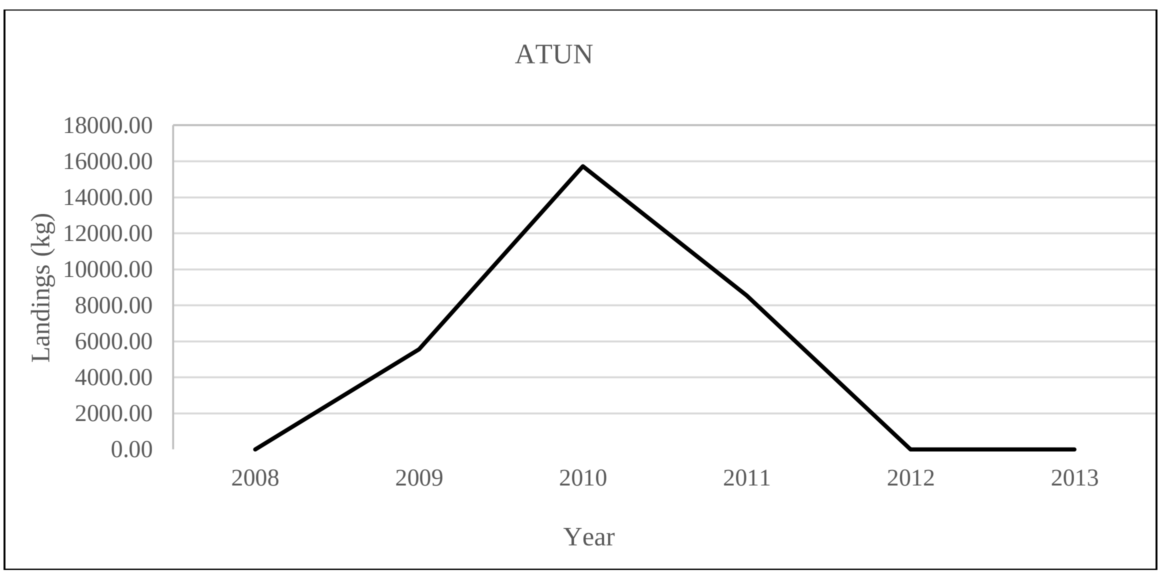

Figure 47 Yearly Artisanal Landings of ATUN – Tárcoles Region (INCOPESCA data)

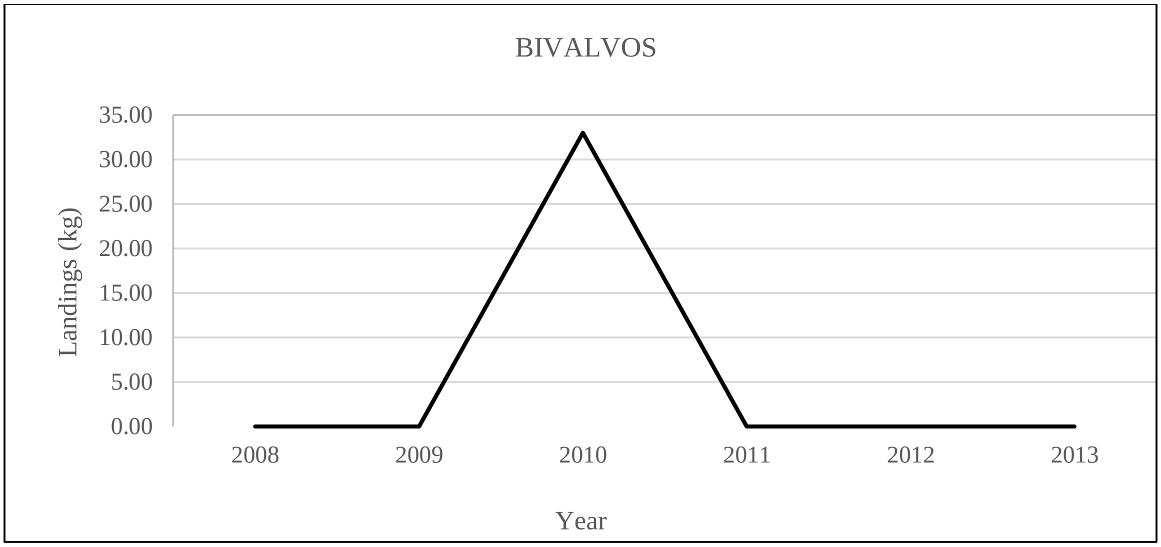

Figure 48 Yearly Artisanal Landings of BIVALVOS – Tárcoles Region (INCOPESCA data)

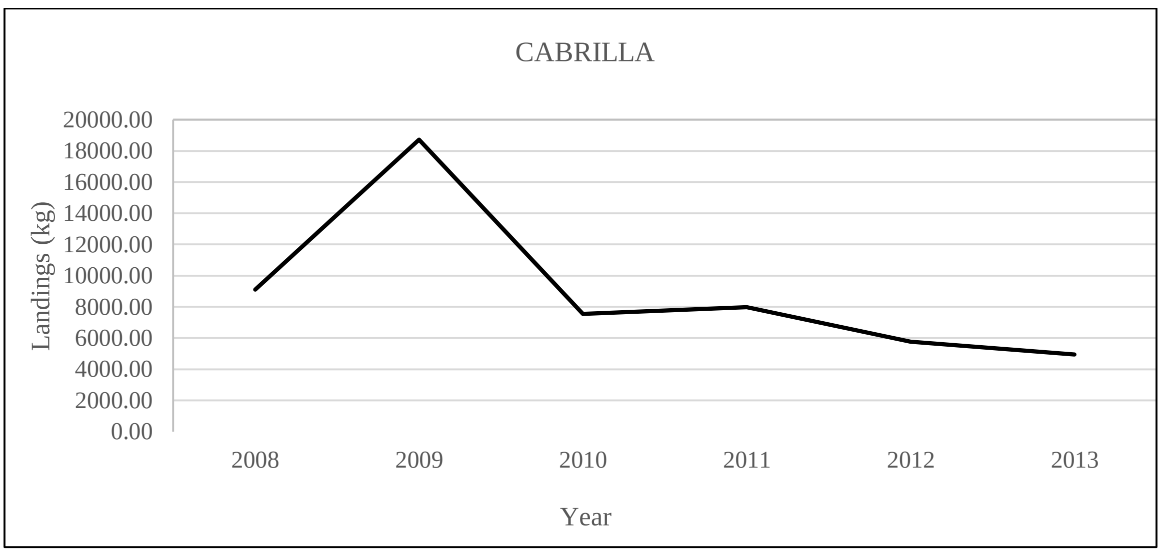

Figure 49 Yearly Artisanal Landings of CABRILLA – Tárcoles Region (INCOPESCA data)

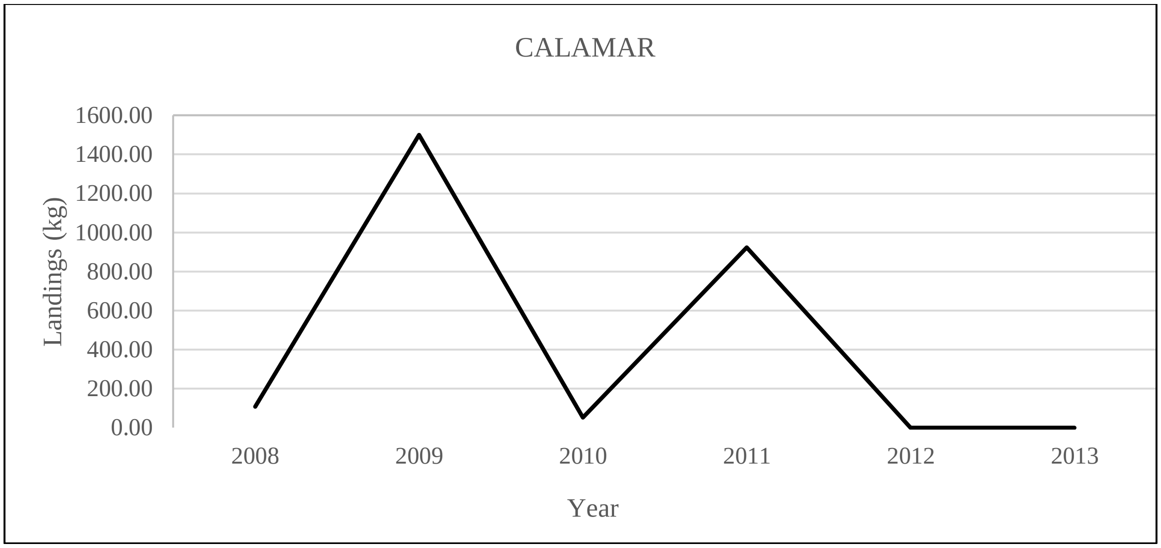

Figure 50 Yearly Artisanal Landings of CALAMAR – Tárcoles Region (INCOPESCA data)

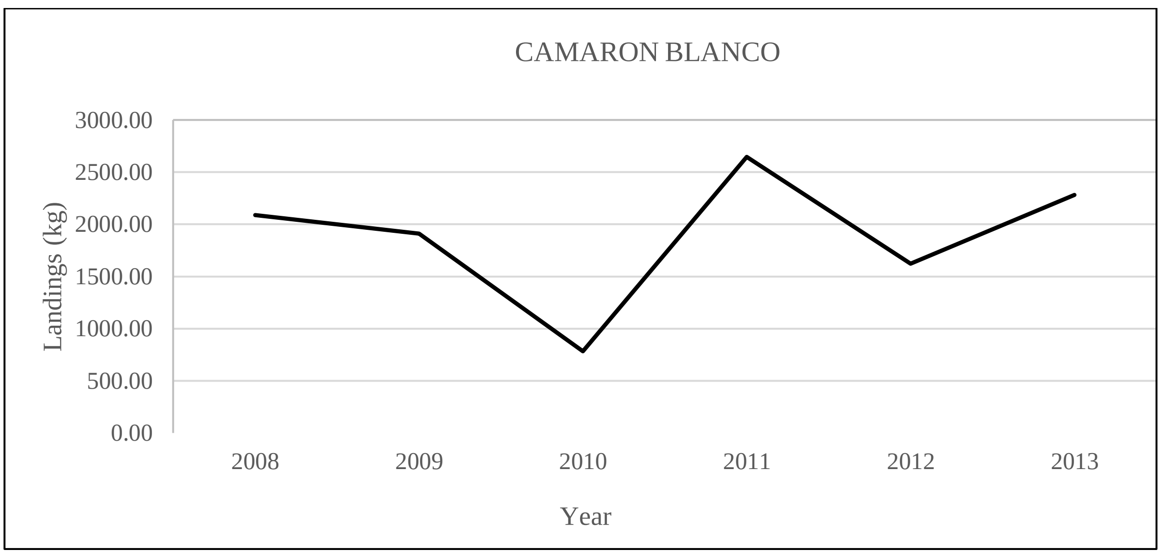

Figure 51 Yearly Artisanal Landings of CAMARON BLANCO – Tárcoles Region (INCOPESCA data)

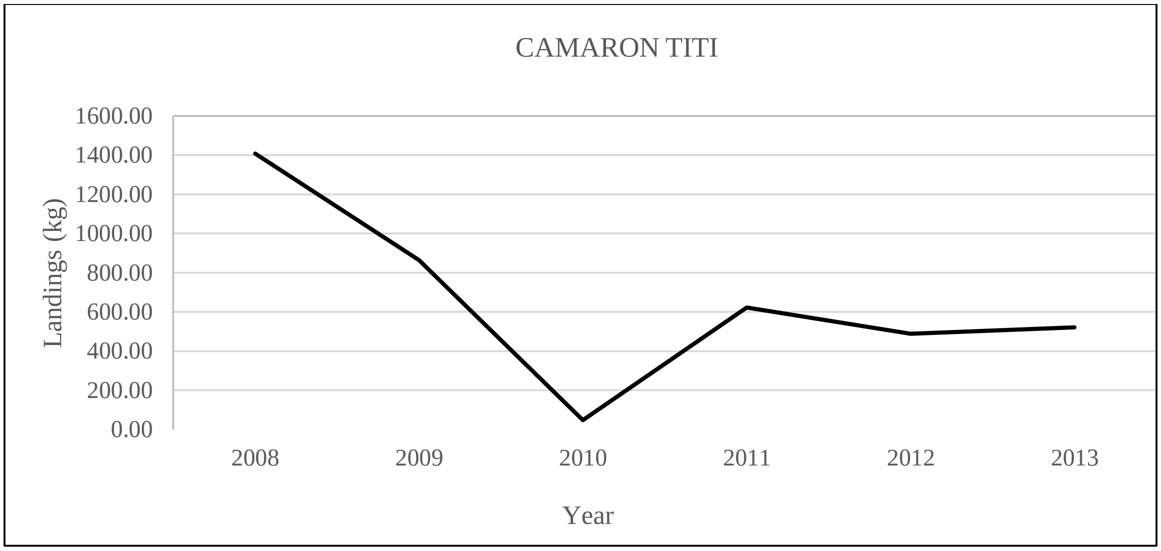

Figure 52 Yearly Artisanal Landings of CAMARON TITI – Tárcoles Region (INCOPESCA data)

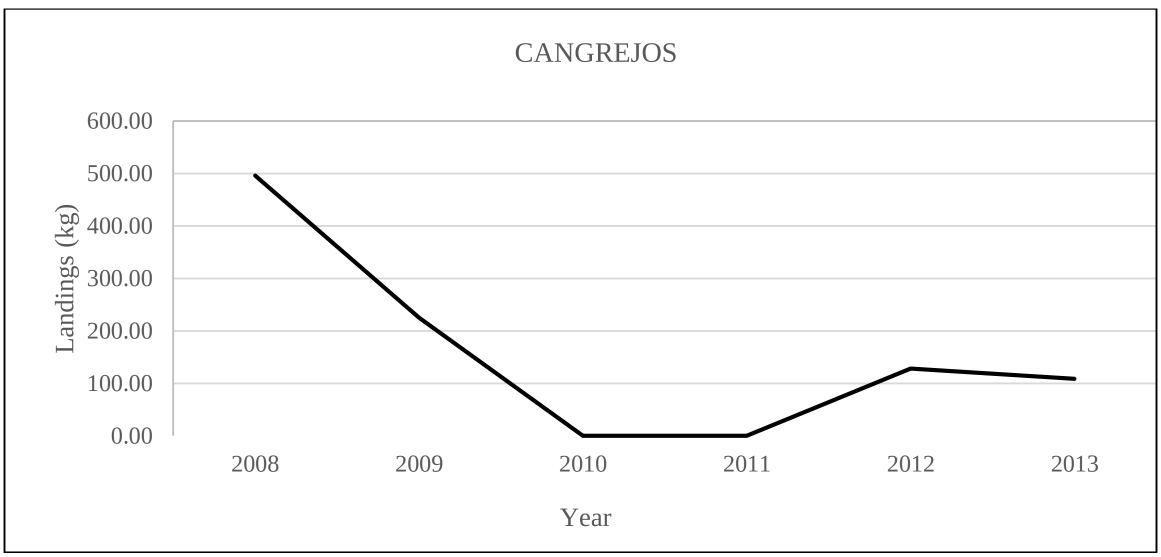

Figure 53 Yearly Artisanal Landings of CANGREJOS – Tárcoles Region (INCOPESCA data)

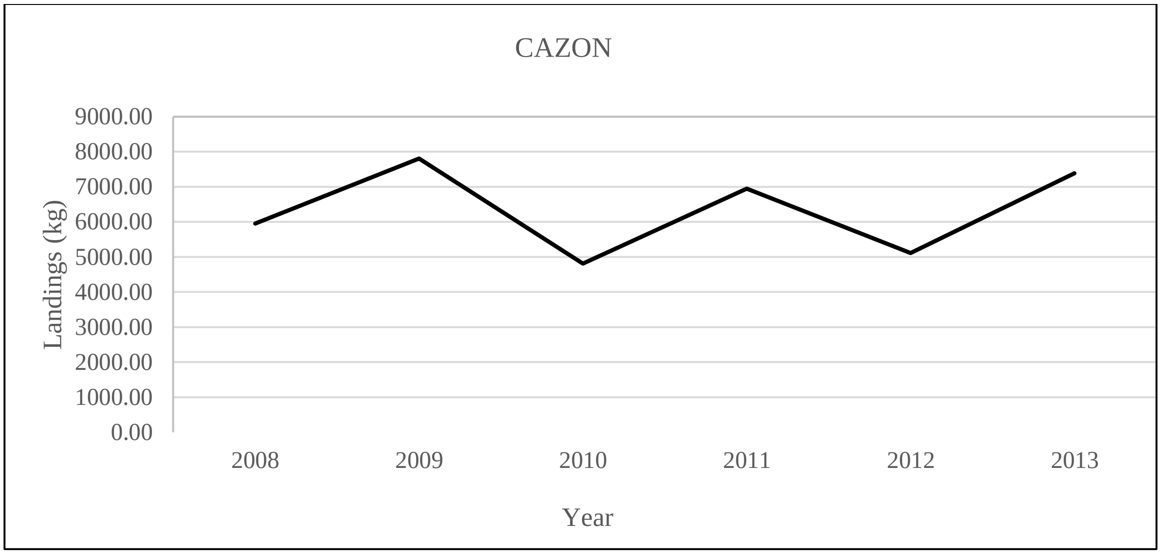

Figure 54 Yearly Artisanal Landings of CAZON – Tárcoles Region (INCOPESCA data)

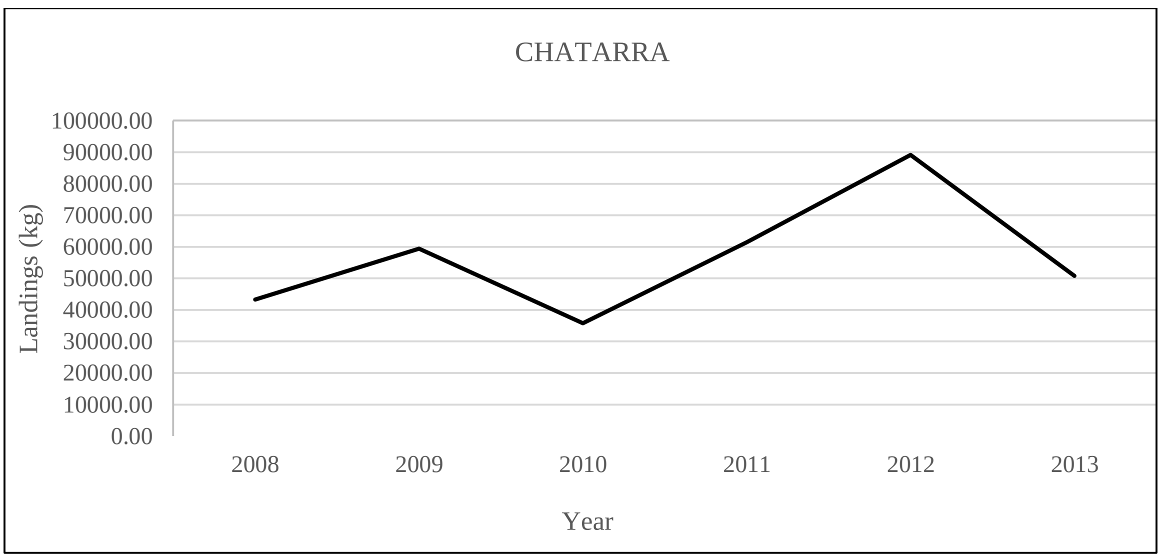

Figure 55 Yearly Artisanal Landings of CHATARRA – Tárcoles Region (INCOPESCA data)

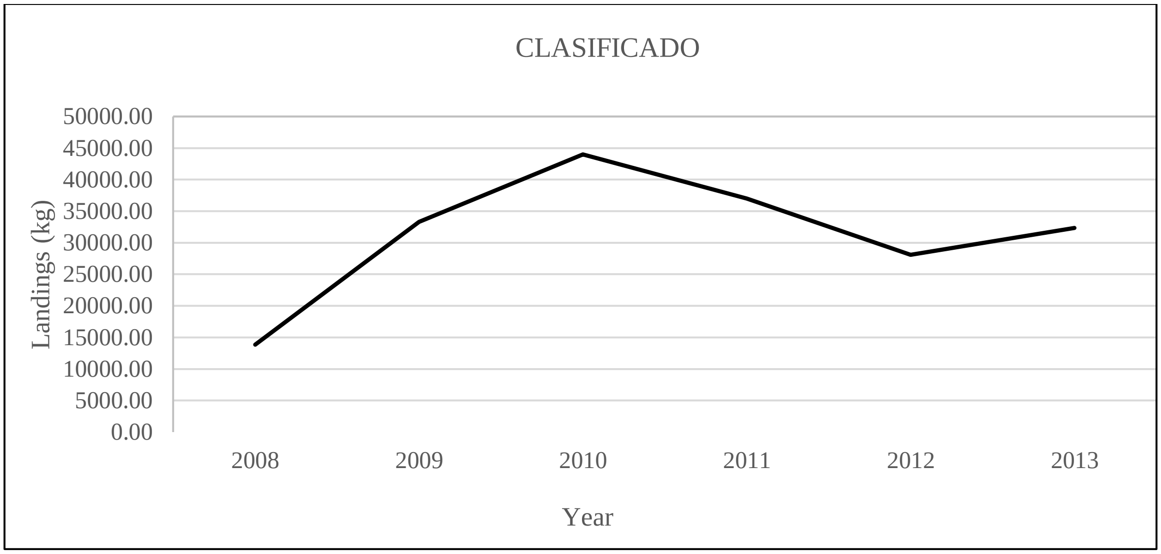

Figure 56 Yearly Artisanal Landings of CLASIFICADO – Tárcoles Region (INCOPESCA data)

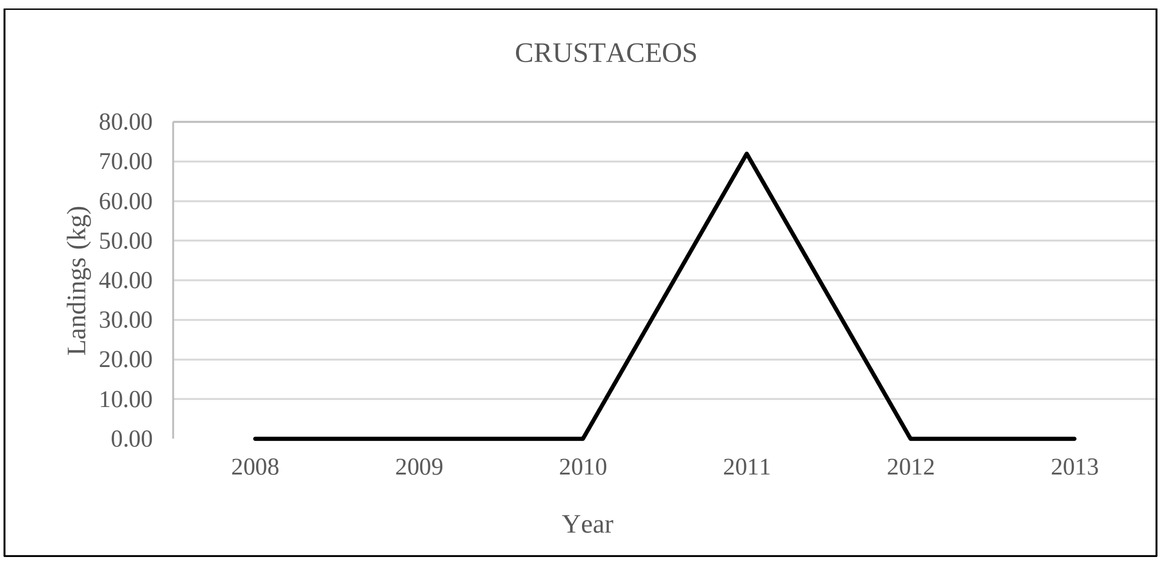

Figure 57 Yearly Artisanal Landings of CRUSTACEOS – Tárcoles Region (INCOPESCA data)

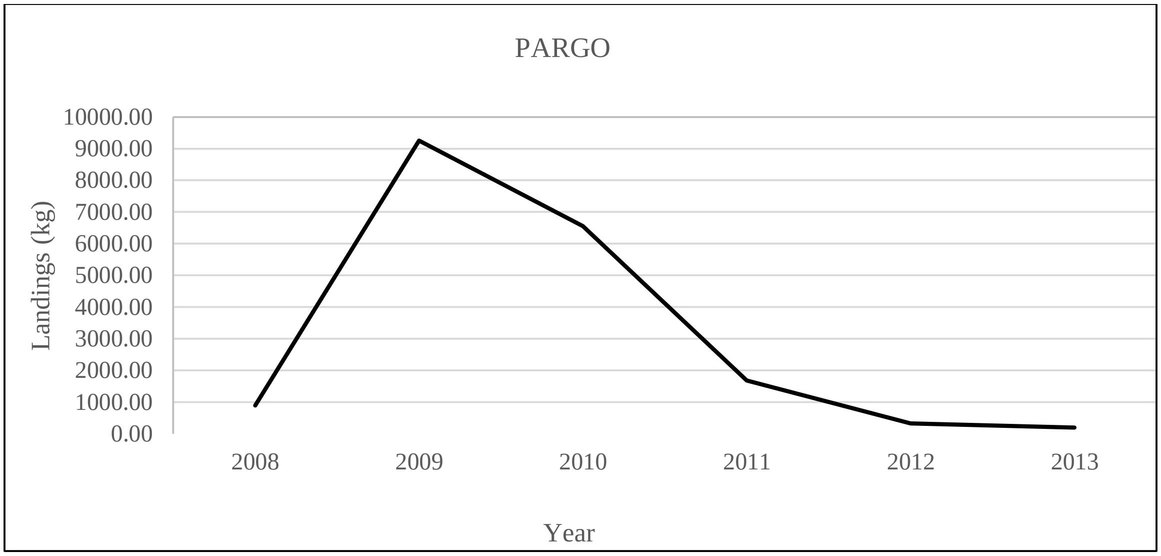

Figure 58 Yearly Artisanal Landings of PARGO – Tárcoles Region (INCOPESCA data)

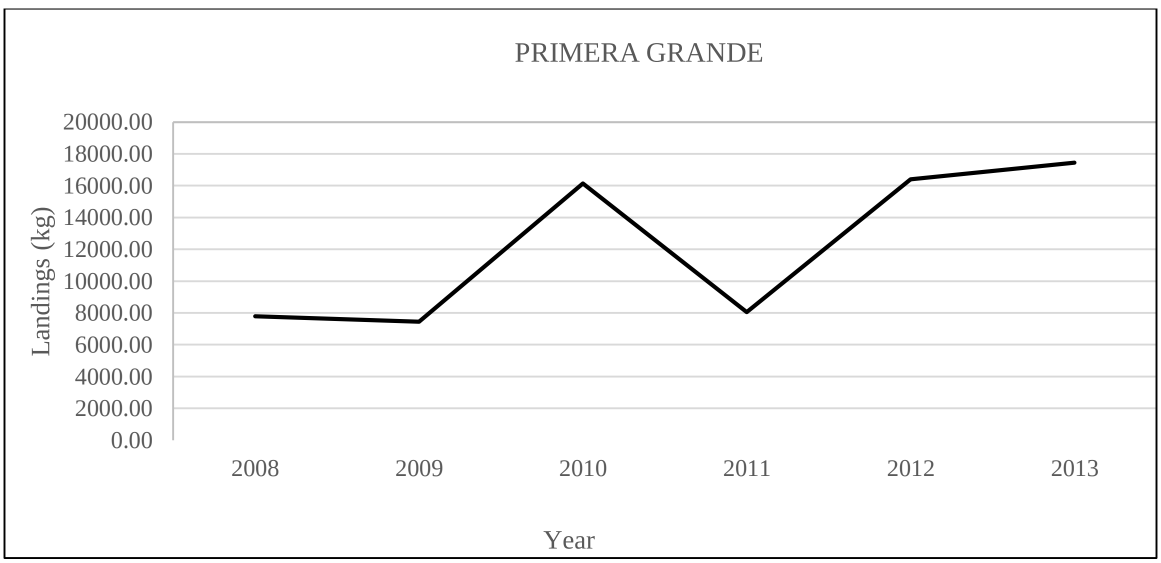

Figure 59 Yearly Artisanal Landings of PRIMERA GRANDE – Tárcoles Region (INCOPESCA data)

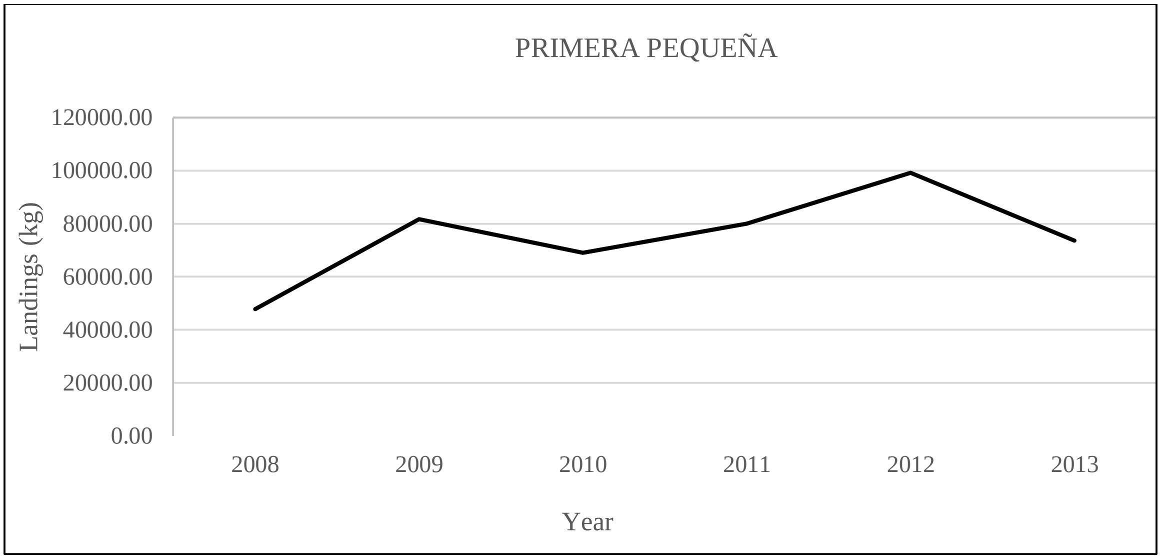

Figure 60 Yearly Artisanal Landings of PRIMERA PEQUEÑA – Tárcoles Region (INCOPESCA data)

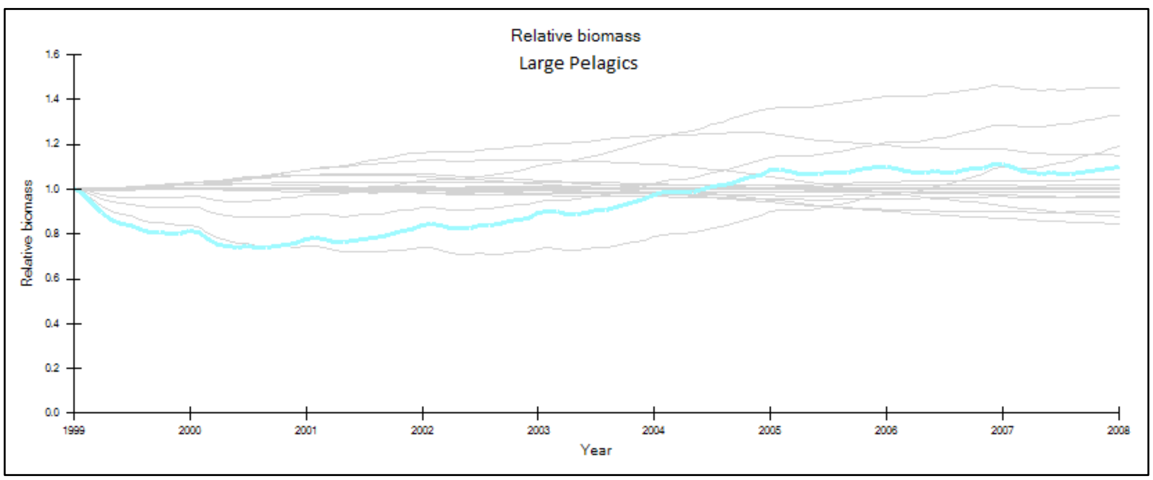

Figure 61 GoN EwE Model Relative Biomass – Dorado

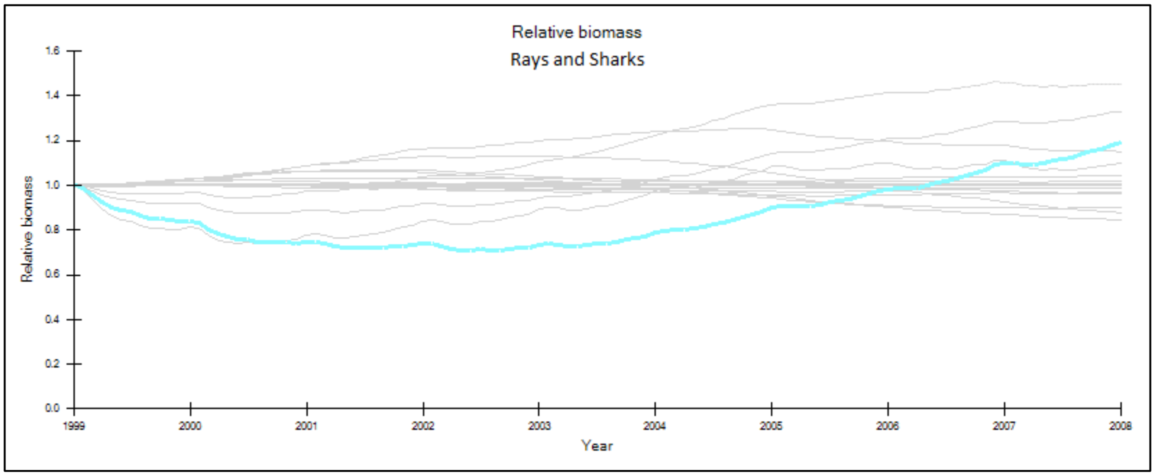

Figure 62 GoN EwE Model Relative Biomass – Rays and Sharks

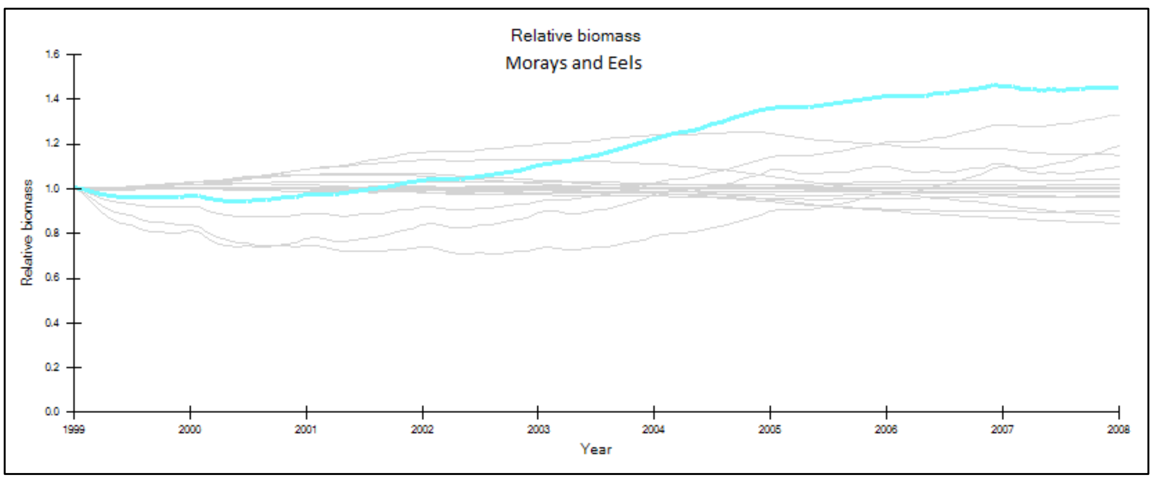

Figure 63 GoN EwE Model Relative Biomass – Morays and Eels

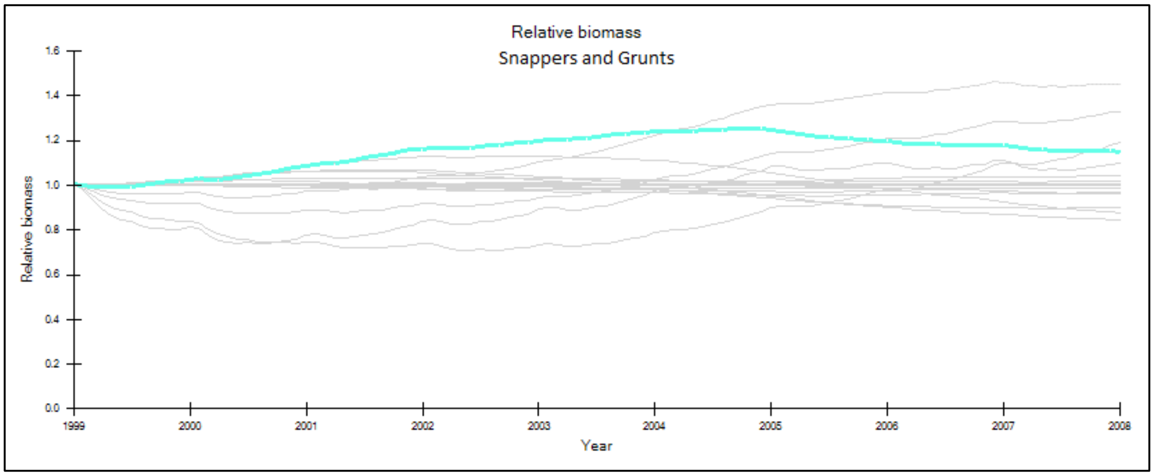

Figure 64 GoN EwE Model Relative Biomass – Snappers and Grunts

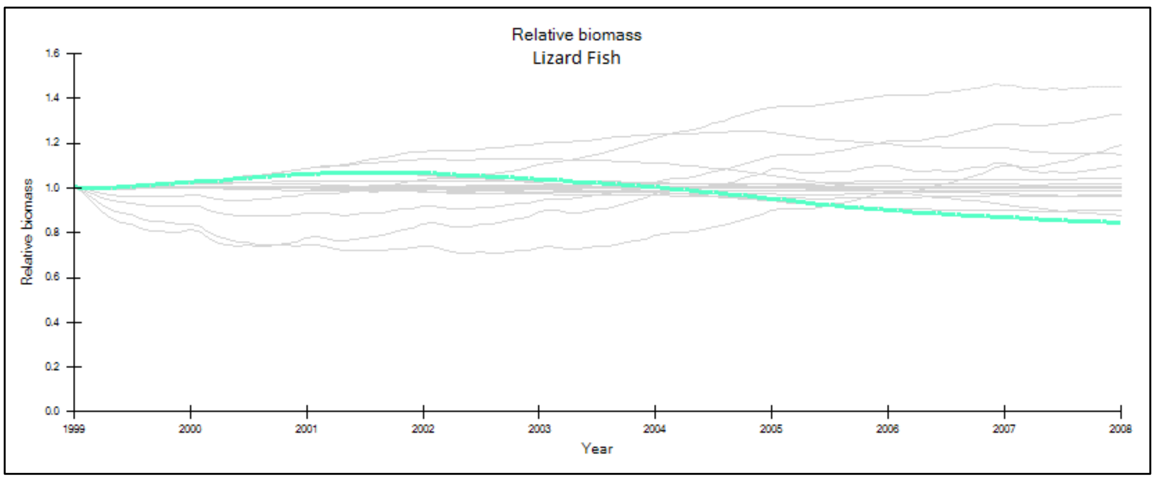

Figure 65 R GoN EwE Model Relative Biomass – Lizardfish

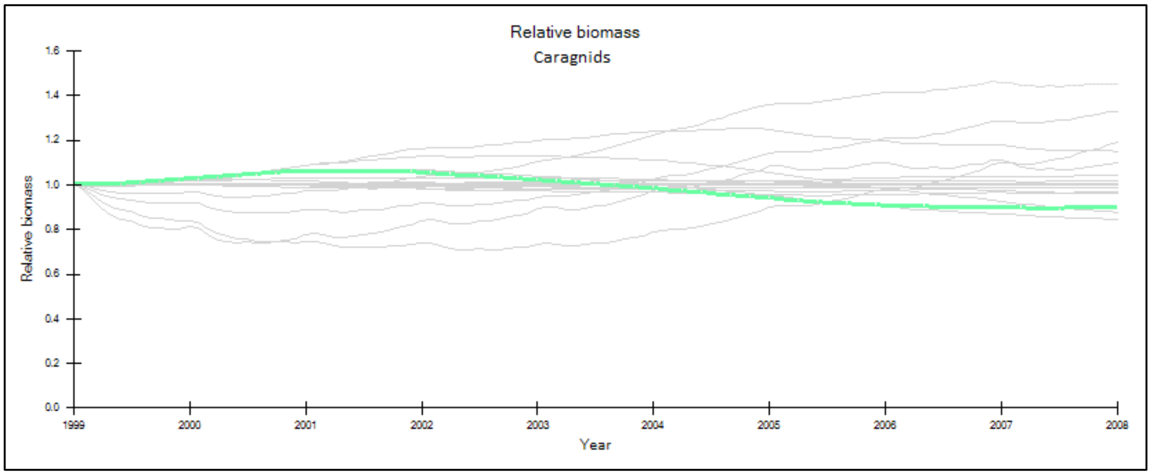

Figure 66 GoN EwE Model Relative Biomass – Carangids

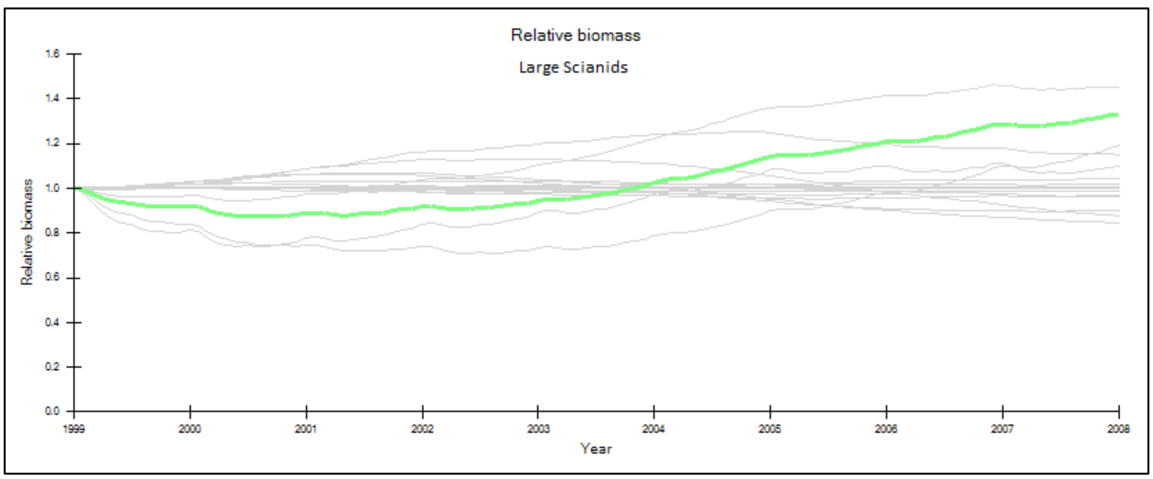

Figure 67 GoN EwE Model Relative Biomass – Large Sciaenids

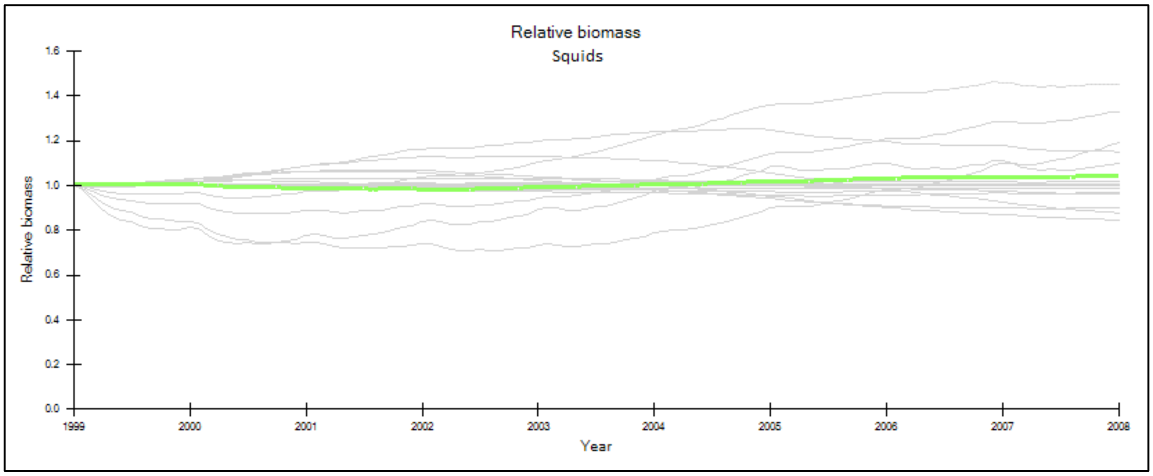

Figure 68 GoN EwE Model Relative Biomass – Squids

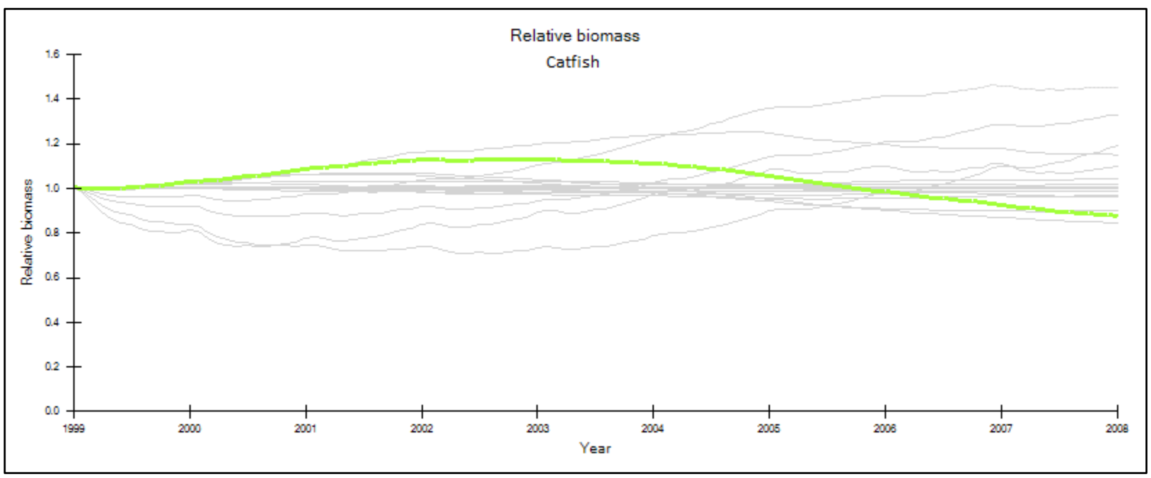

Figure 69 GoN EwE Model Relative Biomass – Catfish

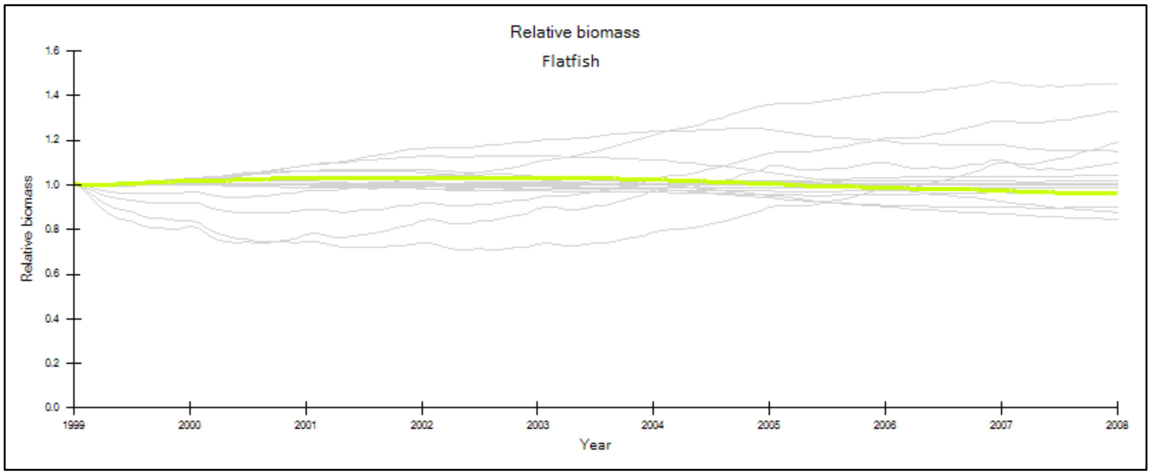

Figure 70 GoN EwE Model Relative Biomass – Flatfish

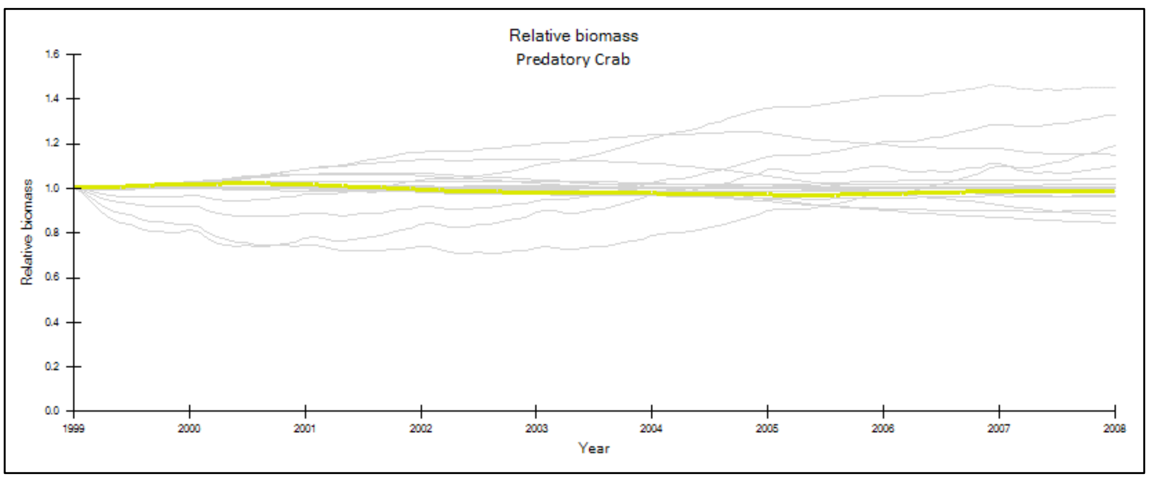

Figure 71 GoN EwE Model Relative Biomass – Predatory Crabs

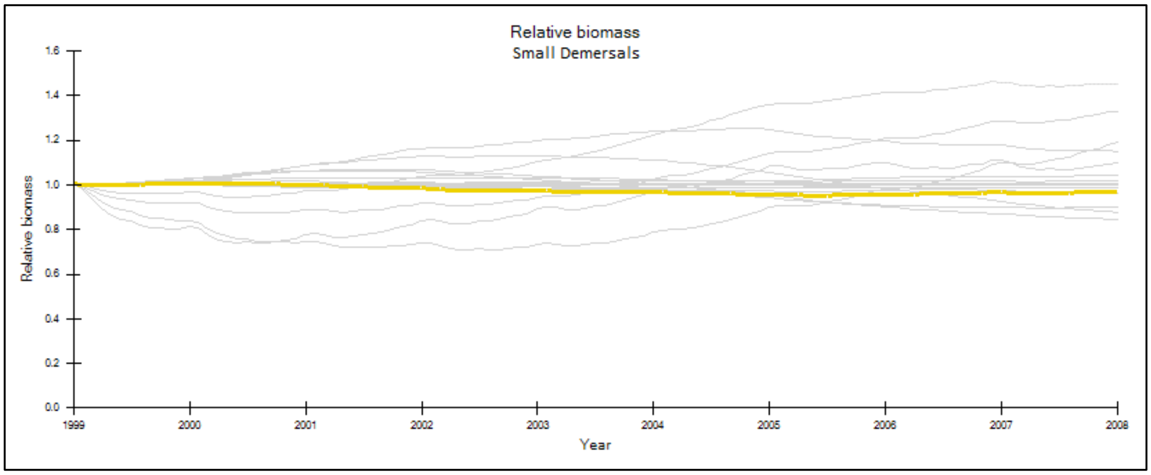

Figure 72 GoN EwE Model Relative Biomass – Small Demersals

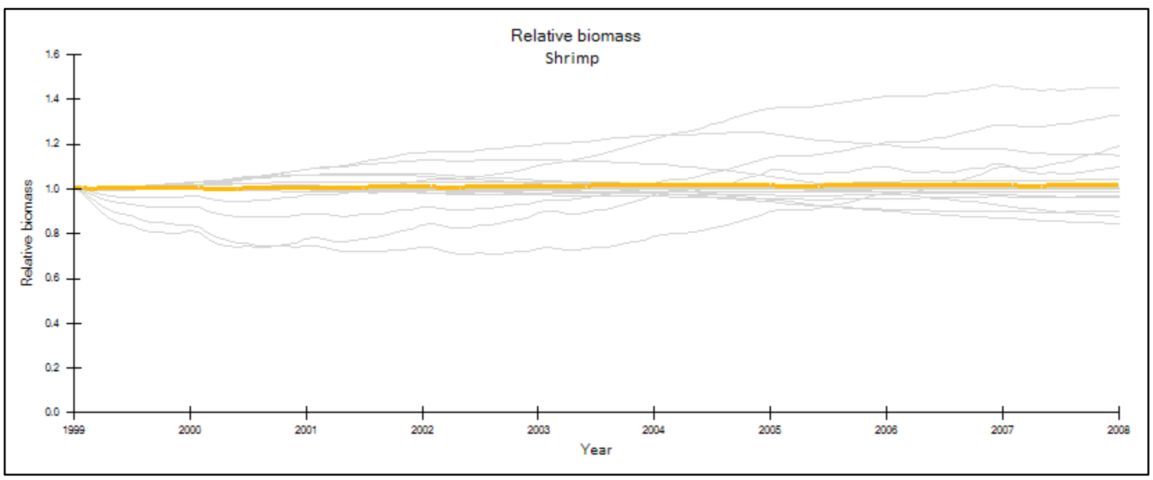

Figure 73 GoN EwE Model Relative Biomass – Shrimps

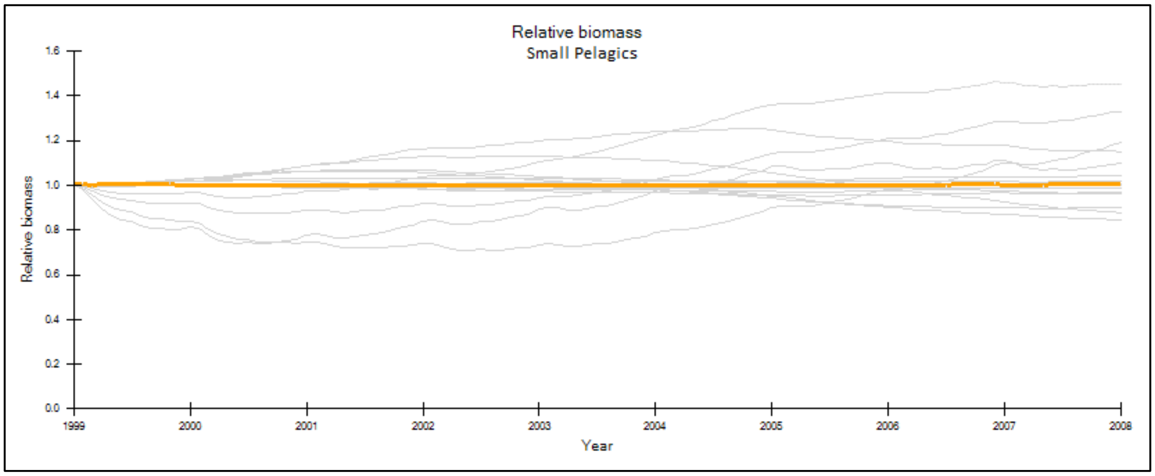

Figure 74 GoN EwE Model Relative Biomass – Small Pelagics

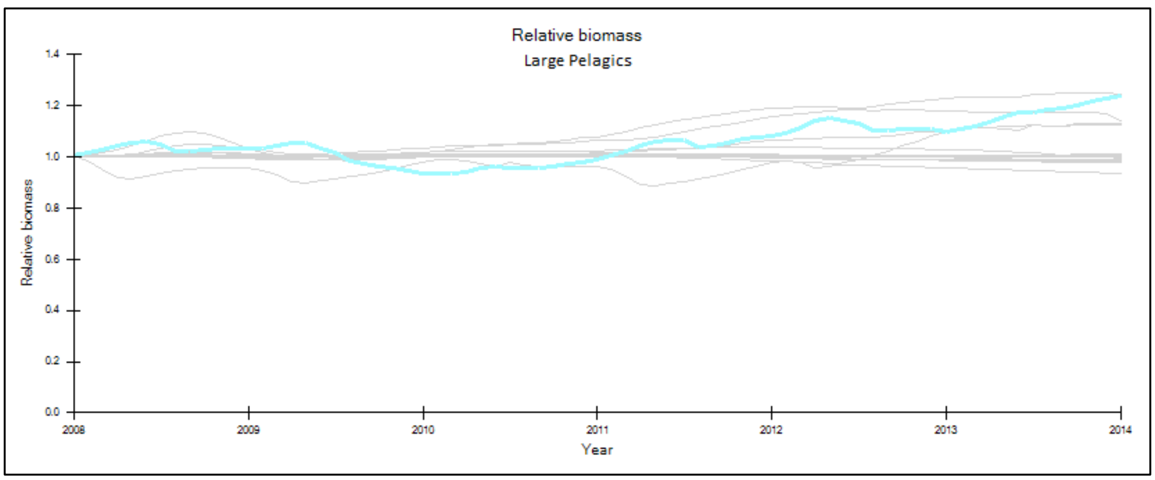

Figure 75 Tárcoles RFMA EwE Model Relative Biomass - Dorado

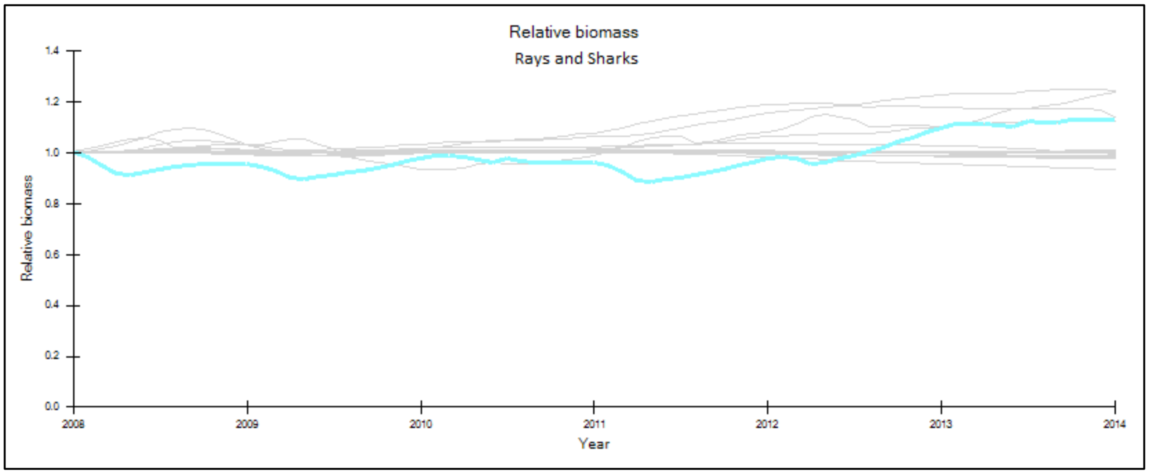

Figure 76 Tárcoles RFMA EwE Model Relative Biomass - Rays and Sharks

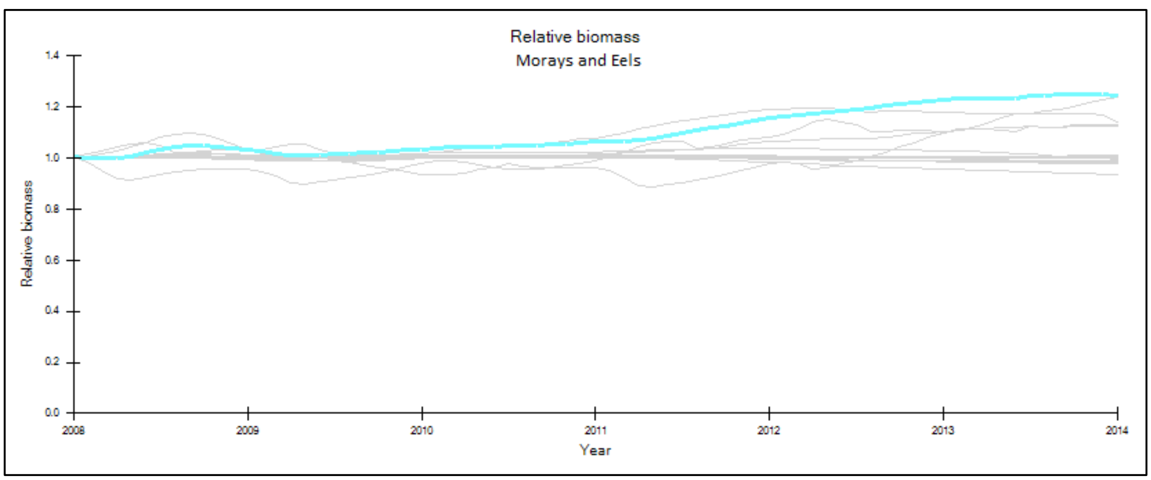

Figure 77 Tárcoles RFMA EwE Model Relative Biomass - Morays and Eels

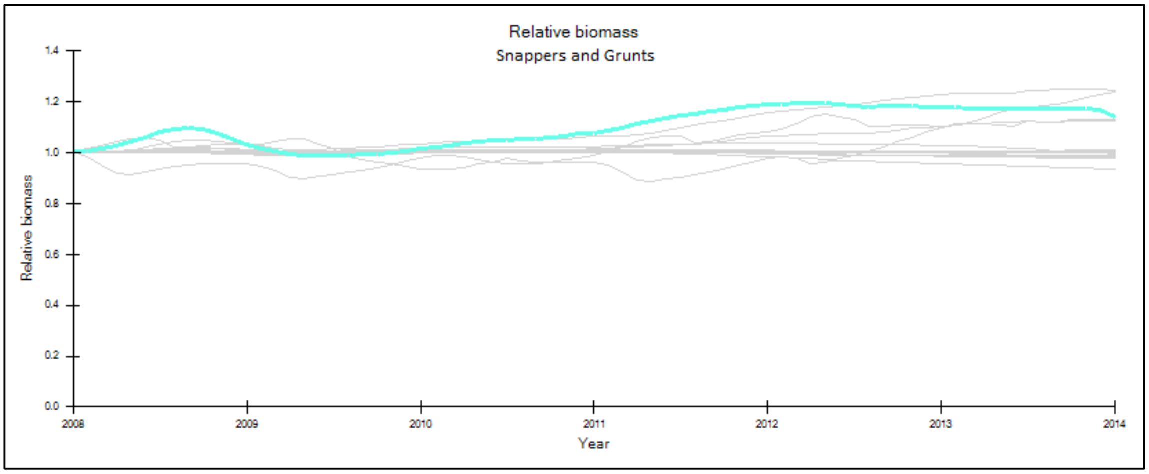

Figure 78 Tárcoles RFMA EwE Model Relative Biomass - Snappers and Grunts

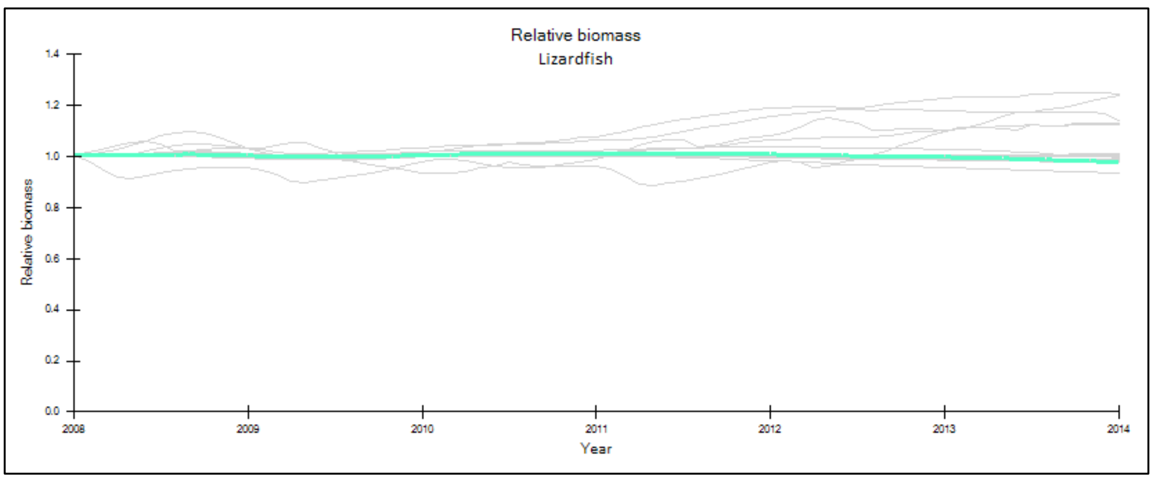

Figure 79 Tárcoles RFMA EwE Model Relative Biomass - Lizardfish

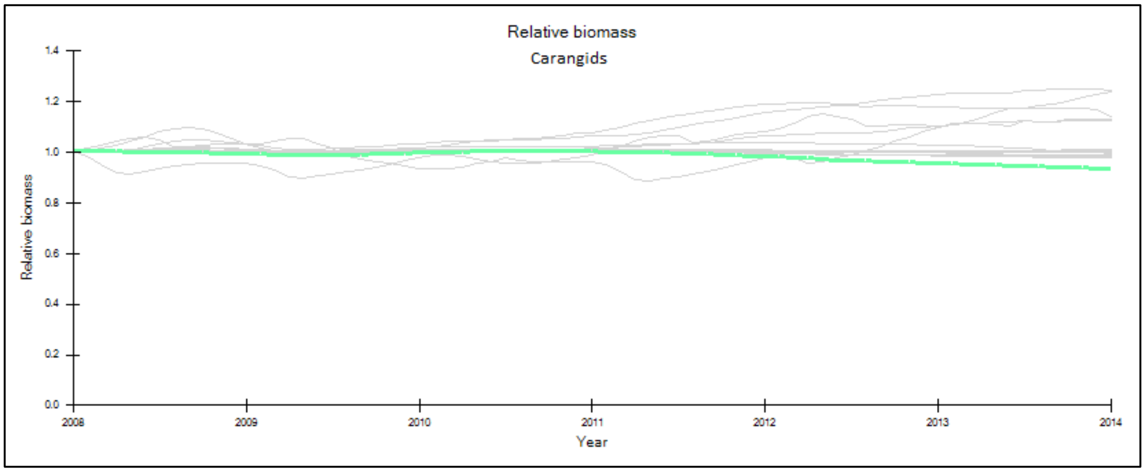

Figure 80 Tárcoles RFMA EwE Model Relative Biomass - Carangids

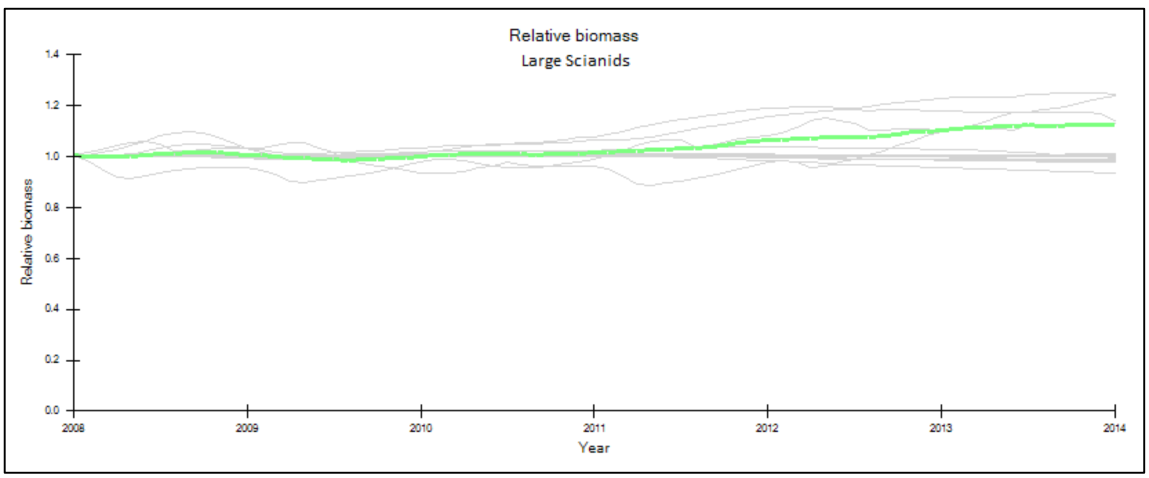

Figure 81 Tárcoles RFMA EwE Model Relative Biomass - Large Sciaenids

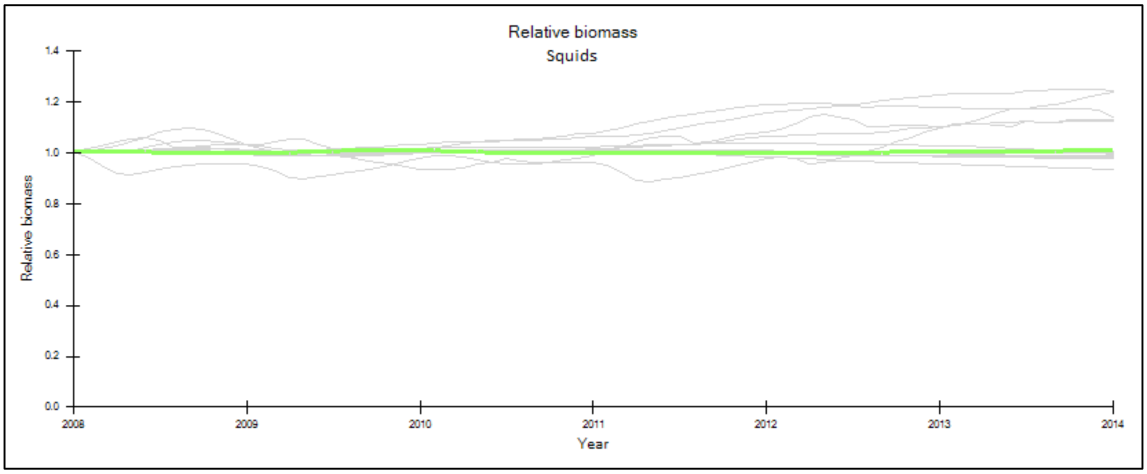

Figure 82 Tárcoles RFMA EwE Model Relative Biomass - Squids

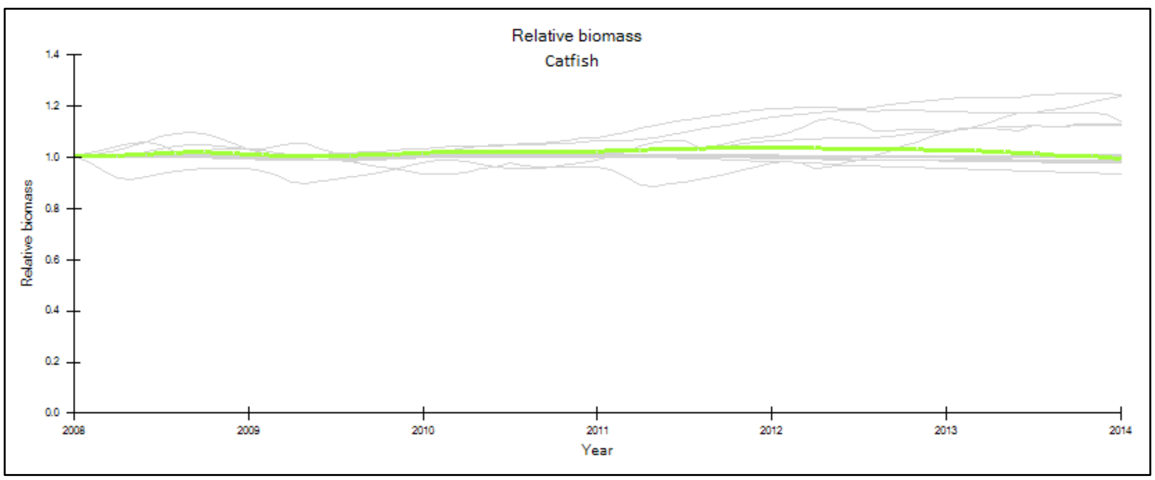

Figure 83 Tárcoles RFMA EwE Model Relative Biomass - Catfish

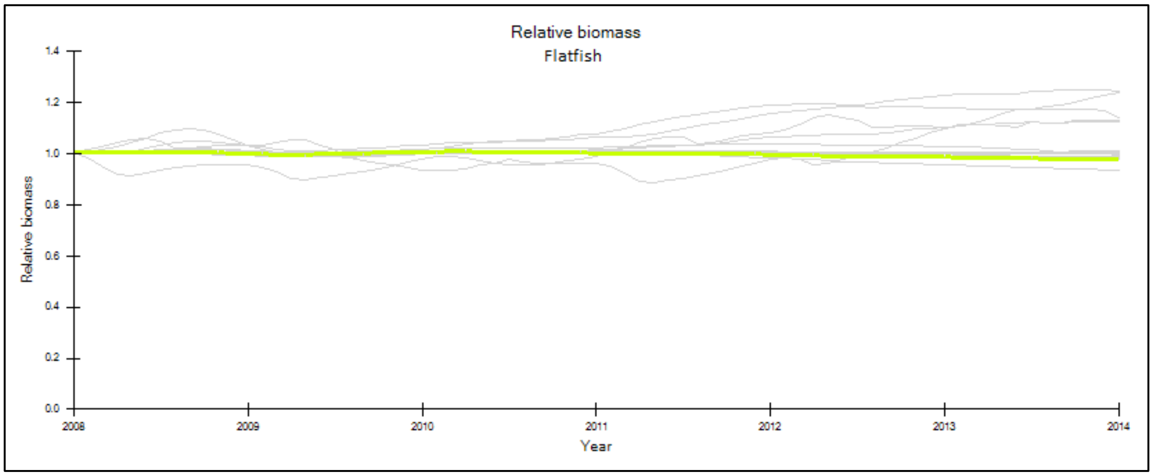

Figure 84 Tárcoles RFMA EwE Model Relative Biomass – Flatfish

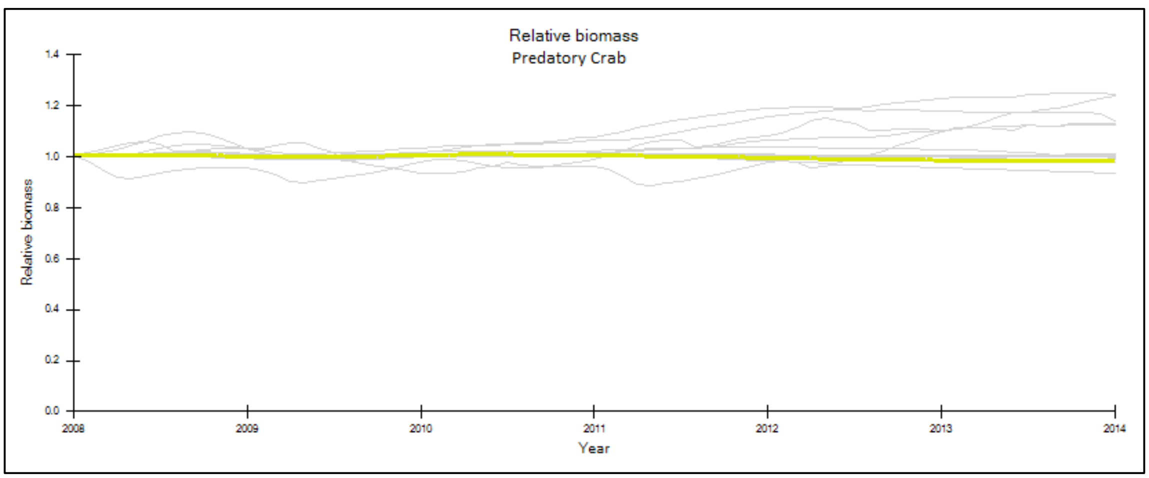

Figure 85 Tárcoles RFMA EwE Model Relative Biomass - Predatory Crabs

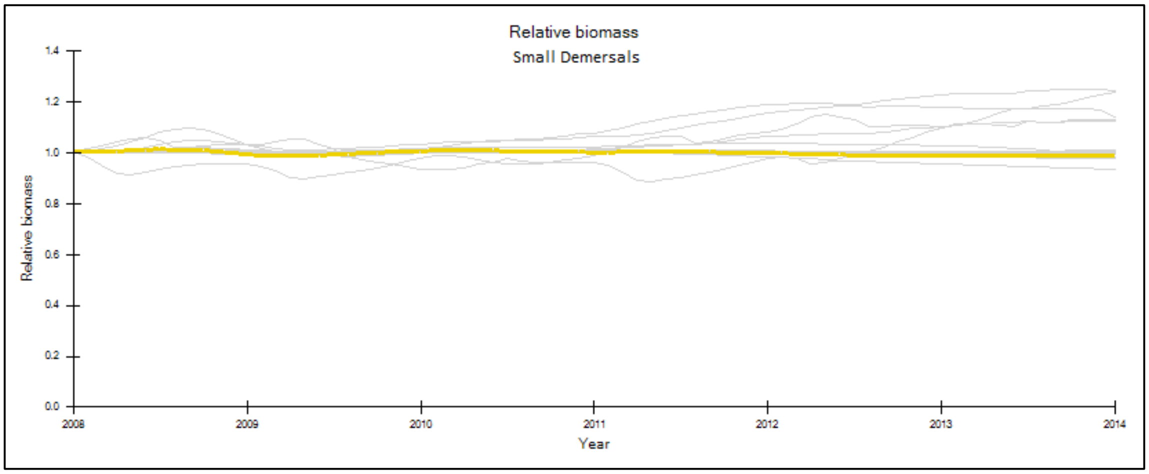

Figure 86 Tárcoles RFMA EwE Model Relative Biomass - Small Demersals

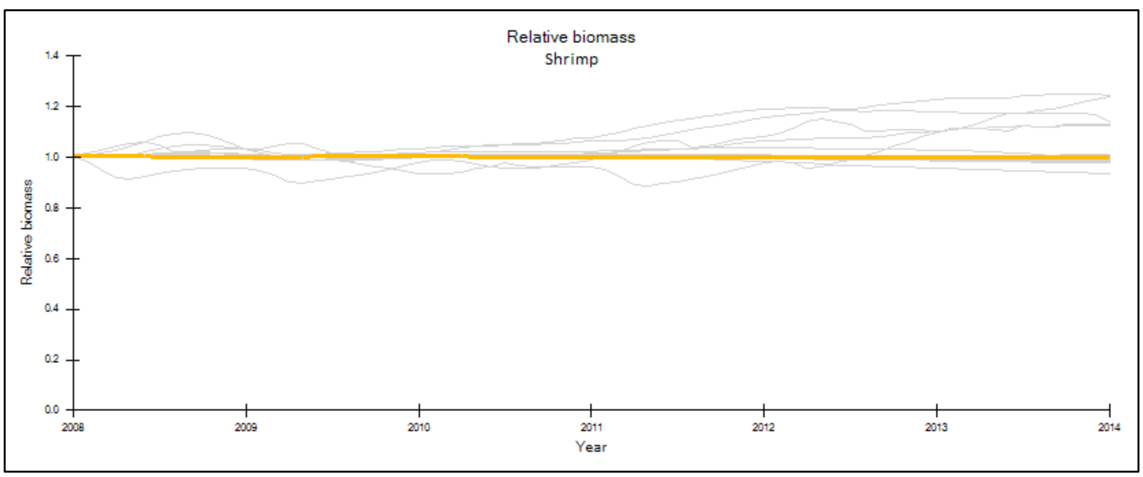

Figure 87 Tárcoles RFMA EwE Model Relative Biomass – Shrimps

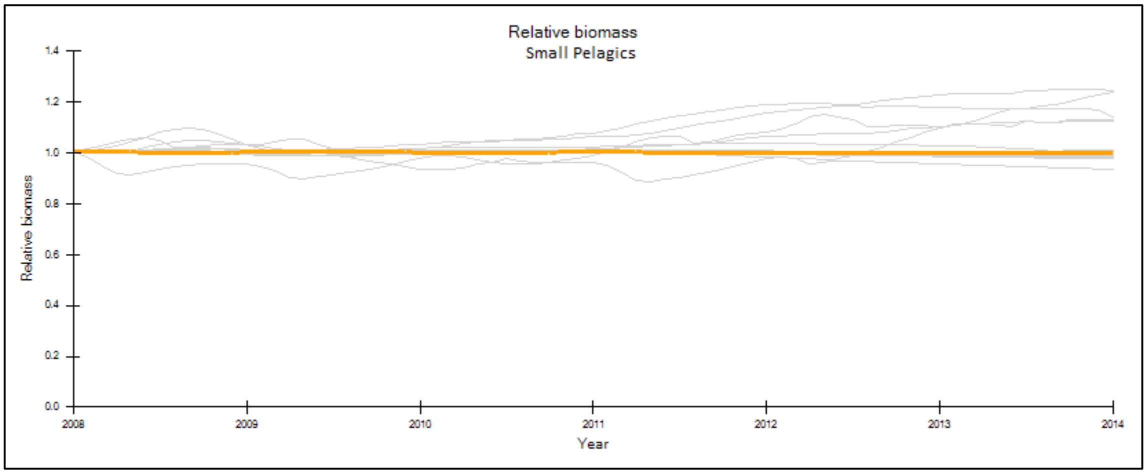

Figure 88 Tárcoles RFMA EwE Model Relative Biomass - Small Pelagics

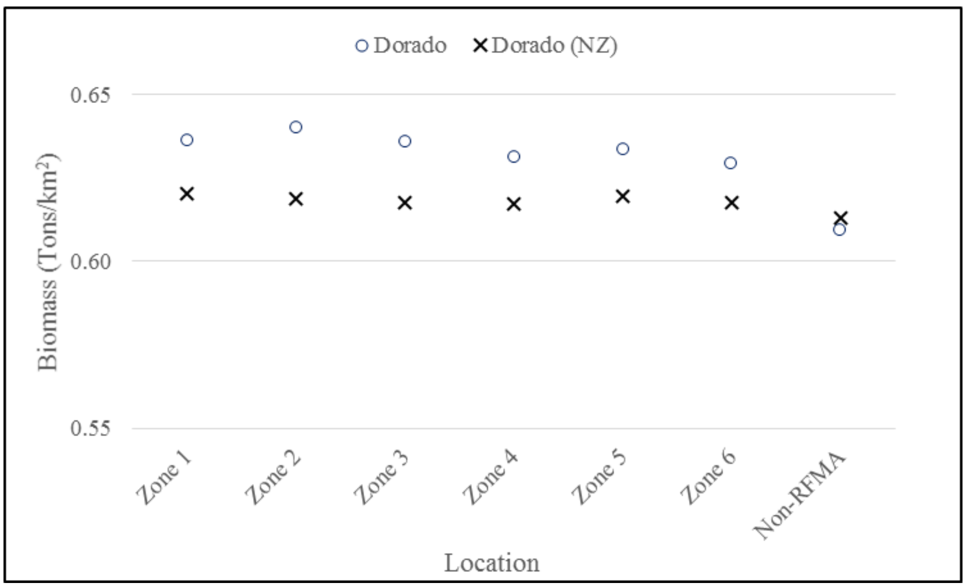

Figure 89 Biomass of Dorado. Baseline Trawl Effort (Ecospace Output). Estimate of Zoning and No-Zoning (ZN) by location.

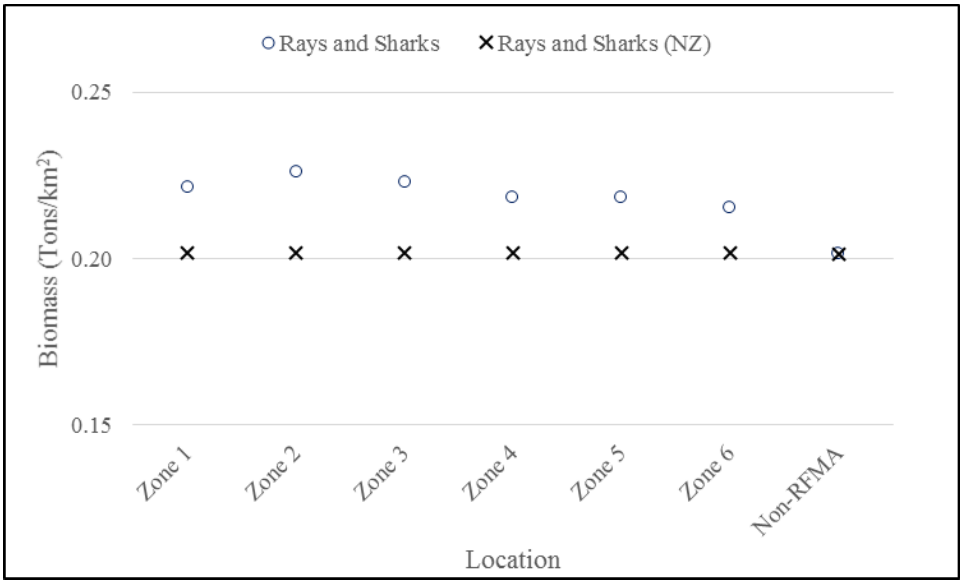

Figure 90 Biomass of Rays and Sharks. Baseline Trawl Effort (Ecospace Output). Estimate of Zoning and No-Zoning (ZN) by location.

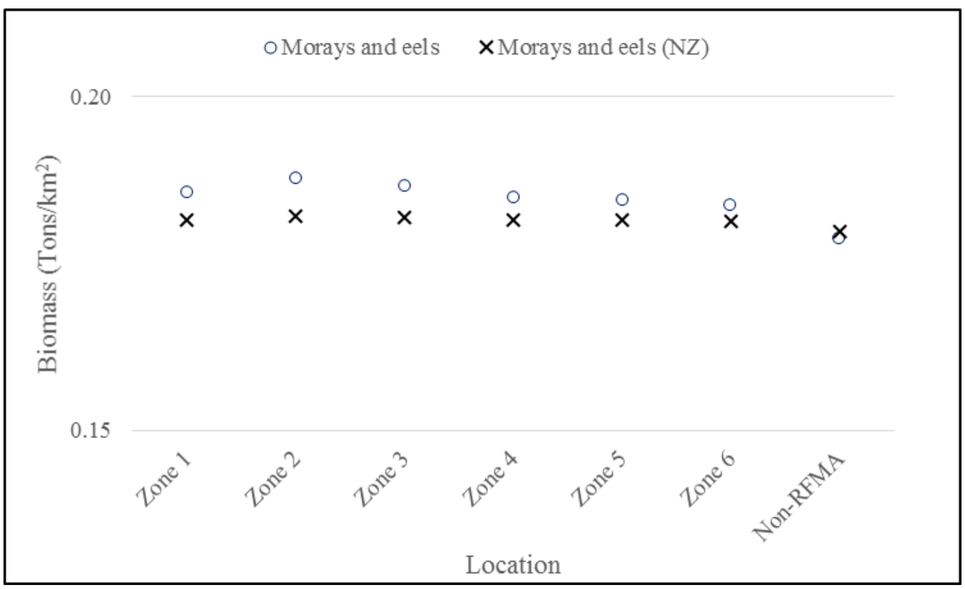

Figure 91 Biomass of of Morays and Eels. Baseline Trawl Effort (Ecospace Output). Estimate of Zoning and No-Zoning (ZN) by location.

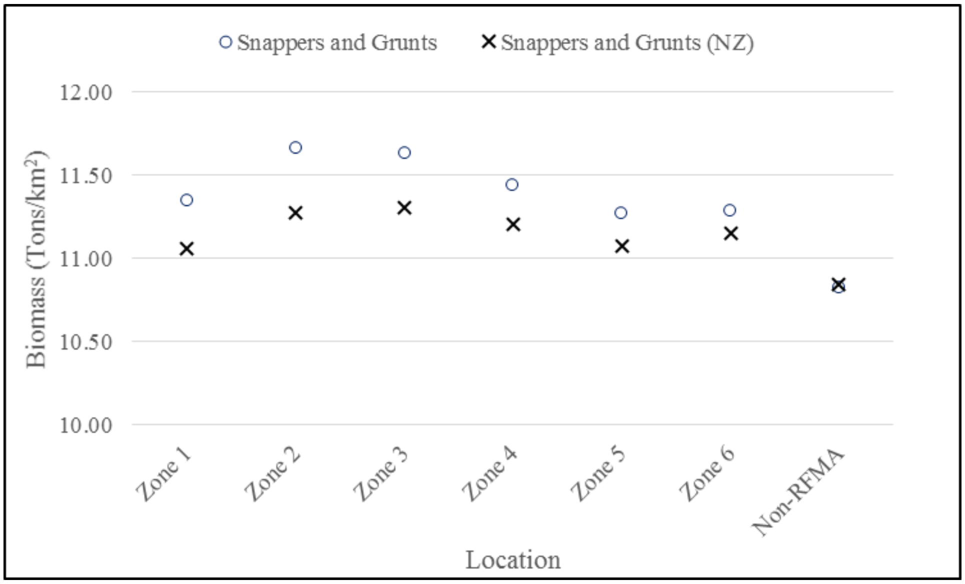

Figure 92 Biomass of Snappers and Grunts. Baseline Trawl Effort (Ecospace Output). Estimate of Zoning and No-Zoning (ZN) by location.

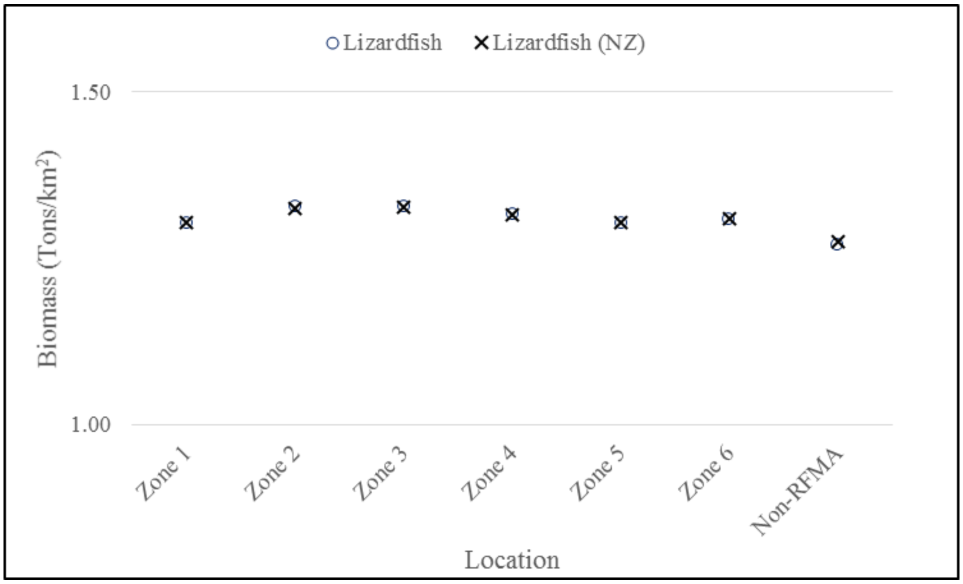

Figure 93 Biomass of Lizardfish. Baseline Trawl Effort (Ecospace Output). Estimate of Zoning and No-Zoning (ZN) by location.

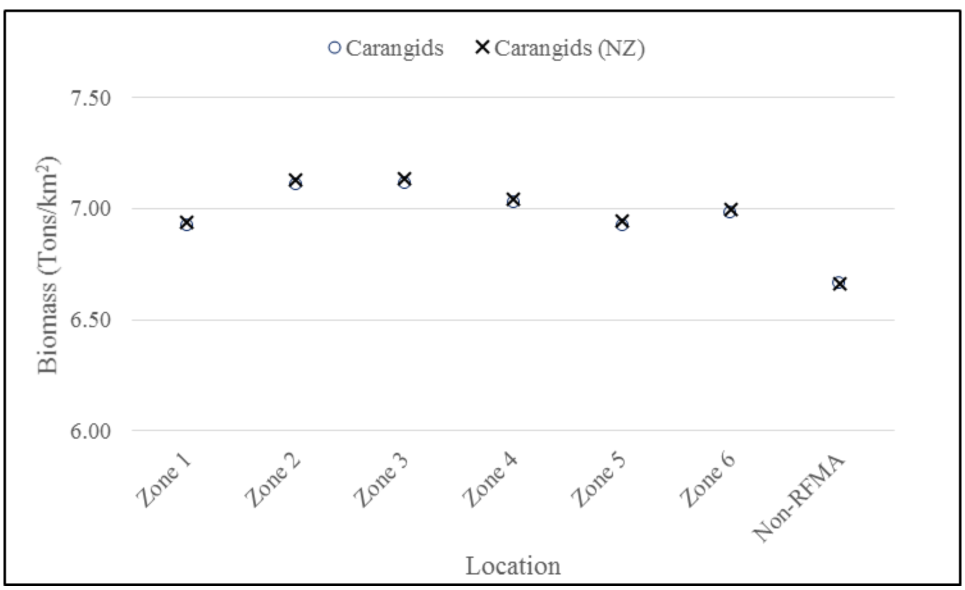

Figure 94 Biomass of Carngids. Baseline Trawl Effort (Ecospace Output). Estimate of Zoning and No-Zoning (ZN) by location.

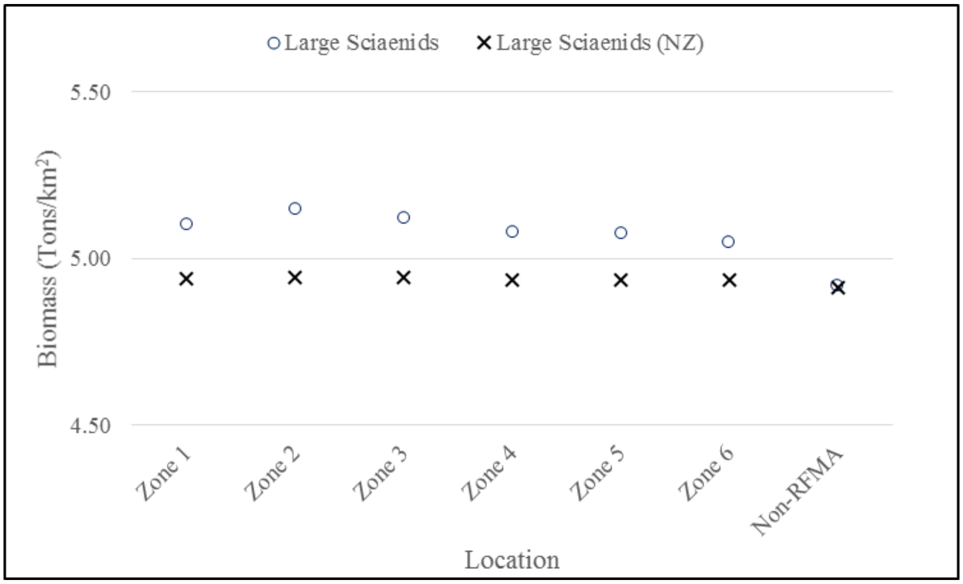

Figure 95 Biomass of Large Sciaenids. Baseline Trawl Effort (Ecospace Output). Estimate of Zoning and No-Zoning (ZN) by location.

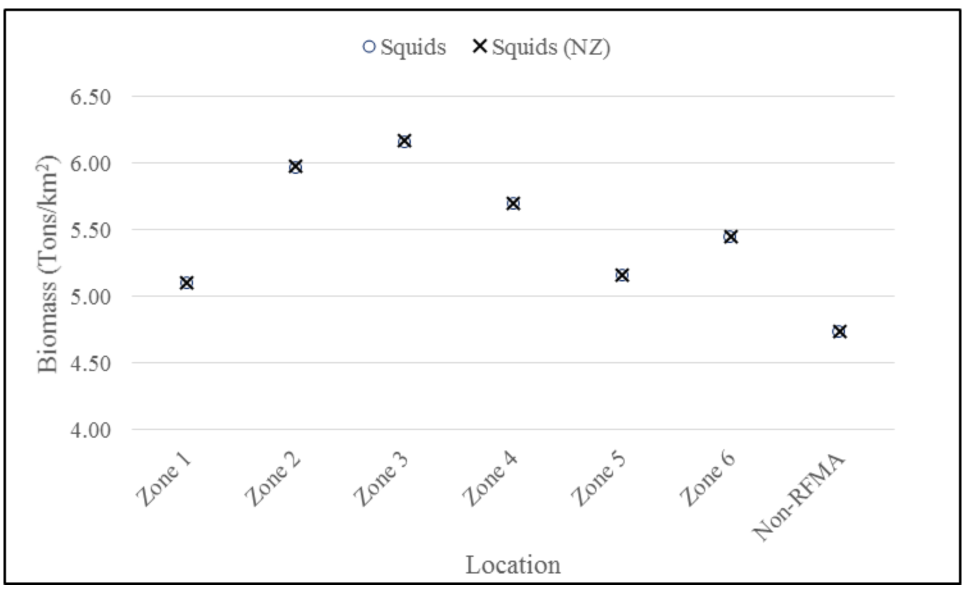

Figure 96 Biomass of Squids. Baseline Trawl Effort (Ecospace Output). Estimate of Zoning and No-Zoning (ZN) by location.

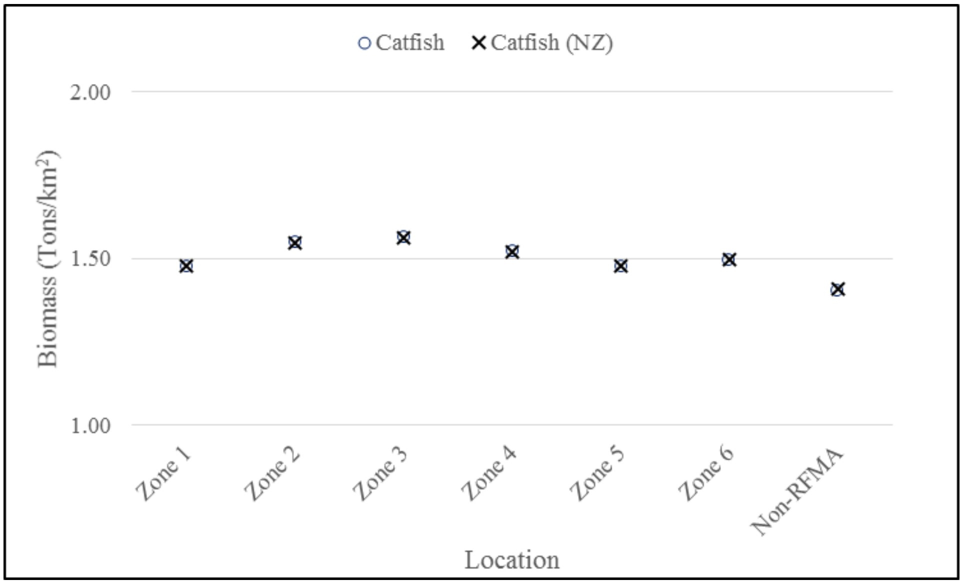

Figure 97 Biomass of Catfish. Baseline Trawl Effort (Ecospace Output). Estimate of Zoning and No-Zoning (ZN) by location.

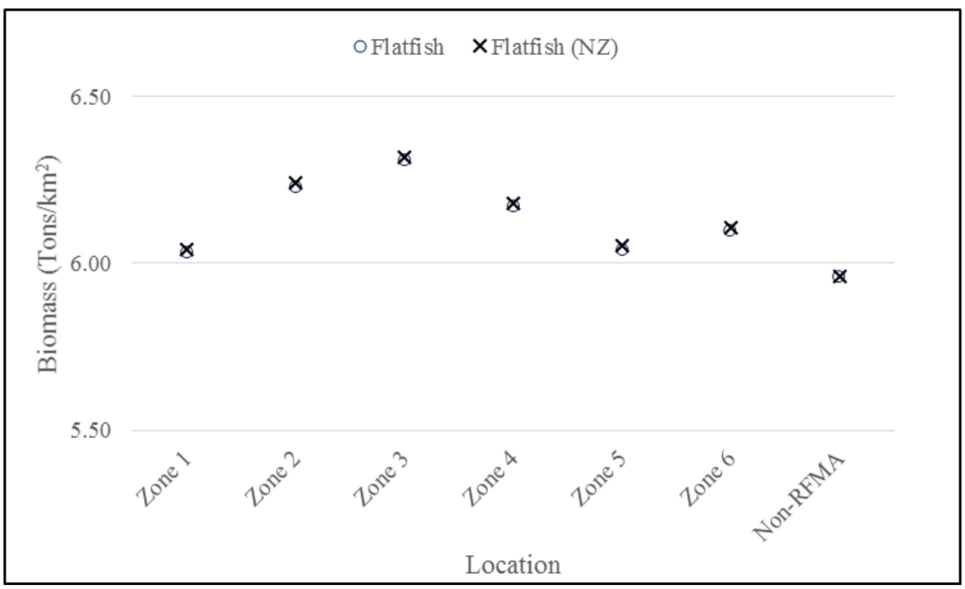

Figure 98 Biomass of Flatfish. Baseline Trawl Effort (Ecospace Output). Estimate of Zoning and No-Zoning (ZN) by location.

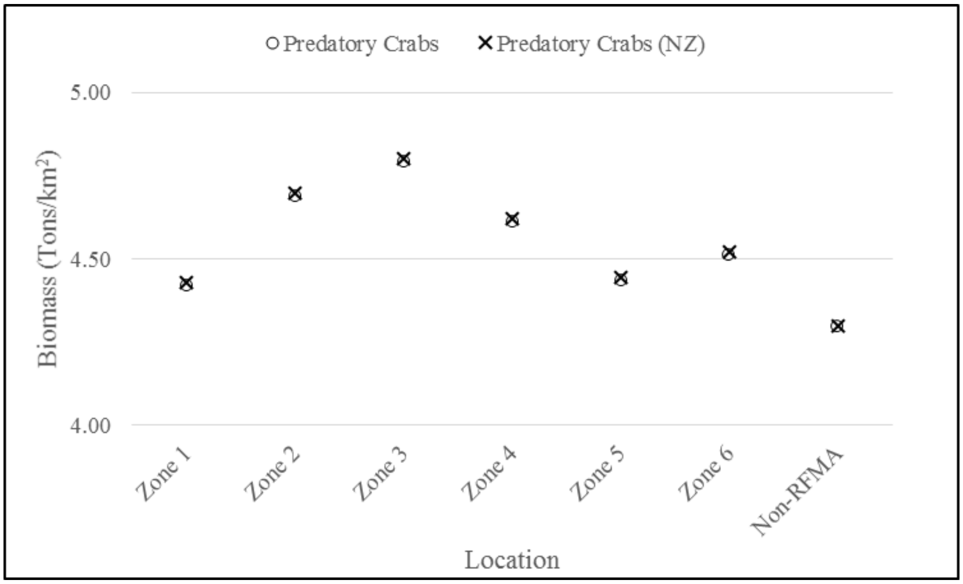

Figure 99 Biomass of Predatory Crab. Baseline Trawl Effort (Ecospace Output). Estimate of Zoning and No-Zoning (ZN) by location.

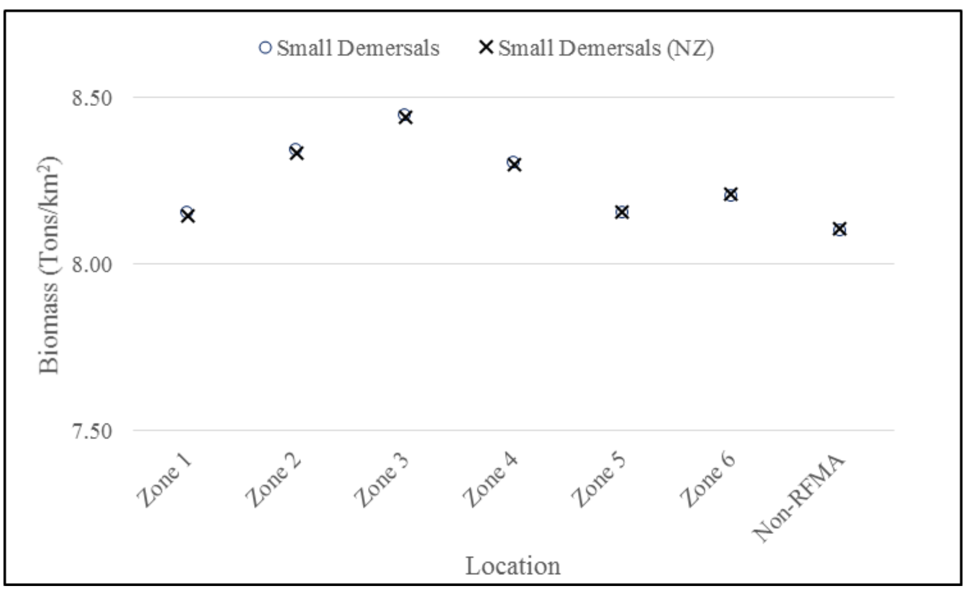

Figure 100 Biomass of Small Demersals. Baseline Trawl Effort (Ecospace Output). Estimate of Zoning and No-Zoning (ZN) by location.

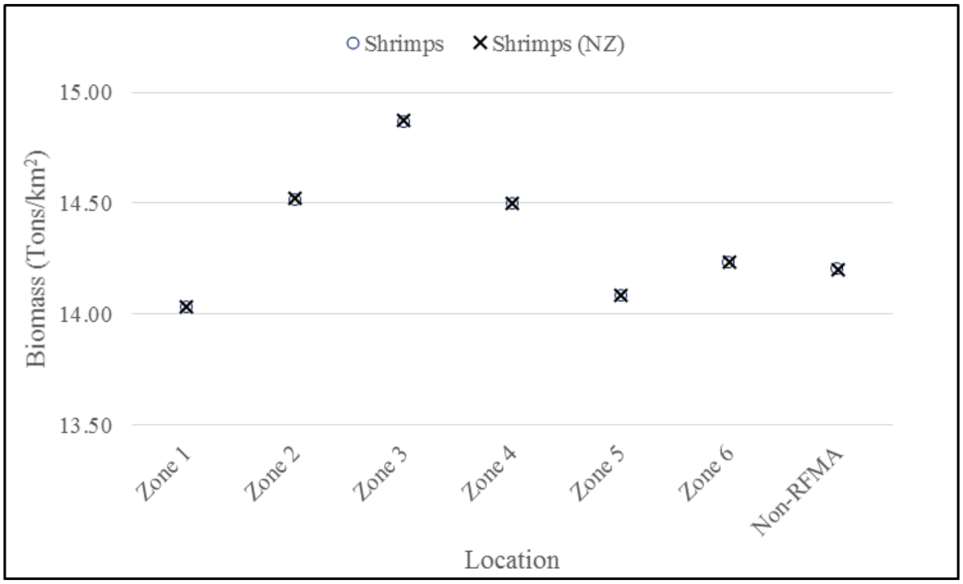

Figure 101 Biomass of Shrimps. Baseline Trawl Effort (Ecospace Output). Estimate of Baseline Trawl Effort (Ecospace Output). Estimate of Zoning and No-Zoning (ZN) by location.

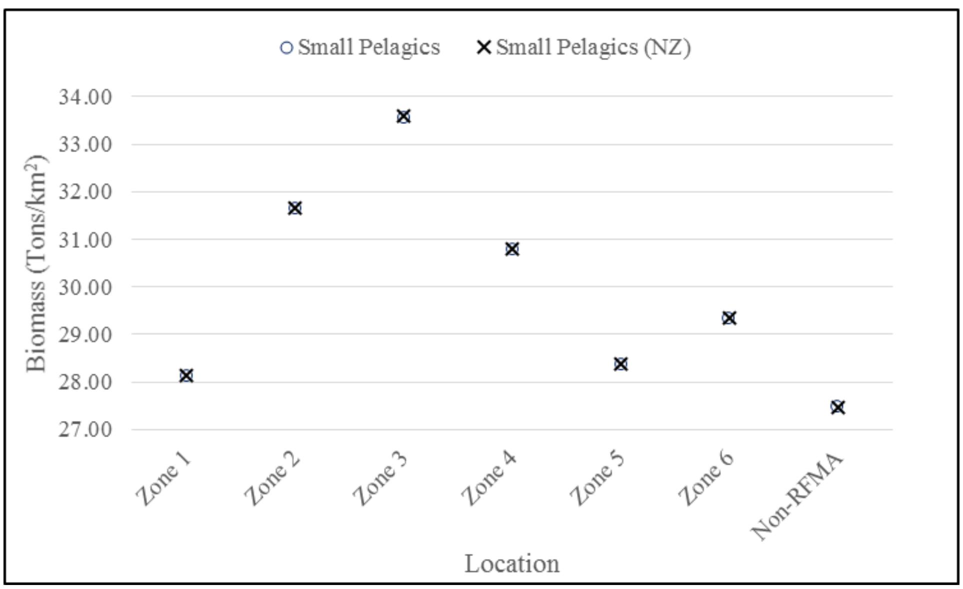

Figure 102 Biomass of Small Pelagics. Baseline Trawl Effort (Ecospace Output). Estimate of Zoning and No-Zoning (ZN) by location.

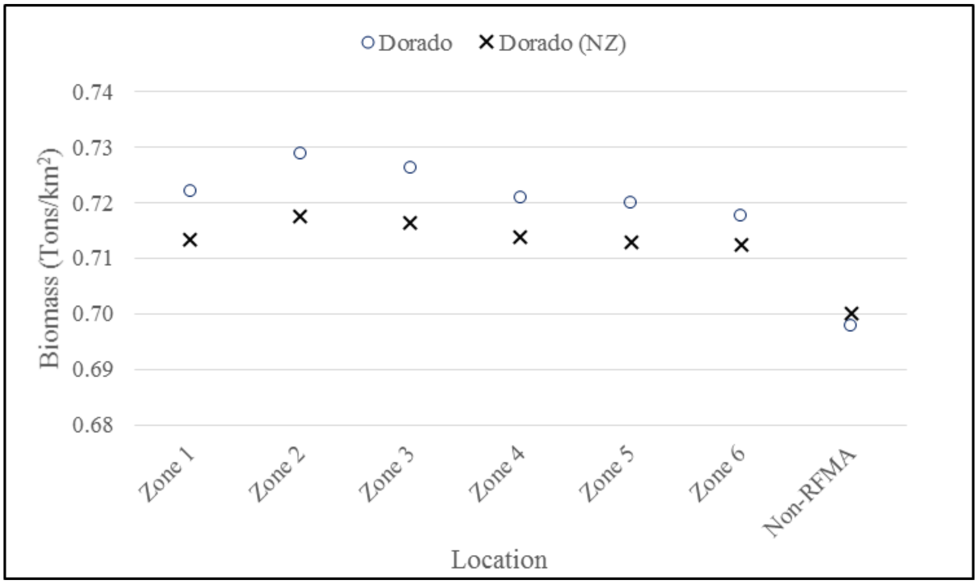

Figure 103 Biomass of Dorado. Reduced Trawl Effort (-50%) Policy (Ecospace Output). Estimate of Zoning and No-Zoning (NZ) by location.

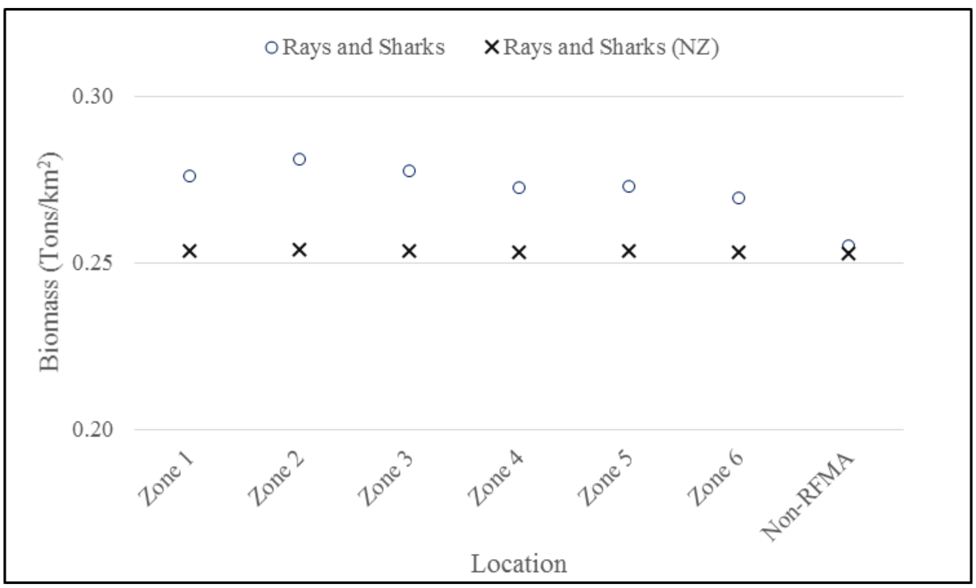

Figure 104 Biomass of Rays and Sharks. Reduced Trawl Effort (-50%) Policy (Ecospace Output). Estimate of Zoning and No-Zoning (NZ) by location.

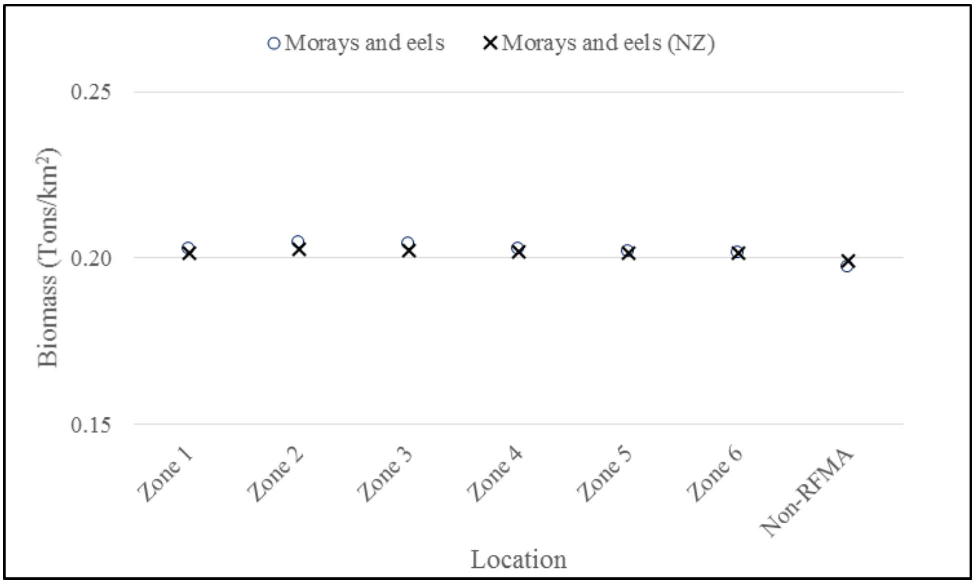

Figure 105 Biomass of of Morays and Eels. Reduced Trawl Effort (-50%) Policy (Ecospace Output). Estimate of Zoning and No-Zoning (NZ) by location.

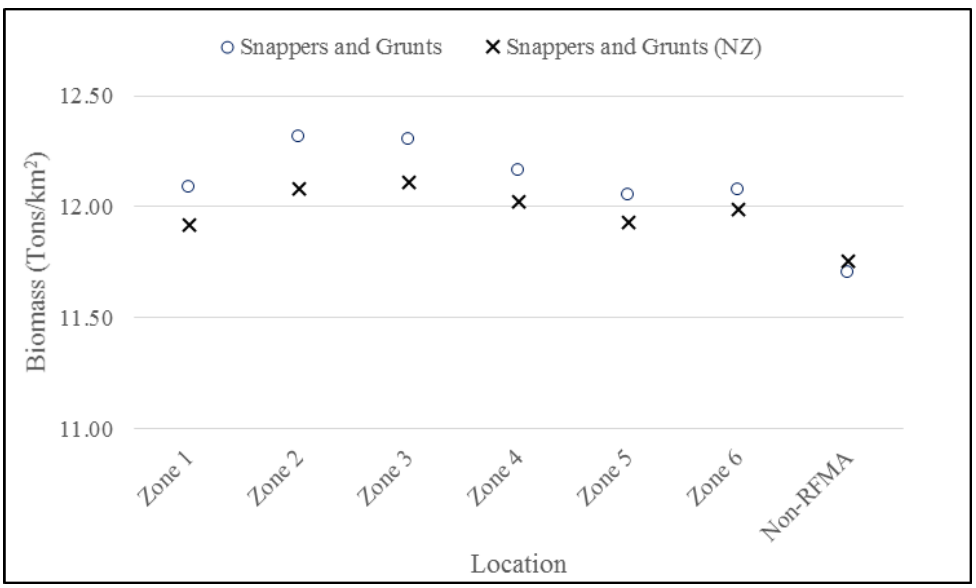

Figure 106 Biomass of Snappers and Grunts. Reduced Trawl Effort (-50%) Policy (Ecospace Output). Estimate of Zoning and No-Zoning (NZ) by location.

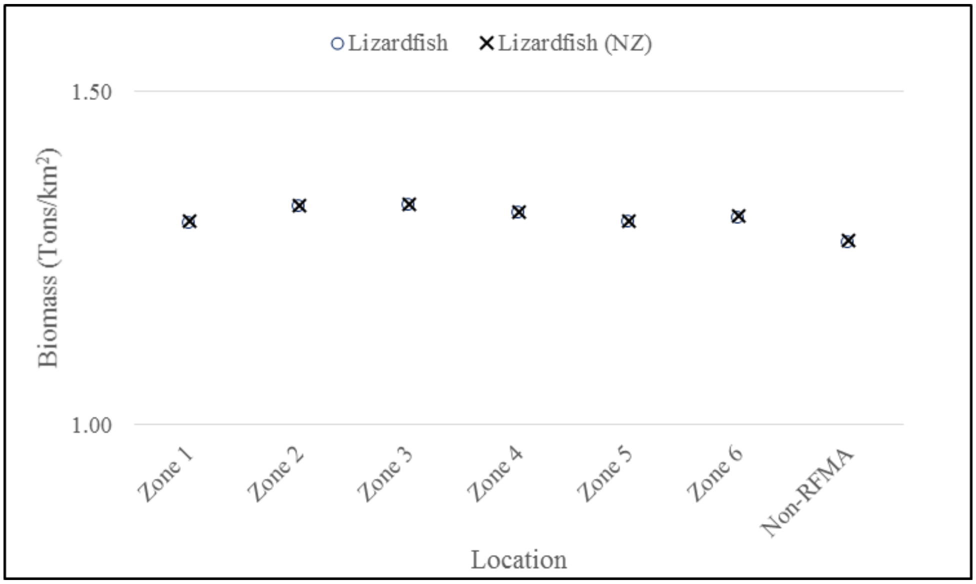

Figure 107 Biomass of Lizardfish. Reduced Trawl Effort (-50%) Policy (Ecospace Output). Estimate of Zoning and No-Zoning (NZ) by location.

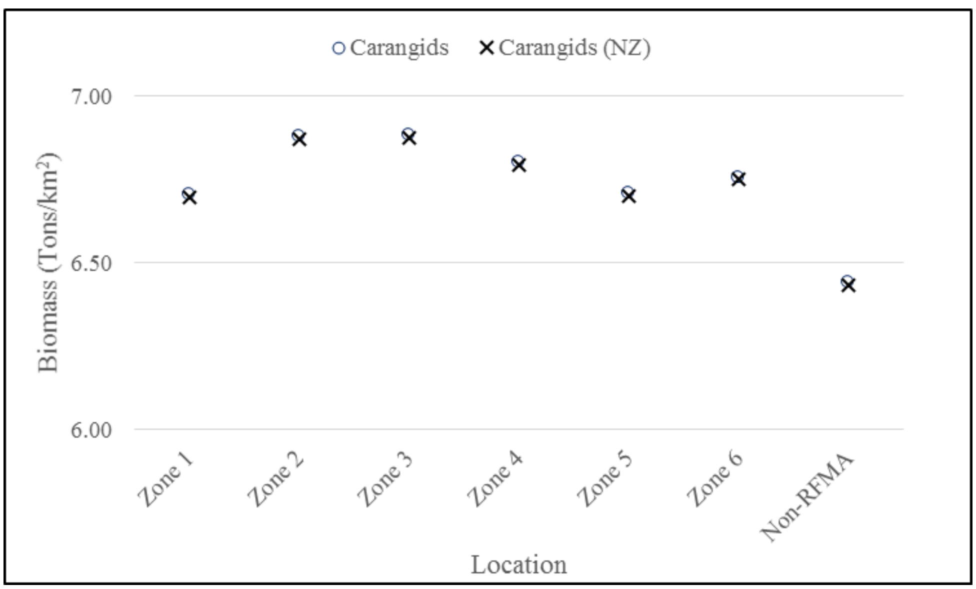

Figure 108 Biomass of Carngids. Reduced Trawl Effort (-50%) Policy (Ecospace Output). Estimate of Zoning and No-Zoning (NZ) by location.

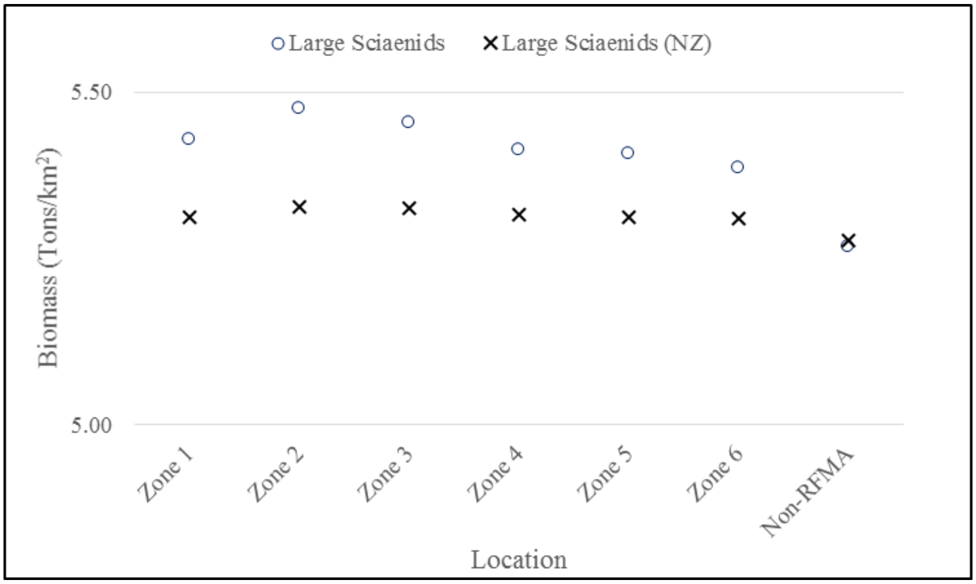

Figure 109 Biomass of Large Sciaenids. Reduced Trawl Effort (-50%) Policy (Ecospace Output). Estimate of Zoning and No-Zoning (NZ) by location.

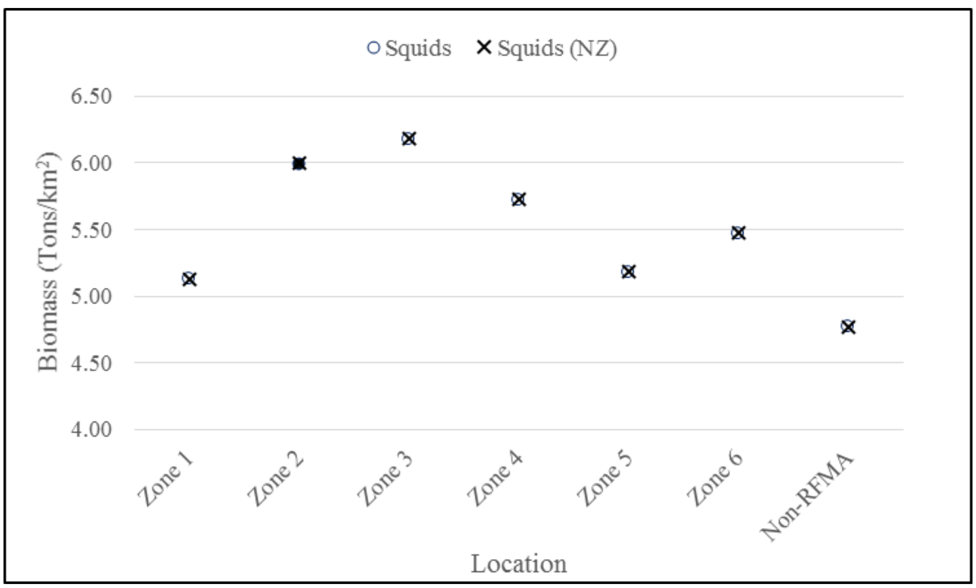

Figure 110 Biomass of Squids. Reduced Trawl Effort (-50%) Policy (Ecospace Output). Estimate of Zoning and No-Zoning (NZ) by location.

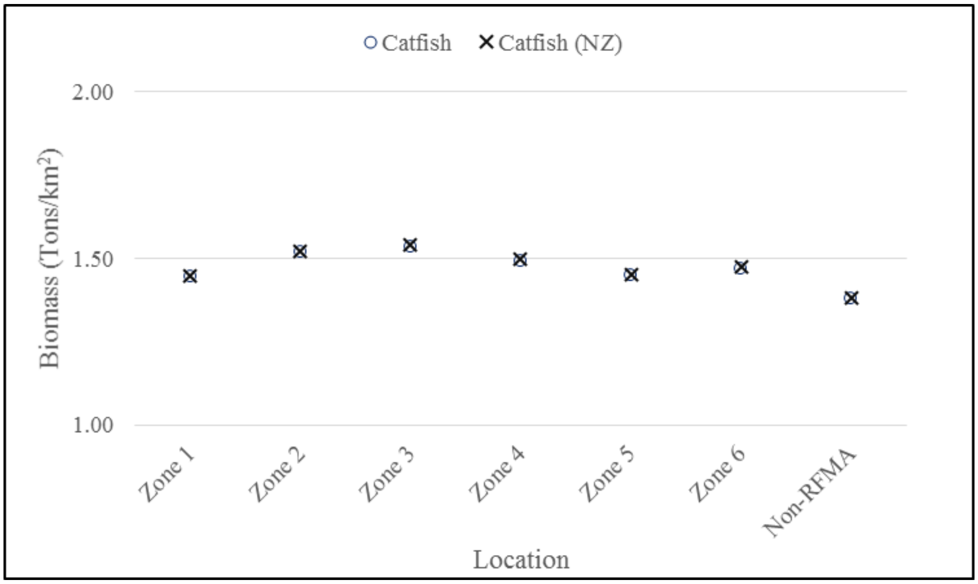

Figure 111 Biomass of Catfish. Reduced Trawl Effort (-50%) Policy (Ecospace Output). Estimate of Zoning and No-Zoning (NZ) by location.

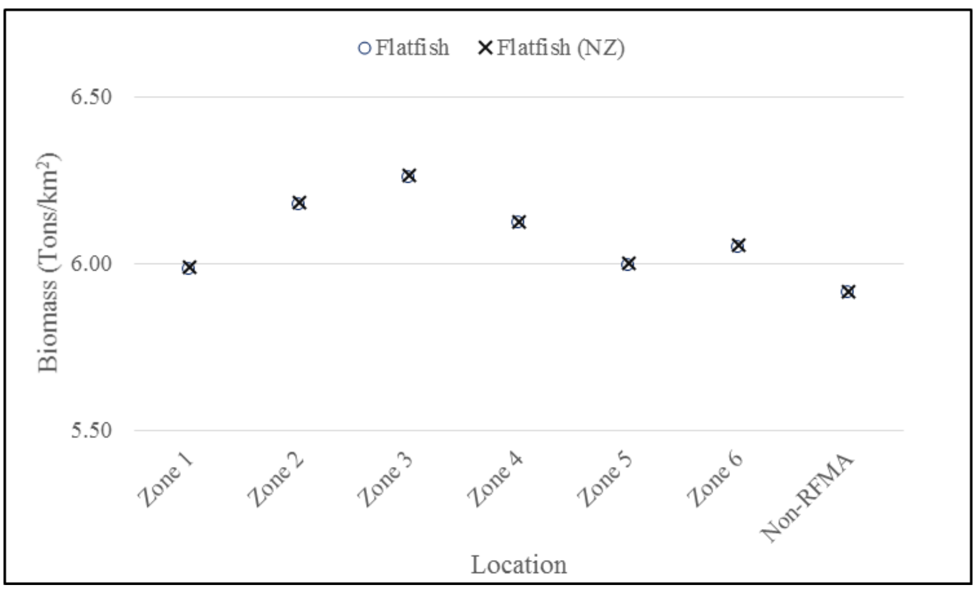

Figure 112 Biomass of Flatfish. Reduced Trawl Effort (-50%) Policy (Ecospace Output). Estimate of Zoning and No-Zoning (NZ) by location.

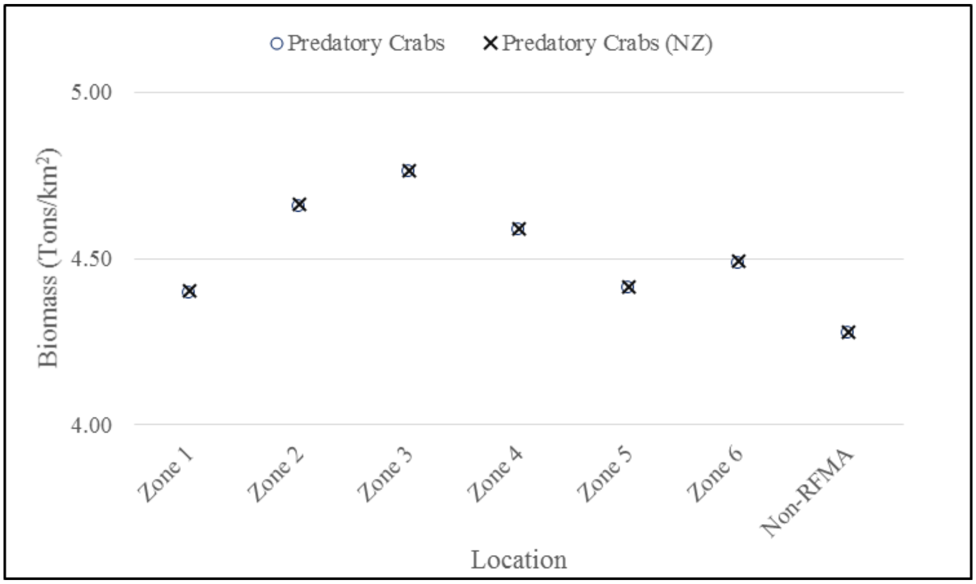

Figure 113 Biomass of Predatory Crab. Reduced Trawl Effort (-50%) Policy (Ecospace Output). Estimate of Zoning and No-Zoning (NZ) by location.

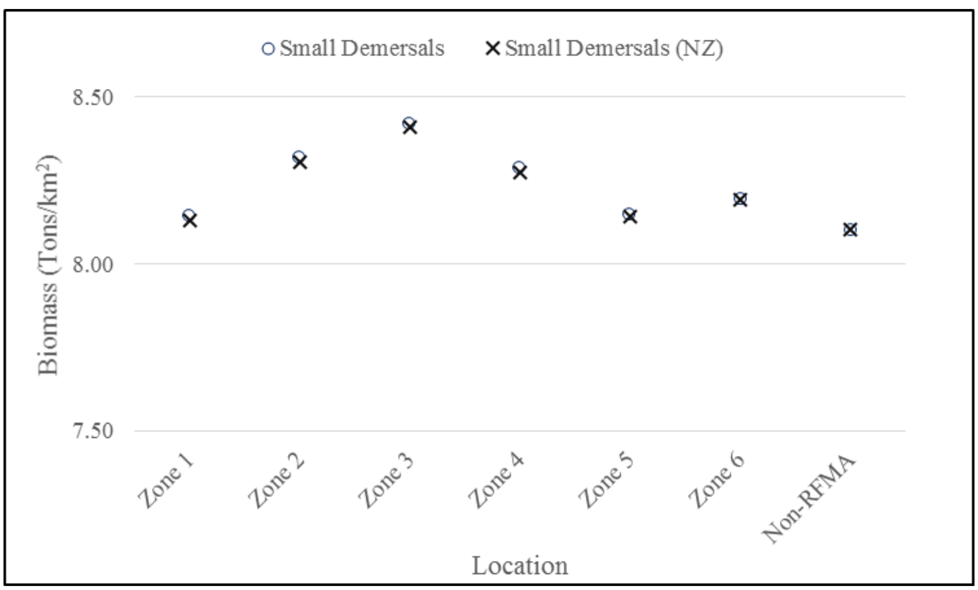

Figure 114 Biomass of Small Demersals. Reduced Trawl Effort (-50%) Policy (Ecospace Output). Estimate of Zoning and No-Zoning (NZ) by location.

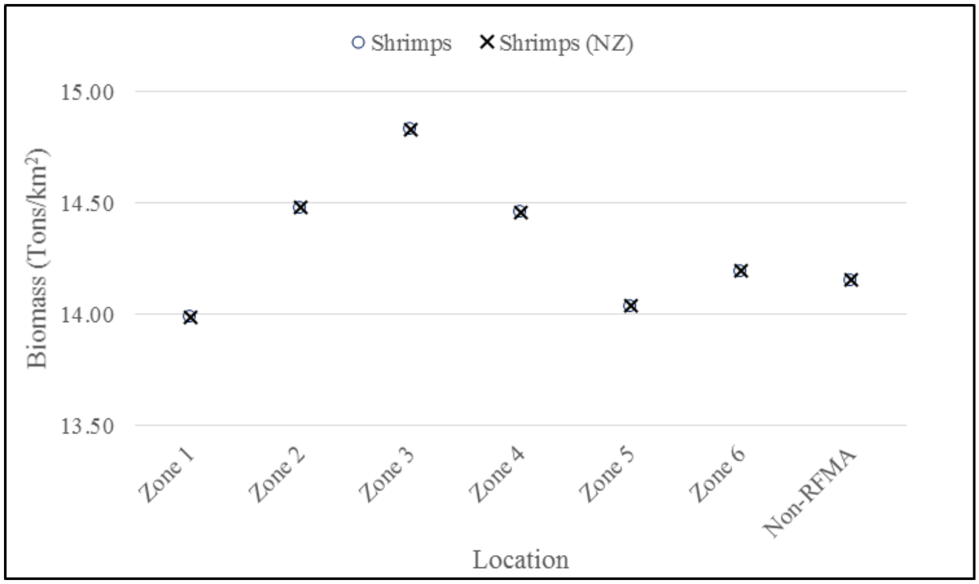

Figure 115 Biomass of Shrimps. Reduced Trawl Effort (-50%) Policy (Ecospace Output). Estimate of Zoning and No-Zoning (NZ) by location.

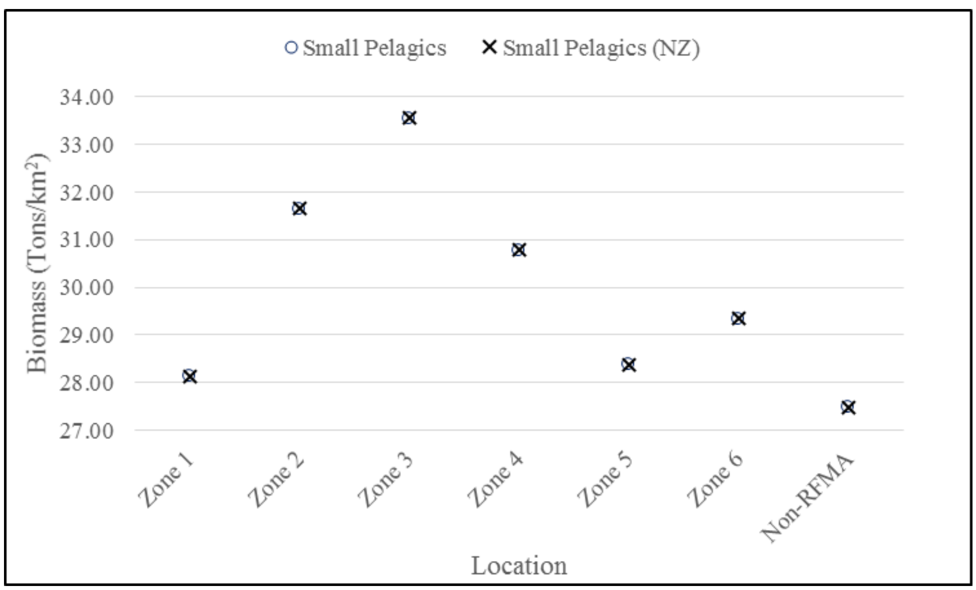

Figure 116 Biomass of Small Pelagics. Reduced Trawl Effort (-50%) Policy (Ecospace Output). Estimate of Zoning and No-Zoning (NZ) by location.

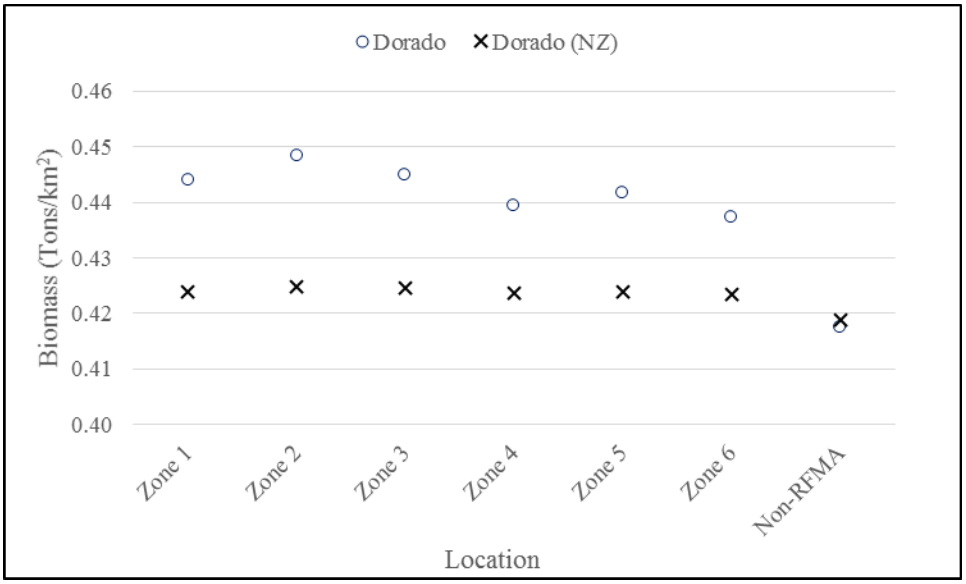

Figure 117 Biomass of Dorado. Increased Trawl Effort (+100%) Policy (Ecospace Output). Estimate of Zoning and No-Zoning (NZ) by location.

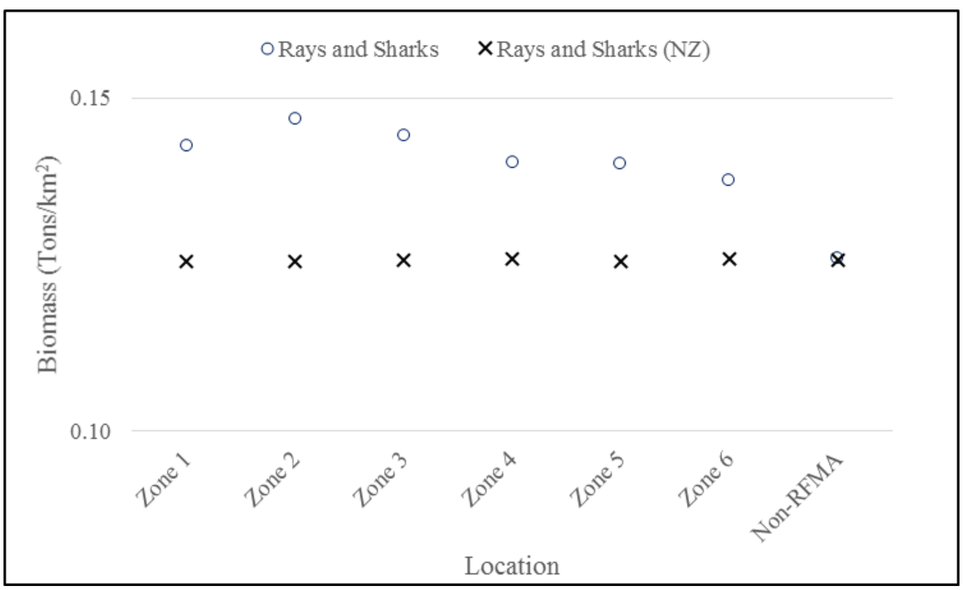

Figure 118 Biomass of of Rays and Sharks. Increased Trawl Effort (+100%) Policy (Ecospace Output). Estimate of Zoning and No-Zoning (NZ) by location.

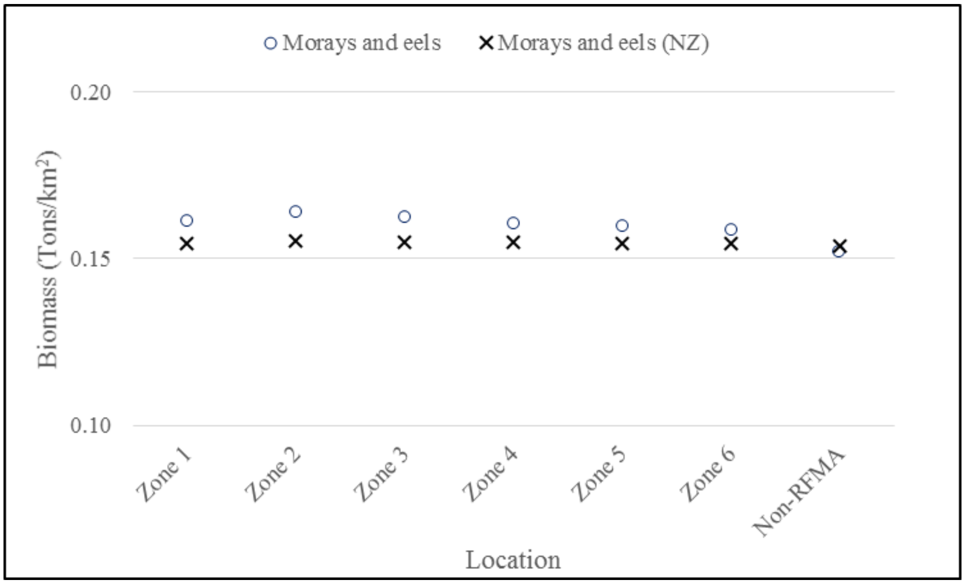

Figure 119 Biomass of of Morays and Eels. Increased Trawl Effort (+100%) Policy (Ecospace Output). Estimate of Zoning and No-Zoning (NZ) by location.

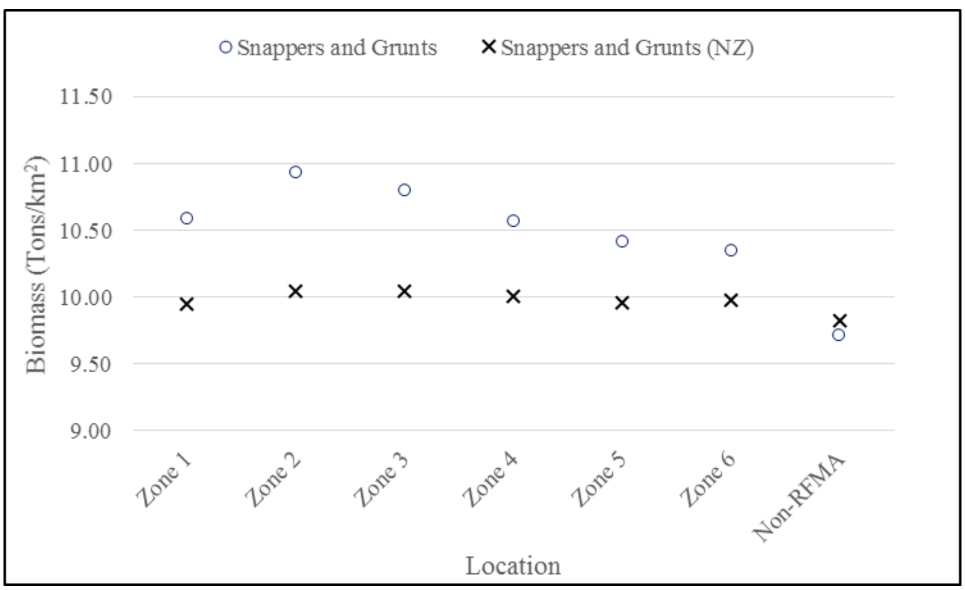

Figure 120 Biomass of Snappers and Grunts. Increased Trawl Effort (+100%) Policy (Ecospace Output). Estimate of Zoning and No-Zoning (NZ) by location.

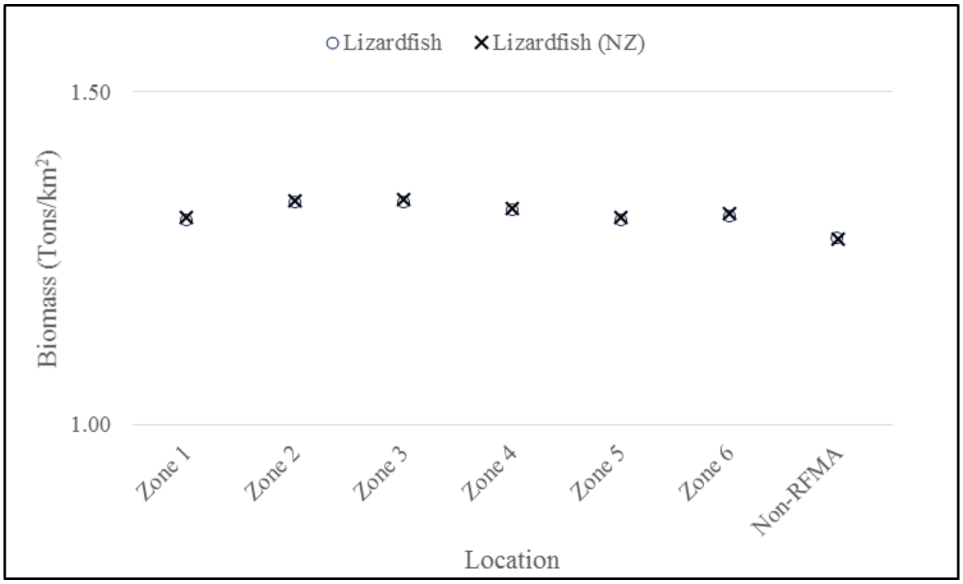

Figure 121 Biomass of Lizardfish. Increased Trawl Effort (+100%) Policy (Ecospace Output). Estimate of Zoning and No-Zoning (NZ) by location.

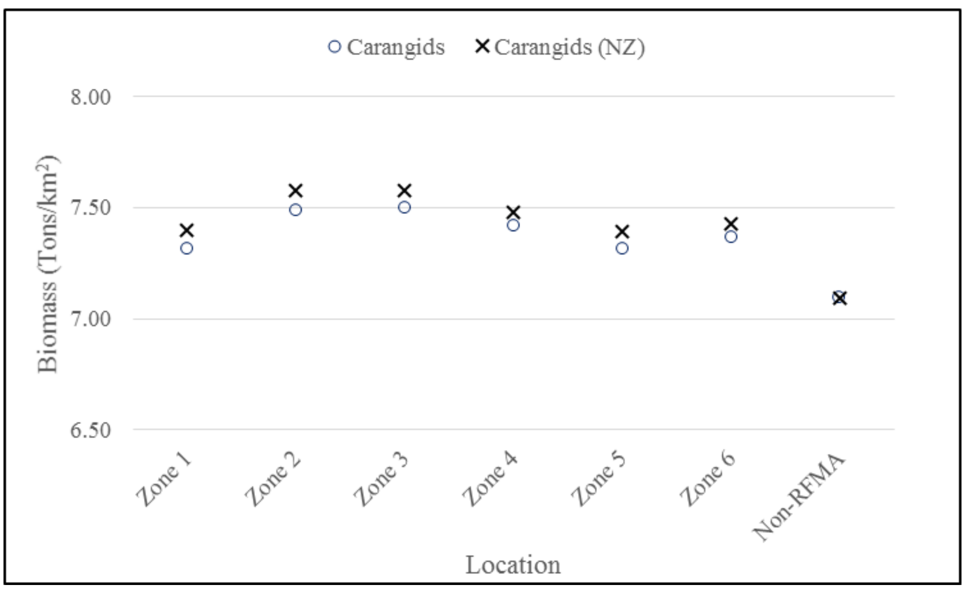

Figure 122 Biomass of Carngids. Increased Trawl Effort (+100%) Policy (Ecospace Output). Estimate of Zoning and No-Zoning (NZ) by location.

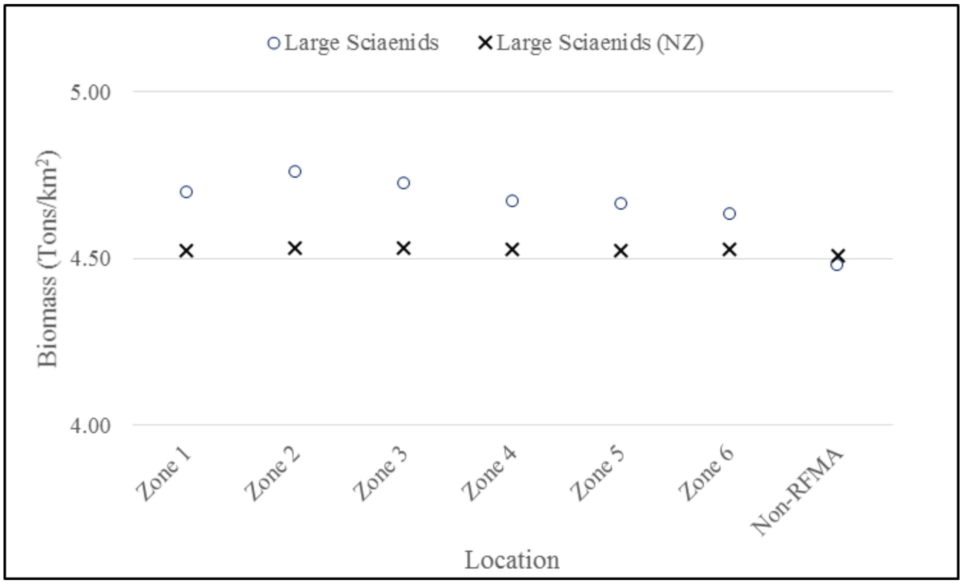

Figure 123 Biomass of Large Sciaenids. Increased Trawl Effort (+100%) Policy (Ecospace Output). Estimate of Zoning and No-Zoning (NZ) by location.

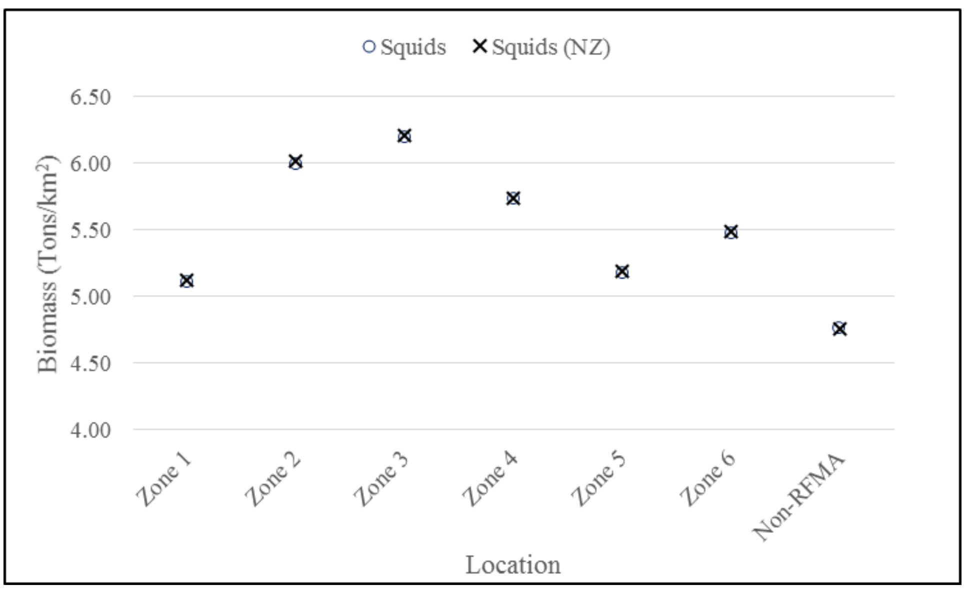

Figure 124 Biomass of Squids. Increased Trawl Effort (+100%) Policy (Ecospace Output). Estimate of Zoning and No-Zoning (NZ) by location.

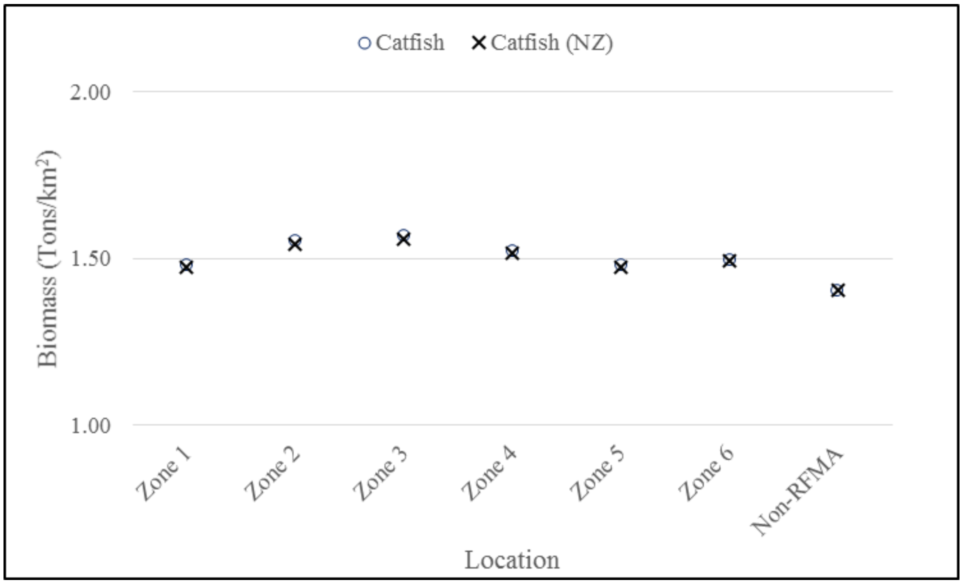

Figure 125 Biomass of Catfish. Increased Trawl Effort (+100%) Policy (Ecospace Output). Estimate of Zoning and No-Zoning (NZ) by location.

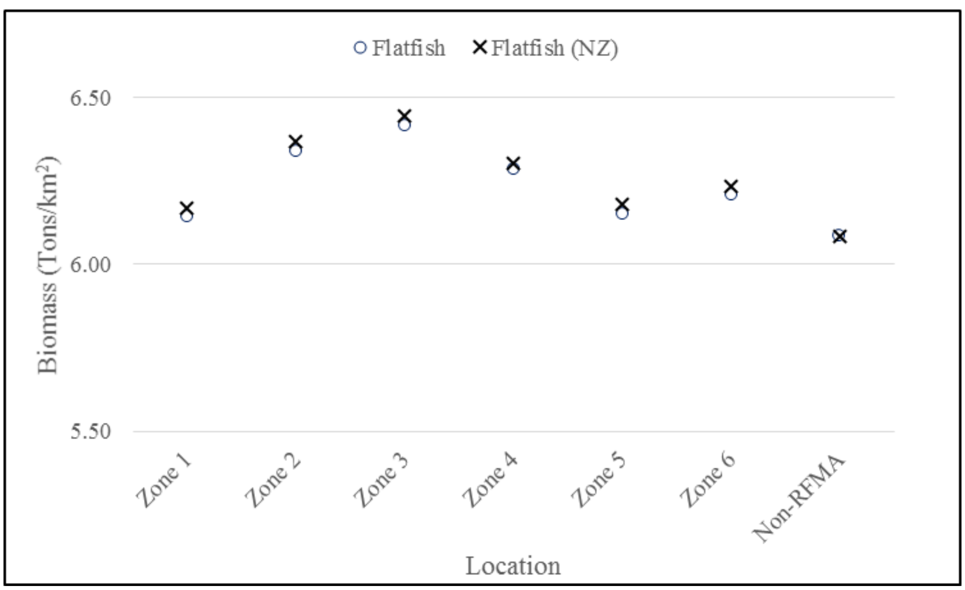

Figure 126 Biomass of Flatfish. Increased Trawl Effort (+100%) Policy (Ecospace Output). Estimate of Zoning and No-Zoning (NZ) by location.

Figure 127 Biomass of Predatory Crab. Increased Trawl Effort (+100%) Policy (Ecospace Output). Estimate of Zoning and No-Zoning (NZ) by location.

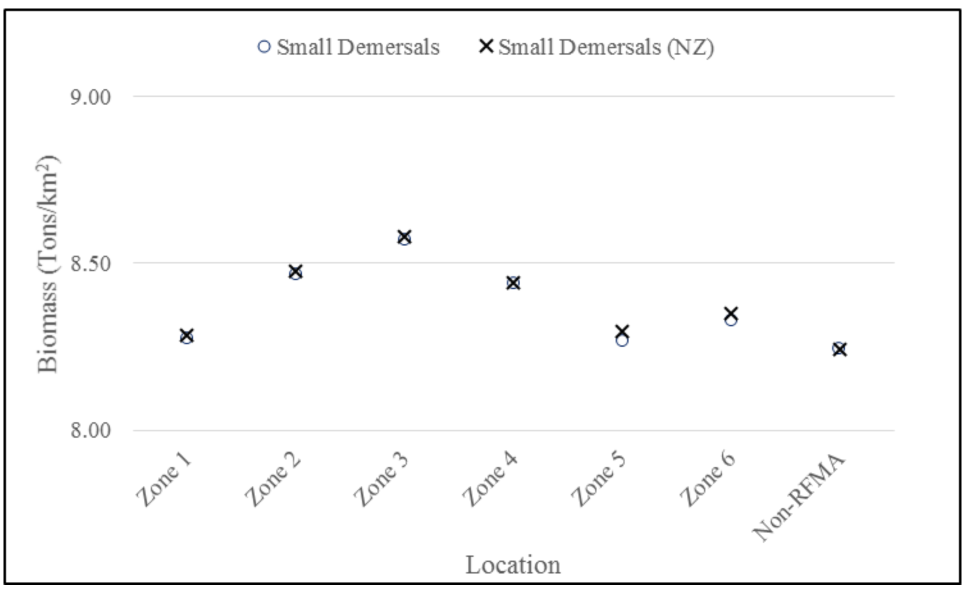

Figure 128 Biomass of Small Demersals. Increased Trawl Effort (+100%) Policy (Ecospace Output). Estimate of Zoning and No-Zoning (NZ) by location.

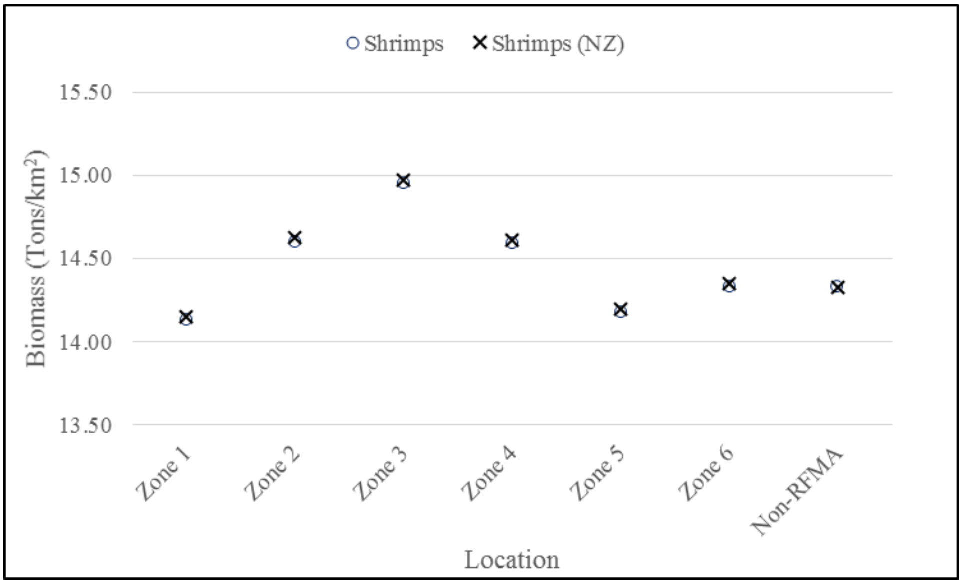

Figure 129 Biomass of Shrimps. Increased Trawl Effort (+100%) Policy (Ecospace Output). Estimate of Zoning and No-Zoning (NZ) by location.

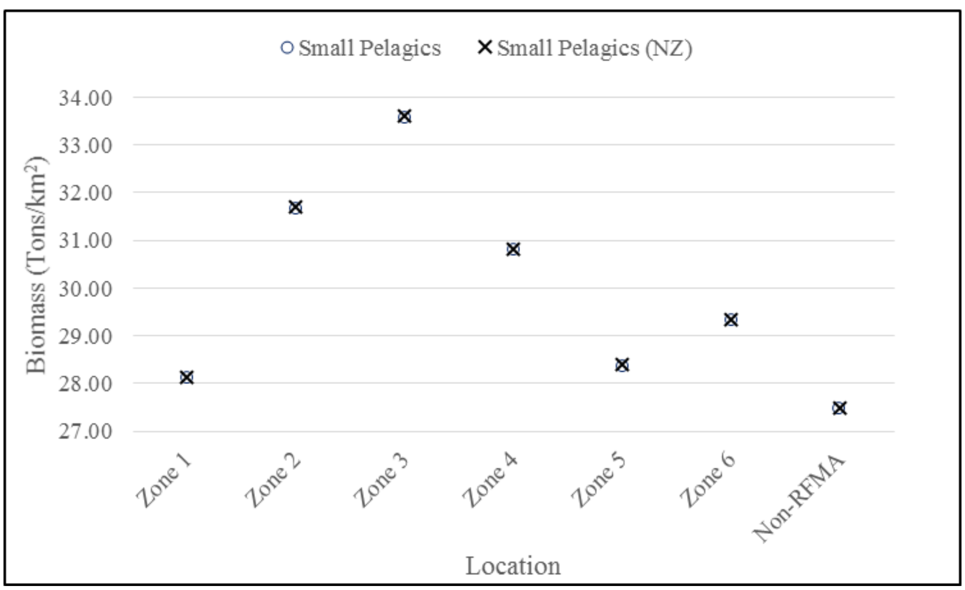

Figure 130 Biomass of Small Pelagics. Increased Trawl Effort (+100%) Policy (Ecospace Output). Estimate of Zoning and No-Zoning (NZ) by location.

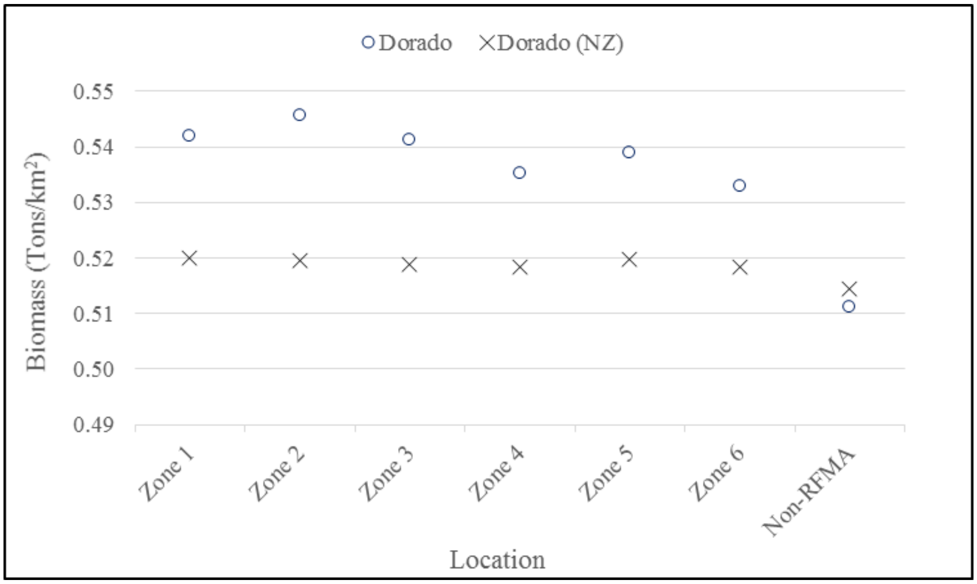

Figure 131 Biomass of Dorado. Increased Trawl Effort (+50%) Policy (Ecospace Output). Estimate of Zoning and No-Zoning (NZ) by location.

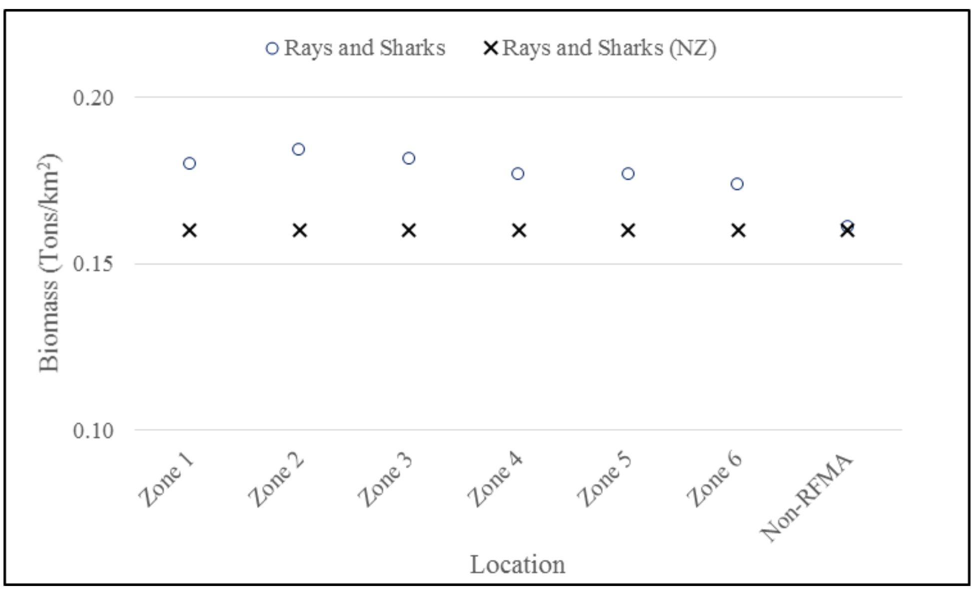

Figure 132 Biomass of of Rays and Sharks. Increased Trawl Effort (+50%) Policy (Ecospace Output). Estimate of Zoning and No-Zoning (NZ) by location.

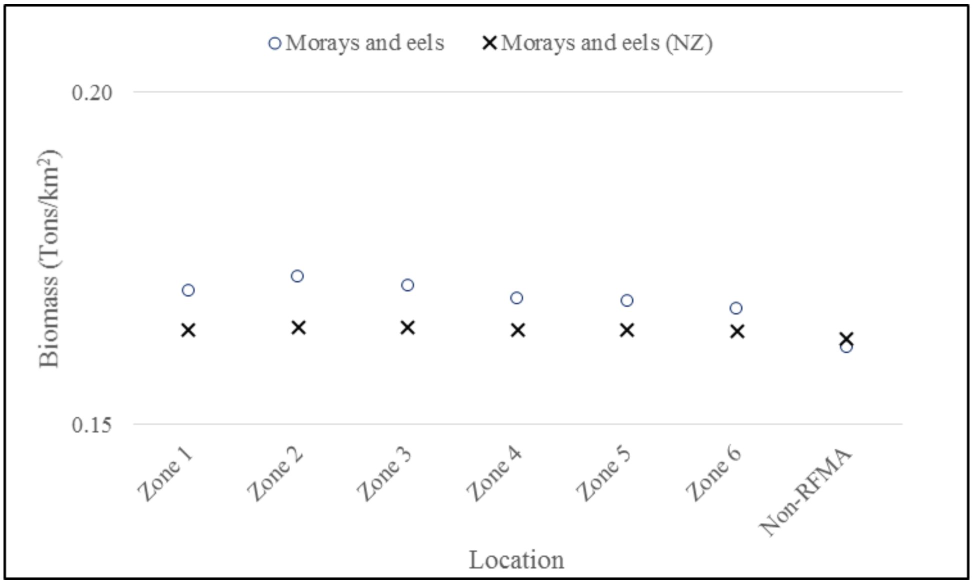

Figure 133 Biomass of of Morays and Eels. Increased Trawl Effort (+50%) Policy (Ecospace Output). Estimate of Zoning and No-Zoning (NZ) by location.

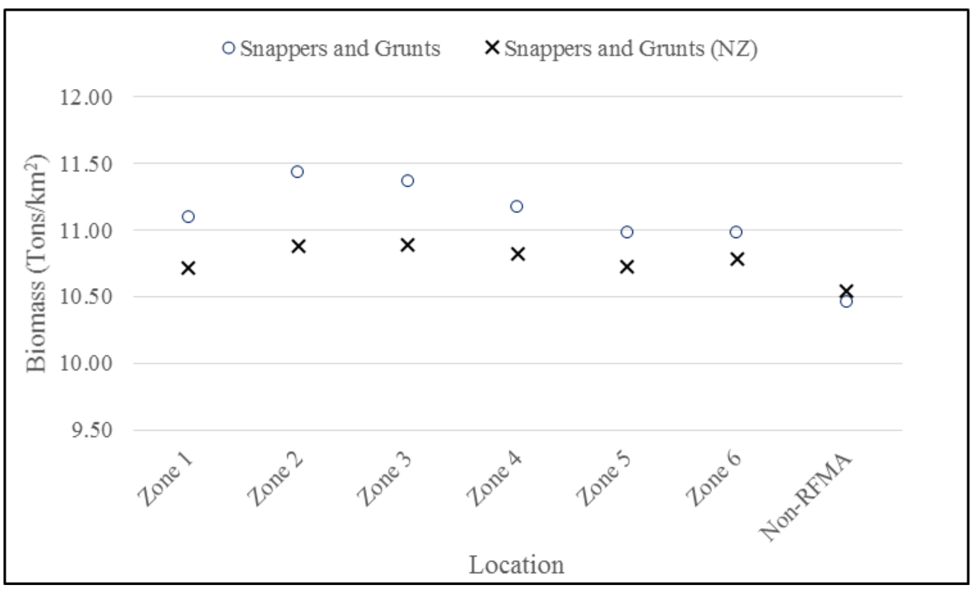

Figure 134 Biomass of Snappers and Grunts. Increased Trawl Effort (+50%) Policy (Ecospace Output). Estimate of Zoning and No-Zoning (NZ) by location.

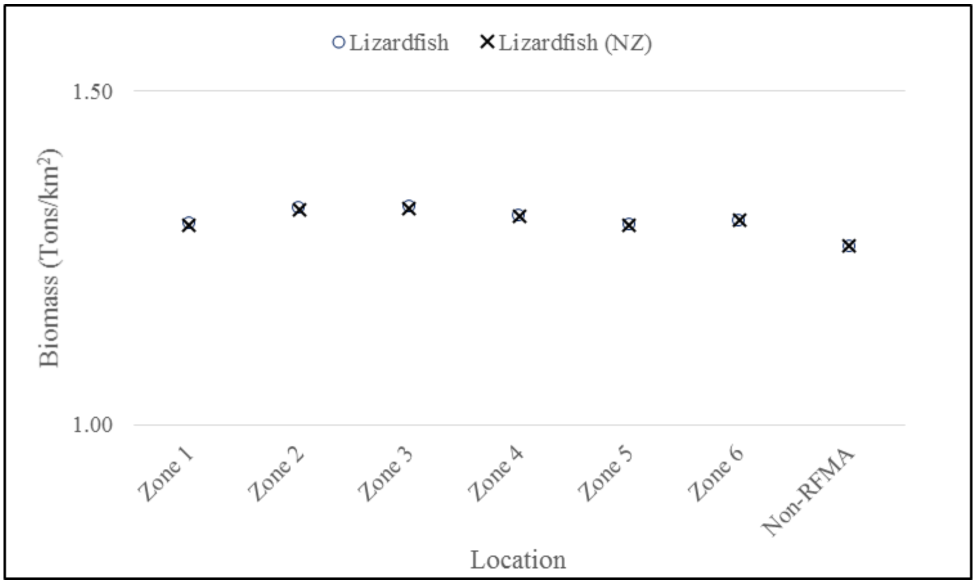

Figure 135 Biomass of Lizardfish. Increased Trawl Effort (+50%) Policy (Ecospace Output). Estimate of Zoning and No-Zoning (NZ) by location.

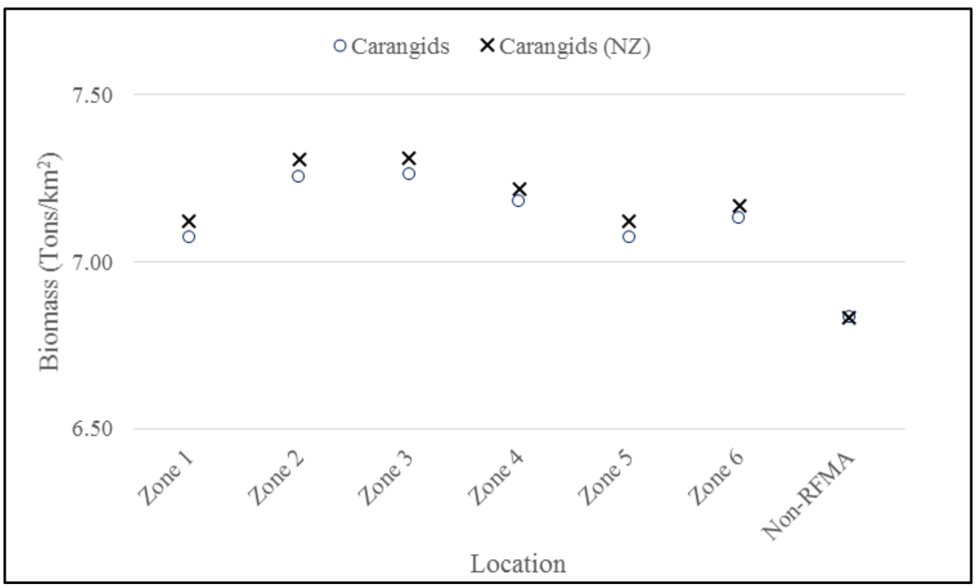

Figure 136 Biomass of Carngids. Increased Trawl Effort (+50%) Policy (Ecospace Output). Estimate of Zoning and No-Zoning (NZ) by location.

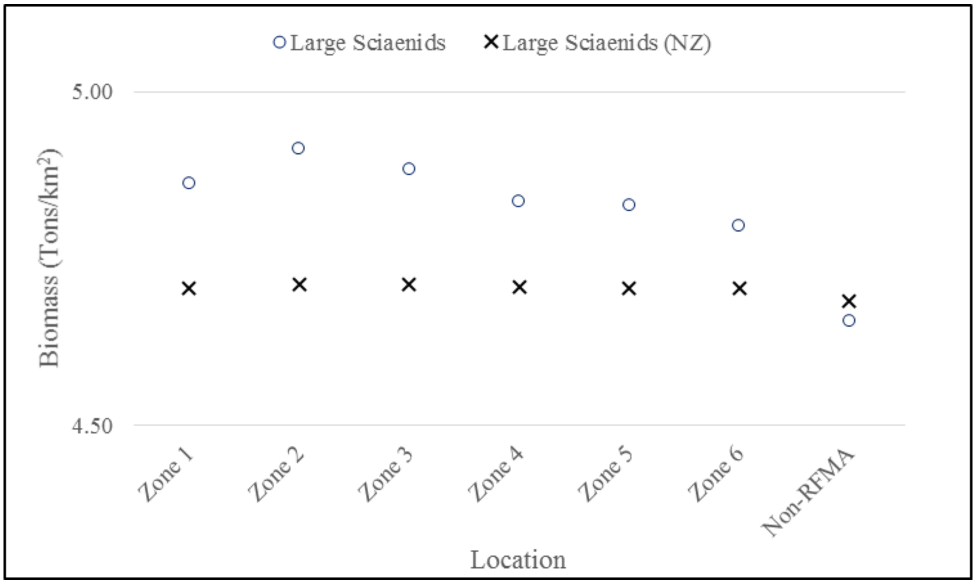

Figure 137 Biomass of Large Sciaenids. Increased Trawl Effort (+50%) Policy (Ecospace Output). Estimate of Zoning and No-Zoning (NZ) by location.

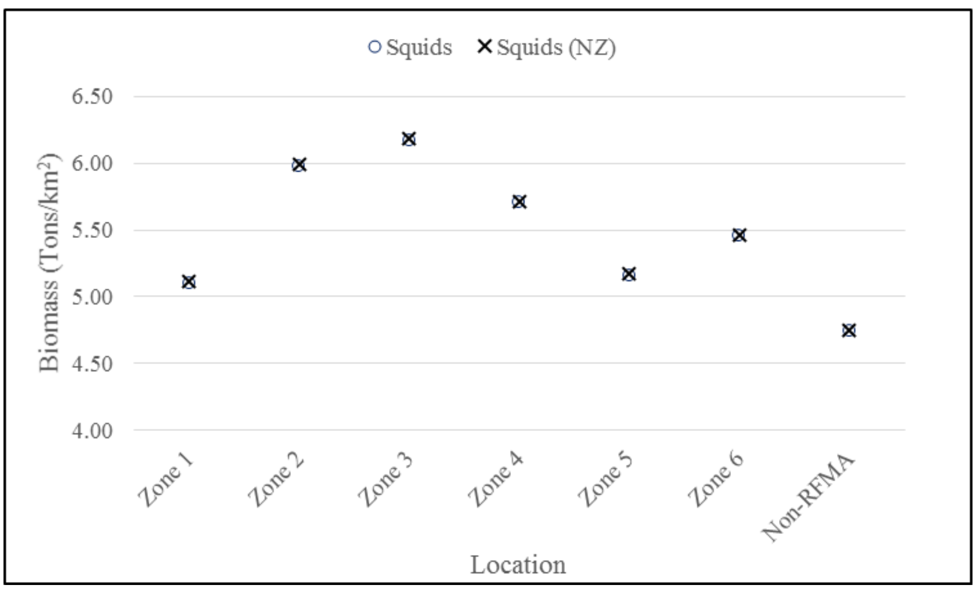

Figure 138 Biomass of Squids. Increased Trawl Effort (+50%) Policy (Ecospace Output). Estimate of Zoning and No-Zoning (NZ) by location.

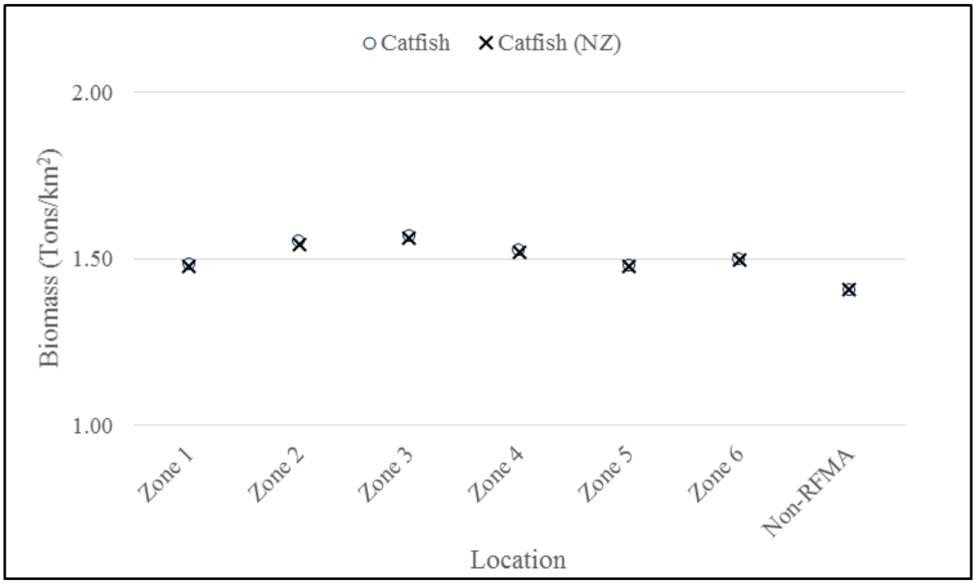

Figure 139 Biomass of Catfish. Increased Trawl Effort (+50%) Policy (Ecospace Output). Estimate of Zoning and No-Zoning (NZ) by location.

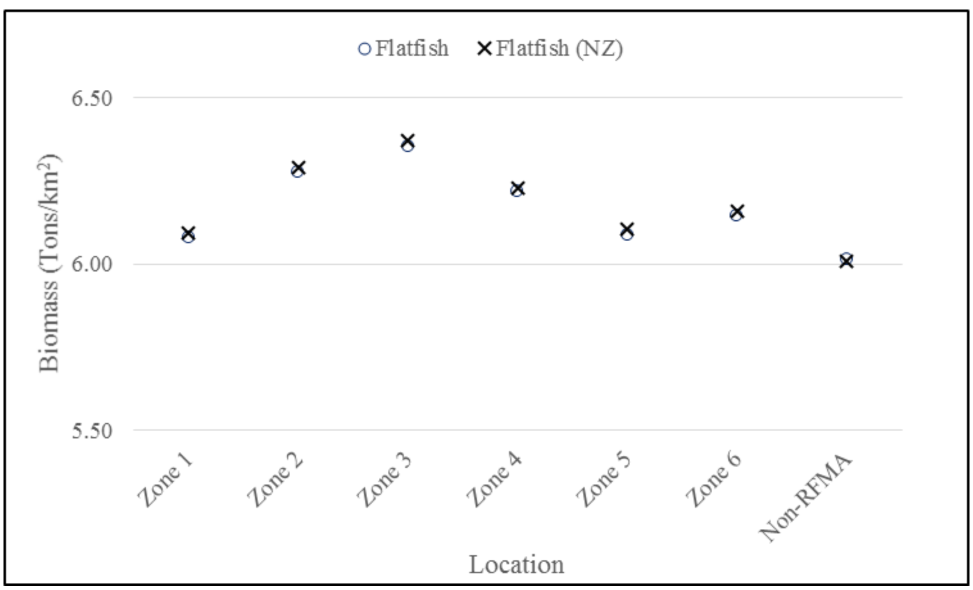

Figure 140 Biomass of Flatfish. Increased Trawl Effort (+50%) Policy (Ecospace Output). Estimate of Zoning and No-Zoning (NZ) by location.

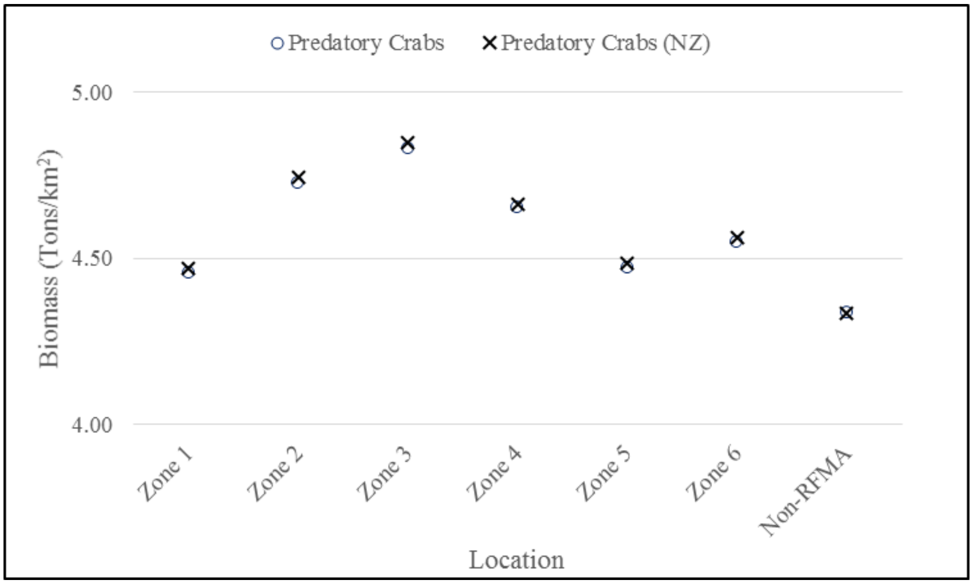

Figure 141 Biomass of Predatory Crab. Increased Trawl Effort (+50%) Policy (Ecospace Output). Estimate of Zoning and No-Zoning (NZ) by location.

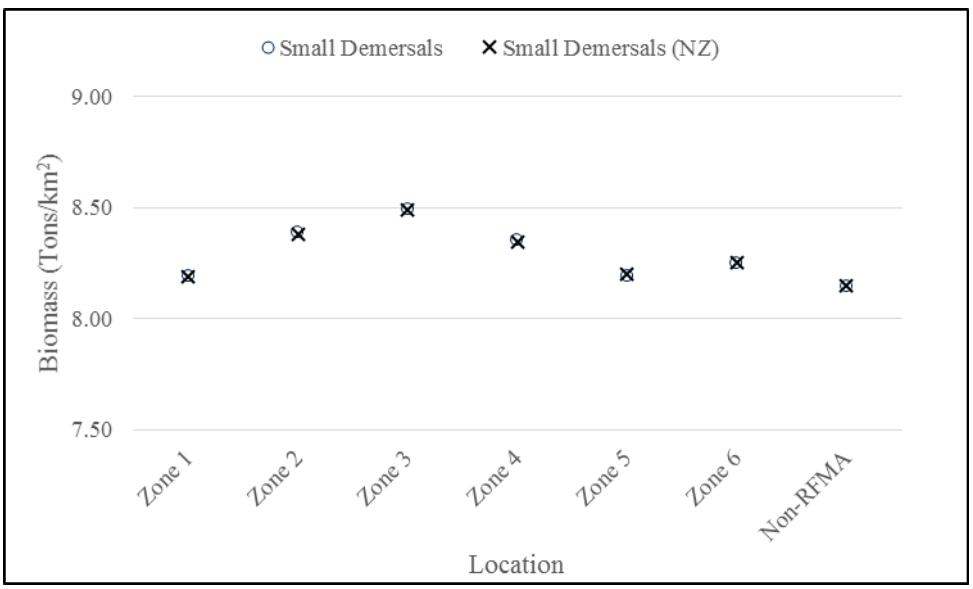

Figure 142 Biomass of Small Demersals. Increased Trawl Effort (+50%) Policy (Ecospace Output). Estimate of Zoning and No-Zoning (NZ) by location.

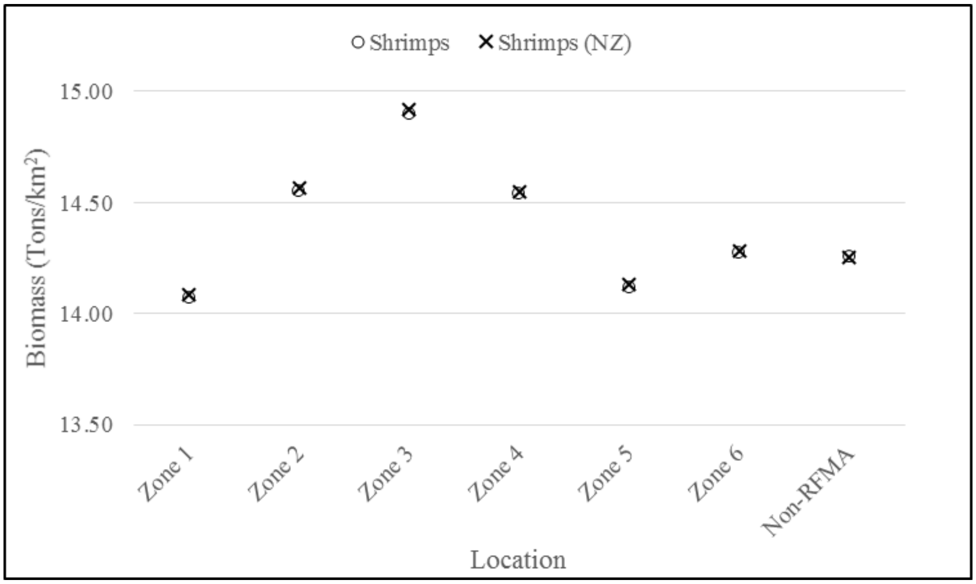

Figure 143 Biomass of Shrimps. Increased Trawl Effort (+50%) Policy (Ecospace Output). Estimate of Zoning and No-Zoning (NZ) by location.

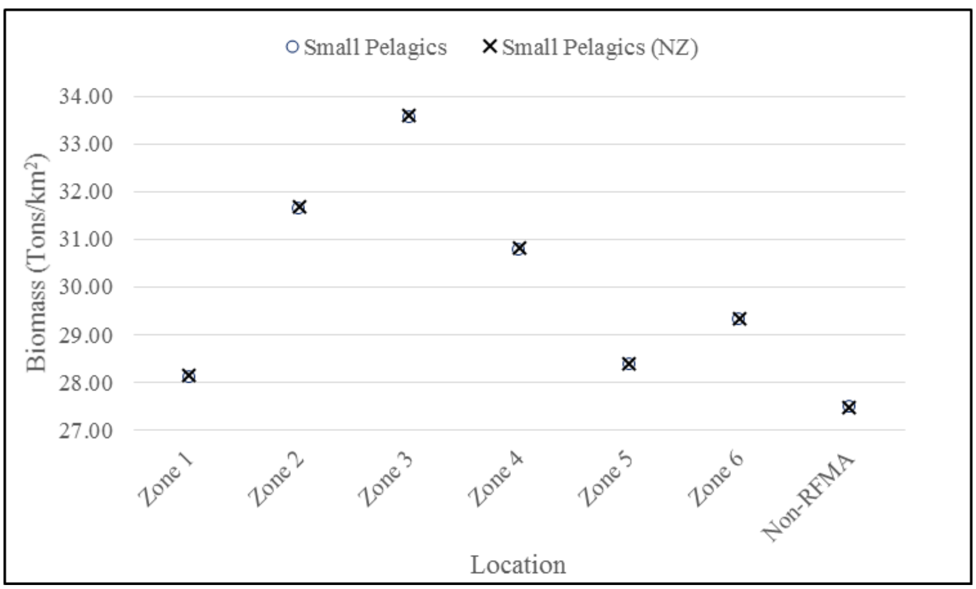

Figure 144 Biomass of Small Pelagics. Increased Trawl Effort (+50%) Policy (Ecospace Output). Estimate of Zoning and No-Zoning (NZ) by location.

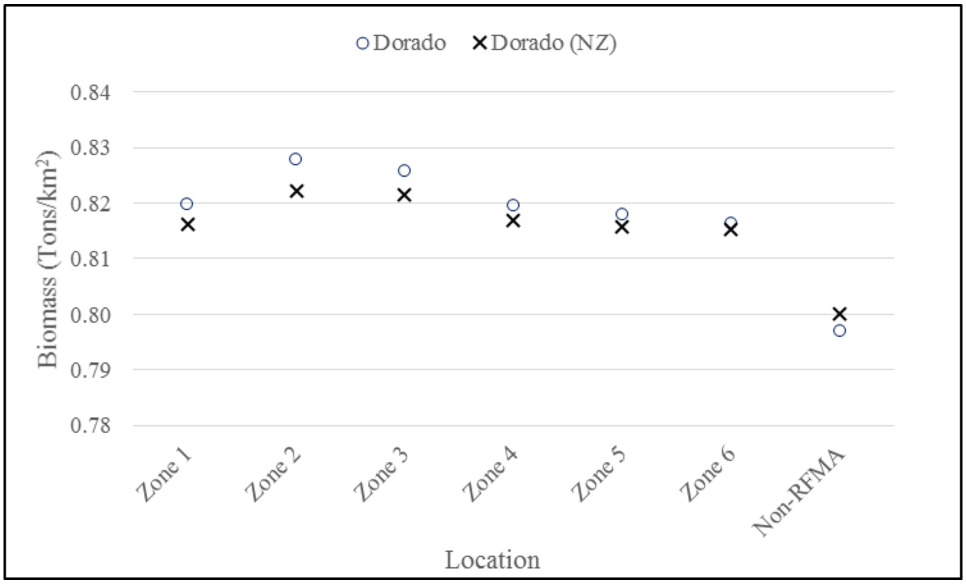

Figure 145 Biomass of Dorado. Reduced Trawl Effort (-100%) Policy (Ecospace Output). Estimate of Zoning and No-Zoning (NZ) by location.

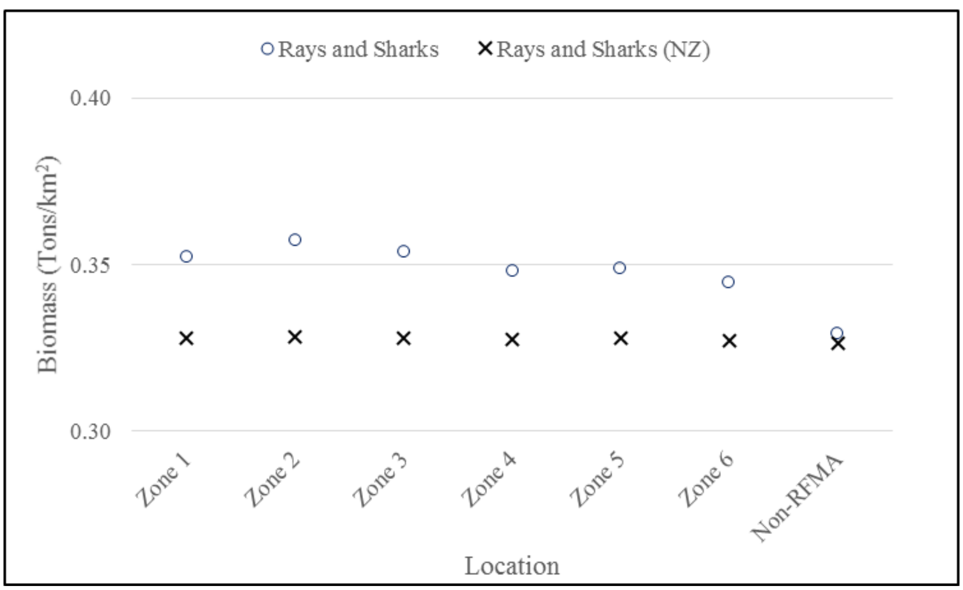

Figure 146 Biomass of of Rays and Sharks. Reduced Trawl Effort (-100%) Policy (Ecospace Output). Estimate of Zoning and No-Zoning (NZ) by location.

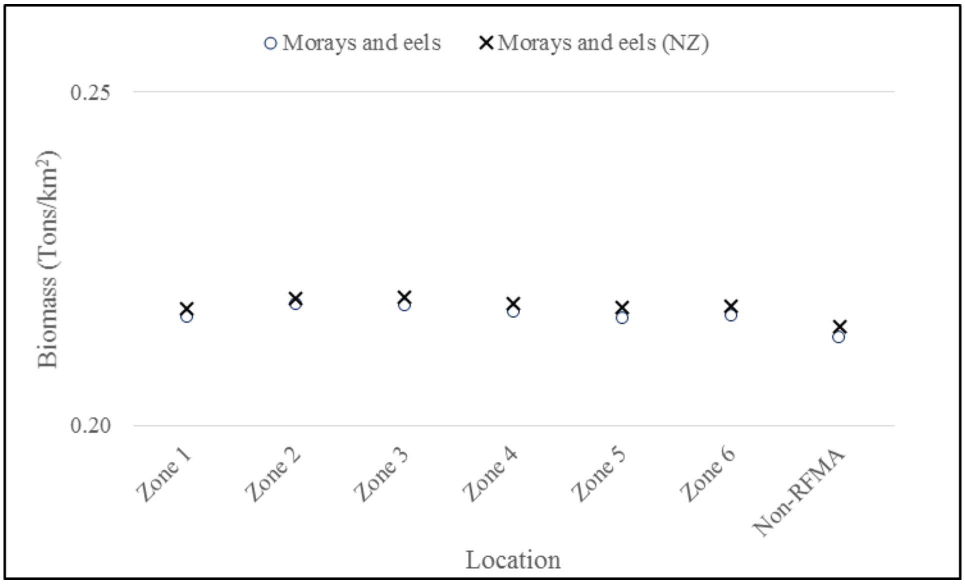

Figure 147 Biomass of of Morays and Eels. Reduced Trawl Effort (-100%) Policy (Ecospace Output). Estimate of Zoning and No-Zoning (NZ) by location.

Figure 148 Biomass of Snappers and Grunts. Reduced Trawl Effort (-100%) Policy (Ecospace Output). Estimate of Zoning and No-Zoning (NZ) by location.

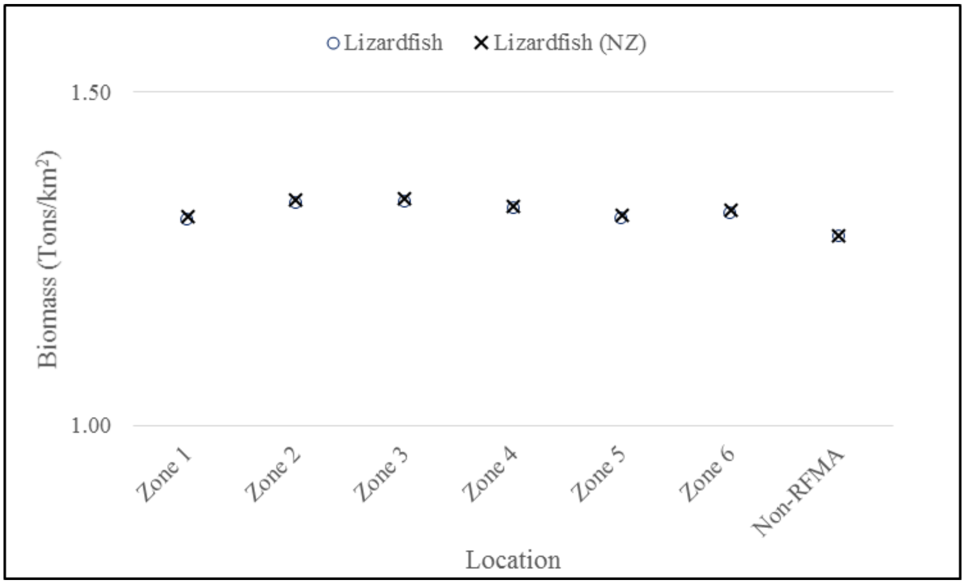

Figure 149 Biomass of Lizardfish. Reduced Trawl Effort (-100%) Policy (Ecospace Output). Estimate of Zoning and No-Zoning (NZ) by location.

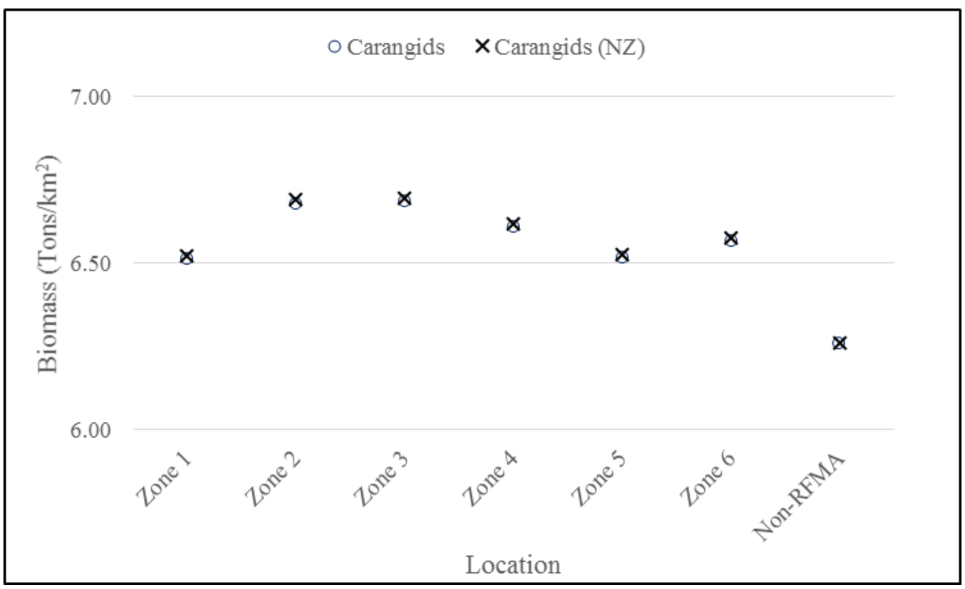

Figure 150 Biomass of Carngids. Reduced Trawl Effort (-100%) Policy (Ecospace Output). Estimate of Zoning and No-Zoning (NZ) by location.

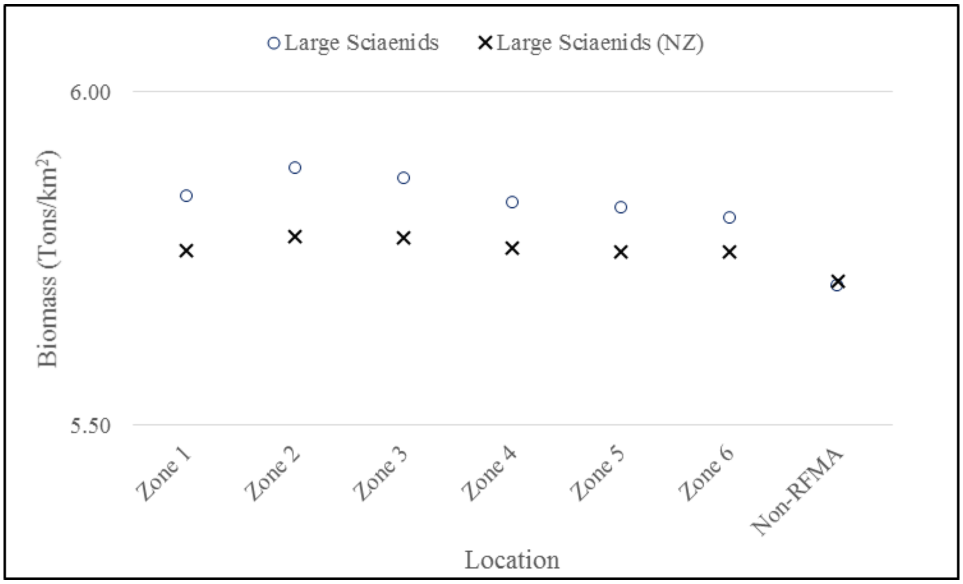

Figure 151 Biomass of Large Sciaenids. Reduced Trawl Effort (-100%) Policy (Ecospace Output). Estimate of Zoning and No-Zoning (NZ) by location.

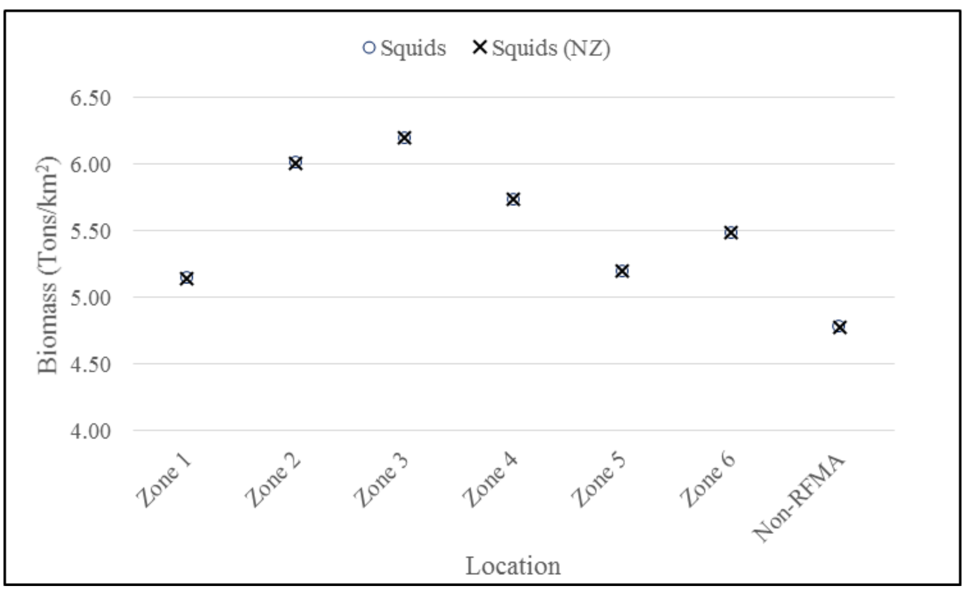

Figure 152 Biomass of Squids. Reduced Trawl Effort (-100%) Policy (Ecospace Output). Estimate of Zoning and No-Zoning (NZ) by location.

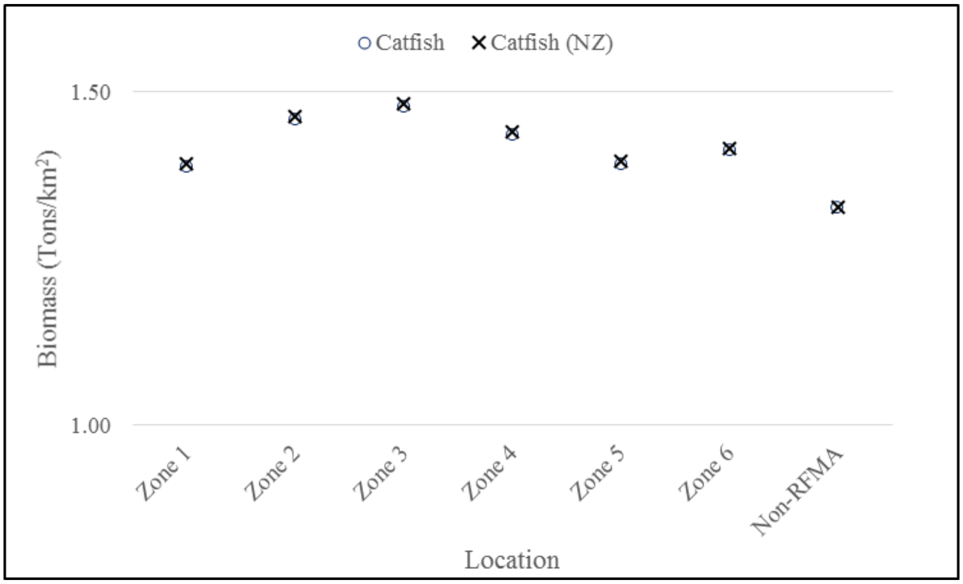

Figure 153 Biomass of Catfish. Reduced Trawl Effort (-100%) Policy (Ecospace Output). Estimate of Zoning and No-Zoning (NZ) by location.

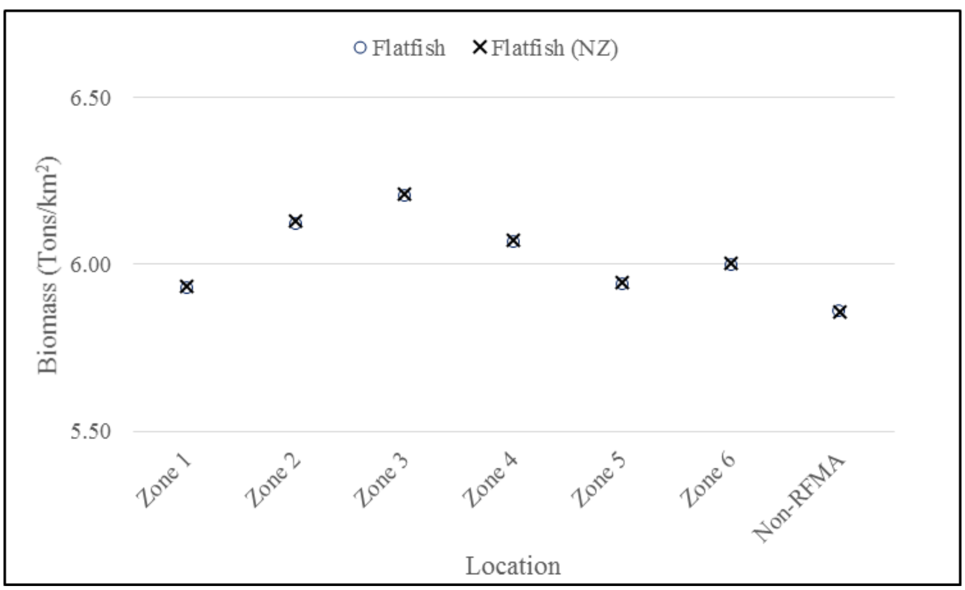

Figure 154 Biomass of Flatfish. Reduced Trawl Effort (-100%) Policy (Ecospace Output). Estimate of Zoning and No-Zoning (NZ) by location.

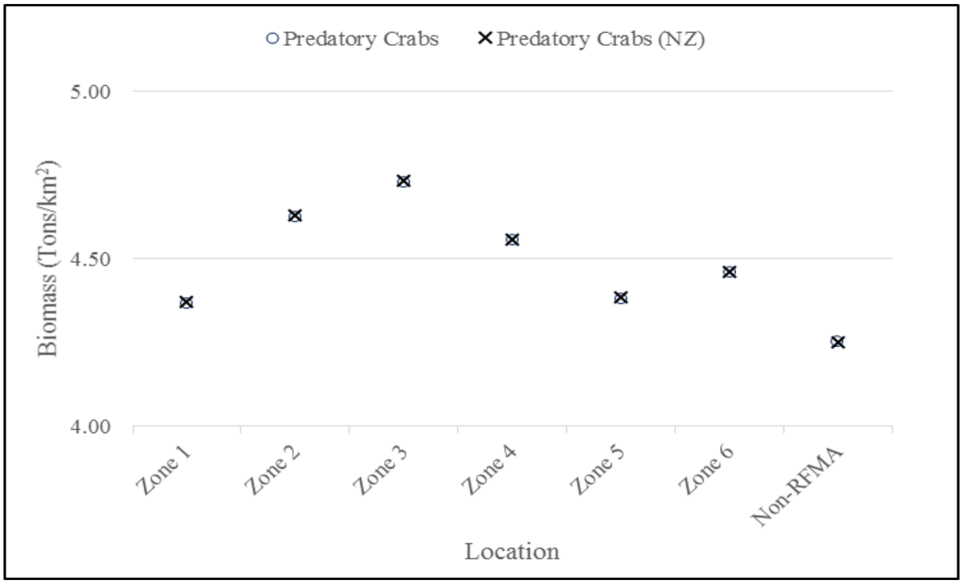

Figure 155 Biomass of Predatory Crab. Reduced Trawl Effort (-100%) Policy (Ecospace Output). Estimate of Zoning and No-Zoning (NZ) by location.

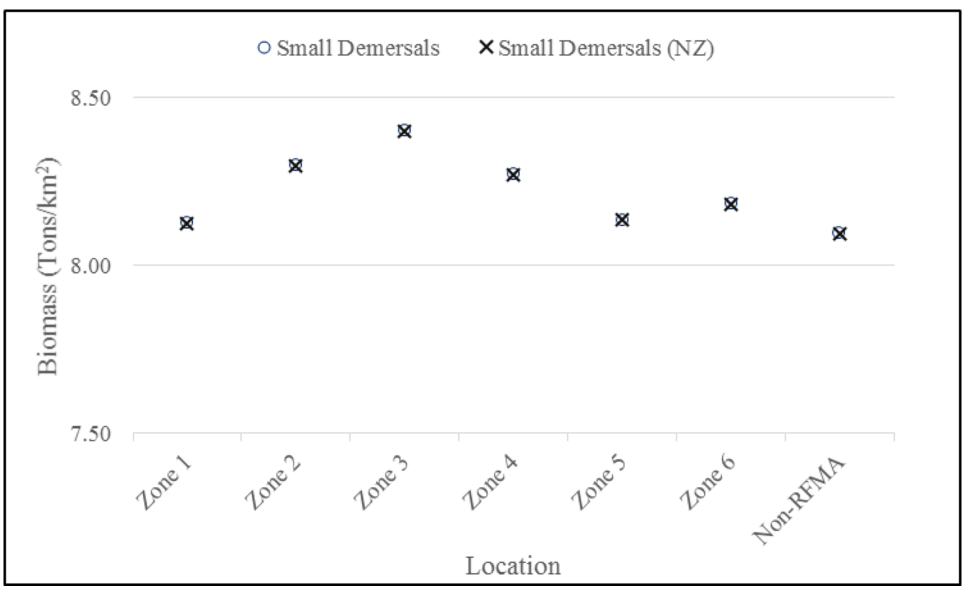

Figure 156 Biomass of Small Demersals. Reduced Trawl Effort (-100%) Policy (Ecospace Output). Estimate of Zoning and No-Zoning (NZ) by location.

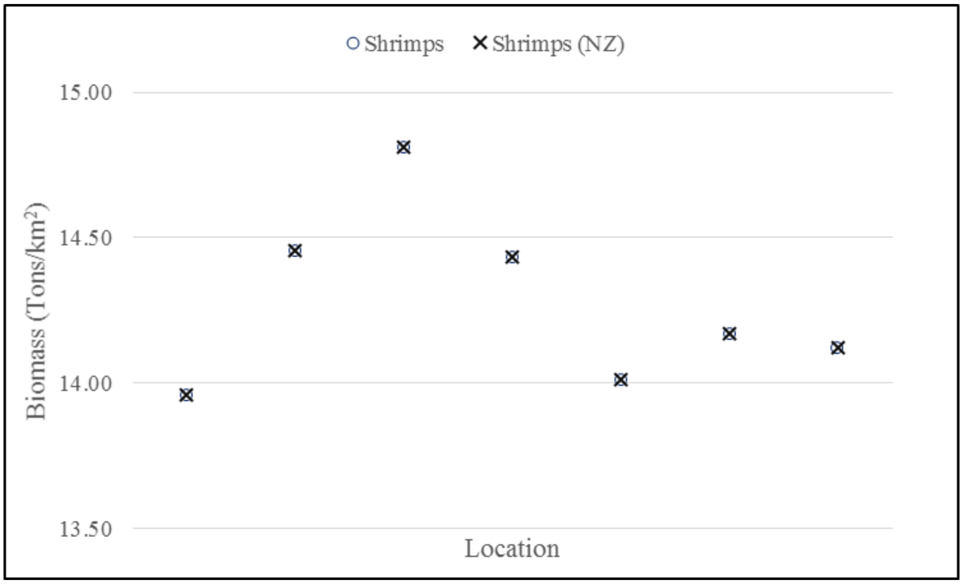

Figure 157 Biomass of Shrimps. Reduced Trawl Effort (-100%) Policy (Ecospace Output). Estimate of Zoning and No-Zoning (NZ) by location.

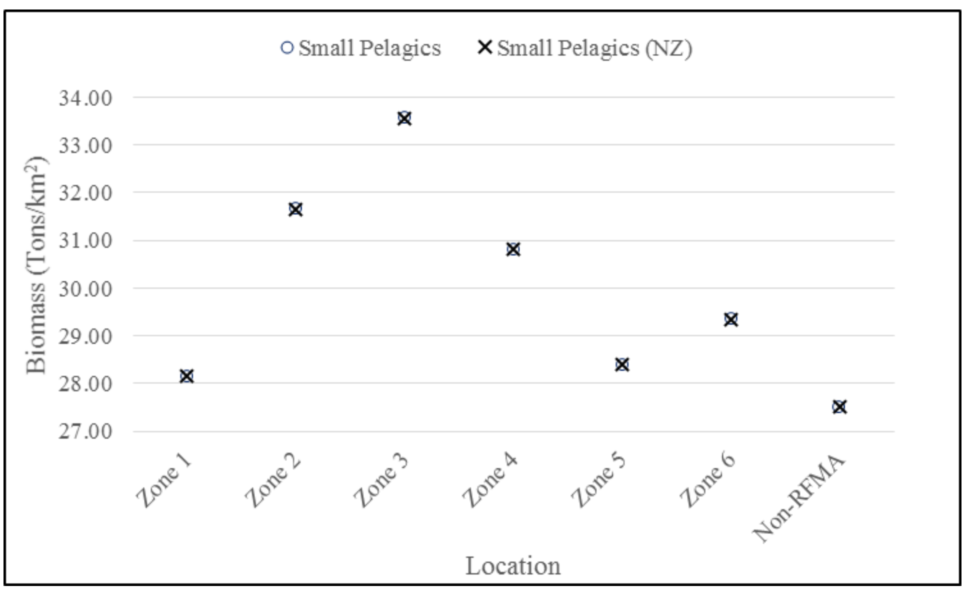

Figure 158 Biomass of Small Pelagics. Reduced Trawl Effort (-100%) Policy (Ecospace Output). Estimate of Zoning and No-Zoning (NZ) by location.

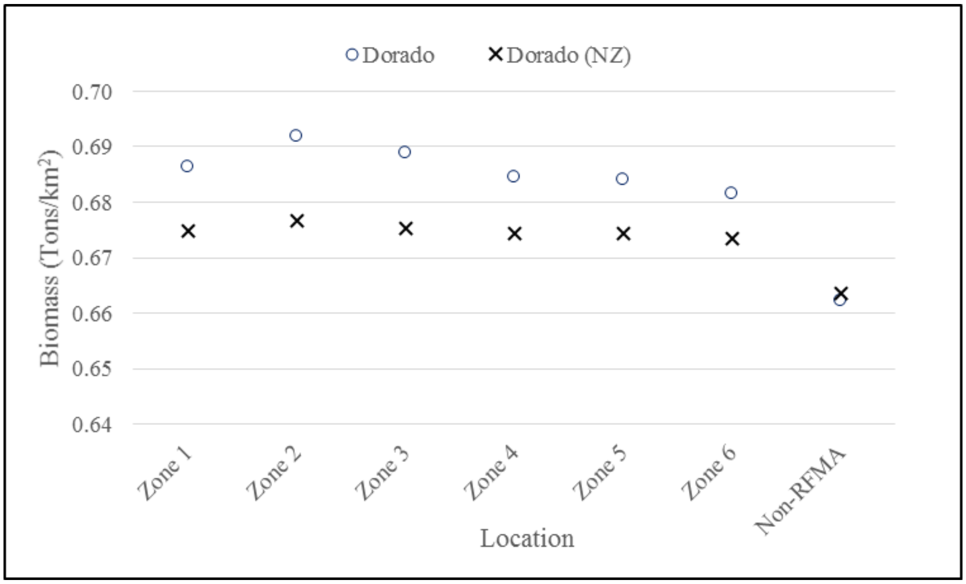

Figure 159 Biomass of Dorado. No Subsidy Policy (Ecospace Output). Estimate of Zoning and No-Zoning (NZ) by location.

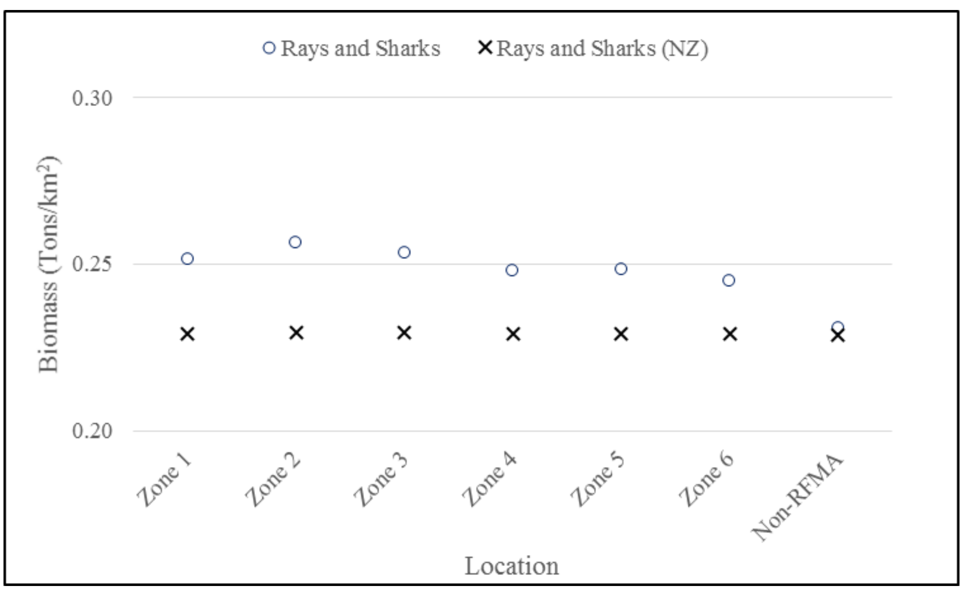

Figure 160 Biomass of of Rays and Sharks. No Subsidy Policy (Ecospace Output). Estimate of Zoning and No-Zoning (NZ) by location.

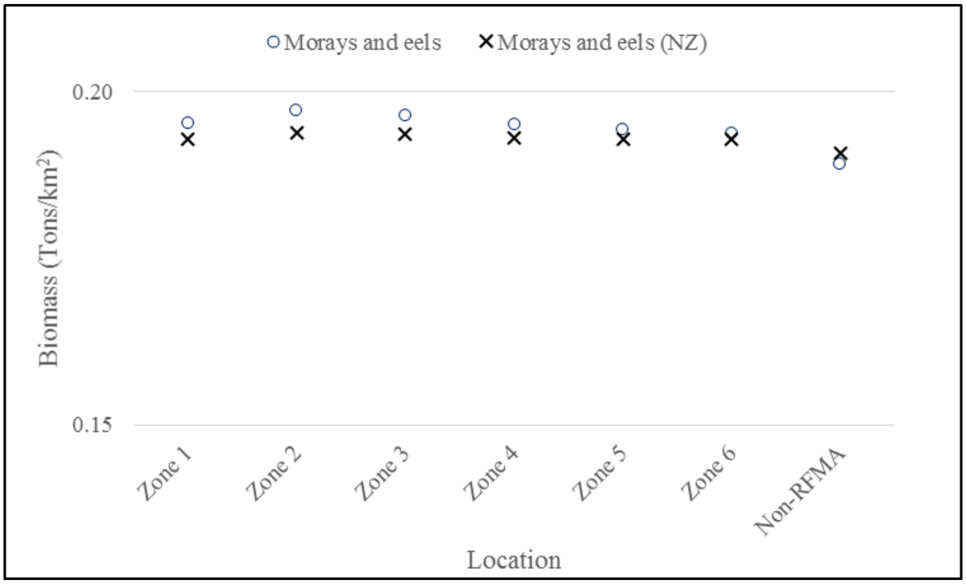

Figure 161 Biomass of Morays and Eels. No Subsidy Policy (Ecospace Output). Estimate of Zoning and No-Zoning (NZ) by location.

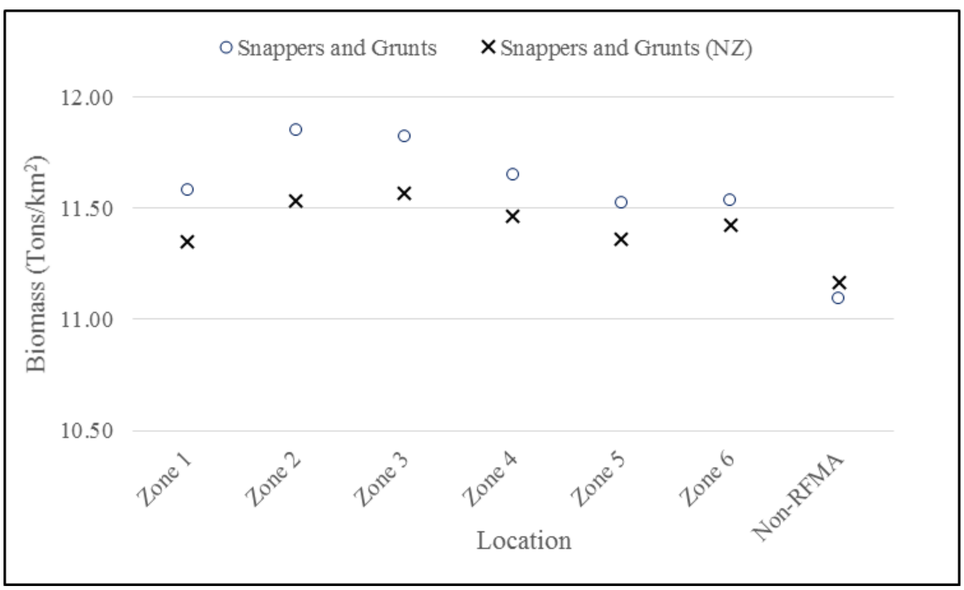

Figure 162 Biomass of Snappers and Grunts. No Subsidy Policy (Ecospace Output). Estimate of Zoning and No-Zoning (NZ) by location.

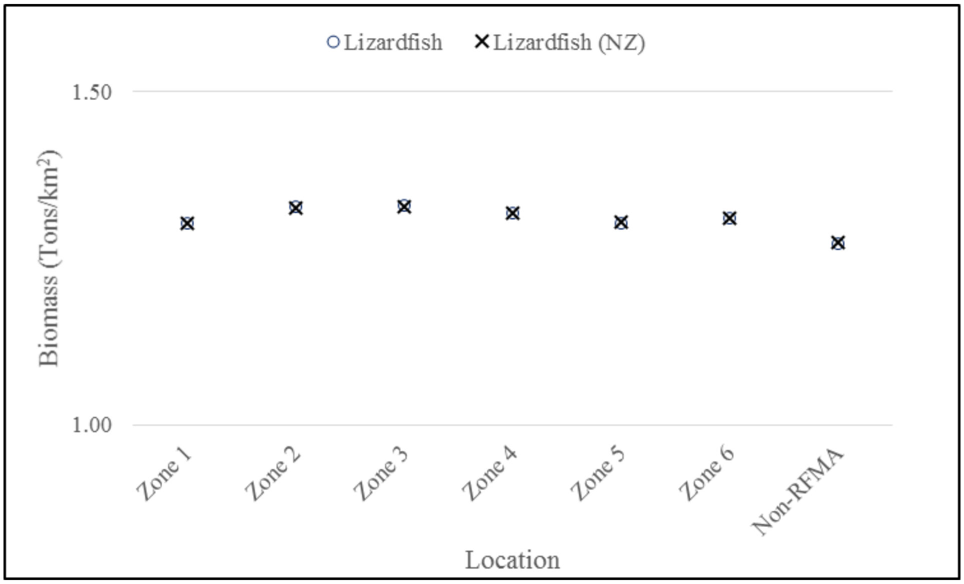

Figure 163 Biomass of Lizardfish. No Subsidy Policy (Ecospace Output). Estimate of Zoning and No-Zoning (NZ) by location.

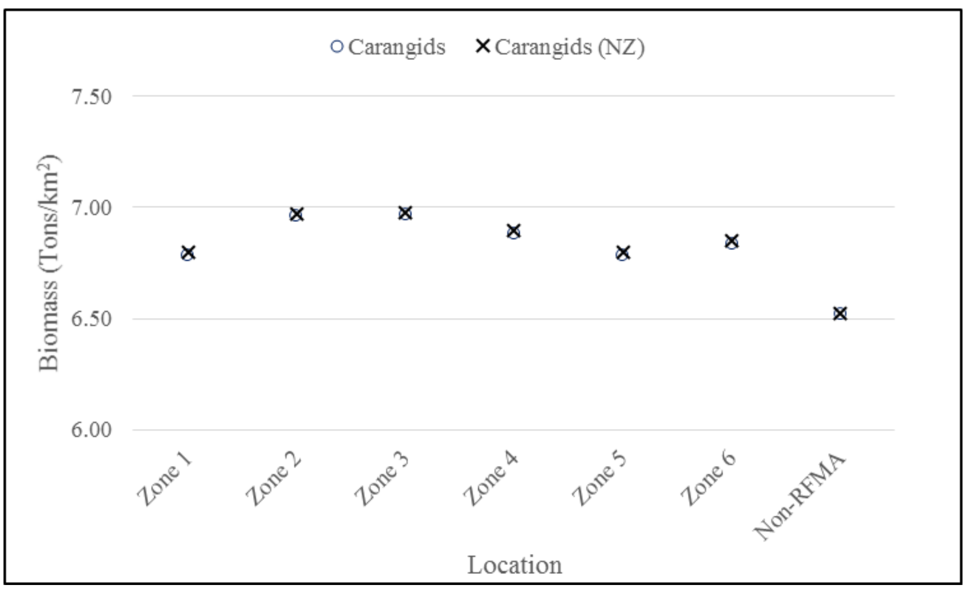

Figure 164 Biomass of Carngids. No Subsidy Policy (Ecospace Output). Estimate of Zoning and No-Zoning (NZ) by location.

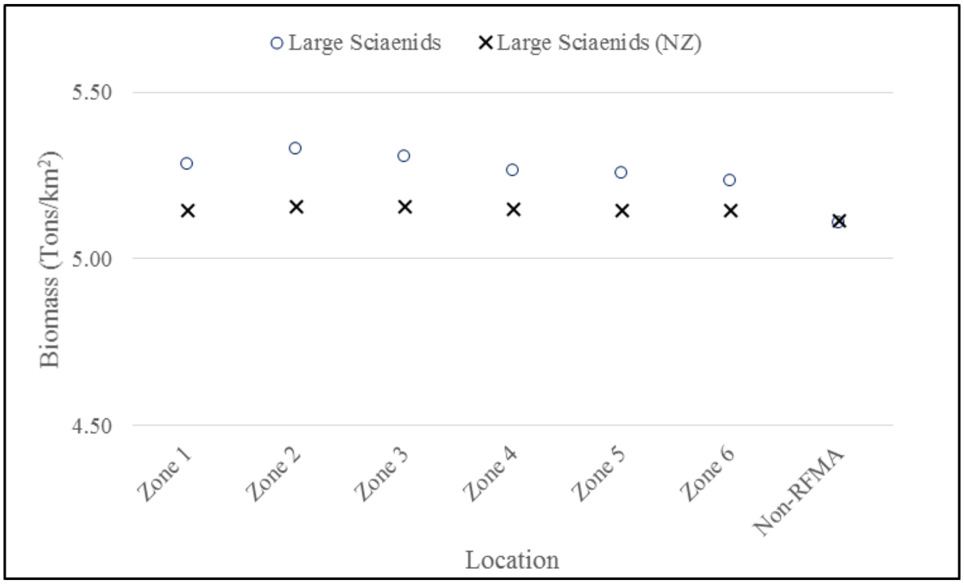

Figure 165 Biomass of Large Sciaenids. No Subsidy Policy (Ecospace Output). Estimate of Zoning and No-Zoning (NZ) by location.

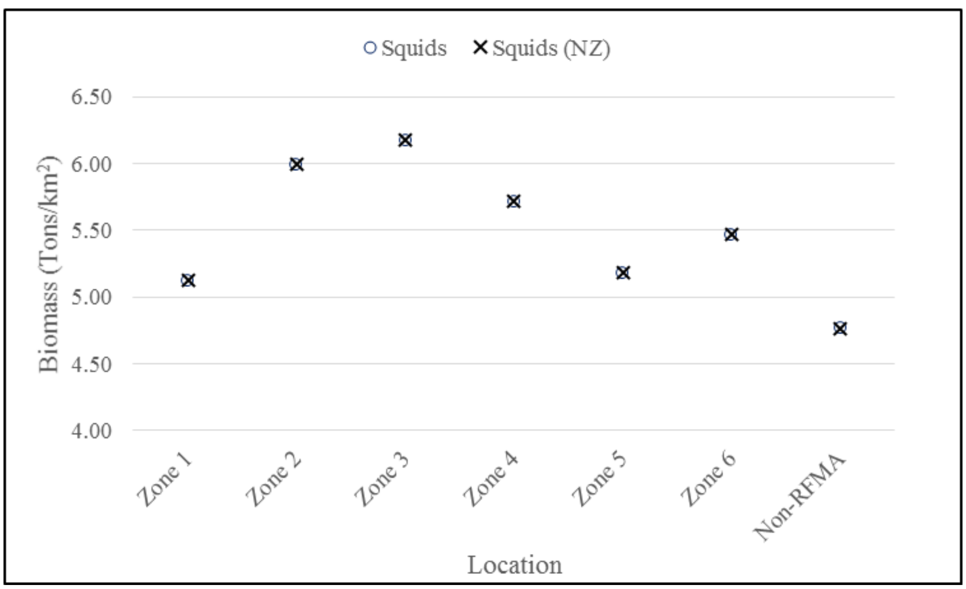

Figure 166 Biomass of Squids. No Subsidy Policy (Ecospace Output). Estimate of Zoning and No-Zoning (NZ) by location.

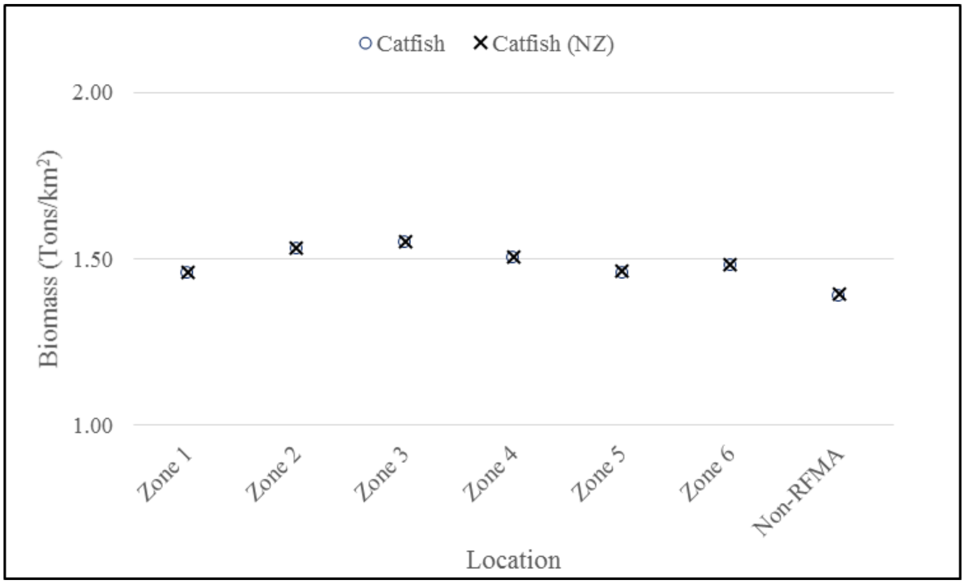

Figure 167 Biomass of Catfish. No Subsidy Policy (Ecospace Output). Estimate of Zoning and No-Zoning (NZ) by location.

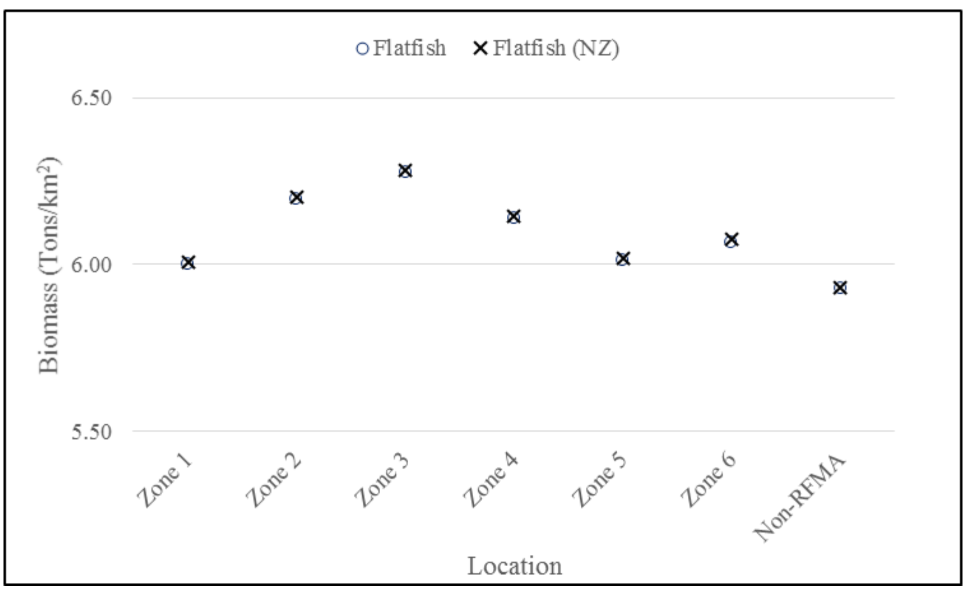

Figure 168 Biomass of Flatfish. No Subsidy Policy (Ecospace Output). Estimate of Zoning and No-Zoning (NZ) by location.

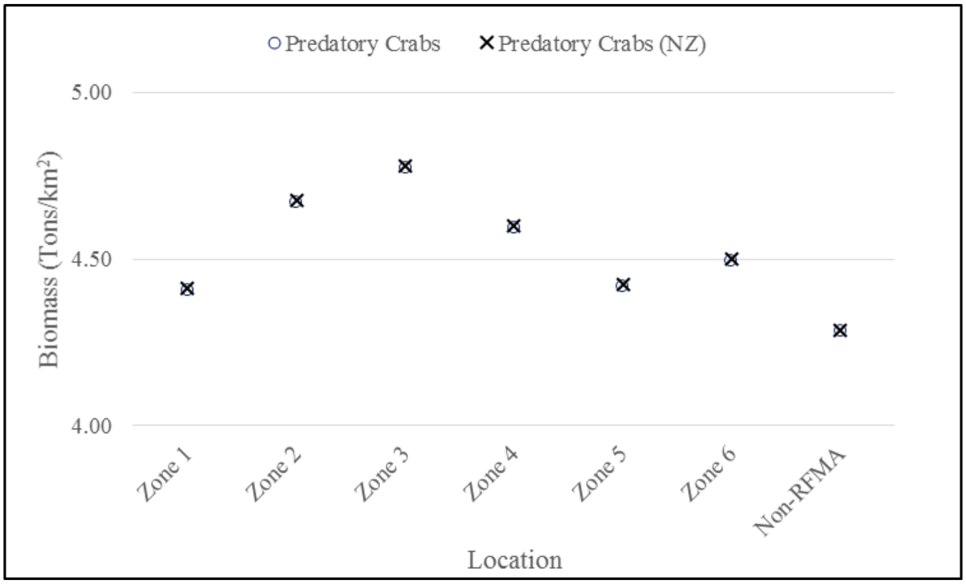

Figure 169 Biomass of Predatory Crab. No Subsidy Policy (Ecospace Output). Estimate of Zoning and No-Zoning (NZ) by location.

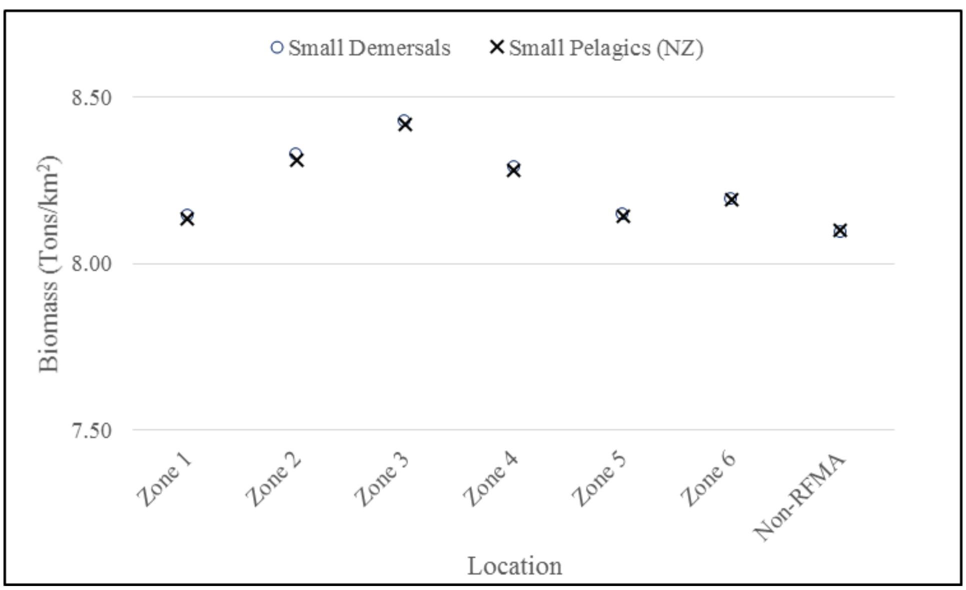

Figure 170 Biomass of Small Demersals. No Subsidy Policy (Ecospace Output). Estimate of Zoning and No-Zoning (NZ) by location.

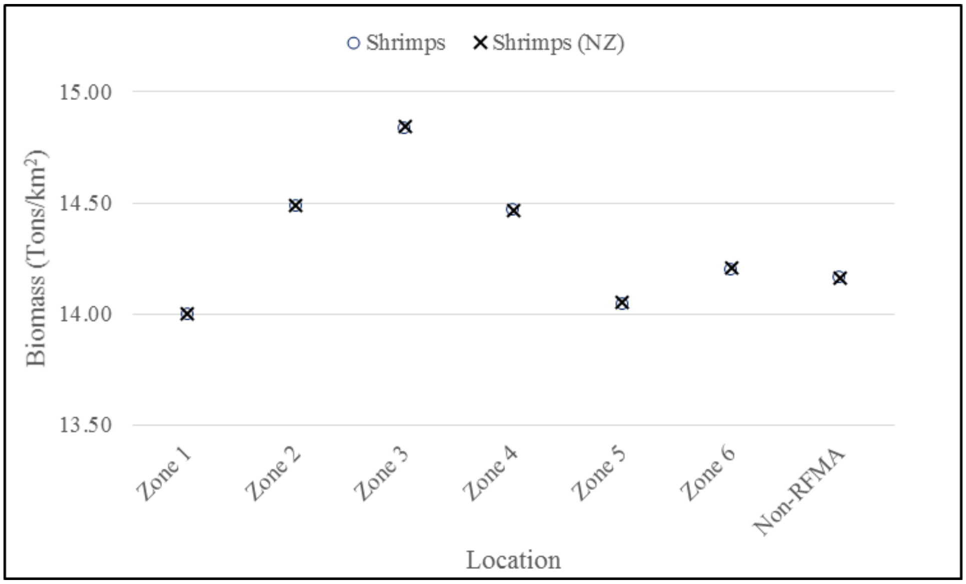

Figure 171 Biomass of Shrimps. No Subsidy Policy (Ecospace Output). Estimate of Zoning and No-Zoning (NZ) by location.

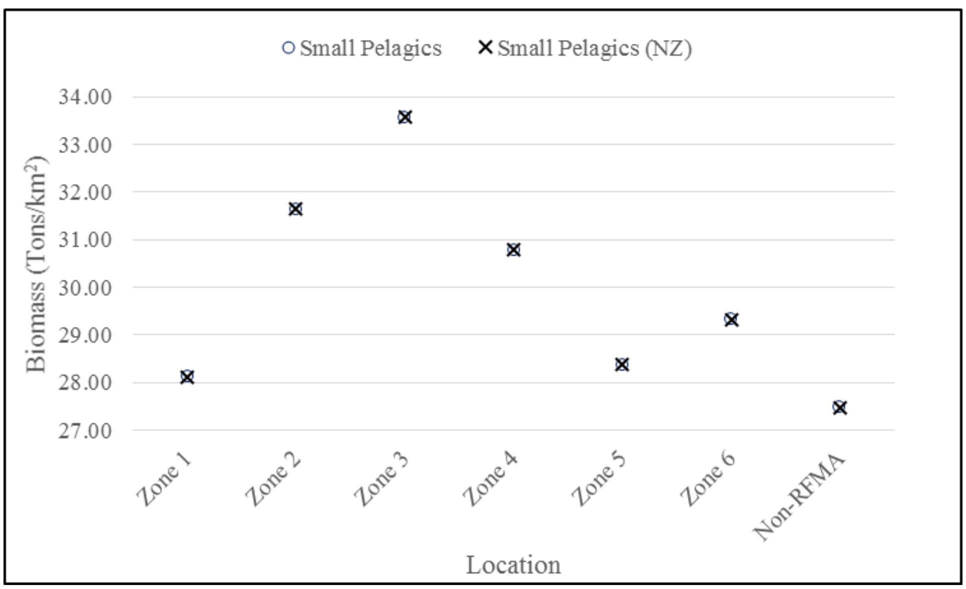

Figure 172 Biomass of Small Pelagics. No Subsidy Policy (Ecospace Output). Estimate of Zoning and No-Zoning (NZ) by location.

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AJDIP 154-2012 Área Marina de Pesca Responsable de las comunidades de Palito y Montero, Isla de Chira

AJDIP 160-2012 Aprobar la Creacion de la Areaq Marina de Pesca Responsable de Puerto Níspero"

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