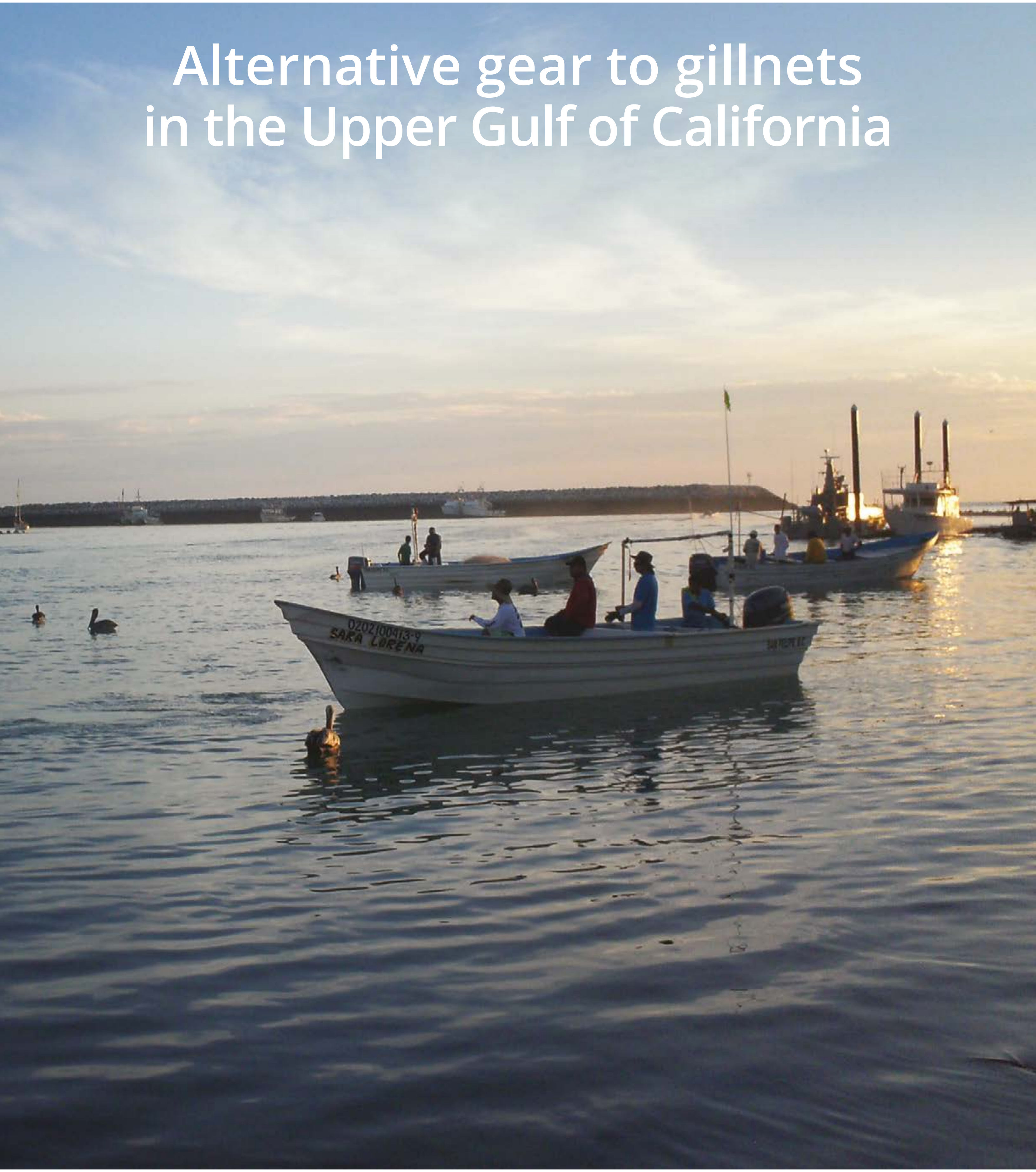
Expert Committee on
Fishing Technologies

2004 - 2016

Alternative gear to gillnets in the Upper Gulf of California



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Acknowledgements

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ECOFT

The ECOFT was formed in July 2016 following a series of meetings and workshops addressing fisheries issues and conservation initiatives. It was formalized to advise the Mexican government on re-directing fishing practices to transition into sounder gear alternatives that can replace gillnets from the Upper Gulf of California, support the fishing communities of the region and minimize impact on the environment.

The ECOFT is currently composed of experts from different parts of the world, namely Mexico, the United States, Canada, Scotland, Denmark, Sweden and Finland. Each expert brings a different perspective on the use of alternative gear, ranging from technical knowledge such as gear functionality to predictions on economic and environmental performance. The ECOFT counts with the support of WWF Mexico who manage the secretariat of the committee.

Message from the Chair

It is my pleasure to present the first of a series of working papers of the Expert Committee on Fishing Technologies (ECOFT) for the Upper Gulf of California (UGC). The ECOFT was created in response to a declaration by then President Obama of the USA and President Nieto of Mexico, to redouble efforts to protect the critically endangered vaquita porpoise.

There is a worldwide concern for the overuse of gillnets which is causing major ecological disruptions and affecting the small-scale fisheries of our communities. In the UGC, this effect is exacerbated by the critical state of endangered species. Since gillnets have historically been the predominant gear type in the region, the level of bycatch recorded is substantial and presents a serious and challenging problem to address; one that needs to be solved immediately. For this reason, it is imperative to begin re-inventing fishing practices to substitute gillnets with alternative gear that can be commercially profitable and not harm endangered species like the vaquita.

The following paper summarizes the existing reports on alternative fishing technology for the main fisheries in the UGC and proposes a series of alternatives which can be used immediately to implement gillnet substitutions in the region's small-scale fleet. Combining different alternative gear types with persistent management that reintegrates the community, these fisheries can be productive year-long and sustain both the livelihoods of the Upper Gulf communities and its ecosystems.

I hope the recommendations from this working paper will help inform critical actions in promoting use of innovative fishing gears as alternatives to gillnets in the UGC and help ensure the survival of the vaquita and other endangered species.

Christopher Glass

A comprehensive review of the research on alternative gear to gillnets in the Upper Gulf of California (2004-2016)

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Abstract

The negative consequences of gillnet overuse in marine ecosystems and productive fisheries are evident in the small-scale fisheries (SSF) of the Upper Gulf of California (UGC). Not only are species like the endemic vaquita porpoise (*Phocoena sinus*) going extinct, but the lack of alternative gear options are driving socio-economic disasters amongst local communities and strengthening the political tension between national and international government bodies, policy-makers and conservation groups. Despite the critical stage of both species and fisheries in the UGC, research on alternative gear exists but remains disperse and rarely consulted. Here, we gather the relevant and available studies on alternative gear in the UGC and present evidence to suggest that gillnet substitutes already exist that can be worked with immediately to alleviate the social, economic and environmental pressure of the region. Our review studies the two main fisheries in the region, shrimp and finfish, and evaluates the state of existing non-gillnet fisheries. Small trawls, traps, hooks and longline gear are highlighted as the most efficient, but other gear options are suggested for improving future research. Other factors affecting viable fisheries and functional gear are discussed, such as fishing port, seasonality and species, but the most frequent report is that fisher versatility and willingness to adopt alternative gear dominates experimental results. We identify that at least 20% of the fishers participating in experimental trials demonstrate skillfulness for alternative gear and can work collaboratively with others to progressively transition into a gillnet-free UGC. The information presented here serves as a basis for future investigations and is critical for improving decision-making for both proper fisheries management and comprehensive conservation efforts.

Introduction

The excessive use of gillnets and the lack of alternative and selective gear options for small-scale fisheries (SSF) is a major threat to the ecosystem health of marine habitats around the world. This issue is of particular concern in the Upper Gulf of California (UGC), between the western peninsula and mainland of Mexico, where fishers livelihoods are under threat and species such as the vaquita porpoise (*Phocoena sinus*) are threatened with extinction as a consequence.

The UGC is one of the most productive areas in Mexico, hosting a rich fishing ground for SSF whilst demonstrating prolific biodiversity (Rodríguez-Quiroz et al. 2012). The constant turnover and input of nutrient-rich waters from continental origin, like the Colorado River, feed its productivity which, in turn, is reflected by abundant schools of fish, shrimp and clams (Álvarez Borrego and Lara Lara 1991; Millán Núñez et al. 1999; Aragón-Noriega and Calderón-Aguilera 2000). Additionally, several protected species of birds, mammals, fish and invertebrates live or migrate to these waters (Cisneros-Mata 2010; NAMPAN 2011). Most of the fisheries production comes from SSF which target mainly blue shrimp (*Litopenaeus stylirostris*), Gulf curvina (*Cynoscion othonopterus*), rooster hind (*Epinephelus acanthistius*), sierra (*Scomberomorus sierra*) and some species of sharks, mollusks and invertebrates (Rodríguez-Quiroz et al. 2010; Cisneros-Mata 2010; Erisman et al. 2011; Erisman et al. 2014).

755 pangas were operating legally in the UGC in 2015

The only fishing unit operated by SSF is the panga, characterized by fiberglass material and a length of about 7 m long and 2 m wide. The panga is equipped with a gasoline powered outboard engine that operates with a horsepower of 48 to 200 HP (Pérez-Valencia et al. 2011).

©Chris Johnson / Earthocean, 2010. San Felipe fishers using gillnets.

Table 1 shows a summary of the legal fishing effort in the UGC, where 93% of the fishing licenses are for gillnet fisheries. The main fishing ports are San Felipe and El Golfo de Santa Clara, who combined possess over 1,300 gillnet licenses of which 95% are for shrimp and finfish. Non-gillnet fisheries exist, such as hookah diving for mollusks or trap fisheries for crabs, but legal licenses represent only a minority.

Table 1. Number of pangas and licences in the Upper Gulf of California.

Town	Number of pangas	Number of fishing licenses				
		Gillnet fisheries			Non-gillnet fisheries	
		Finfish	Shrimp	Sharks	Crab	Other[a]
San Felipe	304	242	220	32	36	20
El Golfo de Santa Clara	451	415	423	33	32	11
TOTAL	755	657	643	65	68	31

a. Other species include octopus, clams, scallops and other shellfish

Source: Pérez-Valencia et al. 2015

93% of the fishing licenses in the UGC are for gillnet fisheries

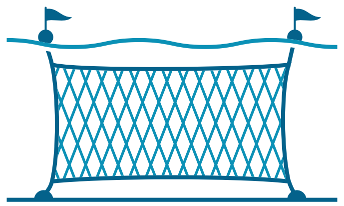
Like with most other SSF around the world, gillnets dominate the fisheries due to their simple deployment and abundant catches (Conanp 2008). In particular, the use of drift nets (gillnets that are left under suspension in the water) is concerning given the lack of control over bycatch. The net, set vertically in the ocean using a series of weights and buoys, functions as an extensive mesh barrier which catches incoming species through entanglement by the gills or the body (Pérez-Valencia et al. 2011). Once deployed the net can be left behind for an indefinite amount of time in order to increase the probability of capture from a single cast. The length of gillnets varies from fishery to fishery, but has increased over time. In the early nineties two gillnets of about 400 m were operated per panga. By 2015 this length doubled, summing to a 1.6 km-long gillnet operation per panga (Cudney-Bueno and Turk-Boyer 1998; Pérez-Valencia et al. 2011).

For the specific case of curvina Golfina, gillnets are operated in a different way. The fishery happens during the spawning season, November to May, and in very specific fishing grounds near the Colorado River Delta (Erisman et al. 2011). Mexican regulations establish that the length of the gillnet is to be less than 275 m and operated as an encircling net. The fishing grounds are small and several pangas operate at once, causing disruptive conditions which, along with the net specifications and deployment, are unlikely to pose a risk to vaquita. There have been no reports of vaquita bycatch in curvina fisheries (D'Agrosa et al. 2000).

The main issue with gillnets is that they produce substantial levels of bycatch (Carreta et al 2003; Jaramillo et al. 2007). It is not uncommon to find reports of birds, turtles, sharks and whales entangled in gillnets. A major concern is the entanglement of the vaquita porpoise, which is on the brink of extinction due to the excess of gillnets in the water. Porpoise bycatch from gillnets is common in other parts of the world, namely the Baltic Sea, Gulf of Maine, South America and the North Pacific and Indian Oceans (Berggrem 1994; Vinther and Larsen 2004; Jefferson and Curry 1994; Cox 1998). However, the case of the vaquita is particularly eminent given that populations are estimated at 30 or less and they exist nowhere other than in the UGC (CIRVA 9).

Since the 60's, the Mexican government has imposed different strategies to preserve the UGC and, since 2008, specific management schemes have been developed to avoid vaquita bycatch in gillnets. The first 20 years of conservation efforts were focused on protecting commercial fish stocks while the subsequent years focused on integrating social issues to manage the growth of SSF and sustainable development (Bobadilla et al. 2011). From 2007 to 2017 the Mexican government has invested millions of dollars in payments to fishers to implement actions and policies preventing the extinction of vaquita. In the last two years of policy-making, a major fishing ban was introduced for protecting vaquita, but throughout this period scientists recorded the most drastic decline in vaquita population with about a 50% drop annually.

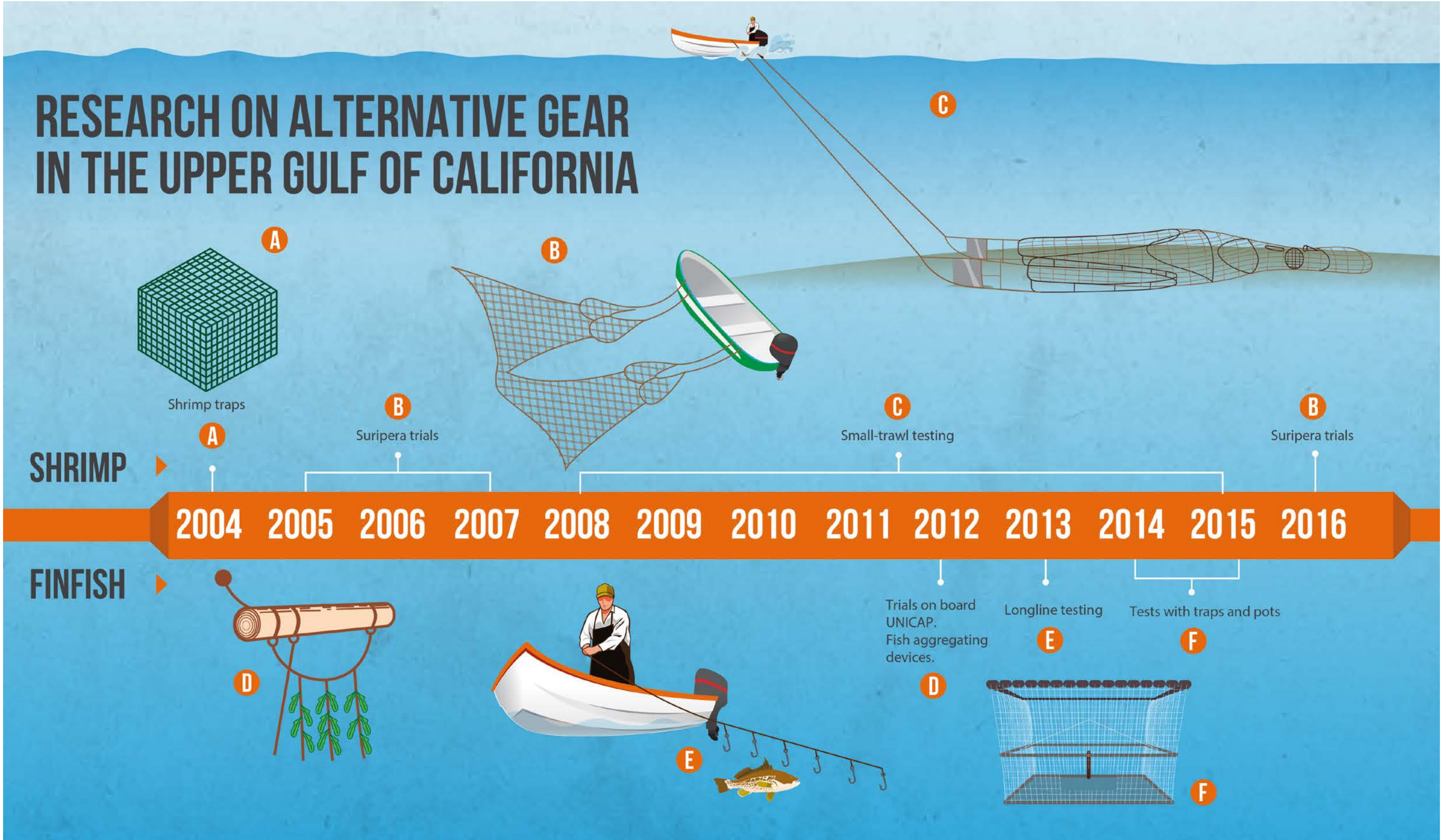
In a scenario where gillnets continue to dominate the fisheries, and while illegal use of gillnets operate under the veil of legal fisheries, public policies will continue to fail. For this reason, it is imperative to begin re-integrating fishing practices with alternative gear that can be profitable, provide substitutes for gillnets and that do not impact or harm vaquita or other endangered species. Alternative gears already exist, but a compilation of the tests and results for gillnet substitutes has not been made. This paper summarizes the existing reports on alternative fishing technology for the main fisheries in the UGC and proposes a series of alternative gear that can be used immediately to replace gillnets in the region's SSF.



On average, each panga fished with **2 gillnets of 800 m each**

The vaquita porpoise is on the brink of extinction due to an **excessive number** of gillnets

©Gustavo Ybarra, Gillnets in a fishing camp.


RESEARCH ON ALTERNATIVE GEAR IN THE UPPER GULF OF CALIFORNIA
A
Shrimp traps
B
C
SHRIMP
A
B
Suripera trials
C
Small-trawl testing
B
Suripera trials
2004
2005
2006
2007
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2015
2016
FINFISH
Trials on board UNICAP. Fish aggregating devices.
D
Longline testing
E
Tests with traps and pots
F
D
E
F

Alternative gear for shrimp fisheries

Efforts for finding **gillnet substitutes** have been evident since 2004

Shrimp is the most important commercial product sold in the UGC for SSF (Rodríguez-Quiroz et al. 2010; Aburto-Oropeza et al. 2017). Until 2013, Mexican regulations dictated that shrimp catch should be conducted with drift gillnets which are, to date, the preferred fishing technology amongst fishers. However, efforts for finding gillnet substitutes have been evident since 2004, where WWF and the Memorial University of Newfoundland conducted tests with shrimp traps and obtained poor catch results. Moreover, from 2006 – 2008, the Mexican Research Institute for Fisheries (INAPESCA) conducted trials to test the potential of suripera nets, local cast-nets used by fishers in the southeast end of the UGC, as gillnet substitutes. The first results in 2008 discarded suriperas as an option (INAPESCA 2008). However, few trials in 2017 suggest that suriperas have potential and should be tested more seriously.

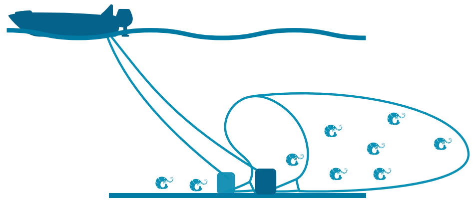
©PNO, 2010. Fishers testing the small trawl in the UGC.

Undoubtedly, the search for alternative gear and the efforts to preserve the few remaining vaquita have been linked in conservation efforts (PACE-Vaquita 2007-2014). From 2007 - 2014, the PACE-Vaquita program called for a series of technological reconversions in exchange for monetary compensations to fishers. The reconversion options ranged from total technological switch-out, where fishers got paid to abandon gillnets, to partial technological switch-out, where fishers got paid to test alternative gear and then decide whether to use it or not. In 2015, the Mexican government set a two-year gillnet ban to prevent further vaquita entanglement. As of July 2017, this ban is now permanent.

Gillnets are **banned** from the UGC as of July 2017

The most studied option for gillnet substitutes in the shrimp fisheries is small trawls. Intensive trials began in 2009 with the introduction of the RS-INP-MX, a small version of an industrial trawl designed by INAPESCA in a joint project with the Food and Agriculture Organization (FAO). The trials were conducted near the port of San Felipe and El Golfo de Santa Clara. However, the success of the small trawl has been conflictive, oscillating between rejection and approval from the fishing sector, INAPESCA and government authorities.

In 2009, INAPESCA trials proved that the RS-INP-MX was effective at catching brown shrimp (*Farfantepenaeus californiensis*) at night. Blue shrimp is caught during the day; however, the presence of gillnets during this time obstructed trawl operations. Therefore, INAPESCA decided to conduct night trials, without gillnet obstruction and obtaining good catch results but from brown shrimp which is abundant at night. Fishers claimed that the trawl was not functional for catching blue shrimp, and that they were not interested in brown shrimp –which has lower prices in the market. As a response, INAPESCA programmed new tests for 2010, under gillnet-free fishing zones where the small trawls could operate free of obstruction. Unfortunately, the gillnet-free zones were not respected and poor catches were obtained. The official report for those trials claimed the no-compliance with the gillnet restriction zones and suggested fisher unwillingness to work with the small trawls as the main cause of poor results (INAPESCA 2011).

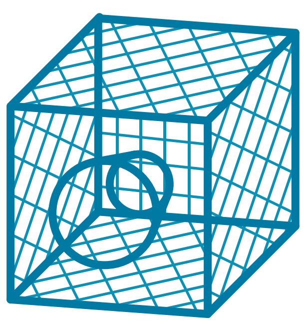


The most studied option for gillnet substitutes in the shrimp fisheries is **small trawls**

INAPESCA proposed further tests prior to the open season, with a small group of fishers that had proved to be keen participants in the tests of 2009 and 2010. These tests were conducted during the summer of 2012, with the support of WWF and the National Oceanographic and Atmospheric Administration (NOAA). During this study results were good with abundant catches of blue shrimp. On one hand, this led to the publication of an official norm regulating the use of gillnets and which implemented a progressive switch-out to the small trawl which aimed to be complete by 2017 (DOF 2013). On the other hand, the fisher community continued to reject the success of the small trawl despite the good catch reports. The fishing sector put forward the following arguments following the 2012 trials: (1) the success of the small trawl in the summer does not indicate success further in the fishing season, (2) the small group of fishers who participated in the project does not represent the greater majority of the fishing community and (3) the tests were done in San Felipe and the results do not apply to El Golfo de Santa Clara.

In response to these arguments, INAPESCA conducted additional trials in 2013 which included a greater number of fishers, both of the fishing ports and the first weeks prior and after the start of the shrimp season. Good catches were seen in the port of San Felipe, contrary to El Golfo de Santa Clara which showed poor catches. The fishing sector argued that the small trawl was inefficient in El Golfo de Santa Clara and that good results at the beginning of the season were not enough to support the functioning of the net during the rest of the shrimp season.

Trials for different finfish species began with experiments onboard the **UNICAP XVI**



Fish trap

In 2015, another set of tests with the small trawl were conducted by INAPESCA in San Felipe and El Golfo de Santa Clara throughout the entire shrimp season. This year coincided with the two-year gillnet ban, causing social uproar amongst the fisher communities. The results of the 2015 trials showed that San Felipe produced good catches with a small amount of fishing trips, while El Golfo de Santa Clara was still obtaining poor results despite a higher number of trips. In 2016, INAPESCA led another series of tests to try alternative gear in El Golfo de Santa Clara, using suripera and some other modified nets. The RS-INP-MX was not tested in San Felipe during 2016, only in El Golfo de Santa Clara, and showed poor results again.

Alternative gear for finfish fisheries

Intensive trials for different finfish species began in 2012 with experiments onboard the UNICAP XVI, a research vessel used by INAPESCA to test several gear at once. These trials aimed to assess the catch efficiency, selectivity and economic yields of eight alternative fishing gear. Trials were undertaken from April to November around the fishing grounds of San Felipe and El Golfo de Santa Clara. The experiments concluded in the identification of three alternative gear subsets: 1) those with poor performance, 2) those that were inconclusive but with potential for development and 3) those with high catch efficiency and good selectivity. The fishing systems that presented better results were longlines, rigid fish traps and fish trawls.

In those cases where the results from the research vessel concluded in high catch efficiency and good selectivity, new tests were conducted on board of local pangas to analyze the efficiency of those types of gear with the regular SSF operations of the region.

In 2013, Pronatura Noroeste (PNO) –a Mexican NGO working in the region, tested the economic performance and catch efficiency of the hook and line longline fishery. The tests were made from February to March and report variables of production (species and kilograms caught per journey), cost of production and product price. Given the variability and size of the fishery results were diverse but overall with positive outcomes and profitable indicators.

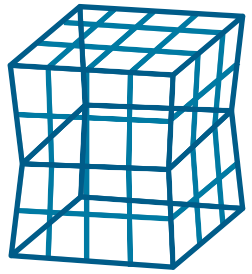
©WWF, 2011. UNICAP XVI research vessel.

In 2015, WWF participated with a group of local fishers in a series of experiments with rigid and collapsible traps to analyze their catch and economic efficiency when operated by pangas in the UGC. A thorough analysis was made regarding the month of fishing and the effort per panga for using traps.

Also in 2015, INAPESCA considered the operation of four different gears onboard local pangas; rigid traps, collapsible traps, stow nets and small trawls for finfish. Trials began in October and spanned midway through December, with tests performed in both San Felipe and El Golfo de Santa Clara. Results were particularly good for traps in San Felipe. Additionally, in 2015, there was a collaborative research effort between the Mexican and US governments taking fishers from the UGC to the state of North Carolina in the United States, to test the performance of stow nets in coastal channels and evaluate the possibilities of adapting the designs to the UGC (Price et al. 2015). Unfortunately, this study was paused due to the possibility of vaquita bycatch given evidence of porpoise entanglements with stow nets in different parts of the world (Kim et al. 2013).

Methodology

The reports available for different fishing technology from 2009 to date were made with different gear and objectives. Therefore, it is not feasible to generate a simple comparison between average catch rates. Rather, it is necessary to follow a thorough comparison that recognizes differences and analyzes the relevant information from the different studies. For all tested gear, our most relevant sources of information are technical reports from INAPESCA, given that they are comparable with some of the databases available from trial observers and the final reports from every operation. For ease of analysis and comprehension, we divide this study in two sections: 1) shrimp gear analysis and 2) finfish gear analysis. Then, we describe the current non-gillnet fisheries and propose a series of viable gillnet substitutes.



Collapsible trap

INAPESCA considered the operation of **four different gears** onboard local pangas: rigid traps, collapsible traps, stow nets and small trawls for finfish

Table 2. INAPESCA small trawl trials from 2009 - 2016.

Year	Format	Casts	Months of operation
2009-2010	Final report; Annexed report on net comparison statistics	1,024	September - December
2010-2011	Final Report; Observer database for 2010	1,084	September - December
2012	Final report to donor; Observer database	66	August - September
2013	Final Report; INAPESCA database	2,528	August - September
2015	INAPESCA report	218	September - December
2016	2016 INAPESCA database	764	September - December
Total casts		**5,684**	

INAPESCA reports frequently suggest that **fisher participation and willingness to cooperate** are strong factors in the success of catches from the small trawls

The **RS-INP-MX** is indeed **a viable alternative** for fishing when employed under appropriate conditions

Shrimp gear analysis (small trawl)

A review of the literature from all Inapesca trials for small trawls from 2009 to 2016 was made to summarize data for catch efficiency, composition and to form a basis for comparative analyses.

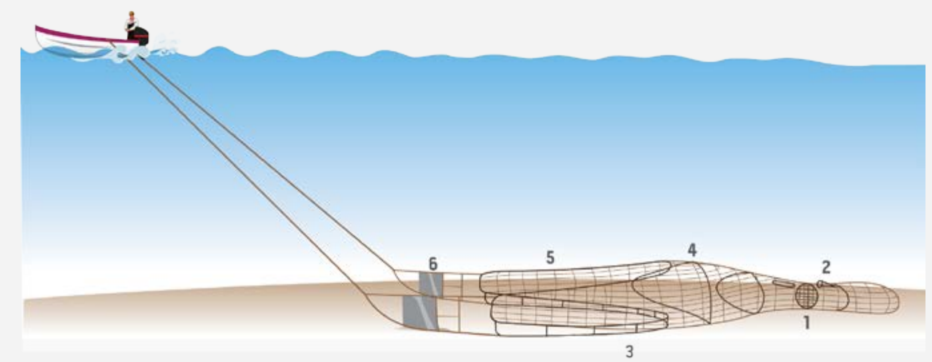
Table 2 shows the different sources of information used to examine trawl data. Our objective is to analyze the efficiency of the small trawl for shrimp fisheries in the UGC. An initial analysis is made, where we gather a series of catch averages and totals from the reports. Nonetheless, there are clear differences in the catch data reported for all of the years. These differences cannot be solely justified by the calculated averages. Therefore, we propose a series of hypotheses to explain which factors contribute to differences in the data, namely shrimp species, fishing port, type of net and fisher catch distribution.

First we analyze shrimp and port as factors for trawl efficiency. We look at the proportion of blue or brown shrimp caught in each year and the average catch per fisher journey in each port, as stated in INAPESCA official reports. Subsequently, we analyze the performance of modified small trawls compared to the original RS-INP-MX prototype. There were various modified versions tested throughout all of the trials, but statistical reports from INAPESCA indicated that the RS-INP-MX was the most efficient (INAPESCA 2011). Information from official reports of INAPESCA was not enough for comparing catches between RS-INP-MX and modified versions, for which we used databases generated by the observers. We have observer databases for 2010, 2012, 2013 and 2016. There are however, some small inconsistencies between the databases and official reports, which are likely an outcome of data processing, potentially excluding possible outliers or anomalies.

INAPESCA reports frequently suggest that fisher participation and willingness to operate the trawl are strong factors in the success of catches from the small trawls. We generate a series of Lorenz curves and Gini indices using the data available from the 2010, 2012, 2013 and 2016 databases, in order to investigate fisher catch distribution and proportionality. These are tools typically employed to study income distribution and inequality, but can be adapted to fisheries science to analyze fisher aptitude. Gini index shows inequality; a Gini index of one, the maximum value, shows perfect inequality. In fisheries, a high Gini index will indicate a huge difference between the catching capacities amongst fishers, and in the case where all other variables are constant, will suggest differences in skills. By analyzing catch distribution, we split the data into quantiles to study whether the difference between fisher catches are significantly large compared to what would be expected from other fishers of similar levels of experience.

Considering that the quantiles support INAPESCA's hypothesis on fisher skills and will to fish, we process and analyze data from a specific subset of skilled fishers using RS-INP-MX data in San Felipe and the average catches of trials under this combination of factors. The information presented hereafter demonstrates that the RS-INP-MX is indeed a viable alternative for fishing when employed under appropriate conditions.

Small Trawl RS-INP-MX

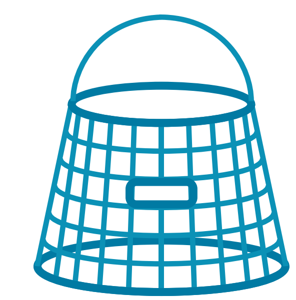


1. Turtle excluder device.
2. 'Fish eye' bycatch reduction devices.
3. Double tensioned footrope.
4. Spectra mesh technology.
5. Progressive reduction in mesh size.
6. Hydrodynamic trawl doors.

Finfish gear analysis

A review of existing literature was performed, using the latest reports on alternative gear focused on finfish species. Table 3 summarizes the information available.

Based on the sources shown above, we found common variables that helped explain experimental results. These were number of tests, catches per test and total catches. These variables allow for the comparison between different alternative gear. To better understand the contents of the reports, we systematize the information in summary tables that include the common variables but also describe various others that reflect the specific outcomes of each investigation. Throughout the results and conclusions made within the reports, we generate our own results that allow us to conclude and generate specific recommendations for the development and adoption of alternative gear to substitute gillnets used in finfish fisheries.



Conical crab trap

Table 3. Sources of information for finfish alternative gear

Date	Source	Description
Apr-Nov, 2012	Report from WWF to IWC; INAPESCA database	Summary of the 8 gear tested by the UNICAP XVI vessel, during 248 days.
Feb-May, 2012	Report from PNO to WWF	Experimental study from PNO on hook and longline fisheries; profitability and catch analyses included.
May-Jul, 2015	Report from WWF to TMMC	Trap performance with profitability and catch analysis
Oct-Dec, 2015	Official report of INAPESCA	Experimental results for traps, small trawls and stow nets

Tests performed with the small trawl

Location	Type of fishing	Seasonality	Conditions	Year	Positive results	Recommendations
San Felipe	Day Fishing	During open fishing season	In presence of gillnets	2010	NO	Enforce gillnet ban
			In absence of gillnets	2015 Between Sep-Oct	YES	Grant fishing permits
				2015 Starting Nov	NO	Test smaller nets and improve trawl power
		During closed fishing season	With expert fishers	2012	YES	Anticipate the shrimp season for small trawls
			With a broader group of fishers	2013	YES	Training for fishers
	Night Fishing		Only brown shrimp caught	2009	YES	Allow regulated night fishing
El Golfo de Santa Clara				2009-2016	NO	Test other gear like suriperas

Fishing gear and tests performed

Gear subgroup	Gear	Year	Observations	Recommendations
Good catch and selectivity	Fish traps	2015	They proved to be efficient but it remains unclear if they are profitable since the bait is very expensive, and it has not been determined which models and designs work best.	Improve bait and repeat tests where the model and design can be determined
	Longlines	2013	Highly selective fishery that demands a close monitoring system for management.	Grant fishing permits and improve monitoring systems
	Trawl nets		They have not been tested under optimum conditions.	Perform tests in a timely manner
Promising	Stow nets	2015	A fishing exchange with North Carolina took place. However it was suspended because the literature indicates incidental capture of cetaceans.	Focus efforts on promising gear
	Conical crab traps		Have not been tested on board of small vessels.	
	Collapsible traps		Less catches than rigid traps.	

Results

Gillnet substitutes for shrimp fisheries

The results of the 5,700 tows done with RS-INP-MX are summarized below, in a format that facilitates the comparison between fishing port, season and type of shrimp caught. A subsequent analysis of fisher catch distribution and proportionality is suggested to identify fisher aptitude and net efficiency.

Table 4. Results from INAPESCA small trawl trials from 2009 to 2016.

Year	Catch per trip (kg)			Season	Proportion of shrimp by type	
	San Felipe	Golfo de Santa Clara	Average*		San Felipe	Golfo de Santa Clara
2009[a]	41.5	2.6	27.6	Autumn	Brown (92%)	Brown (50%)
2010[b]	5.5	6.2	5.7	Autumn	Brown (94%)	Brown (73%)
2012[c]	37.8	-	37.8	Summer	Blue (100%)	-
2013[d]	18.8	5.5	16.0	Summer	Blue (99%)	Blue (97%)
2015[e]	15.2	0.2	1.9	Autumn	-	-
2016[f]	0.8	2.8	1.9	Autumn	-	-

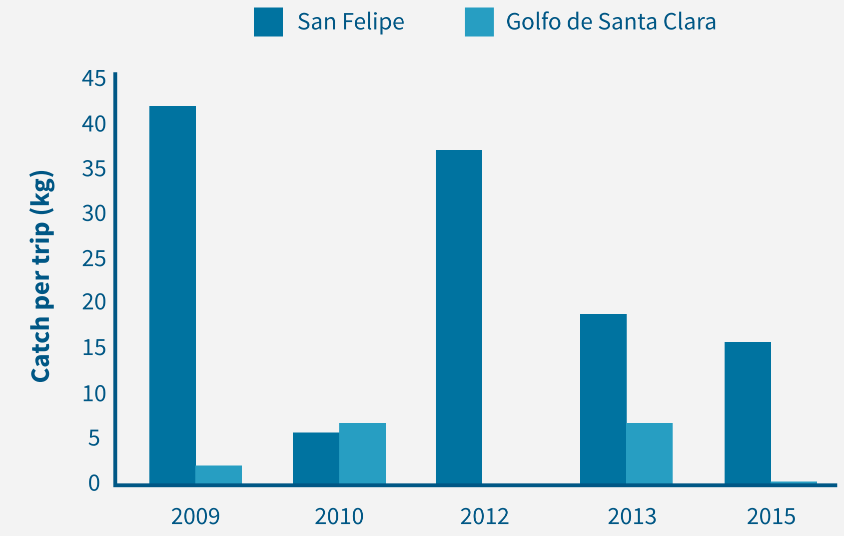
*Average calculated based on total shrimp catch divided by total number of trips

Source: Own elaboration based on: (a) INAPESCA 2010. Pesca Experimental de Camarón con la Red de Arrastre Prototipo RS-INP-MEX en el Alto Golfo de California: Capacitación al Sector Productivo en la Construcción, Operación y Mantenimiento de la Red y Colecta de Información en Campo. Informe Ejecutivo de la Campaña 2009-2010. Doc. Interno. INAPESCA, 2010 28 p. (b) INAPESCA. 2011. Evaluación Biotecnológica de la Red de Arrastre Prototipo "RS-INP-MEX" Para Captura de Camarón en el Alto Golfo de California. 22p. y 12 Anexos. SAGARPA. INAPESCA, México and the database financed by World Wildlife Fund-Mexico. (c) Aguilar-Ramirez, D. y Rodriguez-Valencia, A. 2012. Eficiencia y Selectividad de Dos Diseños de Redes de Arrastre para Pescar Camarón Azul (Litopenaeus Stylirostris) en la Pesquería Artesanal del Alto Golfo de California. 13 p. INAPESCA, México and the database made jointly with WWF, NOAA e INAPESCA in 2012. (d) INAPESCA. 2014. Reporte Final del Proyecto: Experimentación de Artes de Pesca Alternativos para la Captura de Camarón Azul (Litopenaeus stylirostris) por el Sector de Pesca Ribereña del Alto Golfo de California. 47p. y 10 Anexos. SAGARPA. INAPESCA, México y la base de datos generada por INAPESCA para la temporada de camarón del 2013. (e) INAPESCA. 2016. Informe Técnico del Proyecto (periodo septiembre-diciembre 2015): Desarrollo de Sistemas Pesqueros Sustentables para el Alto Golfo. Informe Interno. STPN. 30 pp y anexos. (f) INAPESCA database for 2016 shrimp season (unpublished).

Table 4 shows an aggregated version of the results obtained with the RS-INP-MX prototype, as well as other modified versions of the same design. In 2009 and 2010, there was a promising catch of brown shrimp, which is typically caught at night near the fishing grounds of San Felipe. In 2009, catches in San Felipe were 16 times higher than in El Golfo de Santa Clara. However, the efficiency of the net to catch blue shrimp and developing a net which worked in El Golfo de Santa Clara were topics still subject to further research.

By location

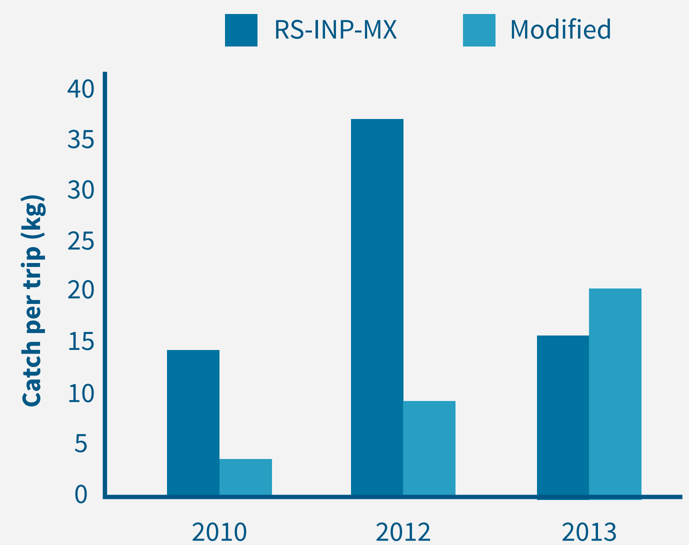
In 2009, catches in San Felipe were **16 times** higher than in El Golfo de Santa Clara



The trials of 2012 and 2013 demonstrated that blue shrimp is indeed vulnerable to the small trawls tested in San Felipe. In 2015, the tests proved that the trawl system can work during the autumn months as well, when the fishing ban is lifted. In most years, except for 2010 and 2016, catches were more promising in San Felipe than in El Golfo de Santa Clara.

Table 5 shows a comparison of catches with the RS-INP-MX prototype and modified designs in San Felipe. We can observe that, in most cases, average catch with RS-INP-MX is more than double that of modified systems. For 2016, no trials were made with RS-INP-MX in San Felipe.

By fishing gear



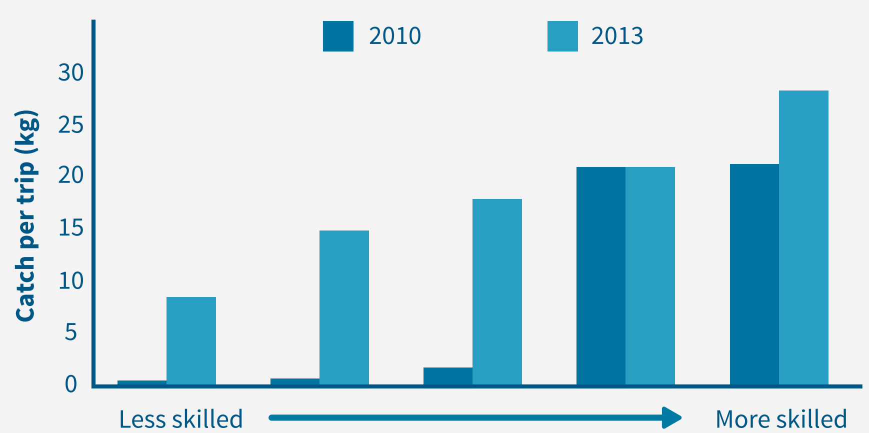
Average catch with the **RS-INP-MX** is more than double that of modified systems

Table 5. Proficiency of the RS-INP-MX prototype compared to modified versions in San Felipe.

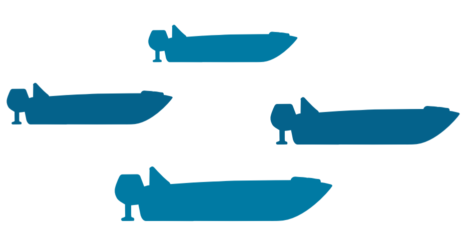
Year	RS-INP-MX			Modified			kg per trip in San Felipe
	Trips	Catch (kg) Total	Catch (kg) per trip	Trips	Catch (kg) Total	Catch (kg) per trip	
2010[a]	45	602	13.4	317	1235	3.9	5.5
2012[b]	17	643	37.8	4	38	9.5	32.4
2013[c]	149	2461	16.5	165	3363	20.4	18.8
2016[d]	-	-	-	126	96	0.8	0.8
Total	211	3706	17.6	612	4732	7.7	10.3

Sources: Own elaboration based on: (a) World Wildlife Fund (WWF) financed database developed by INAPESCA (b) Aguilar-Ramirez, D. y Rodriguez-Valencia, A. 2012. Eficiencia y Selectividad de Dos Diseños de Redes de Arrastre para Pescar Camarón Azul (Litopenaeus stylirostris) en la Pesquería Artesanal del Alto Golfo de California. 13 p. INAPESCA, México and the database created jointly with WWF, NOAA and INAPESCA in 2012. (c) database generated by INAPESCA the 2013 shrimp season. (d) database generated by INAPESCA for the 2016 shrimp season (unpublished).

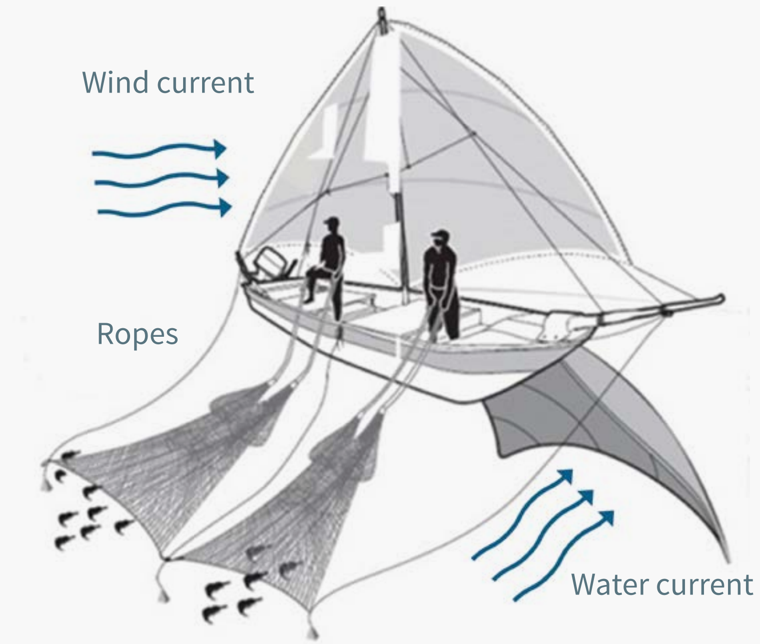
By skill



Fisher skill has a strong influence
in catch results



On the other hand, Table 6 shows the importance of fisher aptitude for the success of small trawl catches; 2010 is particularly noticeable where the first three quantiles had catches that were 10 times lower than the last two quantiles. In the case of 2013, even though the difference was not as large, the fishers from the last quantile were still catching 4 times more shrimp than those from the first quantile. Gini indices of 0.7 and 0.5, like the ones of 2010 and 2016 respectively, show a strong inequality between fisher proficiency.



©Gustavo Ybarra, 2008.

Table 6. Shrimp catch per proficiency quantiles for fishers in San Felipe (kg per trip).

Year	1Q	2Q	3Q	4Q	5Q	Average	Gini
2010[a]	0.2	0.6	2.1	21.9	22.6	5.5	0.7
2012[b]	21.3	34.3	36.7	41.5	68.5	37.8	0.1
2013[c]	8.0	14.8	17.9	21.9	27.8	18.8	0.3
2016[d]	0.1	0.2	0.5	0.9	1.8	0.8	0.5
Weighted average	3.8	7.0	8.9	19.6	23.1	-	-

Sources: Own elaboration based on: (a) World Wildlife Fund (WWF) financed database developed by INAPESCA (b) Aguilar-Ramirez, D. y Rodriguez-Valencia, A. 2012. Eficiencia y Selectividad de Dos Diseños de Redes de Arrastre para Pescar Camarón Azul (Litopenaeus stylirostris) en la Pesquería Artesanal del Alto Golfo de California. 13 p. INAPESCA, México and the database created jointly with WWF, NOAA and INAPESCA in 2012. (c) database generated by INAPESCA the 2013 shrimp season. (d) database generated by INAPESCA for the 2016 shrimp season (unpublished).

When analyzing the data in more detail it is noticeable that fisher aptitude and the type of net together have a strong influence in catch results. 2010 is particularly noticeable given that the first three quantiles used only modified nets which produced very low catches. Catches with RS-INP-MX from fishers in the last quantile produced an average of 26 kg per trip, which is five times higher than the overall average of the entire year. These results make the tests with RS-INP-MX in 2010 comparable to those from other years and are well within a catch range that is commercially viable.

In 2012 average catches were
37.8 kg
of blue shrimp per trip

Considering that small trawls are recognized for their effectiveness in targeting brown shrimp in San Felipe since 2009, that the RS-INP-MX catches appear to be double that of other modified nets and that fishermen competence is an important factor in the catch efficiency of the net, analyzing the interaction between these variables, in addition to seasonality, becomes an important study of catch subsistence. Table 7 shows results from blue shrimp catch, fished with RS-INP-MX in San Felipe and distributed by quantiles of fisher proficiency. The results show that the fishers that are best prepared to fish under these circumstances (last quantile) attain catches of 68.5 kg per trip during summer months. On the other hand, for the autumn months, blue shrimp catches are about 20.6 kg per trip, which is not exceptional but could be compensated with brown shrimp catches that average around 41.5 kg per trip.

©PNO, 2010. Shrimp catches after a day of testing gear.

Table 7. RS-INP-MX catch efficiency per proficiency quantiles for blue shrimp in San Felipe (kg per trip).

Year	Season	1Q	2Q	3Q	4Q	5Q	Average	Gini
2012 [a]	Summer	21.3	34.3	36.7	41.5	68.5	37.8	0.1
2013 [b]	Autumn	6.7	11.2	13.0	14.6	20.6	16.5	0.3

Sources: Own elaboration based on: (a) Aguilar-Ramirez, D. y Rodriguez-Valencia, A. 2012. Eficiencia y Selectividad de Dos Diseños de Redes de Arrastre para Pescar Camarón Azul (Litopenaeus stylirostris) en la Pesquería Artesanal del Alto Golfo de California. 13 p. INAPESCA, México and the database generated jointly with WWF, NOAA and INAPESCA in 2012. (b) database generated by INAPESCA for the 2013 shrimp season.

Note: Quantile data corresponds to 189 registered trips, which includes all of the casts including those that presented technical failures. The average of 16.5 corresponds to that reported by INAPESCA for 149 trips that discarded casts with technical problems.

Gillnet substitutes for finfish fisheries

Finfish gear has not received the same effort nor attention as shrimp alternative gear. Regardless, there have been conclusive reports that suggest strong viability for traps, small trawls and longlines.

Proof of Concept for several types of gear - research vessel based

The UNICAP XVI trials show proof of species vulnerability to rigid traps, small trawls and longlines. Out of the eight gear tested, these had the highest catch efficiencies with best catches per set, unit and hour, as well as lowest bycatch ratios ranging roughly between 1:0 and 1:1. Conic traps, crab traps and stow nets were less effective, but do stand out for their low bycatch levels. It is important to mention that the UNICAP XVI trials, despite proving species vulnerability to gear alternatives, do not show the commercial efficiency of fisher operations at the panga level given that the size of the UNICAP XVI vessel and the length and control over the gear is not comparable. However, more concise information for longlines and traps can be inferred from the subsequent reports.

Table 8. Results from the 2012 UNICAP XVI trials.

Gear	Total catch (kg)	Catch (kg)			Bycatch ratio
		per cast	per gear unit	per gear unit	
Rigid traps	220.55	31.51	5.13	2.79	0.08
Longline	19.00	19.00	0.05	3.17	1.36
Conic traps	6.00	3.00	0.30	0.35	0.50
Crab traps	4.3	2.15	0.14	0.17	1.12
Fish trawl	484.35	19.37	19.37	7.94	0.99
Stow net	3.83	0.18	0.18	0.08	1.55

Source: Own elaboration based on: INAPESCA/WWF. (2012). Supporting the assessment of alternative fishing gears for replacing gillnets that cause bycatch of vaquita (Phocoena sinus) at the Upper Gulf of California. Final report for the International Whaling Commission.

©INAPESCA. Testing fish rigid traps on board of UNICAP XVI.

Longline testing in local pangas

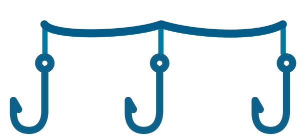
For the longline fisheries, PNO reports that March represents a good core month for fishing, with 57% of the fishing effort and 62% of the total catch results from their trials occurring during this month. Table 9 summarizes these trials.

Table 9. Results from the 2013 PNO hook and longline trials.

Panga name	Total catch (kg)	Fishing journeys	Catch per journey (kg)	Dominant Species[a] (%)
Rib. de San Felipe XXII	2,638	16	165	96%
Rib. de San Felipe VII	2,431	16	152	92%
Marelba IV	1,761	20	88	60%
Marelba XVII	1,706	19	90	53%
Marelba X	1,537	20	77	87%
Rumorosa	985	14	70	70%
Marelba IX	925	16	58	88%
Vikingo	788	14	67	73%
Average	1,596	17	87	-

a. Gold-spotted sand bass and rooster hind were the dominant species for all pangas.
Source: Rodríguez-Ramírez and Salazar-Dreja (2013).

The most important species are gold-spotted sand bass (*Epinephelus acanthistius*) and rooster hind (*Paralabrax auroguttatus*), which constitute the majority of the longline fishery catch. The sand bass and rooster hind represent 80% of the catch, with elasmobranchs (sharks and rays) and curvinas representing another 10% of the fishery. It is important to note that elasmobranch catches, despite having significant commercial value, may constitute several protected species and calls for the establishment of fishery regulations. Likewise, PNO suggests defining a fishery regulation for the catch of serranidae like rooster hind and sand bass, in order to avoid a dramatic reduction in the species population.



Longline

Rigid traps, longlines and fish trawl were the most **promising gear** for finfish

Catch per panga is variable, with total catches ranging from 788 kg to 2,638 kg. This indicates that fisher skills are a significant factor in catchability. Nonetheless, the fishery is reported to be profitable in all tested cases, where on average pangas catch 95 kg per day and report an average profit per journey of about $60 USD[1]. The main costs of the journeys, averaged at $154 USD, come from salaries and gasoline which constitute 93% of the total costs.

Although catch does decrease as the season progresses, rooster hind and sand-basses have been reported available throughout the entire season. Overall, PNO suggests that the fishery is profitable, but strategies do exist to minimize the costs. Additionally, the gear should be tested during other seasons for a better scope of data and to devise important management strategies for fisheries subsistence.

Fish trap testing in local pangas

The trials from 2015 give particular insight into the efficiency and profitability of traps. From Table 10 we can clearly observe that traps used in May and June exceed the catches from traps used in July, and that the effort of pangas can greatly influence the overall catches. The information presented in the report suggests that traps have good catch rates, however the profitability analysis shows poor results. The experienced pangas with best catches get very small profits of $32 USD[2] per journey, whereas all of the "Islas del Golfo" pangas produce negative profits. The major costs for the trials come from gas consumption and bait, where Monterey sardine was the type used. An important point to mention is that gasoline was subsidized for 2015 trials, which is not a good indicator of fuel consumption. Fishers covering their own fuel costs would assess more meticulously whether certain trips are worth making for the catches that are likely to be landed.

Sand bass and rooster hind represent **80%** of the catches with longlines

Table 10. Results from the 2015 trap trials.

Name of the panga	Catches (kg)				Fishing journeys	Number of traps	Average catch (kg)	
	May	June	July	Total			journey	effort[a]
Aguacate	480	510	0	990	9	9	110	12.22
Pamita I	515	449	143	1,108	13	9	85	9.47
Islas del Golfo II	228	74	312	614	16	7	38	5.48
Islas del Golfo VII	136	132	0	268	10	7	27	3.83
Islas del Golfo X	63	78	0	141	9	8	16	1.96
Islas del Golfo XIV	66	142	0	208	8	8	26	3.24
Total/Average	17	1,385	445	3,328	65	48	51	6.03

a. Average catch per unit of effort is estimated as the total catch divided by the number of traps times the number of journeys. Avg catch = total catch / (journeys x traps).

For all of the 2015 trap trials, there is no record of what types of traps where used and therefore no analysis to compare between efficient and non-efficient traps. However, the only traps reported in the trials are collapsible and or rigid. Inferring from the results of UNICAP XVI and from commentaries from local fishers it seems likely that rigid traps are the ones producing better results. Some of the conclusions reported are 1) trap fishing should begin in March and end in June, 2) other inexpensive bait options should be considered, 3) developing fisher capability and training (increasing experience and skills) is necessary for positive trap results and 4) post-capture management and marketing are potential bonuses for the trap fisheries given that live fish sell for higher prices.

Longline fisheries present an average profit of about **$60 USD** per trip

[1]USD to MXN at $1 USD = $12.5 MXN average for 2013
[2]USD to MXN at $1USD = $15.5 MXP average for 2015

The information presented in the report suggests that traps have **good catch rates**

Efficiency of fish traps vs fish trawls and stow nets in local pangas

Also in 2015, INAPESCA tested fish traps, stow nets and fish trawls. Table 11 shows the results of the experiment at which fish traps resulted, by far, in the highest catches by fishing journey. Additionally, catches in San Felipe were five times higher than in El Golfo de Santa Clara. INAPESCA claims that during October to December resources become scarce in El Golfo de Santa Clara due to species migration to deeper waters.

Another claim from INAPESCA, following conclusions made from PNO and WWF, is that catch success depends on fisher skill and experience and not only the alternative gear. Therefore, training is necessary for a scaled-up deployment of alternative gear. Other factors mentioned are that fishing effort is limited by the season, where in November winds become a particular issue, and that for trawls, pangas need auxiliary machinery for raising the nets onboard. INAPESCA recommends that the institute conducts preliminary investigations on resource abundance and topography to guide future fishing operations (contrary to gillnet fisheries where skillfulness is generally not an impediment for catch success).

Table 11. Results from the 2015 alternative gear trials.

Type of gear	San Felipe			Santa Clara		
	Num. of journeys	Catch (kg) Per journey	Catch (kg) Total	Num. of journeys	Catch (kg) Per journey	Catch (kg) Total
Fish trawl	21	6.9	145	33	5.7	188
Stow net	13	0.4	5	18	0.4	8
Traps	64	34.3	2,197	23	7.3	169

Source: INAPESCA. (2016). Informe técnico del Proyecto (periodo septiembre-diciembre 2015): Desarrollo de sistemas pesqueros sustentables para el Alto Golfo. Informe Interno. STPN. 30pp y anexos.

Expanding non-driftnet fisheries

Training is **necessary** for a scaled-up deployment of alternative gear

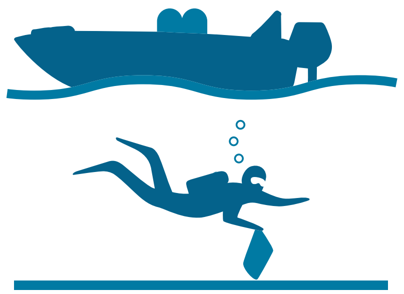
Despite the efforts for substituting gillnets, poor attention has been given to promising fisheries which already employ alternative gear. There is still a 7% of fishing licenses given to SSF targeting shellfish (Pérez-Valencia et al. 2011). Table 12 summarizes the main non-gillnet fisheries.
The species that sustains the crab fishery is Callinectes bellicosus, which is caught in Chesapeake-style traps used in shallow and sandy bottoms. On average, pangas will use around 100 traps, with the capacity to carry 30 traps per journey. The bait employed is varied and ranges from chicken scraps to sardines. Mollusks are fished manually using a hookah dive system by which divers are connected to an air compressor that originates at the surface of the water. For octopus (Octopus bimaculatus), hooks are used to fish out of caves and rocky areas, whereas clams and conch snails (mainly *Hexaplex nigritus* and *Argopecten ventricosus*) are manually pulled from the sandy bottoms and collected in bags.

These fisheries present great potential for expansion and can be managed to cover a year-long fishery.

Table 12. Non-gillnet fisheries in the UGC.

Shellfish	Gear	Season
Crab	Rigid traps	February-November
Conch	Hookah diving	January-August
Octopus	Hooka diving with hooks	November-April
Clams	Hooka diving	Not specified

Source: Pérez-Valencia et al. (2011).



Non-gillnet fisheries present a great potential for **expansion**

Alternatives to drift gillnets also include the encircling gillnet-type net used for curvina fisheries. As previously mentioned, there are characteristics of the curvina fishery (fishing zone, length of the net, fishing operation and fishing dynamics) that make the curvina fishery very selective and considered by some to be non-harming to vaquita or other species. Despite having strong regulations, there are signs that indicate that the fishery is recently becoming a cover-up for illegal fishing (CIRVA 9). Thus, having a gear or fishery that does not harm vaquita directly is not sufficient for securing zero vaquita bycatch, for which it is also necessary to develop management protocols assuring that legal fisheries do not overlap with illegal activities. For this, EDF (2016) is promoting a series of standards that include traceability systems to avoid illegalities in curvina fisheries. Lessons from curvina should be followed when developing new fisheries with alternative gear for shrimp, finfish and mollusks.

©WWF/Gustavo Ybarra, 2015. Collaborative trials for rigid fish traps in San Felipe.

Alternative fishing gears already exist for initiating the substitution of gillnets
in the UGC fisheries

Conclusions and recommendations

The compilation of alternative fishing technology studies give evidence that gillnet substitutes do exist and can be employed immediately and progressively in the UGC. Combining the different fisheries can help produce year-long operations that sustain the livelihoods of the UGC communities without threatening vaquita or other endangered species.

In San Felipe, small trawls are effective at catching shrimp, and the RS-INP-MX prototype is particularly good. At least 20% of the fishers participating in trials demonstrate skillfulness for operating the trawls. When combined, factors like seasonality, port, shrimp species and fisher skill can render the small trawl fishery a highly productive and viable non-gillnet fishery.

For the small trawls to work effectively and immediately it is important to ensure that the gillnet ban remains permanently in place and is enforced aggressively. Fishing licenses should be released to at least the 20% of fishers that demonstrate innate skills for working with alternative gear and progressively to more fishers that prove willingness to learn how to use them. Experimental trials should continue, in order to improve the performance of small trawls and their operation on pangas. Additionally, it would be beneficial to analyze the possibility of granting access to the fishery earlier in the season, with better monitoring during the day and night to allow both brown and blue shrimp catches. Finally, other gear like suriperas should continue to be tested to generate gillnet substitutes better suited to El Golfo de Santa Clara.

Alternative gear for finfish also exist, where rigid traps and longlines are readily available to substitute gillnets. Longline fisheries appear to be highly productive and selective. However, it is important to improve monitoring schemes or implement management plans to avoid dramatic reductions in species populations. While traps are more variable in catch rates, averages are high enough to suggest strong viability for gillnet substitution. Further tests are required to distinguish between the types of traps best suited for panga operations, as well as the bait options that fishers could have. Nonetheless both traps and longlines are well suited for commencing use in the UGC. For small finfish trawls, further research should be conducted to better understand their performance according to seasonality and selectivity, but should not be discarded as potential gillnet substitutes.

Trolling is also a viable method for fishing for sierra and this fishery could and should be expanded in scope as a matter of urgency. The potential use of purse seine and Danish/Swedish seines should also be explored.

Other non-gillnet fisheries are available but still employed at a minor scale. These are worth expanding and investing in further. However, the development of any new alternative gear fishery will likely require regulations, such as those imposed for curvina, in order to minimize potential overlap with illegal fishing. Additionally, training for fishers is indispensable for getting acquainted with gear, becoming more skilled as fishers and making the best out of multiple gear.

These studies demonstrate that alternative fishing gears and strategies already exist and are viable for substituting gillnets in UGC fisheries. However, important profitability analyses must continue to be made, in addition to research on technical improvements, to secure a logical and effective transition to a gillnet-free UGC.

Main findings

- INAPESCA and WWF have been developing alternative fishing technology since 2004. Efforts increased greatly between 2009 and 2016, testing different fishing technologies and systems to substitute gillnets. This has resulted in gear that is now ready for use in the UGC, although not at a region-wide scale yet.
- New gear options for starting a transition to gillnet-free fisheries in the UGC are available, and there is no technical reason to impede this transition from happening.
- For finfish fisheries there are gears that have proven economic profitability; nonetheless it is important to continue with this research to provide options accessible to a greater number of fishers.
- Willingness to participate in gear trials and individual skills have a determinant influence on the results of the experiments.
- The permanent gillnet ban in June 2017 is the first step to begin the transition into a gillnet-free UGC, for which fishers are now in greater urge to develop new fishing methods that do not use gillnets.
- There are other fisheries in the area, such as octopus, crab and conch snails, that do not use gillnets and have great potential for expansion. This should be considered as a viable option for fishers in the UGC.

©PNO, 2012.

References

Aburto-Oropeza, O.; López-Sagástegui, C.; Moreno-Báez, M.; Mascareñas-Osorio, I.; Jiménez-Esquivel, V.; Johnson, A.F.; Erisman, B. (2017). Endangered species, ecosystem integrity and human livelihoods. Conservation Letters. 0 (0) pp. 1-9

Aguilar-Ramírez, D. and Rodríguez-Valencia, A. (2012). Eficiencia y selectividad de dos diseños de redes de arrastre para pescar camarón azul (*Litopenaeus Stylirostris*) en la pesquería artesanal del Alto Golfo de California. 13p. INAPESCA, México. Available at: http://www.inapesca.gob.mx

Alvarez-Borrego, S. and Lara-Lara, J.R. (1991). The physical environment and productivity of the Gulf of California. The Gulf and Peninsular Province of the Californias. pp. 555-567.

Aragón-Noriega, E.A. and Calderón-Aguilera, L.E. (2000). Does damming of the Colorado River affect the nursery area of blue shrimp *Litopenaeus stylirostris* (Decapoda: Penaeidae) in the Upper Gulf of California? NCBI. 48 (4) pp. 867-871.

Bobadilla, M.; Álvarez-Borrego, S.; Ávila-Foucat, S.; Lara-Valencia, F.; Espejel, I. (2011). Evolution of environmental policy instruments implemented for the protection of totoaba and the vaquita porpoise in the Upper Gulf of California. Environmental Science & Policy. 14 (8) pp. 998-1007.

Berggren, P. (1994). Bycatches of Harbour Porpoise (*Phocoena phocoena*) in the Swedish Skagerrak, Kattegat and Baltic Seas; (1973-1993). Rep. Int. Whal. Comm. (Special issue 15).

Carretta, J.V., T. Price, D. Petersen, y R. Read, (2003). Estimates of Marine Mammal, Sea Turtle ans Seabird Mortality in the California Drift Gillnet Fishery for Swordfish and Thresher Sahrk (1996-2002). Marine Fisheries Review 66 (2): 21-25.

CIRVA-9. (2017). Comité Internacional para la Recuperación de la Vaquita – Ninth meeting. Available at: http://www.iucn-csg.org/wp-content/uploads/2010/03/CIRVA-9-Final-Report-May-11-2017.pdf

Cisneros-Mata, M.A. (2010). The importance of fisheries in the Gulf of California and ecosystem-based sustainable co-management for conservation. In: Brusca, R. (Ed.) The Gulf of California, Biodiversity and Conservation. University of Arizona Press, Tucson.

Comisión Nacional de Áreas Naturales Protegidas (Conanp). (2008). Programa de Acción para la Conservación Vaquita (*Phocoena Sinus*): Estrategia Integral para el Manejo Sustentable de los Recursos Marinos y Costeros en el Alto Golfo de California. Semarnat-Conanp, México.

Cudney-Bueno, R. and Turk-Boyer, P. (1998). Pescando entre mareas del Alto Golfo de California. CEDO.

Cox, T. (1998). Documenting the bycatch of harbor porpoises (*Phocoena phocoena*) in coastal gillnet fisheries from stranded carcasses. Fish. Bull. 96:727-734

D'Agrosa, C.; Lennert-Cody, C. and Vidal, O. (2000). Vaquita bycatch in Mexico's artisanal gillnet fisheries: Driving a small population to extinction. Conservation Biology. 14 (4) pp. 1110-1119.

DOF. (2013). Norma Oficial Mexicana (NOM-002-SAG/PESC-2013); Para ordenar el aprovechamiento de las especies de camarón en aguas de jurisdicción federal de los Estados Unidos Mexicanos. Diario Oficial de la Federación. Available from http://www.sagarpa.gob.mx/normateca/Normateca/NOM%20Camaron.pdf

Environmental Defense Fund. (2016). Curvina Fishery Summary. Personal communication.

Erisman, B.E.; Mascareñas-Osorio, I.; López-Sagástegui, C.; Moreno-Báez, M.; Jiménez-Esquivel, V.; Aburto-Oropeza, O. (2014). A comparison of fishing activities between two coastal communities within a biosphere reserve in the Upper Gulf of California. Fisheries Research. 164 (2015) pp. 254 – 265.

Erisman, B.E.; Paredes, G.A.; Plomozo-Lugo, T.; Cota-Nieto, J.J.; Hastings, P.A.; Aburto-Oropeza, O. (2011). Spatial structure of commercial marine fisheries in Northwest Mexico. ICES Marine Science. 68 (3) pp. 564-571.

INAPESCA. (2010). Pesca experimental de camarón con la red de arrastre prototipo RS-INP-MEX en el Alto Golfo de California: Capacitación al sector productivo en la construcción, operación y mantenimiento de la red y colecta de información en campo. Informe ejecutivo de la campaña (2009-2010). Doc. Interno. INAPESCA, (2010) 28p.

INAPESCA. (2014). Reporte final del proyecto: Experimentación de artes de pesca alternativos para la captura de camarón azul Litopenaues stylirostris por el sector de pesca ribereña del Alto Golfo de California. 47p. y 10 anexos. SAGARPA. INAPESCA, México. Available at http://www.inapesca.gob.mx

INAPESCA. (2016). Informe técnico del Proyecto (periodo septiembre-diciembre 2015): Desarrollo de sistemas pesqueros sustentables para el Alto Golfo. Informe Interno. STPN. 30pp y anexos.

INAPESCA. (2011). Evaluación biotecnológica de la red de arrastre prototipo "RS-INP-MEX" para captura de camarón en el Alto Golfo de California. 22p. y 12 Anexos. SAGARPA. INAPESCA, México. Disponible en: http://www.inapesca.gob.mx

INAPESCA/WWF. (2009). Optimización del proceso selectivo de captura de camarón en el Alto Golfo de California mediante la red de arrastre prototipo RS-INP-MEX: Reporte final de la primera campaña experimental (Noviembre-Diciembre 2008). 11p. Available at: http://www.wwf.org.mx

INAPESCA/WWF. (2012). Supporting the assessment of alternative fishing gears for replacing gillnets that cause bycatch of vaquita (*Phocoena sinus*) at the Upper Gulf of California. Final report for the International Whaling Commission.

INAPESCA/WWF. (2010). Tecnologías para reducir la captura incidental en las pesquerías de camarón del Golfo de California. 50p. Available at http://www.wwf.org.mx

Jaramillo-Legorreta, A., L. Rojas-Bracho, R.L. Brownell, A.J. Read, R.R. Reeves, K. Ralls, y B. Taylor, (2007). Saving the vaquita: Inmediate Action, No more data. Conservation Biology 21:1653-1655.

Jefferson, T.A. and Curry, B. (1994). A global review of porpoise mortality in gillnets. Biological Conservation 67(2):167-183

Kim, D.N.; Sohn, H.; An, Y.R.; Park, K.J.; Kim, H.W.; Ahn, S.E.; An, D.H. (2013). Status of the cetacean bycatch near Korean waters. Korean Journal of Fisheries and Aquatic Sciences. 46 (6) 892-900.

Millán-Núñez, R.; Álvarez-Borrego, S.; Trees, C.C. (1997). Modelling the vertical distribution of chlorophyll in the California Current System. Journal of Geophysical Research. 102 (C4) pp. 8587-8595.

North American Marine Protected Areas Network. (2011). Gulf of California Fact Sheet. Comission for Environmental Cooperation.

PACE-Vaquita. (2007-2014). Programa de Acción para la Conservación de las Especies – Vaquita. SEMARNAT. Available from http://www.gob.mx/conanp/acciones-y-programas/programa-de-accion-para-la-conservacion-de-la-especie-vaquita-phocoena-sinus-pace-vaquita

Pérez-Valencia, S.A., M. Gorostieta-Monjaraz, V. Castañeda-Fernández de Lara, R.D. Loaiza-Villanueva, M. Turk-Boyer y C.A. Downton-Hoffmann. 2011. Manifestación de Impacto Ambiental para la Pesca Ribereña Responsable en la Reserva de la Biosfera Alto Golfo de California y Delta del Río Colorado: Costa Oeste. Centro Intercultural de Estudios de Desiertos y Océanos, A.C. Puerto Peñasco, Sonora, México. 221 pp.

Price, B.; Olimon, C.C. and Aguilar, D. (2015). Observations of North Carolina net operations and potential use in the Upper Sea of Cortez. NOAA/SAGARPA/WWF.

Rodríguez-Ramírez, R. and Salazar-Dreja, A. (2013). Análisis de factibilidad técnica-económica de la pesquería de escama con cimbra en el corredor San Felipe-Puertecitos durante la temporada de escama 2012-2013. Pronatura.

Rodríguez-Quiroz, G.; Aragón-Noriega, E.A.; Valenzuela-Quiñónez W.; Esparza-Leal, H.M. (2010). Artisanal fisheries in the conservation zones of the Upper Gulf of California. Biología Marina y Oceanografía. 45 (1) pp. 89-98.

Rodríguez-Quiroz, G.; Aragón-Noriega, E.A.; Cisneros-Mata, M.A.; Ortega-Rubio, A. (2012) Fisheries and Biodiversity in the Upper Gulf of California. Oceanography. pp. 281-296.

Vinther, M. and Larsen, F. (2004). Updated estimates of harbour porpoise (*Phocoena phocoena*) bycatch in Danish North Sea bottom-set gillnet fishery. J. Cetacean Res. Manag. 6(1): 19-24

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