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# QUOTA SYSTEMS BASED ON TOTAL ALLOWABLE CATCH (TAC): A FEASIBLE MANAGEMENT MEASURE FOR SHRIMP FISHERIES IN PANAMA?


Alexis Omar Peña Castro
Aquatic Resources Authority of Panama (ARAP)
Panama City, Panama
alexisp@arap.gob.pa

Supervisor(s):

Hörður Sævaldsson: hordurs@unak.is
Hreiðar Þór Valtýsson: hreidar@unak.is



## ABSTRACT

Shrimp fisheries and processing is an important industry in Panama, and specifically the white shrimp (Penaeidae). Despite its importance, exploitation of the shrimp has varied significantly, and the fishery has declined over the past 20 years. Therefore, it is necessary to apply new and different management plans to ensure the sustainability of the resource and the profitability of the declining fisheries. In this project, fisheries management systems in Australia and Iceland are analysed along with theory of fisheries management, with focus on Ecosystem Approach to Fisheries (EAF). The analyses underlined the pros and cons of various methods to manage fisheries and was found to be a good foundation on which to base the initial recommendation for management of the Panama shrimp fishery. There is no single or simple answer regarding which fisheries management system to follow as a role model. However, it can be said that quota system based on TAC and ITQ have many necessary elements to be an adequate fisheries management for the shrimp fishery in Panama. But nothing is perfect, there are several known drawbacks with TAC and ITQ especially regarding social-economic impact. Review of pros and cons in fisheries management revealed the Ecosystem Approach to Fisheries to be feasible, but the balance between the biological, economical and the social part is for politicians to decide. Further work is needed to fully implement new fisheries management plan with TACs and possible ITQs in Panama shrimp fisheries. However, the objectives of new fishery management need to be discussed and the impact on communities, industry, government, and other stakeholders must be evaluated, the focus should be on sustainable shrimp fisheries for Panama’s future generations.



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# 1 INTRODUCTION

The Isthmus of Panama is the geographic connection between North and South America. The total area of the Isthmus is 75,517 km$^2$ and, it is bordered by the Caribbean Sea to the north, the Pacific Ocean to the south, Costa Rica to the west, and Colombia to the southeast. Panama has a coastline of 2,988 km, and the highest coast / km$^2$ ratio among the continental countries of Latin America (Sorensen & Brandani, 1987) of which 1,700 km is located on the Pacific coast and 1,287 km in the Caribbean (FAO, 2007). With its extensive coast, Panama has a large and productive Exclusive Economic Zone (EEZ), measuring 331,465 km$^2$ (Harper, Guzmán, Zylich, & Zeller, 2014).

Panama also has 1,600 islands and islets with a great variety of marine ecosystems such as mangroves, estuaries, sandy and muddy, swampy or rocky littoral: besides seagrass beds and coral reefs. After the ratification of the Convention on the Law of the Sea in 1996, the maritime domain in Panama was modified and the territorial sea extended to an area 12 nautical miles wide (Araúz, 2008).

Panama has a population of about 4.2 million habitants and in 2017 had a gross domestic product (GDP) of 62,284 billion USD. Of this total, the fishing industry represented 0.4%, that is, a GDP 249 million USD.

The fishing industry and its products (e.g., fish meal, frozen shrimps, fresh and frozen fish, etc.) are important in the economy of Panama, being, for example, the main export in goods in 2016, generating an income of over 96 million U*SD (Figure* 1), representing 15.1% of the Free On-Board (*FOB)* total export value (INEC, 2017). The main export markets are the United States, European Union, China, and Japan.

Fishing represents a considerable source of employment with more than 50,000 fishermen (industrial and artisanal), aquaculture and processing workers. An estimated 1.2 % of the population in Panama, depends directly on the fishing industry. The exploitation of marine resources is key to the economy of the poorest and most isolated coastal communities in the country. Therefore, these resources are of fundamental social and developmental importance (Ehrhardt, 2012).

In the Panamanian fishing industry, one of the main production items is the shrimp, and more specifically, the white shrimp (Penaeidae). In 2014 the total marine catch in Panama was 106,340 tonnes, of this total 2,39% correspond to shrimps and 0.3% to white shrimps (Harper, Guzmán, Zylich, & Zeller, 2014).

The white shrimp *Litopenaeus vannamei* is also important for the aquaculture sector. In April of 1999 a severe outbreak of the disease known as the *White Spot* considerably reduced the production of shrimp in the country (FAO, 2007). The aquaculture sector recovered slowly, from a production of 2,448 tonnes in 1999 to 6,723 tonnes in 2016 (INEC, 2016).

Despite its importance, the exploitation of the shrimps has varied significantly over the past 60 years. In 2007, landing data and the catch per unit of effort (CPUE), suggest that the shrimp fisheries were possibly over exploited (López, 2007).

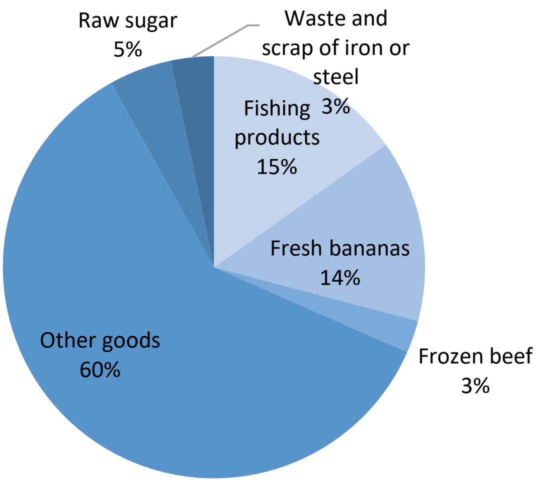


Figure 1. FOB export value, in percentage, of the main exported goods in Panama, in 2016. Source: (INEC, 2017)

## 1.1 Rationale

The population dynamics of shrimp and their responses to exploitation states are not well known in Panama, the management is based on maximum sustainable yields calculated in the 1970s (D' Croz, Chérigo, & Esquivel, 1979) and based on regulations that try to control fishing intensity through closed seasons and delimitations of fishing areas. These management actions have not been enough to stop the decreasing trend in landings over the past 20 years (Ehrhardt, 2012), (AMP, 2017), (INEC, 2016).

It is necessary to apply new and different management measures to ensure the sustainability of the resource and the profitability of the fisheries. The scope of the study is to evaluate the feasibility of implementing of a quota system based on total allowable catch (TAC), as an alternative to the current shrimp fisheries management system in Panama. Other management measures in fisheries applied in countries such as Iceland and Australia, which in many ways are considered some of the most advanced countries in fisheries management (Marchal, et al., 2016), will also be compared and analysed.

# 2 PANAMANIAN FISHERIES

Of the total fishing activity, in the EEZ of Panama, 98.7% is carried out in the Pacific Ocean, the remaining 1.3% in the Caribbean (Harper, Guzmán, Zylich, & Zeller, 2014). During the dry season (January-April), upwelling in the Gulf of Panama, is the basis for high productivity in Pacific waters (FAO, 2007).

The fishing industry in Panama began in the early 1950s, with the development of the shrimp fisheries and the small pelagic fisheries in the 1960s. From then on fisheries have played an important role in the development of the country's economy.

It has been estimated, in the time period between 1950 and 2010, the total of catches within the EEZ of Panama were approximately 8.6 million tonnes. The industrial fishing sector (shrimp and associated discards, small pelagic, and tuna) accounted for 88% of this total *(Figure 2)*, the artisanal sector 10% and subsistence with the recreational fishing just over 1% (Harper, Guzmán, Zylich, & Zeller, 2014).

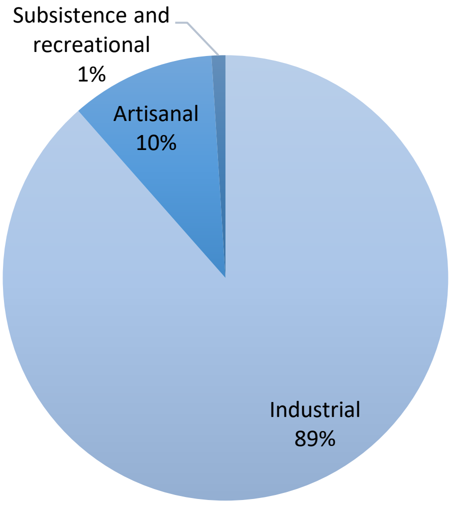


Figure 2. Estimated total marine fisheries catches, by sector, in the EEZ of Panama. Time period between 1950-2010. Source: Derived from (Harper, Guzmán, Zylich, & Zeller, 2014).

The main groups of fish of the marine fisheries estimated between 1950 and 2010, were mainly small pelagic: Pacific anchoveta (*Opisthonema libertate*) and Pacific thread herring (Clupeidae) 55%, finfish (Artisanal, mainly Lutjanidae) 9%, shrimps (Penaeidae) 6.3%; large pelagic: Tuna (Scombridae), dolphinfish (*Coryphaena hippurus*) 5.8%, sharks (Sphyrnidae) are mainly recorded as a bycatch of large pelagic and finfish fisheries 2.2%; other invertebrates: lobster (Palinuridae) and conch (Strombidae) 0.6%, among others *(Figure 3)*. In the shrimp fisheries the bycatch is about 85% (1:7 shrimp to other catch) and shrimp makes up about 15% of the catch. Most of the catch is discarded back into the sea and just over 20% of the bycatch is landed and recorded as marine catches (Harper, Guzmán, Zylich, & Zeller, 2014).

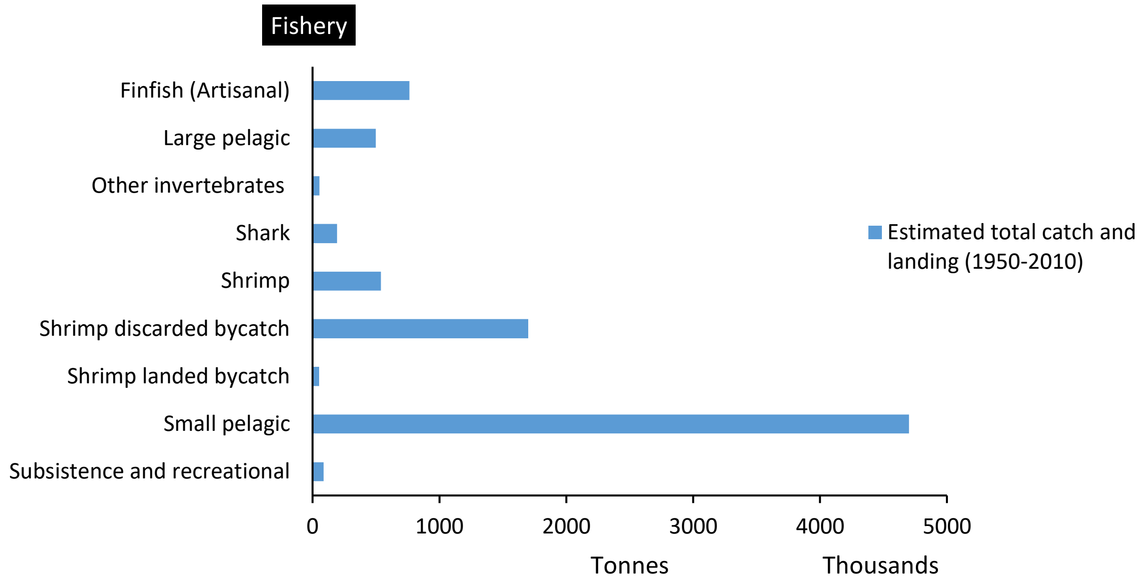


Figure 3. Estimated total catch and landing of the main fisheries in Panama, between 1950 and 2010. Shrimp fishery bycatch has an estimated ratio of 1:7 between the catch and the discard. Source: Derived from (Harper, Guzmán, Zylich, & Zeller, 2014).

## 2.1 Shrimp fisheries in Panama

The shrimp fishery in Panama is concentrated on the Pacific coast, mainly in the Gulf of Panama and the Gulf of Chiriqui. The industrial fleet, dedicated to white shrimp fishing, make their entire catch in three zones: Chiriqui (5%), Chame (5%), and Darién (90%) *(Figure 4)* (AMP, 2017).


Figure 4. Fishing zones (orange shadows areas) for the industrial white shrimp fishery. Source: (AMP, 2017).

Approximately 53% of the national shrimp landings correspond to three species of white shrimp (*Litopenaeus occidentalis, L. stylirostris and L. vannamei*) and the remainder is a conglomerate of species, among which are the small shrimp (*Xiphopennaeus riveti, Trachypennaeus faoea, T. pacificus, and Protrachypennaeus precipua*), carabalí (*T. byrdi*), red (*L. brevirostris*), brown (*L. californiensis*) and deep-water shrimps called fidel (*Solenocera agassizzi and S. florea* ) and bighead (*Heterocarpus vicarius*) (Ehrhardt, 2012).

The shrimp fisheries generate around 5,000 direct jobs and more than 20,000 indirect jobs, with an FOB export value in 2016 of 38.3 million USD *(Figure 5).* Of the different shrimp species that are caught in Panama, the white shrimp has the highest market price (Ehrhardt, 2012). At present, the market price of white shrimp is between 3.63 USD to 4.08 USD/kg (ACODECO, 2018).

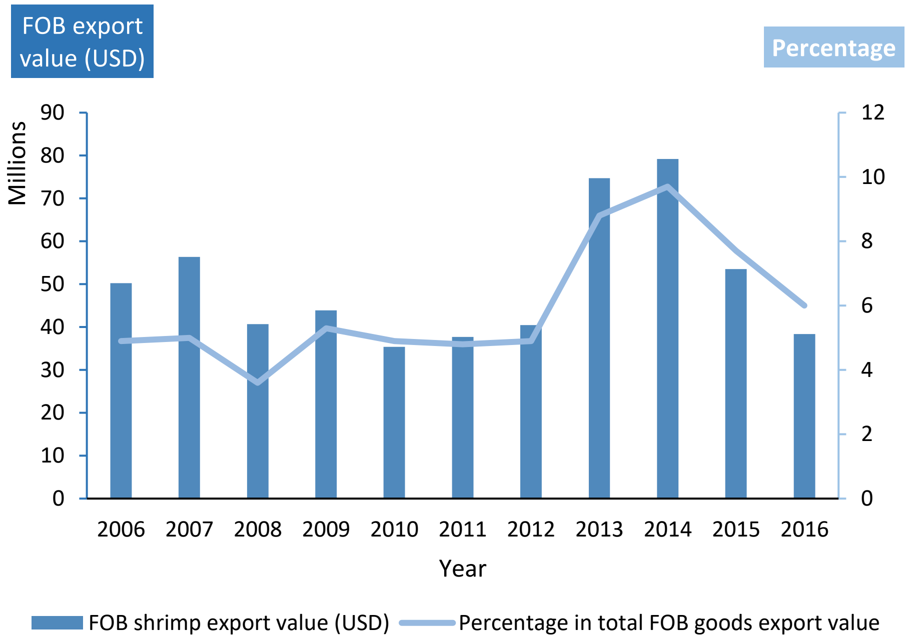


Figure 5. Changes in the FOB total shrimp export value in Panama (left axis) and its percentage in the FOB total export value (right axis), from 2006 to 2016. Source: (INEC, 2017).

The shrimp overfishing has been a problem for over forty years, having an impact on the total catches, with an oversized fishing effort, causing significant decreases in its total production (Araúz, 2008). Despite its economic importance, landing of shrimps has declined considerably and steadily since early 80s from around 7000 tons to less than 1100 tons in 2016. Two peaks are observed in 1997 and 2008, but the catch declines steadily the following years *(Figure 6)* (López, 2007) and (INEC, 2016).

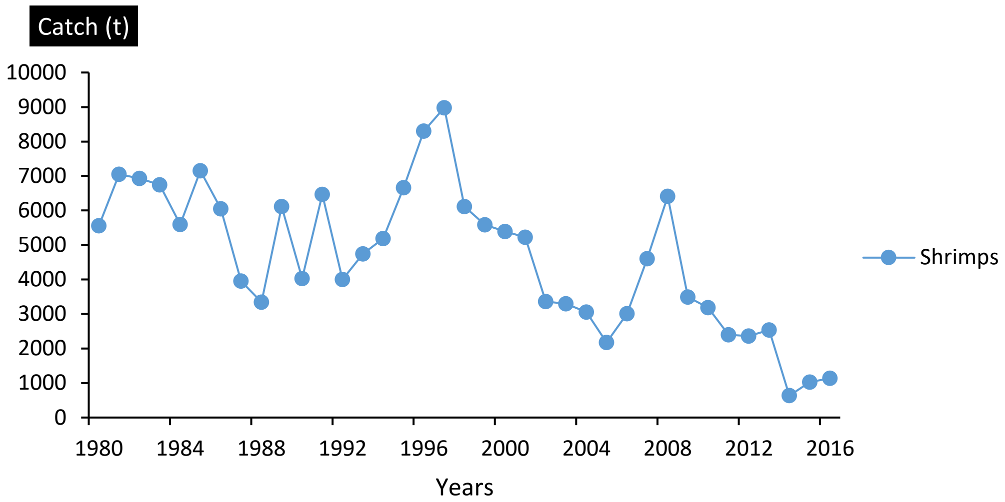


Figure 6. Industrial and artisanal annual landings of shrimps (tonnes) from 1980 to 2016. Since 1997, a tendency can be observed in the decrease of landings. In 2008 was an exceptional year in this trend but the following years, the decrease was maintained to the lower levels. Source: (AMP, 2017) and (INEC, 2016).

### *2.1.1 Development of shrimp fleet and gear*

The shrimp is caught both by the industrial fleet and the artisanal fleet. The division between artisanal and industrial fisheries is based on legislation that establishes that boats less than 10 GRT are artisanal boats *(Figure 7)* (ARAP, 2018).

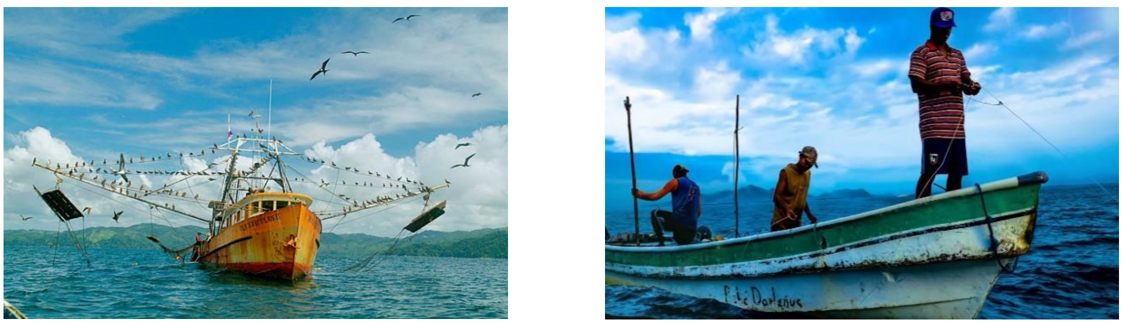

Figure 7. Shrimp fleet in Panama. Industrial vessel > 10 GRT (left) and artisanal boat < 10 GRT (right). Source: *(ARAP, 2018)*

Industrial fishing of white shrimps began in the Republic of Panama with eight vessels in 1950 (D'Croz et al., 1979). By 1957 the fleet had increased to 157 ships. In the sixties the fishery evolved rapidly, and the number of vessels increased to 218. By the 1970s the number of vessels had risen to 260. At present, there are 150 registered industrial vessels *(Figure 8)* dedicated to shrimp fishing (ARAP, 2018). The shrimp vessels have a crew of 5 people and make 1.36 trips per month, the average trip is about 17 days (Ehrhardt, 2012).

The industrial fleet uses wooden boats with iron or fiberglass hull, approximately 20 to 25 meters in length and engines between 210 and 390 HP and fishing gears based on models from the Gulf of Mexico, with trawls of 4 cloths, semi-balloon type that work in both sides of the boat (double rigger). The boats use two nets with the turtle excluding device (TED). Although, in the beginning, a single net was used dragged by the stern, which represented, from 2001, an increase in fishing power by boat of 100% (Araúz, 2008).

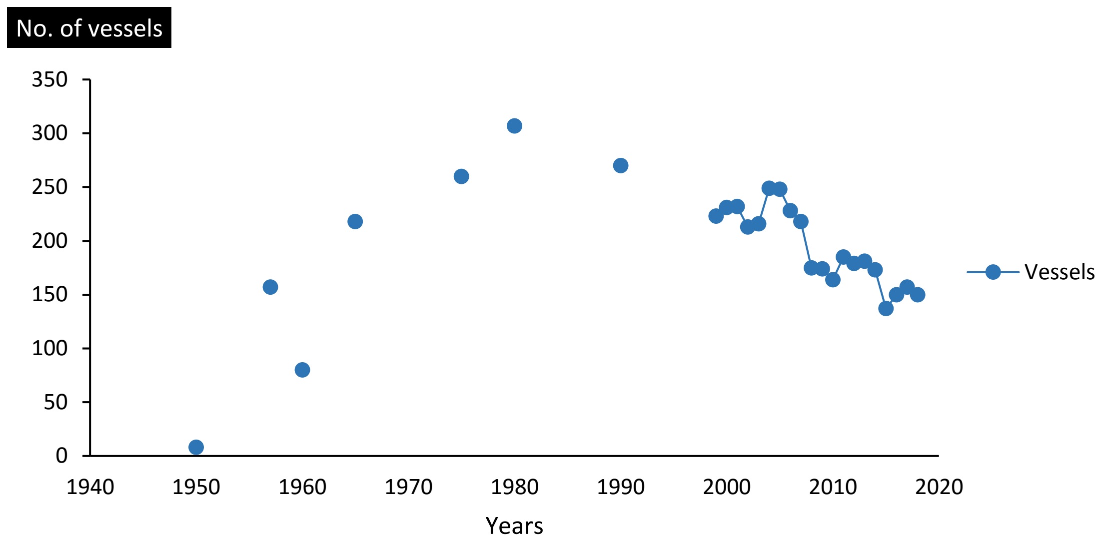


Figure 8. Changes in number of vessels of the industrial shrimp fleet in Panama, from 1950 to 2018. From 2005, there is a trend in decreasing the effort, reducing the number of vessels in the industrial shrimp fleet. Source: (D' Croz, Chérigo, & Esquivel, 1979); (AMP, 2017); (INEC, 2016) and (ARAP, 2018).

### *2.1.2 Development of CPUE in shrimp fisheries*

By 1980, catches showed decreasing trends, remaining below 1,500 t in 2014 *(Figure 6)* (Rodriguez & López, 1988) and (ARAP, 2018), as a response to the excess fishing capacity that exists. A closed season was introduced in 1976, and other measures were subsequently adopted, such as the reduction of fishing effort expressed in days of fishing. Nowadays there are two periods of closure. In early 2000, shrimp fishing vessels that did not fish for shrimp, in most cases, were engaged in longline fishing for tuna and dorado and a few were fishing for small pelagic with trawl gear. As the CPUE of the artisanal fleet increased, the CPUE of the industrial fleet was decreasing. Since 2005 the CPUE trend of both fleets have a similar performance. *(Figure 9).* These changes in the CPUE have greatly affected the profitability of the industry since the operational cost has increased but revenues from the catch has decreased (FAO, 2007).

With the fluctuating numbers of shrimp vessels and consequently catch, the estimates MSY for the white shrimp fishery is in the range of 1,800 and 2,300 t of shrimp tail (approx. 65% of the total weight) (FAO, 2007).

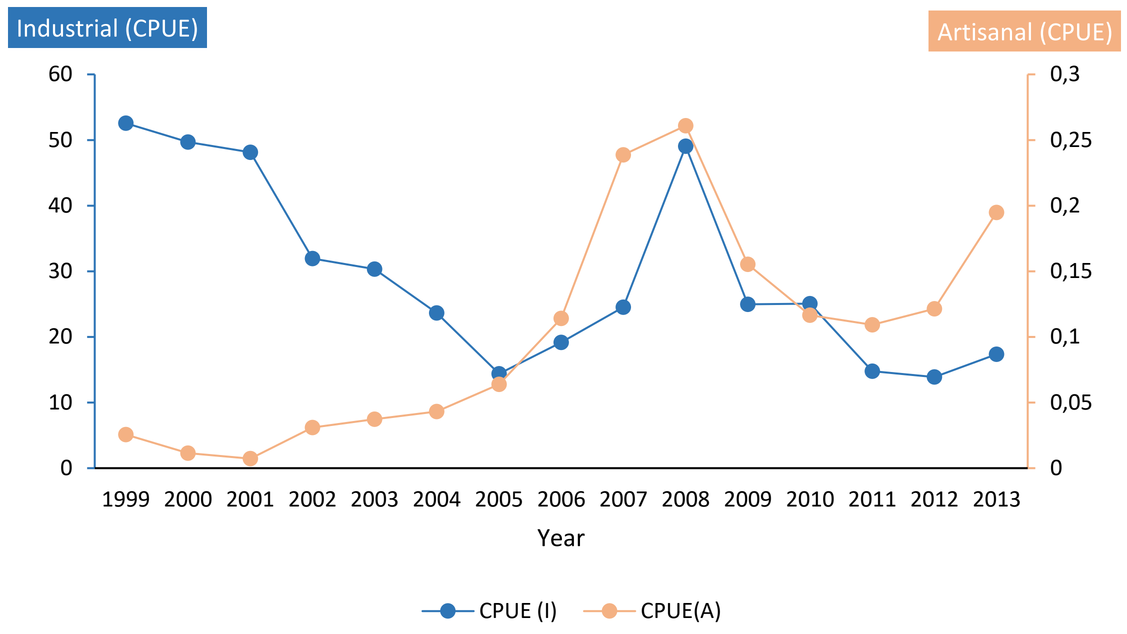


Figure 9. Annual CPUE of the industrial (left axis) and artisanal (right axis) shrimp fishery in Panama, from 1999 to 2013. Source: Derived from (INEC, 2016).

Artisanal shrimp fisheries have been small over the years but growing since 2001. The fisheries can be classified into two groups: subsistence (the smallest) and small-scale fishing. In both groups, the fishermen direct their activity mainly towards the extraction of coastal shrimp and fish. The shrimp fisheries are carried out on boats with an average HP of 25 - 50 (Araúz, 2008).

The beginning of the artisanal shrimp fishery dates from 1982, traditionally engaged in Finfish, with the modification of the legislation in Panama to decrease mesh size from 3 ½" to 2 ¾". This modification allowed the artisanal fleet entry to shrimp fishing (Araúz, 2008).

There is a great competition between artisanal and industrial fishing for resources. In the case of artisanal shrimp fishery, the number of boats doubled from 1999 to 2010 *(Figure 10)*, and in the use of gillnets has had a large impact on shrimp catches. In 1975 gillnets were introduced in the country, at that time the average annual shrimp catch was 1,800 t of tail, coinciding with the entrance of gillnets, there is a growth of the industrial fleet. Landings for artisanal fisheries have increased significantly since 2006 *(Figure 11)* while the numbers of industrial vessels, that fish for shrimp, and industrial shrimp landings are decreasing and the catch per unit of effort (CPUE) has declined *(Figure 9)* (FAO, 2007) (INEC, 2016).

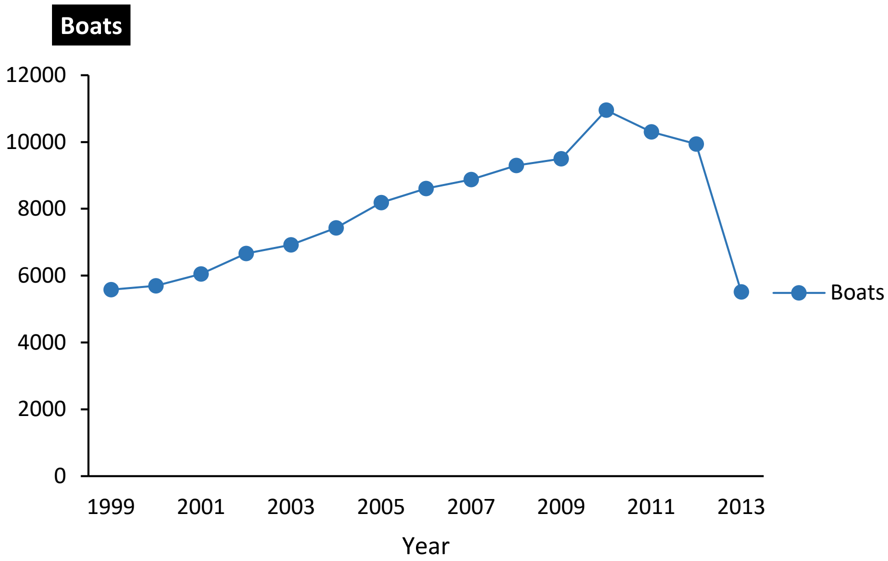


Figure 10. Changes in numbers of boats of the artisanal shrimp fleet in Panama, from 1999 to 2013. For more than 10 years the artisanal shrimp fleet maintained constant growth. This trend was affected since the issuance of new licenses for fishing was limited. Source: (INEC, 2016).

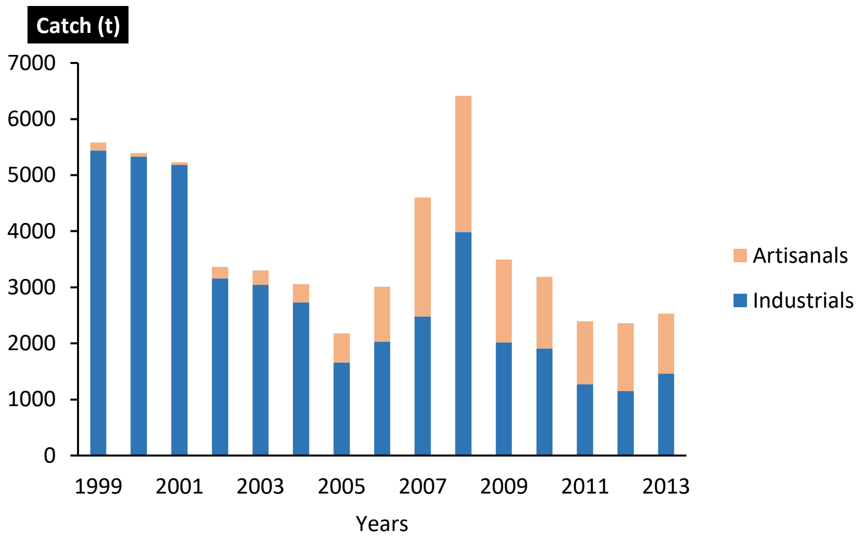


Figure 11. Shrimp landings of the industrial and artisanal fleet in Panama, from 1999 to 2013. With an increase in the number of boats of the artisanal shrimp fleet, their shrimp landings were increasing, almost equalling those of the industrial shrimp fleet. Source: (INEC, 2016).

There is a free access to fishing, although there are restrictions for the permits of artisanal shrimp fishery. Despite the restrictions, the artisanal shrimp fleet had a notable increase in the use of gillnets per boat. The current regulations indicate that no more than 2 gillnets cloths should be used per boat, but some authors indicated that seven is the average used (FAO, 2007). The legislation does not foresee, in the case of artisanal fishing, the way to prevent new access to the fishery. More than 40 % of the artisanal finfish fishermen, dedicate to shrimp fishing, that does have a limit since 1996 (Araúz, 2008).

## 2.2 Fishery management system in Panama

In Panama, the objectives of fisheries management were updated with the creation of ARAP in 2006. The general objective of fishery management is to achieve optimal and rational use of aquatic resources, through sustainable management and development. This approach allows assurance of the conservation, renewal, and permanence of the resource, and that the activity of fishing and aquaculture stays socially, environmentally and economically sustainable. To achieve this goal, ARAP has used the ecosystem approach in fisheries (EAF), integrating stakeholders in all fisheries management decisions and regulations (ARAP, 2018).

ARAP has a Research and Development Department responsible for making scientific recommendations for the management of fisheries resources. These recommendations can be issued along with universities, research institutions such as the Smithsonian Tropical Research Institute (STRI), scientific consultants, environmental NGOs, and the fishing industry. The board of ARAP is made up of representatives from the government, fishing industry, academics, scientists, and environmental NGOs.

In Panama there is a close relationship between the fishing sector and the government; this relationship has strengthened over the last five years since the actual administration decided to work closer with the industry. When the State considers some modification or implementation on the legislation of fisheries management, the authority organises round table discussions with all stakeholders to elaborate measures that allow achieving the common goals and conservation of the resources.

Other fishing management measures in Panama are: the issuance of licenses for different types of fishing (artisanal and industrial), satellite monitoring is applied for industrial vessels, and closed periods have been established for different species (shrimp, dolphinfish and Pacific lobster), prohibitions of catches for others (billfish, parrotfish, conch), establishment of forbidden areas for fishing, reduction of effort (size of the fleet and fishing days) and restrictions on fishing gears (size and number of hooks , quantity of nets used) and utilisation of the turtle excluder device (TED) (ARAP, 2018).

### *2.2.1 Shrimp management system*

The decrease in white shrimp landings has not been reversed by the historical implementation of administrative measures aimed at restricting exploitation and protecting the resource *(Table 1)*. The fisheries were closed for two months in the dry and the rainy season, starting in 1975 *(Figure 12)*. First period: 1 February to 11 April; second period: 1 September to 11 October. During the closure periods, the industrial shrimp fishery takes the opportunity to provide maintenance to the vessels and change the fishing nets. Approximately 5% of this fleet obtains special permission, issued by the fishing Authority, for the fishing of finfish in those periods. The artisanal fleet also continues its fishing activity on finfish. Since the 1990s the fishery has been reduced to less than 20 days during the most important months of reproduction of the species. In the 2000s, Marine Protected Areas (MPA) were created when some areas were closed to fishing activities. Due to these reasons, the traditional shrimp industry is at an economic crossroads that could be having very important social impacts (Ehrhardt, 2012).


Figure 12. Closure seasons for shrimp fisheries in Panama. Source: (ARAP, 2018).

Table 1. Historic events in the development of shrimp fisheries management in Panama. Source: (MarViva, 2011) and (ARAP, 2018).

| Date | Event |
|---|---|
| 1950 | Start of shrimp fishing in Panama with 8 vessels |
| 1957 | Fleet had increased from 8 to 157 vessels |
| 1966 | The shrimp fishery in Panama is regulated |
| 1969 | The shrimp fleet had increased to 218 vessels |
| 1974 | Shrimp landings begin to show decreasing trends, from 6,500 tons in the mid-1960s to 1,772 tons in the late 1970s. |
| 1975 | The fishing gear known as gillnet was introduced into the country and used by the artisanal fleet. |
| 1977 | A period of closure is established in the jurisdictional waters of the Republic of Panama in the Pacific Ocean, which is not applicable to deep-sea shrimp fishing. |
| 1978 | The issuance of licenses for shrimp fishing is regulated |
| 1979 | By the end of this decade, the shrimp fleet had increased to 260 vessels |
| 1985 | Shrimp fishing is regulated in territorial waters of the Republic of Panama |
| 1990 | More regulations were added on shrimp fishing, control over effort by reducing fishing days |
| 1991 | Modifications of Shrimp closure measure established in 1977, excluding deep shrimp and authorises the use of 3.5-inch gillnets. |
| 1994 | The issuance of new deep-sea shrimp fishing licenses was prohibited |
| 1995 | The deep shrimp fishery is regulated. Deep shrimp species are included in those subjects to the fishing calendar (closure season). The fishing of these species may carry out at more than 160 fathoms (288 meters). Fixes in twelve (12) the number of vessels for the depth shrimp fishing activity. |
| 2001 | Measures are established for the control of fishing effort on shrimp populations; a maximum of two (2) trawl nets per boat is established during the fishing operation. |
| 2003 | Two closed seasons are established for all marine shrimp species, and the permanent prohibition of shrimp fishing in coastal areas of the Pacific of Panama. |
| 2005 | The fishing ports of Vacamonte and Coquira, are the accredited ports for the emission of the fishing expeditions to the trawling vessels. The use of the sea turtle excluder device is established. |
| 2006 | Landing tendencies for artisanal fisheries have increased |
| 2018 | The size of the industrial fleet is 150 vessels |

# 3 METHODOLOGY

This study is carried out through a literature review, communication with experts, primary and secondary data on catch statistics and fleet management in Panama, Iceland, and Australia. Well known theories of fisheries management and resources economics will be used in addition to the accrued experience of the author in areas within the Panamanian fisheries that have not been documented before.

With the description mentioned in the project's genesis, the following activities and tasks will be done:

1) a description of the fisheries and fishery management system in Panama, going from the macro to the micro,
2) an introduction of the theory in fisheries management, along with review of relevant literature
3) an analysis of the fishery management systems in Australia and Iceland, as world reference countries in fisheries management and
4) a discussion of the theory of fisheries management applied to the systems used by Australia and Iceland in fisheries, together with recommendations for the management of the shrimp fishery in Panama.

## 3.1 Description of the fisheries and fishery management system in Panama

The fishery in Panama will be analysed through production data and landings collected between 1950 and 2016.

The export fishery products of major importance in the Panamanian economy where extracted from the fisheries data with focus on shrimp fishery. Special attention is given to aspects such as social-economic impact, type of species, fishing areas, description and size of the artisanal and industrial fleet dedicated to activity and historical shrimp landing series.

The Panamanian legislation on fisheries management was reviewed and analysed, as well as the management objectives established, and the tools used by the Fisheries Authority in the management of fishery resources, with emphasis on the shrimp fishery.

The data, as the number of vessels (industrial and artisanal), shrimp landings, fishing areas, export values, were obtained from the official records of the Aquatic Resources Authority of Panama (ARAP by its Spanish acronyms), the Maritime Authority of Panama (AMP by its Spanish acronyms) and the National Statistical and Census Institute of Panama (INEC by its Spanish acronyms). Complementary data was acquired from scientific publication of the University of Panama, Environmental ONGs on shrimp fisheries in Panama.

The total marine fisheries catches data from 1950 to 2010 was used from the publication of (Harper, Guzmán, Zylich, & Zeller, 2014) rather than FAO records, because in that study the authors made a comparation between the data reported by FAO and other collected by government, scientific and academic institutions in Panama, along other estimates based on survey data they constructed historical catch of fisheries. The result was almost 40% higher than reported by FAO for the same period. Other researchers and agencies, such as the Sea Around Us, mention that study as the most reliable on fisheries catches in Panama.

The data was organised in Excel for the calculation and analysis of CPUE for the industrial and artisanal fleets, trends in shrimp landings and export value. For better understanding, the information was presented in tables and excel graphics.

### 3.2 Theories of fisheries management

The theory behind fisheries management strategies was analysed. An extensive bibliographic review of FAO documents and books on marine fisheries management was carried out, with the purpose of defining the ecosystem approach in fisheries (EAF) and its biological, economic, and social objectives.

In the second part of this section, based on the literature, the main fishing management systems and tools are presented and described.

### 3.3 Analysis on the Icelandic and Australian fisheries management systems

For the analysis of successful management systems, Iceland and Australia have been selected. In addition to this characteristic, Iceland was one of the first countries in the world to implement the quota system (Agnarsson, Matthiasson, & Giry, 2016). Australia is a country that has similar shrimp species as Panama (Buckworth, et al., 2013) and serves as a reference in terms of management of the resource.

The fisheries management systems of Iceland and Australia will be presented, through a general description of their development and implementation. Journals like Marine Policy, Fisheries, Ocean and Coastal Management, Marine Sciences and Marine Fisheries Review, collected mainly from ScienceDirect, were consulted for this purpose.

At the end of the section, a comparative table between the fishery management systems of Panama, Iceland and Australia is presented.

### 3.4 Outcome

With the inputs obtained from the description of the fisheries management system of Iceland and Australia, along with the definition of fishing management objectives and measures. The possible implications of implementing a new management system in shrimp fishery in Panama, such as a quota system based on total allowable catch (TAC), will be addressed.

The analysis will focus mainly on the biological, economic, and social consequences of this system, together with recommendations for its better application and development within the fishing system of Panama.

# 4 SELECTED THEORIES BEHIND FISHERIES MANAGEMENT SYSTEMS

## 4.1 The theory of the Ecosystem Approach to Fisheries (EAF)

Studies of management around the world have identified three fisheries management objectives: economic, social, and environmental sustainability. Most fisheries legislation globally is concerned with maintaining resource (and environmental) sustainability foremost, achieving these is often complicated by the potential social and economic consequences that may be explicitly or implicitly considered in fisheries legislation (Pascoe, Plagány, & Dichmont, 2017).

The Ecosystem Approach to Fisheries (EAF) is a system that has the purpose to accommodate the expectations and needs of society in the management without threatening the possibilities of future generations to benefit from the resource ecosystem goods and services (FAO, 2003). The EAF tries to find a satisfactory balance between ecosystem conservation, which focuses on the protection of biophysical components and ecosystem processes, and fisheries management, which focuses on providing food and income for people, through the management of fishing activities.

The EAF attempts to deal with fisheries in a comprehensive manner through the recognition of the economic, social and cultural benefits that can be derived from fisheries resources and their ecosystems *(Figure 13)* (FAO, 2010).

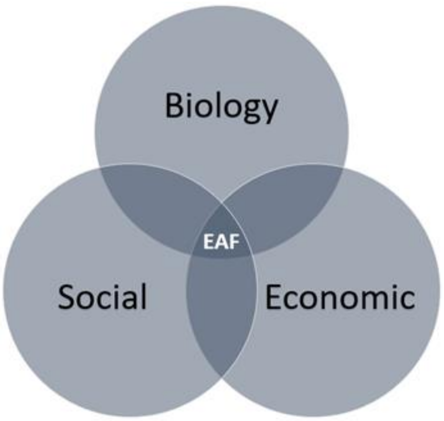


Figure 13. The Ecosystem Approach to Fisheries involves the overlapping of several key management objectives. Source: Derived from (FAO, 2010).

The EAF seeks to achieve a balance between the approach of the biological, social and economic objectives, and its success will depend in how these objectives can be transformed into specific, treatable and effective management actions (Jennings S. , 2004). Making the EAF operational requires that managers identify general and specific objectives, set measurable targets, develop rules on how to apply and adapt fishing regulations and objectively evaluate the performance of management plans through monitoring (FAO, 2010). All this needs to be done with great user participation and capacity building in local institutions.

The objectives set out in the EAF and which are the basis for the establishment of management measures for the shrimp fishery are defined below.

#### *4.1.1 Biological*

Managers should limit fishing capacity and fishing pressure so that populations remain economically and biologically viable (FAO, 2010). Normally fishing activities focus on one or more species of an ecosystem, but often also affect other components of that ecosystem, e.g., indirect effort on other species and damage caused to the ecosystem or effects produced in the food chain. The responsible fisheries must consider the impact of the activity on the whole ecosystem, including biodiversity, and the objective should be the sustainable use of ecosystems and complete biological communities. The management objectives must, therefore, express the need to safeguard the cultural and economic interests of fishers and subsistence users (FAO, 1999). Given this, a sensitive objective is to manage fishery impacts in such a way that populations are relatively stable over time and can deliver sustained income to fishermen.

#### *4.1.2 Socio-economical*

Responsible fishing requires knowing the essential factors in the social and economic dimension of the management system. The social dimension involves a broad set of variables in the human scope. It deals mainly with the interaction between people: how and why individuals and groups behave towards each other and in relation to the fishery resources they use or depend on. These relationships are influenced by a great variety of models, habits and cultural customs, instruments of exchange, institutions and individual and group motivations (FAO, 1999). In addition, fishing is an essentially economic activity and the economic dimension includes income and costs that vary according to the level of exploitation and are related to the dynamic forces of the market. There is a close interaction between the social and economic variables, and likely any management measure will affect, for example, the distribution of income and wealth, the volume and type of employment, the allocation of rights of use, and the composition and cohesion of the groups and subgroups of interest. More generally, the decisions and actions taken in management will influence the attitudes, positive and negative, of the groups concerned. Fisheries management measures can also condition the contribution of fisheries on key policy issues such as food security, net foreign exchange earnings, subsidies and other costs and benefits (FAO, 1999). It may also happen that economic and social interests are opposed, in that case, it will be necessary to seek the greatest possible match between the social and economic objectives of the management plan.

### 4.2 Fisheries management actions

Management actions can be divided into catch controls, effort controls and technical measures *(Table 2)*. Catch control limits the catches of individual fishers or the fleet as a whole, effort controls limit the numbers of fishers in the fishery and what they can do, while technical measures control the catch that can be made for a given effort (Jennings, Kaiser, & Reynolds, 2001)

Table 2. Types of management action. Source: (Jennings, Kaiser, & Reynolds, 2001).

| Technical measures | Effort controls | Catch controls |
|---|---|---|
| Time and area closures | Limited licences | Catch limits |
| Size and sex selectivity | Gear or vessel restrictions | Total allowable catch (TAC) |
| | Effort quotas | Individual quotas (IQ) |

### *4.2.1 Technical measures:*

Technical measures restrict the size and sex of the caught or landed species, the gear used and the times when, or areas where, fishing activity is allowed.

- **Sex and size restrictions:** The sizes of the individuals that are captured must be regulated by minimum landing sizes (MLS). This to reduce the presence of small individuals (non-commercial size) in the landings. Usually, the regulation of the characteristics of the fishing gear, such as the minimum size of the mesh or the dimensions of the upper part of the nets, is intended to control the mortality of a certain component of the resource, such as the smallest specimens, e.g., juveniles of the target species or the bycatch species. Sex restrictions usually restrict the capture of mature or egg-bearing females. They are mainly used in crustacean fisheries (Jennings, Kaiser, & Reynolds, 2001).
- **Areas and time closures:** These measures can protect species at specific phases of their life history. Time closures can protect annual stocks until their production and quality is high. Area closures may stimulate effort redistribution. Time and area closures have been most effective when used together with catch and effort controls (Jennings, Kaiser, & Reynolds, 2001).

### *4.2.2 Effort control:*

The effort controls, also known as input control, limit the number of vessels or fishers who work in a fishery, the amount, size and type of gear they use, and the time the gear can be left in the water. The input controls may also limit the size or power of vessels and the periods when they fish.

- **Licenses:** Restricts the number of boat or fishers in the fishery. Licenses can be transferable.
- **Individual effort quotas (IEQ):** Limitation of the amount of time spent working by a given unit of gear, a vessel, or a fisher (e.g., number of fishing days at sea).
- **Gear and vessel restrictions:** The purpose is to limit the catch capacity of vessels or fishers. These may control the size and design of pots or nets, the dimensions of a fishing vessel or ban specific that are too effective.

### *4.2.3 Catch control:*

Catch controls, one of the most widely used management regulations, and also known as output control, allows estimating the optimum volume of capture of a population using a certain fishing strategy as limiting the weight of catch that fisher can take. Output controls include total allowable catch (TAC) or quotas (Q), which are limits on the total catch to be taken from specified stock, as well as individual quotas (IQ) and vessel catch limits where the TAC is divided between fishing units (Jennings, Kaiser, & Reynolds, 2001).

- **Total allowable catch (TAC):** Total allowable catch (TAC) is a catch limit for a fishery that applies for a defined period. TAC can be used as a management measure for limiting fishing of specific species. Depending on the information available for the species being assigned a TAC, the calculation of the TAC may involve population modelling or set as a percentage of the estimated standing stock of the species. Where no information is available on the stock status, TACs are often based on catch quantities or set at what is assumed to be a precautionary level (Militz, Kinch, Schoeman, & Southgate, 2018). TACs may be good biologically but can be poor economically (Jennings, Kaiser, & Reynolds, 2001).
- **The individual quotas (IQs):** Define as a permit that allow the holder of the quota to catch or transfer a share of a total allowable catch (TAC). Typically, these permits do not expire, although if a fishery must be closed or diminished, the permit is similarly devalued. Most IQ systems allow these permits to be leased or sold to others (Pinkerton & Edwards, 2009).Then they are called Individual Transferable Quotas (ITQs).
  The introduction of ITQ management systems has improved profitability in many fisheries around the world (Pascoe, Plagány, & Dichmont, 2017). ITQs offer environmental and economic benefits, including better conservation of a fish stock and greater profitability for fishers. With some limitations, they achieve fairly good alignment between the profit incentive and stewardship objectives (Soliman, 2014).

When used independently, catch controls, effort controls or technical measures are unlikely to provide a basis for meeting management objectives, e.g., when the ITQs are used in combination with technical measures, had worked most effectively to optimise resource conservation and economic performance of the fisheries (Jennings, Kaiser, & Reynolds, 2001). ITQs were one of the most effective way of controlling exploitation, reducing the race to fish, reducing over-capacity, and increasing profit. Technical measures helped to reduce discarding, control bycatches, and protect target species at vulnerable stages of the life history.

# 5 ICELANDIC AND AUSTRALIAN FISHERIES MANAGEMENT.

Iceland and Australia have been at the forefront, and are a world reference in fisheries management, so much so that they occupy the 4th and 7th place respectively, of the countries that have marine ecosystems in the world, in compliance with the FAO code of conduct for responsible fishing (Alder, et al., 2010). In the same way they are reference examples of fisheries that involve stakeholders, use of legally binding managements targets (Australia), individual transferable quotas, and discard bans (Iceland) (Marchal, et al., 2016).

Australian fisheries is considered one of the best managed in the world and was among the first in the world to embrace a management objective of maximising net economic returns as the primary objective of fisheries management (Pascoe, Plagány, & Dichmont, 2017). Much of this is due to the explicit recognition of the role of incentives in the management of fisheries, and the benefits that can be achieved through the maximisation of economic returns as a key management objective (MEY) (Pascoe S. , Kahui, Hutton, & Dichmont, 2016). These same authors also say that, recently, social objectives have been promoted in fisheries management.

In Australia bio-economic model assessment fitted to multi-species prawn fishery data sets, can provide useful estimates of the overall effort levels required to achieve MEY outcomes (Hesp, et al., 2017).

With Australia, Iceland had been at the forefront of developing management practices such as individual transferable quotas (ITQ), legally binding management targets, stakeholder involvement, and discard bans (Marchal, et al., 2016).

The roots of fisheries management in Iceland date back to the early 1960s with growing concerns of shrimp overfishing. To address the issue, a TAC was set to limit shrimping efforts. The TAC was divided among fishermen as individual quotas (IQ) based on their previous fishing history (Edvardsson, Pastrav, & Benediktsson, 2018).

The development of Icelandic fisheries has been characterised by increased, consolidation of quotas, structural changes, efficiency through rationalisation, increased specialisation, and increased use of technology (Knútsson, Kristófersson, & Gestsson, 2016).

## 5.1 Iceland fisheries management

The main objective in fisheries management in Iceland is to promote the conservation and efficient use of stocks of fishery resources, ensuring the generation of jobs for industry. In practice, greater importance has been given to the greater economic efficiency of fisheries and the sustainability of resources using the Individual Transferable Quotas systems in most fisheries (Marchal, et al., 2016).

In Iceland, there are three institutions in charge of the fisheries management, 1) the Marine and Freshwater Research Institute (MFRI) carries out wide-ranging and extensive research on the status and productivity of commercial stocks, and long-term research on the marine environment and the ecosystem in Icelandic waters. It is the technical advisor for fisheries management measures, 2) the Ministry of Industries and Innovation (MII) bases its policy decisions on annual total allowable catch on the recommendations of the MFRI as well as consultation with stakeholders, and 3) the Directorate of Fisheries allots annual catch quotas to each vessel by distributing the total allowable catch according to the quota shares attached to each vessel.

In Iceland, the fisheries administration is in the hands of the public sector. However, the industrial sector plays an important role in the management. Among the members of the board of directors of the Marine Freshwater Research Institute (MFRI), there are representatives from the industry, as well as in the official committees in charge of overseeing the fisheries administration. Representatives of the fishing industry are also consulted for the drafting of the regulations.

The Individual Transferable Quotas (ITQs) systems is the main management tool for fisheries in Iceland (Arnason R. , 1995) cited in (Marchal, et al., 2016). All major commercial stocks are subject to ITQs, except the specific coastal jigging fisheries which is an effort system with TAC. All species subject to the system are issued a TAC annually, but prior to the issuance 5.3% is deducted and held back by the authorities. This proportion is then utilised as temporary support to coastal region communities. The Directorate of Fisheries calculates and issues the annual catch quota (kg) to individual vessels, by multiplying the TAC with the vessel's quota share (%) to result in vessels ITQ. Under certain circumstances, it is permitted to transfer both quota shares and annual catch quotas between vessels. There are specific limits to quota, these limits apply to both individual species quota and total quota shares cumulated over all species. Icelandic fishing companies contribute financially to fisheries management expenditures through a resource tax (Marchal, et al., 2016).

Fishing in Iceland is divided mainly into 4 fisheries: First and foremost is a demersal fishery, which generates between 80% and 90% of the total wetfish value. The main species in this fishery are cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*), redfish (*Sebastes sp.*) and saith (*Pollachius virens*). In second place is pelagic fishery based on herring (*Clupea harengus*), capelin (*Mollotus villosus*), Atlantic mackerel (*Scomber scombrus*) and blue whiting (*Micromesistius poutassou*), the wetfish value is variable, but it remains between 5-8% of the total. In the third place, due an environmental factor, a collapsing crustacean fishery, represented by shrimps and Norwegian lobster, the wetfish value is lower than pelagic fishery. Finally, a mollusc fishery based on scallops. This fishery is fairly insignificant with less than 1% of the total catch value (Arnason R. , 1996)

Iceland was one of the first countries to introduce property rights- based fisheries management systems. At the beginning of the 70's, the Individual quotas system (IQs) was introduced in the herring fisheries *(Table 3)*. In 1979 these individual quotas became transferable, being called Individual Transferable Quotas (ITQs). Iceland was one of the first countries in the world to apply this system in its fisheries. During the 1980s, all fisheries in Iceland were adopting this system and it was not until 1990 with the *Fisheries Management Act of 1990*, that all fisheries were regulated under this system (Arnason R. , 1996).

Table 3. Process of the introduction of the ITQ´s in Iceland fisheries. Source: Derived from (Arnason R. , 1996).

| Date | Event |
|---|---|
| 1975 | The herring fishery: individual quotas |
| 1979 | The herring fishery: individual quotas made transferable |
| 1980 | The capelin fishery: individual quotas |
| 1984 | The demersal fisheries: individual transferable quotas |
| 1985 | The demersal fisheries: effort quota option introduced |
| 1986 | The capelin fishery: individual quota made transferable |
| 1988 | Individual transferable quotas in all fisheries. Effort quota option retained |
| 1990 | A complete uniform system of individual transferable quotas in all fisheries |
| 2004 | ITQ´s introduced also for smaller boats (special quotas for long-line fishing) |

### *5.1.1 Islandic ITQs fisheries management system*

The individual transferable quotas (ITQs) as Icelandic fisheries management system is characterized by the following:

- All fisheries have defined catch quotas per vessel.
- Quotas represent a fraction in the Total Allowable Catch (TAC).
- TAC is based on scientific advice from the Marine Freshwater Research Institute.
- The quotas are permanent, perfectly divisible and can be freely transferable fairly.
- The allocation of quotas is subject to a small annual cost, which is used to cover the costs of its implementation.

In addition to these features, the ITQ system in Iceland is made up of the following components:

- **Total Allowable Catch (TAC)**: As mentioned before, The TAC of the most important fishing species, is determined by the Ministry of Industries and Innovation (MII) based on the recommendations of the Marine and Freshwater Research Institute (MFRI). Among the main species subject to TAC and consequently to individual quotas, can be mentioned, between the demersal species, cod, haddock, saith, redfish, Greenland halibut and plaice *(Hippoglossoides platessoides*), pelagic species (herring, capelin, blue whiting and Atlantic mackerel), the shrimps, lobsters and scallops. These species represent 95% of the total volume of fishing and more than 90% of the value in Iceland (Arnason R. , 1996).
- **Permanent quota shares**: Each vessel, legally established for fishing, is assigned a permanent share in the TAC, for each species for which there is a TAC. These permanent quota shares are called TAC-shares.
- **Initial allocation of permanent quota shares**: The methodology applied for the allocation of permanent quota shares varies among the types of fisheries. In the demersal, lobsters, scallop and deep-sea shrimp fisheries, the TAC-share is based on the historical record of the fishing catches during a certain number of years, e.g. in demersal fisheries, the average catch of the 3 years prior was used at the introduction of the vessel quota system in 1984. In the inshore shrimp and herring fisheries the initial TAC-shares were equal for all eligible vessels. Eligible vessels were those with

a recent history of participation in the fishery at that time. The same rule applied to the capelin fishery except, that one-third of the TAC-shares were initially allocated based on vessel hold capacity. The size of the annual quota assigned to each vessel is the product between the TAC for the corresponding fishery, and the vessel's TAC-share. While the TAC-share is expressed as a percentage, the annual quotas are expressed in volume terms. It is important to mention that in some cases, e.g. the capelin fishery and some inshore shrimp fisheries, where the biological management periods are less than a year, the quota periods are equivalently shorter.

- **Divisibility and transferability**: The permanent TAC-shares and the annual quotas are transferable (although subject to some restrictions) and are perfectly divisible, i.e. any fraction of a given quota may be transferred. Regarding the transferability of the quotas, there is a difference between annual quota and the permanent TAC-share. The annual quotas present minor restrictions on transferability, while TAC-share are transferrable without any restrictions.
- **Maximum quota share:** Was introduced in 1998, to restrict a company's quota allowance. This was commonly named a "quota ceiling", introduced to reduce the consolidation of ongoing quotas and to prevent a handful of firms controlling all fishing in the country. The current maximum quota share is 12% of the total quota issue in cod-equivalents kilos. For individual species the ceiling is normally 20%, although in certain species it reaches 35% (Ministery of Industries and Innovation, 2016) and (Directorate of Fisheries, 2018) .
- **Restricted access (Licenses)**: All commercial fishing vessels must have a fishing license; this is additional to the catch quotas. Fishing licenses were issued to vessels that were actively fishing in 1990. These vessels may be replaced if the fishing power is comparable with the new one. Licenses, unlike annual quotas and TAC-share, are not transferable.
- **Quota flexibility**: The quota system allows some flexibility in it use every year. The holder of the quota can exceed his capture limit by 5%. This surplus will be subtracted from the next year's allocation. In the same way, the owners of the quotas can postpone the harvesting of up to 20% of their annual allocation until next year. It is also allowed to change 5% of the annual quota in value terms from one species to another within the year.
- **Quota fees**: To cover the cost associated with managing and supervising the use of marine resources a payment was established as a fee for the assignation of the quotas. The fee was based on cod-equivalent kg of allocated quota, which is a measure of the value of different species based on their market rate and has been used in Iceland to compare the value of landings of different species. The ratio represents the relative value of each species to cod (*Gadus morhua*), which always has the cod equivalent coefficient of 1.0. This fee was introduced for the first time in 1990. At that time, the fee was USD 0.0005 per cod-equivalent kg. Since the establishment of this value in 1990, different modifications have been made to this fee, always moving towards an increase in the amount. However, since 2014 it has remained stable in USD 0.079 per cod-equivalent kg. In 2014 another special fishing fee was set in Iceland at USD 0.23 and 0.19 per cod-equivalent kg of pelagic and other species, respectively. The resulting fishing fee was close to 6% of the catch value from 2012 and 2014 and

approximately 3.5% of the export value of Iceland fisheries during that time (Gunnlaugsson, Kristofersson, & Agnarsson, 2018).

The application of the ITQ system in Iceland was in response to the need, raised by fishery scientists, to implement a new system for the management of stocks. Since its implementation some measures, difficult to assimilate by the industry, were applied, e.g., the reduction in the number of vessels to increase efficiency. The ITQ system has been a controversial issue in Iceland for more than 30 years, has been criticised in many ways and has been the subject of intense political debates (Saevaldsson & Gunnlaugsson, 2015).

One of the main criticisms to the ITQ system in Iceland has been the consolidation of quotas, following sales or mergers, decreasing the number of vessels and factories, affecting adversely the investment and employment opportunities within the industry. Other problems also resulted from the transferability of the quota, creating displacements between geographical regions, negatively affecting some fishing communities.

More matters of disagreement can be mentioned: 1) Initial quota allocation and complicated access for newcomers. The high value of limited quotas is making it very difficult for newcomers to enter the industry unless they are wealthy or have inherited vessels and quotas. 2) Holders of quotas gain wealth by selling out their share at a sizable profit. This has created discontent and given rise to complaints of disparity, unequal distribution of common rights and the privatisation of these rights. 3) Fishing fee, the settling was explained above, but the problem remains of the quota holders wanting a minimal fee, while others maintain that fees should at least cover the cost of monitoring catches, enforcing regulations and conducting fisheries research plus a certain amount for the use of common property (Saevaldsson & Gunnlaugsson, 2015).

### 5.2 Australia fisheries management

In Australia, the main objective of fisheries management is to find the optimal balance between the conservation of fisheries resources and their use to achieve maximum economic yield (MEY) (FAO, 2003).

The management of fisheries in Australia is shared between Commonwealth (Federal) and State governments. State fisheries management operates up to three nautical miles off the Australian coast, while Commonwealth fisheries management is applicable between the three nautical miles and the Australian EEZ boundaries. The Australian Fisheries Management Authority (AFMA) manages sixteen Commonwealth commercial fisheries based on targeted species, area fished, and/or gear used (Marchal, et al., 2016).

The scientific information is generated by independent scientific entities. The Australian Fisheries Management Authority (AFMA) is advised by the Commonwealth Scientific and Industrial Research Organisation (CSIRO). These include fisheries research laboratories that are part of each state or territory fisheries management agencies and various universities in Australia. Generally, research is carried out by the agencies that also have legislative responsibility for a specific fishery (FAO, 2003).

In Australia, as in Panama, there is a strong relationship between the stakeholders. The decisions and actions of The Australian Fisheries Management Authority (AFMA) are endorsed by fishermen, environmental NGOs, and scientists.

The Total Allowable Catch (TAC) is a management tool and is used together with the Individual Transferable Quotas (ITQs) system. Few fisheries are handled exclusively with production data. A series of measures to control access to fisheries are used: legal fishing rights, limited access, restrictions on fishing equipment and spatial fisheries management. (Marchal, et al., 2016).

Like Iceland, the Australian fishing industry contributes financially to fisheries management expenditures through a cost recovery scheme (Marchal, et al., 2016).

The Australian Commonwealth (i.e. Federal Government) were among the first fisheries jurisdictions to adopt maximising net economic returns as a primary management target to capture both economic efficiency and ecological sustainability. Many Australian States have also identified social as well as economic objectives of management as important, while consideration of social objectives is also being undertaken at the Commonwealth level (Brooks, et al., 2015) cited in (Pascoe, Plagány, & Dichmont, 2017).

In the early 1980s Australian scientific advice clearly indicated that the level of catch from the Southern bluefin fishery was not sustainable (Majkowski & Caton, 1984), cited in (Meany, 2001). Two main factors contributed to this: first, the level of total catch (by weight); second, the high number of small fishes being taken, especially in the Western Australian sector of the fishery.

When a fishing resource begins to show alarm signals such as reduction in catches, variation in size composition (more juveniles than adults), habitat degradation, excessive increase in fishing effort and less economic income in the commercialisation of the product, it is the time to take actions.

In their action taking, the Australians take into account these scientific data, which indicated the seriousness of the situation. Policies were established with the following objectives: from a biological perspective were therefore: (a) to achieve a significant reduction in total catch and a diversion of fishing effort away from one and two year-old fish; and (b) from a socio-economic perspective, to achieve a substantial fleet reduction while minimising social dislocation and hardship. It is important to mention that the biological, social, and economic objectives were clearly defined. To accomplish these objectives Australia established the Total Allowable Catch (TAC) and Individual Transferable Quota (ITQ) as a management tool for the southern bluefin tuna fishery (SBF) (Meany, 2001).

After establishing the ITQ as a management measure, they proceeded to determine the process to assign the catch quotas for the vessels, considering the annual catch limit established by calculations of the maximum sustainable yield (MSY).

The industry/government Southern Tuna Management Advisory Committee advised in 1985, that 143 boats had initially been allocated quota, but that after ITQ transfers only 85 remained. A total of 6750t of quota about (46%) had been transferred. Most of these transfers were associated with intra-state transfers, which largely represented consolidation of quota-holdings. The rights-holders were disappointed with their initial allocation of SBT quota, this was because most failed to differentiate between the impact of the allocation formula itself and the reduction in the TAC that occurred at the same time. This TAC reduction, which continued after the introduction of ITQs was essential for the long-term survival of the commercial fishery. The catch reduction has resulted in hardship for many in the fishery, irrespective of whether ITQs or some other management mechanism was used. Regardless of this, most fishers appeared to ignore the inevitable consequences of the reduction in the TAC and tended to place all the blame for dislocation to their fishing activity that followed their introduction, on the ITQ-system (Meany, 2001).

The reduction in the TAC meant that all fishers suffered a reduction from their historic catch-levels. For some this meant having to buy additional quota to remain viable. For others, it meant having to sell quota and cease tuna fishing. It might be noted that many fishers, particularly those in New South Wales and Western Australia, were only part-time tuna fishers. The sale of tuna quota by these fishers meant that they were not forced to leave the fishing industry but could continue to fish by targeting other species (Meany, 2001).

### *5.2.1 TAC and quotas systems in Australian shrimp fishery*

The Northern prawn fishery (NPF) is a Commonwealth managed multispecies tropical prawn (shrimp) fishery, which are the tiger prawn (*Penaeus semisulcatus*) and the banana prawn (*Penaeus merguiensis)*. The NPF has one of the longest histories of model development in Australian fisheries for use in management, with a range of tactical biological and bioeconomic models being developed over the last 30 years and used to estimate optimal fleet size, target fishing effort levels, seasonal closures, and other specific management issues (Pascoe, Plagány, & Dichmont, 2017).

This community used the Maximum Economical Yield (MEY) as a management tool for their fisheries and is considered one of the first in the world to implement it (Dichmont, Pascoe, Kompas, Punt, & Deng, 2010).

The existing management focused models of the NPF do not consider the use of ITQ, instead they applied TAC based on MEY and the status quo, in which the banana prawn fishery is closed after catch rates for specific periods fall below a trigger of 500kg/boat-day (Buckworth, et al., 2013).

# 6 RESULTS AND DISCUSSION

The socioeconomic conditions of Panama, Iceland and Australia are distinct (*Table 4)* despite having similar fisheries problems, management tools, principles, and management objectives. This possibly explains why their fishing policies have developed in different directions, according to their priorities in terms of economic profitability, social development, and conservation of the resource.

Table 4. Socioeconomic indicators for the fisheries in Panama, Iceland, and Australia.

| | **Panama** | **Iceland** | **Australia** |
|---|---|---|---|
| **Population**[1] | 4,162,618 | 337,780 | 24,772,247 |
| **EEZ (Nm)** | 200 | 200 | 200 |
| **Fleet size (commercial boats)**[2] | 5,465 | 1,276 | 290 |
| **GDP in 2017 (USD)**[3] | 62.284 billion | 23.909 billion | 1.323 trillion |
| **GDP-PPP in 2017 (USD)**[3] | 100.288 billion | 18.14 billion | 1.192 trillion |
| **GDP per capita in 2017 (USD)**[3] | 15,196.397 | 70,056.873 | 53,799.938 |
| **Fishing GDP (%)** | 0.4 | 10 | 1.02 |
| **Fishing GDP (USD)**[4] | 249 million | 2.39 billion | 13.49 billion |

[1]Derived from: (Worldpopulationreview, 2018)
[2]Derived from: Panama (ARAP, 2018); Iceland and Australia (OECD, 2016)
[3]Derived from: (WorldBankGroup, 2019)
[4] Approximation based on Fishing GDP (%)

One of the common characteristics between Panama, Iceland and Australia is that they are countries with a fishing culture. That is why management plans have been developed and applied to make fishing a sustainable and profitable activity. These countries have developed management strategies that fit their reality and are aligned with their fisheries policies. Practically, these countries have the same government structure for decision-making in fisheries; there is an entity that is the highest authority on fishery, which bases its technical decisions on a scientific advisory institution. However, this is where we find the first significant difference between these countries; while in Iceland and Australia this advisory institute enjoys a certain independence, in Panama, the scientific advisory body is a General Directorate of the Fishing Authority *(Table 5)*. This could lead to a conflict of political and social interests, on issues related to the exploitation of fishery resources, since the objectivity and independence of the decision-making could be questioned.

The main objectives of fisheries management have been clearly defined in Iceland (sustainability and economic profitability of the industry) and Australia (Maximum economic yield in some communities and security and job stability in others) (Marchal, et al., 2016), however, the situation in Panama is not so clear. The government has tried to prioritise the conservation and sustainability of fishery resources, but economic and political interests have not allowed these objectives to be clearly achieved. Taking this into consideration, the strategy that Panama has used is the application of the Ecosystem Approach to Fisheries to find a balance between biological, economic, and social objectives. The development of any management system or measure will depend on the clarity with which these objectives are defined, and this is one of the first things that should be done in Panama, taking as an example the experience of countries like Iceland and Australia.

The objectives of fisheries management, together with its measures and tools, are elaborated and developed in response to a fishing problem, which may compromise the stability of stocks, economic development and food security and labour stability of people who depend directly or indirectly on fishing. According to the particularity of each case, today Australia and Iceland are considered a world reference in fisheries management (Alder, et al., 2010), but reaching this status took many decades. The application of management actions such as technical measures, control of effort and control of catches, do not always positively affect the three components of the EAF. For example, in the control of catches the application of the quota system can reduce the race for Fishing, which is a positive aspect from the biological point of view, however it increases the economic profitability of the industry, and tends to the greater efficiency of the industry, which leads to a significant reduction in jobs *(Table 6)*. These are the impacts that must be considered to choose the management action that can be implemented.

Table 5. Summary of the differences and similarities of the fishery management systems in Panama, Iceland, and Australia. Source: Adapted from (Marchal, et al., 2016).

| | | **Panama** | **Iceland** | **Australia** |
|---|---|---|---|---|
| **Processes** | Decision-maker(s) | Authority | Minister | Minister |
| | Scientific advice | Scientists and stakeholders | Mainly scientists | Scientists and stakeholders |
| | Stakeholder involvement | Formal consultation in decision-making<br>Inclusive participation in scientific advisory process | Informal consultation in decision-making<br>Limited participation in scientific advisory process | Mandatory and formalised consultation (decision-making scientific advice) |
| **Objectives/strategies** | Broad principles | Conservation/utilisation | Conservation/utilisation | Conservation/utilisation |
| | Specific targets | Socioeconomic development of the fishing sector | Explicit for stocks subject to management plans | $B_{MEY}$ or $F_{MEY}$ |
| | Strategies | Ecosystem approach of fisheries (EAF) | Management plans (currently applied to some stocks) | Harvest Strategy Policy (applied to most stocks) |
| **Tools** | Conservation | Technical measures<br>Effort control and fishing gear restrictions | TAC<br>Technical measures | TAC<br>Input control measures |
| | Access | Fishing licenses/permits<br>Delimitation of the fishing areas | Fishing licenses/permits<br>ITQs widespread | Fishing licenses/permits<br>ITQs in some fisheries |

As mentioned earlier in this document, the development of new fisheries management measures should focus on the Ecosystem Approach to Fisheries (EAF). Based on this premise, a positive balance must be achieved between the biological, economic, and social impacts generated by implementing new management measures for fisheries resources. However, this only seems to work in theory and not in practice. This assumption suggests, then, the non-existence of a "perfect" management system that allows the correct balance between the pillars of the EAF.

When it is required to change and / or incorporate new policies or management measures for a resource, the pillars of the EAF that would be among the conservation and / or development objectives must be considered, also analysing the possible negative impacts in the other pillars, which are not weighted equally in the implementation of the any new system.

The individual Transferable Quotas system (ITQs) offer environmental and economic benefits, including better conservation of fish stock and greater profitability for the fishing industry (Jennings, Kaiser, & Reynolds, 2001); (Sumaila, 2018). With some limitations, they achieve good alignment between the profit incentive and stewardship objectives (Turris, 2010); (Soliman, 2014); (Pascoe S. , Kahui, Hutton, & Dichmont, 2016); (Agnarsson, Matthiasson, & Giry, 2016); (Gunnlaugsson, Kristofersson, & Agnarsson, 2018); (Merayo, Nielsen, Hoff, & Nielsen, 2018). However, some experts mention negative impacts on social objectives, such as the decline of small-scale fisheries, reduction of the economic benefits of the most remote fishing communities and centralisation and monopoly in the fishing industry (Bromley & Macinko, 2007) and (Bromley, D.W., 2009) cited on (Soliman, 2014).

Given that the adverse opinions or objections to ITQs are mainly focused on social objectives, some of these, along with the biological implications, will be address below:

- **Biological**

The quota system restricts the catch of individual fishers or boats, this causes a reduction in the race for fishing, since there is a determined amount in what can be fished. This limits the opportunities for overfishing, which translates into positive actions for the conservation of the resource. However, for this system to have these positive biological effects, a good monitoring, control and surveillance system (MCS) is required, since an ITQ implemented without adequate supervision can cause an increase in the discarding, high -grading and misreporting of catch (Sumaila, 2018).

The implementation of a good MCS will represent an extra cost in monitoring and enforcement; this extra cost can be covered by economic benefits that ITQs are supposed to create. Regarding managing the artisanal fisheries, which are typical species rich and data poor, there are doubts about the usefulness of ITQ schemes (Pauly, 1996). The resolution of the high multispecies catch problem, which results in the capture of non-target species in the form of bycatch, should be addressed with special interest.

- **Economic**

The ITQs are a management action for promoting economic efficiency, rather than social equity (Hannesson, 1996). The increase in economic income from a more profitable activity allows a reduction in the fishing fleet which, in addition to reducing operating costs, has a positive environmental effect by reducing the number of greenhouse gas emission units in the atmosphere. The quality of the catches is also improved since there is a catch limit. On the other hand, the higher income in the industry, i.e., higher contribution to GDP, generates the possibility for the establishment of new taxes that can be used for the development of better monitoring, control and surveillance systems (MCSs) or subsidies for artisanal fishermen, that may be affected negatively by the quota system. The negative aspect of this system is that it is indeed necessary to implement new MCSs. This translates into a significant economic investment by the government, while the industry assimilates and adapts to the new quota system, to generate new incomes, which could take some time, and all the while the economic benefits may be as expected.

There could be a negative external economic impact on remotes communities. The fishing activity developed in a quota scheme tends to be more efficient and centralised, that is, a vertical development. But this efficiency can have other consequences, larger vessels can take their catch directly to processors in major facilities, rather than obtaining services of processing their catch in remote communities. The effects for these communities can be negative: loss of employment, emigration, loss of traditional fishing culture and a wide income gap between quota holders and no holders (Soliman, 2014).

Another problem that can arise with this system is the centralisation or monopolisation of the activity, by the owners of the largest quantities of quotas, in addition to the "armchair fishers" that will be described later, which creates an unfair distribution of the profits generated by the fishing activity. When the activity is concentrated, the specialisation of the jobs and duties also emerges, this implies that the fishermen who cannot adapt to these changes, generated by the ITQs, will not obtain the same economic benefits gained by the owners of the quotas, who are exploiting a resource that is of public domain, therefore going against the socio-economic objectives.

- **Social**

With the income generated by the implementation of the ITQ system, the quality of life of fishermen who are part of the activity can be improved, since their salaries should increase in proportion to the income generated by the fishing industry. There is greater opportunity for training and specialisation in their jobs. Significant economic income can be diverted to the development of social programs in fishing communities.

On the other hand, the countries, with marine ecosystems and fishing tradition, consider fish stocks as a common good and free access for all their citizens. In countries where the ITQs have been implemented, e.g., Iceland and Australia, the state grants fishermen the quota initially at no cost. The criticism that is made to the system in this sense is that fishermen can sell, at market price, a fishing right that was granted by the state, free of charge. In this scenario, only one person would be receiving an economic benefit, by selling a fishing right over a publicly owned fishing resource. In some of the countries (e.g., Iceland), this problem was later fixed through the establishment of fishing fees, however, this should be addressed from the beginning of the allocation.

In some cases, the fishing activity is not carried out directly by the owner of the quota, but by another person, who does the activity directly and to whom this quota is leased. These types of owners are called "armchair fishers", since they receive all the economic benefits of fishing, without performing the activity properly. The objection to the system at this point, is that the benefits are obtained by people who are not involved in the activity directly. The system only seeks the economic efficiency of the activity; however, it does not consider the distribution and an equalitarian access to the profits by the fishermen, who do the “ground” labour as part of the social objective, within the ecosystem approach to fisheries (EAF).

Reviews of pros and cons in fisheries management revealed the Ecosystem Approach to Fisheries to be feasible, but the balance between the biological, economical and the social part is for the politicians to decide.

Table 6. Impact of fisheries management actions on social, economic, and biological characteristic of a fishery. Arrows summarise how each technical measure most frequently affected fishery characteristics; compared with the period before it was introduced. Note that all the OECD fisheries studied were not affected in the same way because they were influenced by different social, biological, and economic factors and because the initial management regimens were different. Source: Derived from (OECD, 1997) cited in (Jennings, Kaiser, & Reynolds, 2001).

| | **Catch Control** | | | **Effort Control** | | | **Technical measures** | |
|---|---|---|---|---|---|---|---|---|
| **Characteristic** | Total Allowable Catch (TAC/Q) | Individual Quota (IQ) | Individual Transferable Quota (ITQ) | Licenses | Individual Effort Quotas (IEQ) | Vessel/gear restrictions | Sex and size limits | Time and area closures |
| Race to fish | ↑ | ↓ | ↓ | ↑ | ↓ | ↑ | ↑ | ↑ |
| Profitability | – | ↑ | ↑ | ↓ | ↓ | ↓ | ↓ | ↓ |
| Employment | ↑ | ↓ | ↓ | ↑ | ↓ | ↓ | ↑ | ↑ |
| Capacity | ↑ | – | ↓ | ↑ | ↑ | ↓ | ↑ | ↑ |
| Fishery safety | ↓ | – | ↑ | ↓ | ↑ | ↓ | ↓ | – |
| Stability of catch | ↓ | ↑ | ↑ | ↓ | ↑ | ↓ | – | – |
| Quality of catch | ↓ | ↑ | ↑ | ↓ | ↑ | ↓ | ↑ | – |
| Discarding | ↑ | ↑ | ↑ | ↓ | ↓ | ↓ | ↑ | – |
| High grading | ↑ | ↑ | ↑ | ↓ | ↓ | ↓ | – | – |
| Resource conservation | ↑ | ↑ | ↑ | ↓ | – | – | – | – |
| Misreporting of catch | ↑ | ↑ | ↑ | ↓ | ↓ | ↓ | ↑ | ↑ |
| Assessment cost | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ | – |
| Administrative cost | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ | – |
| Enforcement cost | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ | – |

The experience of most countries, where the quota system has been implemented, reflects that it is a controversial management measure that is far from perfect, however, it has shown that it generates important economic benefits for the industry (Agnarsson, Matthiasson, & Giry, 2016); (Gunnlaugsson, Kristofersson, & Agnarsson, 2018) and (Turris, 2010).

In order to achieve success in the implementation of the quota system based on TAC, and to minimise the negative impacts of previous experiences, four important factors must be considered: 1) the recovery time of the Stock, 2) the estimated cost of implementing this system, as well as the quantification of the economic benefits and the time in which these would be obtained, 3) close loopholes, being a new measure of fisheries management, it is necessary to change the Panamanian fisheries legislation; this is in order to avoid legal gaps that would affect the proper implementation of the system, and 4) the impact on society must be determined, questions such as the number of fishermen affected, the effect on artisanal fishermen involved in shrimp fishing, employment, equity in fishing rights and economic benefits, should be answered before being able to recommend and implement the quota system.

As result of the four factors mentioned, the list of strategies that need to be part of a fisheries management system which incorporates the ITQs to achieve the biological, economic and social outcomes are as follows:

- Quotas need to be allocated to the "ecosystem" first before catch quotas are set. It is another way of expressing the safe minimum biomass. The allocations of biomass (as catch quotas) to the industry must be made only after the mandated ecosystem goal has been attained.
- ITQs must be supported by a strong monitoring, control and surveillance system (MCSs). This is the basis for quota systems to work. Only in this way, can the quotas be allocated correctly and reliable statistical data to manage the resource, can be established.
- Some restriction on the ownership of the ITQ must apply to avoid armchair fishing and foreign investors appropriating common property. It is important to establish limitations on the owners of the quotas and their participation in the fishing activity, in order to promote social equity, prior to a resource that is public property. The quotas should not be granted to foreigners since it is a Panamanian common property.
- Limits to the quota that can be held by each quota owner in order to avoid the concentration. A maximum limit must be established on the number of quotas that a single owner can have, to avoid concentration and monopoly in the activity.
- Auctioning, fishing experiences or special banking credit system can be used to deal with the problem of initial allocation and its equity implications. The initial allocation should be based on a type of payment or fixed rent in proportion to the percentage of the quota received and its time of use.
- Fees to the shrimp fishing industry. The payment can be a percentage on the net incomes of the industry. This income could be used by the state to improve the MCS system, social assistance programs and subsidies to artisanal fishermen, who may be affected by the implementation of the quota system.

- Economic incentive schemes to make the IUU unprofitable. The reporting of catches should be promoted through economic incentives or special banking credit to the fishermen who correctly present the catch records of the logbooks.
- Establish an add value to bycatch to reduce the discarding. The Panamanian state must generate a market for the consumption of bycatch, which would represent an extra economic input, especially to artisanal fishermen. This would lead to a better use of the resource.
- Manage other stock for the artisanal fisheries. Artisanal fishermen, who could be the main parties affected in the introduction of the quota system in shrimp fishery, should direct their efforts to other species, which must be given an equal attention in fisheries management, to avoid overexploitation.
- ITQ needs to be based on the EAF under the scheme of co-management. ITQs need to be carefully designed as part of a broad ecosystem-based fisheries management scheme so that they meet the three generally accepted pillars of modern fisheries management objectives, that is, biological, economic, and social sustainability. This can only be achieved with the integration of stakeholders in decision making.

Quota systems based on total allowable catch (TAC) is a feasible management measure for shrimp fisheries in Panama?

The answer to this question could be more complicated than it seems, since there is no single or simple answer on what management system to use.Whether it is feasible or not, it is something that cannot be answered at this time, however, it can be said that quota systems based on TAC have all the necessary elements, to be an adequate fisheries management alternative to improve the current shrimp fishery management system in Panama.

Further work is needed to fully implement new fisheries management plan with TACs and possible ITQs in Panama shrimp fisheries. However, the objectives of new fishery management need to be discussed and the impact on communities, industry, government, and other stakeholders must be evaluated. The focus should be on sustainable shrimp fisheries for Panama future generations.

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