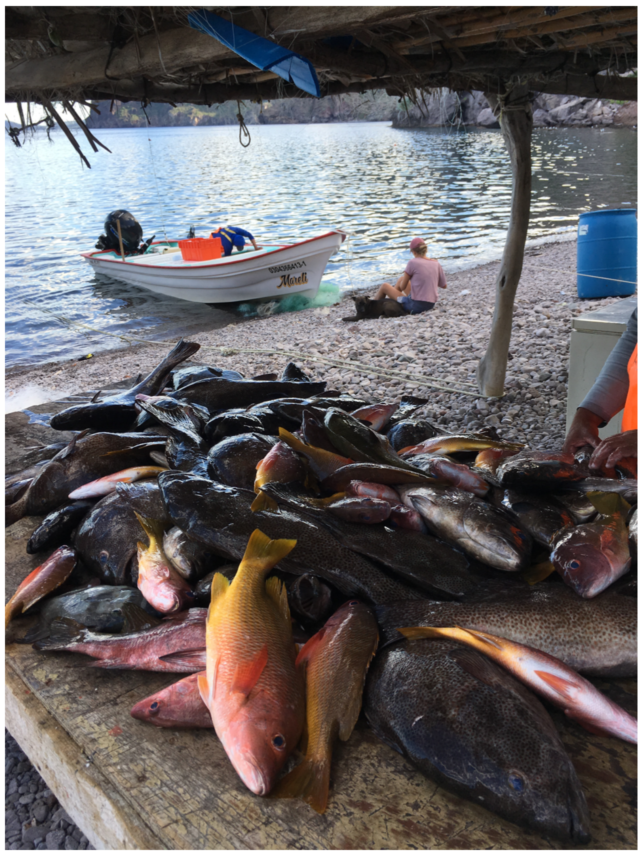
El Corredor Fishery:

Management Feasibility Analysis



Dr J.D. Prince

January 2020

SOCIEDAD DE HISTORIA NATURAL
Niparajá

Table of Contents

1. Introduction

This document provides analysis on the feasibility of alternative forms of management for El Corredor, BCS Mexico, finfish fishery with the aim of providing reasoned advice on the implementation of effective adaptive management for the fishery.

To that end this initially introductory section defines the terms, concepts and methodologies used in fisheries management. The second section briefly describes the nature of the fishery and the governmental instrumentalities to which the broader concepts and management methodologies must be applied. The third section aims to narrow the discussion and supported by the logic of the first two section provide practical advice about the most feasible forms of management given the character of the fishery. Finally, in the last two sections the document discusses how the recommended management framework, or harvest strategy could be made adjustable or 'adaptive' with harvest control rules within the multi-species context of fishery. So that, over time management can respond to experienced learned with the fishery, the development in community and institutional capacities for management, the evolution of fishing technologies and behaviour, as well as the changes in fisheries productivity that can be expected with climate change.

1.1. Objectives of Fisheries management

To prevent potentially conflicted objectives leading to confused and ineffective management outcomes it is important that the objectives of management are clearly and explicitly stated. Clear definition of management objectives, and particularly their relative priority within the management policy can hope to make potentially competing objectives explicit and so minimise actual conflict leading to more effective outcomes.

1.1.1. Optimise Sustainable Yields

In recent decades the main focus of fisheries management has become sustainability, which we can describe as 'optimising sustainable yields'. Described in this way sustainability has two elements, the first being the biodiversity related objective of sustainability; ensuring that the species which provide the natural resource are never be pushed into extinction. The second being to ensure sustainability is achieved at a level that optimises the level of benefits provided by the resource to both humans and the broader ecosystem (other species), in the form of yields. Describing the biological objective of management in this way makes it explicit that sustaining a species as some small relic of its original biomass is not success, the resource must be sustained at an abundant level capable of supporting a relatively high level of productivity.

Note also we are explicitly avoiding the over-used term 'maximum sustainable yield' (MSY). Although widely used in the literature this has come to be recognised as a dangerous concept developed in the early and mid-twentieth century before the susceptibility of fisheries to depletion was full appreciated, and when the main focus of management was to maximize our use of the growth potential of stocks. Now we fully appreciate the potential for fisheries to deplete the reproductive capacity of fisheries, it is clear that the aim of maximising sustainable yields inevitably and explicitly implies managing for heavy fishing pressure, so that the last little bit of potentially sustainable catch can be taken to maximise the catch. Applying that heavy fishing pressure so that sustainable yields are maximised inevitably leads to poor outcomes for other aspects of the fished ecosystem, the socio-economic wellbeing of the fishers, and management regimes prone to making mistakes and inadvertently collapsing fish stocks. Striving to maximise catches from a fishery is a very natural human objective, which the combination of vested interests and limited capacities for assessment and management all too often facilitates. The objective of fisheries management should be to guard against this tendency and outcome, rather than explicitly encouraging it by including it in the objectives.

In contrast the concept of optimising sustainable yields implies relatively high sustainable catches, but within the tolerance levels of ecosystem, community and institutional capacities, and a level of catch that can be taken at moderate levels of fishing pressure, something Hilborn (2009) has termed Pretty Good Yield (PGY).

Sustainable Yields are optimised by addressing two of the three facets of overfishing:

1.1.1.1. Growth overfishing

Growth overfishing occurs when fish are caught before they have grown to their optimal size for harvest. In every species the processes of growth and mortality work against each other through their life cycle. In the early juvenile phase, the biomass (or total weight) of a year class (or cohort) increases rapidly as individuals grow and gain weight faster than they die off through processes of natural mortality. Although the number of fish in each cohort declines rapidly with age, the increasing weight of the surviving individuals causes the biomass of each cohort to steadily increase until around the size the fish become adult. Once the individuals in a cohort mature, they begin diverting the energy derived from food away from growth and into reproduction, with the result that the growth of a cohort's biomass slows down. As the reproductive output of a cohort peaks there will be little energy left over after bodily maintenance for growth, so the processes of natural mortality overcome that of growth causing the biomass of each cohort to begin declining. The hiatus between rapid juvenile growth ending and maximal reproductive output being achieved, is where each cohort achieves its maximum biomass, and this size is called 'optimum length' or 'optimum weight'.

Catching fish smaller than the 'optimum size' wastes their potential for growth resulting in what we call 'growth overfishing' and sub-optimal catches from a fishery. One of the aims of management should be to prevent growth overfishing by minimising the catching of fish smaller than their optimal size. Conversely delaying fishing too far beyond the age at which optimum size is achieved will also reduce yields below optimum levels because a high proportion of fish may live out their natural life and die without being caught. We can refer to this as 'under-fishing' a resource.

1.1.1.2. Recruitment overfishing

In fisheries science the process of small fish growing up to become part of the harvested population is referred to as 'recruitment'; as in the recruitment of young fish to the fishery. While growth overfishing refers to catching fish before they have fulfilled their full potential to produce harvestable protein, recruitment overfishing, refers to catching fish before they have completed sufficient reproduction to generate the recruitment needed to replenish the population. Recruitment overfishing depletes the reproductive potential of the stock causing recruitment to decline, or even collapse suddenly, resulting in long term lower stock levels and catches than optimal, and in the most severe cases and prolonged cases to local extinctions.

In theory growth and recruitment overfishing are distinct phenomena and it can be possible to growth overfish without recruitment overfishing. A phenomenon we term 'sustainable overfishing'. However, in practice when fishing pressure is increasing, recruitment overfishing follows very soon after, if not coincidentally, with growth overfishing. So, while the two forms of overfishing are distinct and different, they are normally very closely linked, and importantly for management, preventing recruitment overfishing normally also corrects growth overfishing. However, if accomplished too aggressively, making a fishery robust to overfishing, can protect a stock so strongly, that catches are reduced below optimal levels because too large a proportion end up avoiding being caught entirely, and instead of adding to the catch end up dying of old age. A phenomenon called under-fishing, which is of course totally sustainable because recruitment is maintained at high levels, but which threatens the management objective of optimising yields.

1.1.2. Optimise Economic and Social objectives:

Fisheries management implicitly takes place within the context of trying to achieve socio-economic benefits for fishing communities and broader societies. If the objective is to simply preserve biodiversity then fisheries can be closed and we no longer need to discuss fisheries management. Instead the discussion becomes one of how best to manage marine reserves.

Previously economic objectives were often prioritised over sustainability objectives, and when commercial interests dominate, they often become short term, aiming at maximising catches in the short term, rather than emphasising the need for catches to be sustained over the long term. The objectives discussed above, of preventing growth and recruitment overfishing, and optimising sustainable yields, provide the main socio-economic context for management by ensuring that the potential for catches is maintained at permanently high levels. These final objective socio-economic objectives concern minimizing the cost of harvesting, how the benefits of fishing should be distributed, and preventing benefits from being dispersed too widely away from the fishing communities themselves.

1.1.2.1. Economic overfishing

Economic overfishing occurs when fishing pressure escalates above the level needed to make the catch, because fishers are competing excessively with each other. Without effective management a 'race to catch the fish' commonly results amongst fishers each motivated to maintain or maximize their own individual shares of the catch from a finite resource. This competition leads to a fishing 'arms race' which unchecked by management will in time result in excessive fishing effort and fuel consumption, as well as the 'over-capitalization' which comes from building more boats and infrastructure than needed simply to land the catch.

The long-term detriment resulting from this is:

1. Economic inefficiencies stemming from, unnecessary expenditure of man-power, fuel, equipment and bait, as well as low catch rates caused by fishing pressure being greater than needed to land the catch. Together these result in low rates of return from fishing
2. Unsafe fishing practises being incentivised by the desire to compete by fishing every day, even in unsafe weather.
3. Dispersal of the fisheries benefits away from fishers due to their increased need for fuel, boats, engines and other materials bought from external and even international sources.
4. High level of fishing pressure which if growth and recruitment overfishing are not protected by other management measures, can result in the unsustainable depletion of stocks. Even if other forms of management protect the stock against heavy fishing pressure, the low catch rates and returns resulting from economic overfishing, increases incentives for non-compliance with fishing regulations, and / or developing legal means of increasing fishing power beyond target levels, all of which puts pressure on management regimes and the capacity of management agencies.

1.1.2.2. Broader Social Objectives
Beyond simply managing for economic efficiency, by ensuring that the optimal amount of fish is sustainably harvested, with an optimally low level of fishing effort and expense, there can also be broader social objectives for a fishery. Some of the common broader socio-economic objectives may not be mutually compatible with each other, or with the broader aim of avoiding economic overfishing. For this reason, it is normally not possible to optimize all social objectives together, choices need to be made and social priorities decided.

- Profitability is the most common socio-economic objective and should be an outcome of successfully preventing the economic overfishing discussed above.

- Maximising opportunities for employment in remote fishing communities is another common objective which implicitly implies maximising the number of fishers and encouraging some degree of economic overfishing.

- Equitable access to the resource, either to ensure food security for subsistence fishers, or opportunities for recreational fishers, can also be another valid socio-economic objective. By aiming to allow the greatest number of fishers to access the fishery, this objective must also conflict to some extent with preventing economic overfishing.

These are all potentially valid objectives for fisheries management, but their potential for conflict needs to be acknowledged, and their relative priority made explicit, so they are not confusingly combined into a wish list of mutually exclusive objectives.

1.2. Forms of management, strengths & limitations
This section defines and describes the three main categories of fisheries management; controlling the size of fish selected for catching, the amount of effort put into catching the fish, and the amount of catch taken out of the fishery.

1.2.1 Size selectivity Management
Size selectivity refers to directly controlling the size of the fish being caught to prevent growth and recruitment overfishing (Table 1.). The size of fish caught can also be indirectly managed by controlling fishing pressure at levels that ensure fish survive long enough to grow to target sizes, but this will be discussed below under "input Controls'. Here we are only considering direct controls on the size of fish that are caught, measures which have their impact independently of the fishing pressure applied.

Managing size selectivity was the earliest form of management used and since at least the 1800s has been used to correct growth overfishing by setting the size at which fish first become vulnerable to being captured, to be the same as the size they mature. More recently size selectivity management has been recommended as a very simple way of managing to prevent recruitment overfishing, by setting the size of first capture to be 10-20% larger than the size of maturity (Prince & Hordyk 2018).

1.2.1.1. Minimum & maximum size limits

One of the most common ways to directly control the size of fish being caught is to regulate a minimum or maximum size for the fish being landed. This is most easily done when the type of fishing allows the fisher to choose which fish to catch (e.g. dive fisheries in which fish or shellfish are visually and individually selected for catching) or where fish can be caught and then released with little damage and a high chance of survival (e.g. hook and line fishing in shallow water). Management that requires fishers to discard illegal sized fish that are unlikely to survive is inevitably unpopular, which can foster resistance to implementation and non-compliance. Despite this, size limits are often applied in such situations, aiming to force fishers to modify fishing practices and reduces their catch of illegal size classes (i.e. fish in places, at times and with gears which minimize the capture of smaller fish).

Maximum size limits are recommended by some with the aim of protecting so called 'mega-spawners' (defined by Froese (2004) as being more than 10% larger than size of maturity), size classes which are claimed to contribute disproportionately to the reproductive capacity of a population. But those who recommend this form of management rarely make explicit, that imposing a maximum size limit will only conserve larger more fecund individuals if fishing pressure is also managed at levels that are low enough to ensure fish survive long enough to reach the maximum size limit. If fishing pressure is not carefully managed nothing survives to reach the protection of the maximum size limit. Thus, the effectiveness of maximum size limits is entirely contingent on effective management of fishing pressure. This begs the question of whether a maximum size limit really adds anything further to the management regime than the control of fishing pressure its effectiveness is contingent on? If fishing pressure can be managed at sustainable levels why have a maximum size limit as well? For fisheries in which fishing pressure cannot be effectively managed at sustainably low levels the implementation of minimum size limits to protect fish until they have completed a sustainable minimum level of reproduction (i.e. 20% SPR) is simpler and more effective than maximum size limits.

1.2.1.2. Gear regulation

Some types of fishing are not inherently very size-selective but can be made more size selective by regulating the design of the gear that is sued. Regulating minimum mesh or hook sizes commonly reduces the capture of small size classes of fish, as does incorporating escape ports, or gaps, into the sides of traps, to allow small fish to escape as the trap is pulled.

1.2.1.3. Regulating Time and Place of Fishing

Regulating when and where fishing gear is deployed can also make fishing more size selective because commonly fish of different sizes are found in differing locations, depths and times e.g. small fish are often found in estuaries and shallow water, while only adult fish are found in spawning aggregations or on deeper adult feeding grounds.

1.2.1.4. Banning Non-Selective Fishing Gear

On the other hand, some types of fishing are inherently non-selective in the size of fish they catch (i.e. small mesh trawl nets, small mesh beach seines and ring nets) and to prevent growth and recruitment overfishing it may be necessary to ban them outright.

Depending on the nature of the fishery, and either in addition to, or the absence of minimum size limits, the size selectivity of a fishery might be managed through some combination of prohibiting or permitting certain gear types, regulating the construction and design of fishing gear, and regulating seasons, locations and depth of fishing.

1.2.1.5. Strengths:

1. Size selectivity management can be used to prevent growth & recruitment overfishing and ensure biological sustainability and pretty good yields (Table 1.).

2. Effective size selectivity management can be developed using simple length-based assessments, like Length Based Spawning Potential Ratio assessment (LBSPR), which are cheap and only require size of maturity information and relatively basic technical capacity (Table 1.).

3. Size selectivity management is simple and cheap to implement, and if done correctly does not need re-adjustment over time, although it can also be used adaptively if required (Table 1.).

4. Simple to enforce, because the regulations involved can be self-enforced by fishing communities simply by looking at the catch and fishing gear of other fishers and in markets.

1.2.1.6. Weaknesses:

The primary weakness of size selectivity management is that used by itself it cannot manage economic overfishing because it does not control how much fishing occurs (Table 1.).

1.2.2. Input Control Management

Input controls manage the amount of fishing pressure being put into the fishery such as the number of fishers, or the number, size and type of fishing vessels, the number and types of hooks, nets, traps that can be deployed (Table 1.). They can also involve regulating the length and timing of fishing seasons, the days of the month or week when fishing may take place, or trip or bag limits controlling how much fish may be caught over a defined time period (normally 24 hours) or per fishing trip.

Input controls work by directly managing the level of fishing pressure and so the longevity of fish in the fishery which indirectly determines the size composition of the fish being caught and the reproductive potential of stocks. Heavier fishing pressure results in shorter longevity in the population, smaller fish on average and lower reproductive potential, while lighter fishing pressure allows fish to survive longer, grow larger and reproduce more.

1.2.2.1. Strengths:

1. Input controls can manage growth, recruitment & economic overfishing (Table 1.).

2. Input controls only require an intermediate level of complexity for assessment, such as surplus yield models which use basic biological information about the stock to interpret long term trends in catch and effort (Table 1.).

3. Input controls only require an intermediate level of monitoring (trends in catch and effort) & enforcement (compliance with input control regulations) and periodic (5-10 years) adjustment of regulatory settings. Consequently, they require an intermediate level of governmental capacity and management cost.

4. Some level of self-enforcement is possible for communities who by observing the fishing patterns of other fishers can have some idea of whether others are complying or not.

1.2.2.2. Weaknesses:

1. Input controls can be relatively inefficient at managing economic overfishing as individual fishers are still incentivized to compete with each other and 'race for the fish'. This provides a strong incentive to develop strategies for increasing fishing efficiency to maximise personal shares of the catch within regulatory frameworks. This in turn leads to 'effort creep', because fishers are continually innovating to make their operations more effective, so that fishing pressure increases over time, often in ways that are difficult to measure and detect (Table 1.).

2. Effort creep makes adaptive management necessary. This involves ongoing monitoring of long term catch and effort trends, and the collection of detailed biological information so that better population models can be developed and regularly (3-5 year) updated, to inform periodic adjustment of the input regulations (Table 1.).

1.2.3. Output Control Management

Output controls directly control the catches coming out of a fishery through the annual setting and enforcement of Total Allowable Catches (TAC), which may be administered through a competitive fishery which is closed when the TAC is reached, or the allocation of shares of the TAC to either individuals, companies or communities, who must stop fishing when they have fulfilled their allocated share of the TAC (Table 1.). Competitive TACs were the earliest form of Input Controls trialled, and are now generally accepted as being a very poor form of management, because of the extent to which they encourage intense competition between fishers and produce poor economic outcomes. On the other hand, systems in which shares of TACs are initially allocated to individuals, companies and communities, and then become tradable, called Individual Transferable Quota (ITQs) or catch shares, have in some, but not all cases, produced sophisticated management outcomes, but are complex and expensive to implement and operate.

1.2.3.1. Strengths:

1. Output controls can effectively achieve all the management objectives of preventing growth, recruitment and economic overfishing (Table 1.).

2. When implemented effectively through the allocation of shares of the TAC they can be a very efficient way of managing economic efficiency as fishers are incentivized to optimize the value of their catch, rather than total catch. However, applied as competitive TACs they achieve the reverse effective and strongly incentivize effort creep and overcapitalization.

1.2.3.2. Weaknesses:

1. Output controls require accurate annual biomass assessments so that TACs can be accurately estimated. This requires accurate long-term statistics on total catch and effort, and preferably also some form of fishery independent biomass survey, along with detailed biological knowledge including age, growth and maturity so that a detailed age-based population model can be developed (Table 1.).

2. Output controls require high governmental capacities so that catches can be adjusted, monitored, controlled in real time, similar to the way bank balances are tracked. There are two facets to this; the first being the tracking and accounting for long and short term buying, selling and leasing of catch shares between fishers, so that annual entitlements to land catch can be

tracked. The second being the real time accounting for catches as they are landed each year, so they are correctly subtracted from the within year balance of each fisher (Table 1.).

3. Because of their requirement for accurate real time assessment, their operational complexity, and the high level of real-time governmental capacity required, output controls are expensive and complex to implement and maintain. In Australia where numerous ITQ systems are in operation it is generally believed that fisheries with a total annual value of catch <USD50 million are unlikely to be able to support the cost of ITQ management.

4. Because the catch of individuals must be accurately tracked over extended time frame to know whether they are complying with the system of output controls it is almost impossible for fishing communities to self-enforce this form of management.

1.3. Enabling Conditions for Effective Management

Successful fisheries management is more about successfully managing the behaviour of people in fishing communities than managing the biology of the fished species. A number of factors have been recognized as enabling effective fisheries management (Gutiérrez et al. 2011, Gilmour et al. 2012).

Three of the most important factors are:

1.3.1. Exclusive Access rights to Incentivise Stewardship by Fishers

It is essential that the fishing communities are incentivized to support management. This will only occur if the fishers believe that they will be the ones who will receive the long-term benefit from complying with management restrictions. Internationally it is recognized that this incentive is created when fishers have some form of exclusive access right to their resource, reserving for them the future benefits of their good stewardship (Table 1.). Such systems exclude fishers from outside a management system, from coming in and 'free-riding' by taking a share of the resource they have not contributed to managing. Without some form of secure exclusive access right, and in the absence of a strong fear of effective enforcement, fishers have little motivation to comply with management.

Exclusive Access can be provided in different ways to suit differing communities, resources and legal frameworks:

The most widely used form is to restrict the number of permits granted to participate in a fishery which may be defined by some combination of, species or collection of species, type/s of fishing gear, and or geographic region. This form of exclusive access right is suited to mobile and broad scale stocks, that are fished by many (relatively heterogeneous) communities over a wide area. Exclusive access rights can also be defined for communities or individuals as the exclusive right to harvest a species, or collection of species, from a specific area. This is termed Territorial User Rights Fishery management (TURF). TURF systems can be specific to species and gear, or multi-species and multi-gear in nature. They are particularly suited for smaller (and more homogeneous communities) and for use with relatively sedentary, or localized, resources, the characteristic of which commonly vary greatly between locations and so require localized management regimes. The Mexican system of fishing concessions is a form of TURF management.

1.3.2. Leadership & Community Organization

Human capital is the extent to which communities trust each other and are willing to work together to achieve relatively intangible and longer-term community wide goals. The success of fisheries management is directly related to the level of human capital within a fishery and all the elements that build and support human capital contribute to the success of fisheries management (Gilmour et al. 2012). In this context cohesive well-organized communities with effective leadership and transparent representative processes are more able to support the dialogue needed to develop, implement and comply with effective management (Gutiérrez et al. 2011). Supporting the development of human capacity by developing community leadership and effective consultative processes will support wise fore-sighted community-based decision making and the effective implementation of community supported management regimes.

1.3.3. Co-Management Systems

Fisheries management is most effective when it is a collaborative process between the fishers, scientists assessing the stocks and the authorities implementing and enforcing management regulations (Gilmour et al. 2012). Consultative processes and committees should be established involving representatives of all groups for the purpose of fostering communication between these groups of stakeholders and sharing responsibility for decision making.

1.4. Adaptive Fisheries Management

Both the human and biological aspects of fisheries are dynamic and change over time requiring management to evolve and respond in response. The abundance of fish stocks and fishing pressure vary through time under the influence of natural and anthropogenic climate variability, management decisions, and evolving fishing technology and practices. Management regimes need to be robust to these changes and adaptable to changing resource status. In addition, the capacity of government and community to understand and implement management is likely to develop over time as they learn from the management experience, so that it should become possible to implement more sophisticated forms of management in the future. To take advantage of this fisheries management should be conceived of and planned, as an evolutionary process that will continue for decades, rather than as an immediate end-point to be locked permanently into place.

.

The capacity to adapt and adjust management should be designed into the management plan to facilitate 'Adaptive Management'.

Adaptive Management plans are called Harvest Strategies the elements of which are:

A. Management objectives as discussed above.
B. Indicators of fishery status that will be used to monitor and assess the status of the fishery.
C. A methodology for assessing the fishery based on the indicators being monitored.
D. A framework of management regulations that can be incrementally adjusting in relation to the assessed status of the fishery.
E. Harvest Control Rules which define how the management regulations will be incrementally adjusted in response to assessment results.

The aim of the harvest strategy system is to keep the process of adjusting management disciplined and transparent and as free as possible from influence by political processed driven by vested interest groups. For this purpose, Harvest Strategies should be designed and agreed by stakeholders outside the process of making actual decisions about changing management regulations.

2. Characterisation of El Corredor Fin Fish fishery

2.1 Description of El Corredor Finfish Fishery

The information in this section is based on a synthesis of information provided by Castro-Salgado et al. (2019).

The finfish fishery in the San Cosme Corridor to Punta Coyote area Baja California Sur, Mexico, which we refer to here simply as El Corredor fishery, consists of 13 isolated coastal communities spread over approximately 150km of coast line in and containing approximately 660 inhabitants. In these communities there are approximately 173 active fishers operate as crews of 2-3 fishers from about 104 20-24' fiberglass pangas powered by 65-115HP outboard motors. They generally fish on a daily basis for 4-12 hours, although some fishing trips may last for several days.

The fishery deploys a complex mix of hook and line techniques, using a variety of baits, such as mackerel, sardine, squid or shrimp, much of which must also be caught by the fishers. As well as with gillnets and fish traps. Some 33 species are fished down to depths of approximately 250m, and total catches are in the order of 1100t per annum and worth ~USD2-3 million/annum.

Eleven species comprise approximately 98% of the catch, and in diminishing order of importance are:

Huachinango (*Lutjanus peru*) – 25%
Jurel (*Seriola lalandi*) – 15.5%
Pierna (*Caulolatilus princeps*) – 12.5%
Cadernal (*Cephalopholis colonus*) – 11.5%
Cochito (*Balistes polylepis*) – 10.8%
Estacuda (*Hyporthodus niphobles*) – 7.5%
Cabrilla sardinera (*Mycteroperca rosacea*) – 6.5%
Pargo amarillo (*Lutjanus argentiventris*) – 3.9%
Pargo mulato (*Hoplopagrus guentherii*) – 2.2 %
Baqueta (*Hyporthodus acanthistius*) – 1.2%
Guarepa (*Caulolatilus affinus*) – 1.1%

2.2. Data Availability & Potential for Stock Assessment

There are no fisheries independent abundance data and only limited biological information for most species. Since 2011 some fisheries dependent data on the main species have been gathered by community-based data collectors. With these data it will not be possible to develop accurate age-based biomass assessment models for any of the species.

Going forward, if current resources can be maintained, it should be possible to monitor:

- Species composition of the catch
- Size composition in the catch of the main species by location
- Relative trends in catch and effort by location
- CPUE trends by species and in aggregate.

This should make it possible to develop Length Based SPR assessments (Hordyk et al. 2015a) which could be further informed by relative trends in catch and catch rates.

2.3. Governance Management Framework & Capacity

In Mexico, the legal framework for fisheries management is in place, but at least in the context of El Corridor fishery there is little if any effective management in place and relatively low capacity for implementing management. Developing these capacities needs to be an explicit part of implementing management.

Fishing activity is regulated by the General Law of Sustainable Fisheries and Aquaculture issued on June 25, 1992 under Article 27, section I, of the Constitution of the United Mexican States, "Only Mexicans by birth or by naturalization and Mexican societies have the right to acquire ownership of land, water and its accessions, or to obtain mining or water exploitation concessions ". This law encourages the administration and use of fishery and aquaculture resources in the national territory, likewise, said law provides that the National Fisheries Charter (CNP) must contain indicators on the availability and conservation of fishery resources.

The CNP, in accordance with article 32 of the General Law of Sustainable Fisheries and Aquaculture (DOF 2007), is defined as the cartographic and written presentation that contains in summary the information necessary for the diagnosis and evaluation of fishing and aquaculture activity, as well as indicators of availability and conservation of resources, with it, the decision for the control of fishing effort management measures, application for permits and concessions for the exploitation of resources remains as a reference in this document.

The files of each resource in the CNP contain the summary of the necessary information of the diagnosis and integral evaluation of the fishing and aquaculture activity, as well as of the indicators on the availability and conservation of the fishing and aquaculture resources in waters of federal jurisdiction. The content is informative for the productive sectors and is binding in the decision making of the fishing authority in the adoption and implementation of instruments and measures for the control of the fishing effort, in the resolution of requests for concessions and permits for the realization of fishing and aquaculture activities, and in the implementation and execution of actions and measures related to said administrative acts.

The instruments responsible for regulating and administering fisheries in Mexico are: (1) Fisheries Management Plans, (2) Official Standards and currently (3) Fishing Shelter Areas.

2.3.1. Fishing Permits

According to article 41 of the General Law of Sustainable Fisheries and Aquaculture (LGPAS), access to fishing is regulated by fishing permits granted by the Ministry of Agriculture, Livestock, Rural Development, Fisheries and Food (SAGARPA) through the National Commission of Aquaculture and Fisheries (CONAPESCA), however, in the vast majority of cases they do not specify which species they are aimed at and therefore the user can have a wide variety of species.

At the current time the permit system seems to be mainly orientated towards ensuring that only fishers are legally entitled to operate in the fishery, rather than to control the total number of participants operating in a specific fishery.

2.3.2. Management Plans

Fisheries management plans are the set of instruments that regulate and manage fishing activities, inducing the sustainable use of fishery and aquaculture resources based on their availability, historical information, uses and development potentials, fishing or aquaculture capacity, benchmarks for the management of fisheries and in a manner consistent with the ecological order of the territory. The publication of this instrument will be in charge of CONAPESCA, together with community groups, civil society organizations and academics.

Fishery management plans are instruments that contain a set of suggested actions aimed at developing the fishing activity in a balanced, comprehensive and sustainable manner; based on updated knowledge of the biological, ecological, fisheries, environmental, economic, cultural and social aspects of it. The management plans are included in the instruments of fisheries management, but are not binding, they are reference documents that constitute the official guide for making management decisions. It is the responsibility of CONAPESCA to implement fishery management plans, as well as their publication Official Mexican standards (NOMs) are binding provisions of a technical nature issued by agencies of the federal public administration (SAGARPA). Its objective is to establish rules, specifications, guidelines and characteristics applicable to fishing management.

2.3.3. Fish Refuge Zones

Fishing refuge zones (ZRP) are delimited areas in the waters of federal jurisdiction, with the primary purpose of conserving and contributing, naturally or artificially, to the development of fishery resources due to their reproduction, growth or recruitment, as well as to preserve and protect the surrounding environment.

In the multi-species fishery that works in the CSCPC, the ZRP also stands out as a measure for the management and administration of the fisheries. These areas are kept free of fishing throughout, without exception, however, there are no management or management plans that dictate benchmarks or control tools for any of the resources that are used in that region.

2.4. Logistical Constraints

The main logistical constraints for implementing and maintaining systems of adaptive management concern the lack of data on total catches and fishing effort, surveys of stock abundance, and detailed biological information about the species in the catch. This lack of information prevents accurate data-intensive forms of assessment being developed, and there are not the institutional resources and forms of expertise necessary to begin gathering these forms of information and developing such assessment models. Furthermore, even if such informational gaps could be filled, there is currently limited institutional resources for enforcing complex fishing regulations, let alone the measuring and controlling of catches, and catch entitlements, in real time that the most advanced and complex forms of output management would require. Assuming all of these logistical difficulties could in time be surmounted the small scale and relatively low value of this fishery will preclude the development of more complex and expensive forms of management.

3. Feasible Forms of Management & Management Recommendations

The characteristics of El Corredor finfish fishery described above provide the context in which the management regime must be developed and implemented. The most important characteristics of this fishery are:

- The complexity and challenge of implementing and maintaining a system of adaptive management is of course multiplied by the complex multi-species catch composition and the multiple gear types deployed in landing the catch so that data collection systems, assessments and management interventions must all be designed to account for hat complexity,
- Compounding the complexity and scale of what must be achieved is the great lack of existing information and knowledge, there are no accurate relative or absolute long term (multi-decadal) catch and effort trends, no surveyed trends and very few biological studies and partly as a consequence only a few rudimentary stock assessments have been developed.
- Into the future this situation is unlikely to change because of the relatively low value of this small-scale fishery and the relatively low governmental capacity for data collection, conducting detailed biological studies, developing stock assessment and, implementing and enforcing management regulations.

In this situation the system of adaptive management and the harvest strategy which will support it must be designed to be extremely simple and cost-effective and operate in an on-going data-poor environment.

3.1. Output Controls are Infeasible

Management of this fishery with any form of output controls (TAC, ITQ & Catch shares) is going to be infeasible, at least in the foreseeable future, because there is currently (Table 1.):

- o No accurate annual biomass assessment to establish to establish an initial TAC and annually update it,
- o Insufficient trend data and biological information to support biomass assessment modelling, a gap in information which would take several decades to rectify, even if such a data collection program could be implemented immediately,
- o No policy or regulatory framework for allocating shares of a TAC,
- o No governmental mechanism or capacity to track and control the catches and catch shares of individual fishers in real time.

Even if these current deficits can be remedied in the future, output management will still probably not be feasible or advisable for the fishery because of:

- o The relatively low value of the fishery relative to the expense of management by output controls and the;
- o The expense and technical difficulty of developing and maintaining accurate biomass assessments for the multi-species assemblage being fished.

For these reasons the implementation of output controls for this fishery is considered infeasible and of no priority, they will not be considered further by this report. Instead the management regime developed for this fishery should involve a combination of size selectivity and input controls.

3.2. Size Selectivity Management

Some use of size selectivity management is an obvious part of any management regime for this fishery, and if successfully implemented, could by itself put the fishery onto a robust biological basis by preventing both growth and recruitment overfishing (Table 1.).

Size selectivity in the fishery could be managed through a combination of:

- Minimum size regulations on the size of fish which can be retained for landing and or marketing.
- Regulating the types of gears to reduce the catch of sub-optimal size classes of fish. Various aspects of the different fishing gears influence the size of fish they catch. The size mesh in nets, hook size and shape (circle or J), the placement, number and dimensions of escape ports or gaps in traps, all influence the size composition of catches.
- Controls on the times, seasons, places and depths of fishing to reduce fishing when sub-optimal size classes are more likely to be caught.
- Prohibition of some types of fishing gear and techniques which are inherently non-size-selective or in this context cannot be made size-selective.
- Controlling the types of bait being used can also influence the size of fish caught

Size selectivity management should be the immediate short-term priority for management implementation in the fishery, because even implemented alone it could put the fishery onto a biologically sustainable basis, it is also the strategic form of management with which to immediately begin a longer-term process of management reform (Table 1.). Some forms of size selectivity management could be voluntarily implemented by agreement of the fishing communities, meaning that implementation is not contingent on government support, this is in contrast with other management mechanisms discussed below. When initiatives can only occur with the support of government, and especially when they require regulatory or legal reform, a lengthy process must be expected which is likely to frustrate practically minded fishing communities. This makes size selectivity management the strategic starting point for implementing management in El Corredor, because the fishing communities could start immediately with some small steps, and initial progress need not be contingent on government, although in the long-term implementation of more complete management reform will be strengthened by, and need, government support and regulation.

The fact that the some El Corredor fishers have already begun discussing the size composition of their catches and asking questions about the optimal sizes for capture, makes commencing the reform process with size selectivity management even more strategic. The dialogue that has already started should be informed and facilitated by using the LBSPR methodology and estimates size of maturity to develop recommendations for the optimal size of capture. Prince & Hordyk (2018) demonstrate that setting minimum sizes to be 1.2 times the size of maturity, or the size at which 50% of fish are selected for retention by nets, traps or hooks at 1.3 times the size of maturity, will maintain >20% of their spawning potential (SPR) and ensure fish will at least replace themselves before being caught. With these recommendations facilitated community discussions could develop the most pragmatic and feasible combination of regulations to avoid or minimize catching sub-optimal size classes. Regulations developed in this way would have a high chance of being broadly accepted, and even if entirely voluntary, successfully implemented and largely self-enforced, and so consequently likely to place relatively low demands on existing governmental capacities. And returning to the point made above, because progress with this would not be contingent on governmental change, this dialogue and process could begin immediately, initiating the longer-term process of more comprehensive management reform.

3.3. Exclusive Access to Incentivise Stewardship

A second immediate priority for implementing management should be developing a system of exclusive access for the fishery by strengthening the existing permit system and limiting the number of permits allowed (Table 1.). The primary aim of this is to foster a sense of corporate ownership and stewardship amongst El Corredor communities by ensuring any dividends from good management will flow to community members and cannot be dispersed amongst a relatively unlimited pool of fishers from outside, who may not share in the sacrifice of implementing the new management practices. Making access to fisheries exclusive in this way fosters a sense of corporate ownership of the resource and incentivises a spirit of good stewardship amongst fishers which in turn creates an enabling environment for the implementation of effective management.

The effect of this should so far as is possible be to fix the number of participants in the fishery to the current level and prevent new fishers from outside, or inside the area, accessing the resource in the future. This will also have the effect of limiting the potential for future effort creep which will buy time for developing and implementing management. It will also constitute an initial step towards flexibly managing fishing pressure and developing a capacity for adaptive management (which will be discussed further below).

The process of strengthening the exclusivity of access to this fishery should also begin immediately and proceed alongside that of making the fishery more size selective. However, as it will require changing or developing new government policy it can be expected to proceed more slowly than the implementation of voluntary measures to make fishing more size selective. Neither of these initiatives need be contingent on the successful conclusion of the other, although both will support the other. Ideally both would be in place as soon as possible to facilitate developing further capacities for management.

Exclusive access for this fishery could be strengthened by:

3.3.1. Developing a Specific Management Plan for El Corredor Fishery

The legal definition of El Corredor fishery should be strengthened so that it is covered with its own specific management plan with the aim of making it separate and distinct from other fishing regions and reserving the resources for the exclusive use of the El Corredor communities, in a way that makes it illegal for people from outside the region to fish within the region. This could potentially be achieved under the Mexican system of concessions by establishing El Corredor as a concession for its fishing communities.

3.3.2. Definition & Limitation on Permitted Number of Fishers and Vessels

In addition to geographically closing off El Corredor, within the region the number of fishers and vessels in the region should be defined and limited to the current number. The aim of this being to place an upper ceiling on fishing pressure and reduce the potential for it to expand, which is otherwise is to be expected as populations grow and individual fishers seeking to maximize personal shares of the catch. Consideration should also be given, if possible, to defining and limiting the size of fishing boats, and the types and amount of fishing gear being used. In this respect, the existing law on the maximum size of outboard motors provides a useful limit on boat size and effectiveness, and should be more effectively implemented and enforced. This definition and limitation of number of fishers, boats and gear being used will provide the pre-condition for developing more sophisticated capacities for adaptive management by incrementally adjusting fishing pressure in the fishery.

3.4. Managing Inputs of Fishing Pressure

In the longer-term mechanisms for adjusting fishing pressure will also need to be developed with the aim of managing the economic profitability of the fishery (Table 1.), and enhancing the capacity of management to respond to resource depletions that might be detected by stock assessment, and the escalation of fishing pressure to be expected from effort creep. Fishing pressure will be most feasibly managed in this fishery by defining and regulating the amount of gear being used in terms of the number of fishers, fishing boats and the number of nets of defined length, or traps of defined size, number of hooks and lines deployed per boat, and how often these gears are being used. This form of management will be extremely difficult for the fishing communities to develop amongst themselves on a voluntary basis and will in all probably necessitate governmental development of policy and a regulatory framework (Table 1.). Consequently, reform of this type is likely to take an extended period of time, so this should be the longer-term objective that is pursued in parallel to implementing size selectivity management and enhancing the exclusivity of access to the fishery. The implementation of size selectivity management and access exclusivity should not be delayed until input control mechanisms have been developed, but should proceed independently of progress with implementing input controls.

The most direct way of changing fishing pressure in any fishery is to reduce or increase the number of fishers and boats, but changing the number of fishers and boats, especially reducing it, is always socially and politically difficult. To avoid the social difficulty of changing the number of fishers and boats, in the longer term incrementally reducing or increasing fishing pressure will need to involve either:

1. Proportionally changing the amount of fishing gear that can be used by each fisher, or by
2. Defining and regulating the time allowed for fishing to take place, this could possibly the days of the week on which fishing is permitted, or the number of weeks per month, or months in the year. Note that longer contiguous periods of closure are generally easier to monitor and enforce, but are also more disruptive of market supplies and cash flows through fishing communities.

Developing this framework for incremental and adaptive adjustment of fishing pressure should be the long-term objective for management implementation in this fishery (Table 1.).

4. A Harvest Strategy to Implement Adaptive Management

Adaptive management is codified and implemented within a framework called the Harvest Strategy of a fishery, which is comprised of objectives which the management of the fishery aims to achieve, reference points against which actual achievements are compared to determine the relative success or failure of management at any point in time, and also to determine the extent to which the current management settings need iterative adjustment. To make the adaptive process possible the on-going performance of the fishery is monitored by collecting data on various indicators of stock status and socio-economics, and these are iteratively compared to the reference points using the structural logic and assessment methodology of the harvest control rule to determine sequential adjustments to the management settings.

The aim of this section is to begin bringing together and fleshing out all the elements of a harvest strategy for El Corredor fishery, providing some basic descriptions of management objectives, reference points, harvest control rules, the required monitoring and assessment as well as the potential methods for incrementally adjusting management.

4.1. Methods for Incrementally Adjusting Management

Assuming some combination of size selectivity and effort control management, described above is implemented, it should become possible to adaptively manage through some combination of:

1. Periodically adjusting fishing pressure by incrementally changing the time allowed for fishing (possibly days of the week, weeks in the months, months in the year etc)
2. Periodically adjusting the amount of fishing gear permitted to be deployed by each boat and / or the length of time the permitted amount of gear can be left in the water.
3. Periodically adjusting the regulations and agreements developed to manage size selectivity to increase or decrease the size of first capture and the level of reproductive potential being protected.
4. Theoretically the extent of protected areas could also be adjusted adaptively, but without detailed understanding of the resident time of each species within those areas relative to the distribution of fishing pressure this would be difficult or impossible to effectively operationalize.
5. More pragmatically the area allowed for fishing might be adjusted adaptively with restriction on the depth ranges fishing is allowed in, shallow closures to increase protection of juveniles and deeper closures to increase protection of adult size classes.

4.2. Objectives & Reference Points

For El Corredor fishery the primary objective recommended for this fishery would be to maintain Pretty Good Yields as described by Hilborn (2009) which is basically equivalent to managing for close to Optimal Sustainable Yields. Compliance with this objective could be tracked by adopting the internationally recognized target reference point of SPR 40% which would be monitored by applying the LBSPR methodology to the size composition of catches. Catch rate trends could supply additional information about trends in stock status in relation to the reference points and because they respond to changing stock status more quickly than size composition will serve to shorten the response time of assessment and management process.

The secondary objective of management should be the maintenance or enhancement of current relative economic well-being which could also be tracked with CPUE and catch relative to the bench-mark of originally estimated levels (i.e. current CPUE and catch). The objective here would be to keep catches and catch rates as high and stable as possible relative to current levels, as long as SPR was being maintained around the target level of 40%.

Commonly other social indicators are included as management objectives in fisheries management plans, beyond simply CPUE (i.e. income of fishers, profitability, price received for fish, employment levels, landed value of the catch). But most of these other indicators are determined by factors that are largely outside the control of fisheries managers (e.g. fuel and market prices). While it is of course natural for fishers and other stake holders to be interested in these measures of fisher well-being, it makes no sense to monitor management against externally driven factors which outside the influence of the management decision. Consequently, my advice is that having lots of objectives and indicators serves to distract rather than inform management and that is better to keep them simple and focussed on what can be directly impacted through fisheries management i.e. trends in SPR, CPUE and catch which also have a direct bearing on economic welfare regardless of external trends in prices.

4.3. Form of Harvest Control Rule

Prince et al. (2011) & Hordyk et al. (2015b) both demonstrate that when used iteratively within a slope to target algorithm size-based assessments of SPR (i.e. LBSPR) can provide a robust basis for an HCR without any underlying population model. However, reliance solely on size-based assessment of SPR makes the HCR very conservative. This is because size compositions change rapidly during the fish down of a stock but recover slowly as a stock rebuilds as the last aspect of a rebuilding stock to recover is the size and proportion of the oldest fish in the stock (Prince et al. 2011). This dynamic causes HCR based solely on size-based assessments to respond quickly to depletions and slowly to rebuilding processes. However, adding a CPUE trend to the size-based HCR can make it much more dynamic so that it will respond much more quickly to a rebuilding stock. Prince et al. (2011) found that an HCR based on size based SPR metrics and informed by CPUE trends could be as dynamic and robust as HCRs based on full parameterized accurate biomass assessment models.

Consequently, a similar form of HCR is recommended for development here. Such an HCR would incrementally increase or reduce fishing pressure in relation to trends in the key indicators around the reference points to keep the stock around target reference points. With incremental changes being greater or smaller depending on the steepness of the trajectory back towards the reference points.

4.3.1 Primary HCR Indicator

The primary metric for the HCR will be SPR which will be evaluated in relationship to three internationally accepted reference points and ranges:

- The target reference point will be 40-50% SPR which is a range of values used in international law variously as the upper end of Maximum Sustainable Yield (MSY) proxies (40%) and also (50%) for Maximum Economic Yield (MEY), the level at which a fishery should be most profitable because catches, catch rates and body sizes should all be optimally high. As the target this should be the range of SPR that stocks remains relatively stable within, and within which no adjustments to management would be required. Below 40% SPR small incremental reductions to fishing pressure would begin to be iteratively applied, above 50% SPR small incremental increases in fishing pressure could be iteratively applied.
- The reference point ~30% SPR is internationally recognized as the low end of the proxies used for (MSY). In this context it is suggested it would be a Reference Point used as a break point to define that SPR is falling towards undesirably low levels and that the magnitude of iterative reductions in fishing pressure needs to increase.
- The internationally accepted Limit Reference Point is 20% SPR which is regarded to be the level at which recruitment rates are expected to decline. Stocks should never be allowed to fall this level and in many jurisdictions national fisheries policy require targeted fishing to cease at this level. If below this level drastically large reductions in fishing pressure would be required to rapidly boost SPR back towards target levels.

4.3.2 Secondary HCR Indicators

Catch rates will provide a secondary indicator of stock trend and the primary socio-economic indicator. CPUE is expected to respond more quickly to changing stock status than the size-based SPR, so that while SPR is still revealing a relatively stable trend, rising or falling CPUE could indicate SPR is going to do the same a few years later. Using this dynamic management adjustments might be graduated more effectively, so that even while SPR remained close to target levels, small iterative management adjustments might be made in response to falling CPUE trend, in the hope of forestalling a later decline in SPR. In the same way iterative changes in fishing pressure could be larger if SPR declining out of the target range was accompanied with declining CPUE.

Unlike the SPR metric there are no established absolute reference points for evaluating the meaning of CPUE, rather its trends and levels will need to be evaluated in a relative context. The overall objective will be to keep CPUE as high and stable as possible, in conjunction with maintaining the SPR target, and to avoid and reverse CPUE declines. In general terms, within the context of SPR being the primary indicator, a CPUE trend that is relatively high and /or increasing will be regarded as good, while a CPUE trend that is low and / or declining is bad.

With some of the stocks (e.g. Huachinango) catch and CPUE trends could be available as separate indices for both adult and sub-adult components of the stock. In this situation the CPUE trend for the sub-adult portion of the stock might provide an index of the relative abundance of the recruitment entering the adult stock. In this situation it could provide an additional and more forward-looking stock indicator, which might possible fore-caste future trends in adult stock abundance. This might support the future development of an HCR based on three indicators.

4.3.3 Conceptual Interplay of Indicators

It is envisaged that the primary index in the HCR would be the trend in SPR and its level relative to internationally accepted Reference Points (RPs), while secondary indicators would be relative trends in CPUE and catch. As with Prince et al. (2011) the assessment logic to be encapsulated in the HCR would be similar to the logic underpinning Virtual Population Assessment (VPA). The level and trend in the primary index (SPR) being checked and qualified by the trend in the secondary indicators (CPUE and catch) to inform the management response.

So, for example the SPR index above the target level and stable, would indicate fishing effort and catch could rise while the SPR index above target and rising would suggest the increase in fishing pressure could be greater. A level of SPR just outside the target range and falling slowly would require a small reduction in fishing pressure, while a lower level of SPR near the Limit Reference Point and falling slowly would require a bigger reduction in fishing pressure, and SPR near the LRP and falling rapidly would require a much larger step down in fishing pressure.

Further informing the trend in primary SPR index and in a more dynamic fashion will be the secondary index of CPUE which should respond more instantaneously to changes in stock status than SPR, particularly when management intervention drives rebuilding. Its main use will be to augment and qualify the SPR trend, so that the trend in SPR will be evaluated more harshly if the CPUE is falling, or more favourably of the CPUE is rising. At times contrast in the SPR and CPUE trends may also be informative, so for example increasing CPUE and falling SPR could indicating effort creep (unmeasured increases in fishing pressure) or abrupt changes in recruitment.

The LBSPR assessment methodology also estimates the metric of relative fishing pressure (F/M) and potentially which could also be used to inform the magnitude of management change required and augment the SPR slope-to-target algorithm. This would require some further methodological development

4.4. Monitoring Requirements

The monitoring of this fishery should focus on monitoring species and size compositions of daily landings of the main species in the catch which comprise approximately 95% of landings:

Huachinango (*Lutjanus peru*)
Jurel (*Seriola lalandi*)
Pierna (*Caulolatilus princeps*)
Cadernal (*Cephalopholis colonus*)
Cochito (*Balistes polylepis*)
Estacuda (*Hyporthodus niphobles*)
Cabrilla sardinera (*Mycteroperca rosacea*)
Pargo amarillo (*Lutjanus argentiventris*)
Pargo mulato (*Hoplopagrus guentherii*)

4.4.1 Size of Maturity Estimation

Local estimates of size of maturity are needed for this suite of species to initiate LBSPR assessment but once having been completed need not be repeated routinely as a part of ongoing monitoring, unless factors likely to change size of maturity such as major changes in fish density or temperature regime.

For some species in the catch assemblage size of maturity studies have already been conducted for the La Paz region which will be sufficient for our purposes.

For the other species in the assemblage my recommendation is that simple macroscopic studies be undertaken to determine size of maturity, rather than microscopic (or histological) studies. Macroscopic studies can be conducted without expensive technical histological procedures and so are simpler and cheaper to complete. There is also mounting evidence that they provide a better estimate of the size at which fish become functionally adult, as opposed to the size at which gametes are first produced estimated with histological techniques. The third benefit of using macroscopic techniques is that they can be conducted in communities allowing fishers to participate and learn in the process, enhancing their 'ownership' and understanding of the results.

Conducting size of maturity studies will necessitate measuring the length and recording the gonadal status of 100-200 fish of each species. The sample of fish needed for this purpose should be selected to equally represent the size classes that cover the transition from 100% immature through to 100% mature. This work could be done in the fishing communities working alongside fisher's landing and cleaning their catches. With appropriate training the data could be collected by the fishers themselves. In other artisanal fisheries it has been observed that teaching fishers these skills can be transformational for their ability to perceive the impact of their fishing and their subsequent engagement in community-based management.

4.4.2. Size Composition Sampling

The basis of the LBSPR assessment which will provide the main stock indices used for this fishery will be monitoring changes in the size composition of the adult portion of each species' stock. For some of the species in the assemblage (e.g. Huachinango) the catch is primarily comprised of the juveniles found in shallower water, being juveniles the LBSPR analysis of the size composition of this part of the catch will tend to suggest that there is no reproductive potential in the stock. For these species it will be necessary to identify the seasons, depth ranges and locations where the adults are caught and to focus size composition sampling on this portion of the catches.

For each species the target should be to measure ~1000 fish per annum. These data should accurately represent the size composition of the catch and sampling protocols must be put in place to prevent samples being biased by observers inadvertently preferencing any particular size class or classes for sampling.

For some of the lesser species in the catch it may be difficult to accumulate annual sample sizes of ~1000 fish. This need not be an insurmountable problem. Size compositions are not expected to change rapidly, so that it is valid to aggregate size composition data over 1-3 years. In this context the minimum target for annual sample sizes should be ~350 fish which would enable sample sizes of ~1000 fish to be accumulated by aggregating data across 3 years of sampling.

4.4.3. Catch and Effort Monitoring

Trends in catch, effort and catch rate (CPUE) will also be used in the harvest control rule as described above. The proposal here is to monitor relative trends in catch and effort rather than attempt to monitor the absolute level of total catches. The latter being a task which is judged too difficult to achieve with any degree of accuracy with the existing level of resources available.

To track relative trends in catch, effort and CPUE it is only necessary to collect representative data from a relatively stable sub-sample of the fishery. In a small-scale fishery such as this the target should be to collect data for at least 15% of landings, with the intensity of sampling being distributed relative landings, across the geographical range of the fishery, the types of gears being used and the targeting they are used for.

For the sampled landings the minimum amount of information collected should be:

- Date of Landing,
- Type of fishing gear used,
- Location & depth of fishing,
- Weight of each of the main species (as defined above) in the landing,
- Time spent fishing.

A log-book system by which selected volunteer fishers are trained to collect data on their own catch could be a way of augmenting the current collection of data by designated enumerators. Many fishers enjoying collecting systematic data about their own operations as this helps them learn from their own experience, and this can provide an alternative motivation for enhancing data collection.

5. Multi-species Management

Much of the proceeding discussion has been simplified by avoiding or minimising the complex multi-species nature of this fishery that will need to be confronted through the implementation process. The MSC pre-assessment (Castro-Salgado et al. 2019) proposes using three evaluation units differentiated by the main species in those assemblies. The first corresponds to the assembly of species associated with shallow reefs and is represented by two indicator species, the sardine cabrilla (*Mycteroperca rosacea*) and cochito (*Balistes polylepis*), the second corresponding to deep demersal species, is represented by, the huachinango (*Lutjanus peru*) and the third, is represented by the indicator species, jurel (*Seriola* *lalandi*). Comprising approximately 60% of the landings from this fishery it would seem reasonable to proceed by initially focusing the implementation of management and the development of HCRs on these primary species and many of the measures proposed above including limiting the extent to which fishing pressure can grow and making fishing more size selective are likely to benefit the entire species assemblage and not just these main species.

However, as the capacity to assess and manage this fishery grows the aim should be to explicitly expand the scope of both assessment and management beyond these four indicator species. In this expansion process it will be wise to keep some conceptual linkages between species in mind. The first of these concepts is that of 'target' and 'incidental' species, and the second concept is that of 'weak-link' species.

5.1. Target and Incidental Species

Some species are more easily targeted for catching than other species, and these species will tend to dominate catch compositions, while others are just caught incidentally while the fishers try and catch the target species, these tend to be less important in catch compositions. Some species that can be caught in large quantities and could be targeted for catching, may not actually be targeted by fishers because for one reason or another they are not currently valued by the fishers as being worth targeting. A status which might change if its value is recognized or for some other reason it starts being considered worth targeting, but until that time, it may remain just an incidentally caught species. The dynamics of a multi-species fishery are primarily determined by the target species and the behavior of fishers is generally decided in relation to the availability of target species.

Management should primarily aim to cover all the targetable species, as generally speaking, it is these species that will be under most fishing pressure. Precisely because fishing pressure is targeted at them. In a situation where only some of the targeted species are managed restrictively it is to be expected that fishers will transfer their effort and fishing pressure across to the other targetable species not yet been protected by management, so that restrictive management of some target species is likely to necessitate management of the other target species. Similarly, management restrictions commonly drive fishing effort and pressure towards the most common incidental species by encouraging fishers to seek alternative opportunities and turn them into new target species.

5.2. Weak-link Species

In any assemblage there will also be some species that are more susceptible to fishing pressure than other species, either because they can be more effectively targeted than others, or because their biology makes them particularly susceptible to depletion (i.e. exceptionally long-lived and large bodied species relative to short lived small bodied species). These 'weak link' species may need specifically focused management measures to ensure that they are not pushed into local extinction by long-term levels of fishing pressure that may be sustainable for the rest of the assemblage. The management objective for such species may also need to be sustainability below a level that could optimize yields from that species. In some cases, preservation with zero yield may need to be the objective in order that yields can be maintained from other more important species in the assemblage.

In the context of developing assessments and implementing management, it is important that the extent to which all the main species in the assemblage can be targeted by fishers be understood, and that potentially weak-link species are identified. Noting that these are commonly incidentally caught species, rather than target species, and so might otherwise not be a priority for management. Much of the information for these purposes can come from the fishers themselves. The target species are the ones they plan their operations around catching and can deliberately maximise catches of, whereas, weak-link species might be identified from anecdotes of abundance declines, and their biological characteristics (e.g. long-lived, large body size, low fecundity, highly catchable).

5.3. Planning to Incorporate Species-interactions into Management

In the multi-species context adaptive management should be designed with an eye to the eventual need to incorporate a greater proportion of the species assemblage into the system of assessment and management than may initially be envisaged and possible. In developing assessments and HCRs, and implementing management the aim should be to extend beyond the four indicator species identified by Castro-Salgado et al. (2019) , and incorporate all the target and weak link species explicitly into the framework size selective fishing with managed levels of effort.

6. References

Castro-Salgado J.C., C.M. Álvarez-Flores, O.T. González-Cuellar, A.H. Weaver. 2019. Preevaluación MSC: pesquería multispecifica en el Corredor San Cosme – Punta Coyote en Baja California Sur, México. Reporte técnico no publicado. Pronatura Noroeste A.C., Programa de Conservación Marina y Pesca Sustentable. Ensenada, Baja California, 245 pp.

Froese, R. 2004. Keep it simple: three indicators to deal with overfishing. *Fish and Fisheries*, 5: 86–89.

Gilmour, P.W., Dwyer, P.D., Day, R.W. 2012. Enhancing the agency of fishers: A conceptual model of self-management in Australian abalone fisheries. *Marine Policy* 37: 165-175.

Gutiérrez, N.L., Hilborn, R., Defeo, O. 2011. Leadership, social capital and incentives promote successful fisheries. *Nature* 470: 386-389.

Hilborn, R. 2009. Pretty Good Yield and exploited fishes. *Marine Policy* 34: 193-196. 700 doi:10.1016/j.marpol.2009.04.013

Hordyk, A., Ono, K., Valencia, S.V., Loneragan, N., Prince, J.D. 2015a. A novel length-based estimation method of spawning potenential ratio (SPR), and tests of its performance, for small-scale, data-poor fisheries. *ICES Journal of Marine Science* 72: 204-216. doi:10.1093/icesjms/fsu004

Hordyk, A., Loneragan, N., Prince, J.D. 2015b. An evaluation of an iterative harvest strategy for data-poor fisheries using the length-based spawning potential ratio assessment methodology. *Fisheries Research* 171: 20-32. http://dx.doi.org/10.1016/j.fishres.2014.12.018

Prince, J. D., Dowling, N.A., Davies, C.R., Campbell, R.A., Kolody D.S. 2011. A simple cost-effective and scale-less empirical approach to harvest strategies. *ICES Journal of Marine Science* 68: 947-960. doi:10.1093/icesjms/fs May 2011.

Prince J.D. and Hordyk, A. 2018. What to do when you have almost nothing: a simple quantitative prescription for managing extremely data-poor fisheries. *Fish and Fisheries* 20: 224-238. doi: 10.1111/faf.12335

Table 1. Summary of potential forms of management, their strengths, weaknesses and requirements for implementation which have been taken into account in formulating this report's recommendations on feasibility for implementation in El Corredor fishery.

		Management Tools			
		Exclusive Access framework	**Size Selectivity**	**Input Controls**	**Outputs Controls**
Description		Restrictions on who can fish to a fixed number of fishers. An enabling Condition for all management	Regulations to control the size of fish being caught; size limits, gear types, places and times for fishing.	Regulations to control how much fishing occurs; number of fishers, number & size of boats, number and length of nets or hooks & lines, number & size of traps, length of fishing season	Regulations to directly control how much fish is caught; ending fishing seasons when Total Allowable Catch (TAC) is reached, or TAC shared by fishers who stop fishing when their share is caught.
Strengths		**1.**Enables successful management by incentivising proactive & co-operative behaviour. **2.**Slows the increase of fishing pressure	**1.** Can prevent growth & recruitment overfishing, 2. Only requires simple snapshot size-based assessment. 3. Easily self enforced by communities, **4.** Simplest & cheapest form of management so can be applied to small scale fisheries	**1.** Can prevent growth, recruitment & economic overfishing, 2. Only requires basic forms of model based trend assessment. 3. Intermediate level of governmental capacity required **4.** Some level of self enforcement possible by communities	**1.** Can prevent growth, recruitment & economic overfishing, 2. When implemented effectively with allocated TAC shares effectively incentivises fishes to optimize the value of their catch
Weaknesses		**1.** Excludes some people from catching fish	**1.** Cannot prevent economic overfishing	**1.** Incentivises competive behaviour and effort 'creep', 2. Effort creep requires adaptive ongoing management interventions, **3.** Requires intermediate level of governmental capacity required, 4. Requires model based trend assessment. **5.** Requires accurate monitoring of relative trends in catch & effort, **6.**Not easily self enforceable by communities	**1.** Requires accurate and highly technical annual biomass modelling to set TACs 2. High data requirement; age based biology & accurate catch & effort & biomass indices **3.** Requires high level of governmental capacity to monitor and enforce individual catches in real time & maintain annual assessment process, 4. Very expensive form of management only works for large valuable fisheries
Stock Assessment Requirement	Length-Based SPR Assessment		X		
	Catch & Effort Dynamics Modelling			X	
	Biomass Modelling				X
Information Requirement	Catch & Effort Trends			X	X
	Catch Size Composition		X	X	X
	Detailed Biology			X	X
	Size of Matuirty		X	X	X
Required Management Capacities	Real Timing Accounting For Catches and Catch Shares				X
	Enforcement of Catch Entitlements				X
	Enforcement of Concessions, Permits & Fishing gear	X		X	X
	Enforcement of gear types		X	X	X
	Enforcement of Size Limits		X	X	X
Fisheries Value		Not Important	Not Important	>USD5 million/annum	>USD50 million/annum
Priority for Implementation		**1.** Immediate implementation but requiring policy & legal development could take time. High immediate priority.	**1.** Immediate implementation should proceed independently of progress with implementing Exclusive Access which may take time. High Immediate priority.	**2.** Contingent on developing policy and governmental capacities probably making this a long term objective. Low immediate priority.	**3.** Contingent on development of governmental policy and capacities but even with these unlikely to ever be feasible due to the low value of these fisheries. No priority.

SOCIEDAD DE HISTORIA NATURAL

Niparajá

January 2020