Finding alternative fishing gears in the upper Gulf of California
Bait preference and finfish pot catches

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Innehåll

Introduction

The vaquita has been declared critically endangered due to bycatch from both illegal and legal fisheries. Since May 2015 the majority of the upper Gulf of California (UGC) has been declared a no gillnet zone (A. Jaramillo-Legorreta and others 2017). This has left fishers in the region without any income besides the presumably time-limited compensations from the government. Therefore, it is crucial to develop alternatives to gillnett fisheries in the UGCto ensure a sustainable legal income to the fishers. One alternative to gillnets is pots. Fishing with Pots for finfish is considered a low impact and fuel efficient capture technique (LIFE) (Suuronen and others 2012) and has proved profitable for many species as for example cod (*Gadus Morhua*)(Königson and others 2015). Pots can be considered a possible alternative to gillnets in the grey seal-affected fishery of Atlantic cod in the Baltic Sea (Königson and others 2015).
Pot fishery for finfish can be deployed in very shallow areas and up to 370m deep waters (Hughes and others 1970), on hard substrate bottom where other types of gear are restricted and are allowed to use in some marine reserves (Coleman and others 2013). Pots can be deployed individually or in strings including many pots. The pot size can be as tiny as a few liters and up to several cubic meters (D. Furevik, 2010). The catch is alive when caught, enabling high quality and high prices at the market and returned discard has evidently low mortality (D. Furevik, 2010). Pots is considered an environmentally friendly form of fishing, however downsides are low catch rates compared to many other gear types (Suuronen and others 2012) along with continued ghost-fishing if a pot is lost at sea (Bullimore and others 2001). Ghost-fishing, however, can easily be remedied by incorporating biodegradable material, usually where the fisher empties the pot or in the selection panel if present.
Several studies have described how the catch of pot fishery can be affected by the design of pots (D. M. Furevik & Løkkeborg, 1994, Hedgärde and others 2016, Jørgensen and others 2017, Königson and others 2015). Further, pot catches can be affected by abiotic factors such as current, wind, light levels, depth, soak time, stimuli, season, temperature, while biotic factors including prey density and target species abundance are also important. According to Stoner (2004) the abiotic factors should be given more weight, as they can affect the behaviour of the target species more, than the sheer number of target species available (A. Stoner, 2004).
The catch process of a pot can be divided into three steps: attracting the fish to the pot, luring the fish inside the pot, and retaining the fish until the pot is hauled (He, 2010).
For the first step, attracting the fish to the pot, for the majority of pot fisheries, the bait constitutes an important role as one of the main attractants together with visual presence of the pot (D. M. Furevik & Løkkeborg, 1994). The properties of an effective bait are usually that they maintain their consistency and scent and attract fish during a long time period. Scavenging fish follow the odour of the bait by chemoreception and olfactory senses (Lokkeborg, 1995) and the attraction over time is correlated with the duration of the odour which is believed to be influenced by the content of lipids and shedding of amino acids (Busdosh and others 1982). A study to assess the attractants of bait in seawater over time,

using amino acids as a proxy for attractant, concluded that the first 1.5 hour amino acid shedding decreased rapidly, thereafter a slower decrease was observed, proposing that baited gear, such as pots, should be most effective shortly after it is deployed (Løkkeborg, 1990). To strengthen that result, Furevik (1994) reported, in a study, that most fish were most attracted to the baited pot within the first two hours after setting. However, Königson and others 2015 showed that pot catches increased up to 6 days.
When a pot with bait is deployed the bait attractants disperse down current in what is labeled a odour plume (Løkkeborg and others 2014). Fish approach the bait in zig-zagging motions usually following the plume downcurrent from deployment. When a certain level of attractants has triggered the olfactory senses an individual response level is reached and the fish pursues the bait (D. M. Furevik & Løkkeborg, 1994, Løkkeborg and others 2014).
As mentioned the visual appearance of an object can also attract fish. Antillean pots, used in the Carribean, will attract fish to the pot for other reasons than fouraging such as the pot representing a shelter, social interaction or curiosity. Conspecific attraction has also been documented (Renchen and others 2012) and in the Carribean the more complex the visual outline of the pot/trap, the larger the attraction and subsequently the ingress rate (Munro, 1974).

As the fish approaches the pot, the fish needs to be lured inside the pot. Even though many fish approach the pot, catch rates remain comparably low. Valdemarsen & Johannessen, (1977) showed that only 1.5% of gadoids enter the pot, when attracted to the area by pots, suggesting that, only a fraction of the fish in contact with the pots are caught. Another study from the Japanese pot fishery for pufferfish (*Lagocephalus wheeleri)*, suggested that 2% of the fish in contact with the gear, made it inside the pot (Hirayama and others 2011). The critical moment in the catch process is when the fish moves into the entrance area (D. M. Furevik & Løkkeborg, 1994). An entrance should both be easy to enter but difficult to escape. Unfortunately, many species have different affinity towards different openings which make it difficult to design an entrance that works for multiple species. As an example: Atlantic cod and Wolffish *(Anarchicas lupus)* have no issue moving through a net panel of polyethylene, whereas Ling *(Molva molva)* and Haddock *(Melanogrammus aeglefinus)* are more cautious when searching and refrains from entering if resistance is met (D. Furevik, 2010).
Stoner (2004) reported that any environmental factor that has an effect on fish activity could have an effect on any part of the catch process. With most fish being ectotherm, water temperature has an impact on the total catch (Gjøsæter, 2002). Changes in water temperature have therefore an effect on activity and by that on feeding behaviour (A. W. Stoner and others 2006). All fisheries have seasonal peaks in catches. These are often correlated with water temperature, but it seems that the effect of season in pot fishing is exacerbated by low fish activity as fish needs to actively move to the pots or nothing will be caught. Another circumstance that relates to ingress behaviour is pot saturation. When a certain number of fish is in the pot, relative to the pot size, the ingress rate tends to go down (High & Beardsley, 1970).

The UGC is one of the most biologically productive marine regions in the world. The strong tidal mixing, thermohaline circulation, and coastal upwelling ensure an exceptionally high

primary production and by that: an ecosystem that is among the most diverse and reproductive on earth (Zeitzschel, 1969, Mercado-Santana and others, 2017, Brusca and others 2017). The biggest freshwater outlet into the Gulf used to be the Colorado River. This is, however fully drained now. The large diversity and high reproductivity enables a viable and economical fishery. There is a large fishery with small artisanal boats with outboard engines, so called *pangas,* fishing with gillnets, a fleet of bottom and pelagic trawlers that are fishing for shrimp and lastly an illegal fleet of pangas fishing for the totoaba croaker to export their unusually large swim bladders to the Chinese illegal market (Pennisi, 2017).
The legal artisanal boats are primarily catching Sierra Mackerel *(Scomberomorus sierra)* and Corvina *(Cynoscion othonopterus*) using gillnets. Gillnets are also used to catch blue shrimp (*Litopenaeus stylirostris)*, Chano (*Genyonemus lineatus)* and different species of sharks and rays. A small number of fishermen target rooster hind *(Epinephelus acanthistius)* with longlines or collect bivalves from the seabed using divers (D'Agrosa and others 2000).
Bottom – and pelagic trawlers are primarily targeting shrimp and the fishing fleet only in the UGC consisted of 1456 vessels in 2005 (FAO & Aguilar & Grande-Vidal, 2008). The illegal fishery for totoaba using totoaba gill nets - *totoaberos* (20-30.5 cm in mesh size, (Vidal, 1995) is threatening the totoaba population as well as the vaquita population as the vaquita is getting caught as bycatch in the totaberos in the areas where the totoba fishery is carried out (A. Jaramillo-Legorreta and others 2017).

Based on the advice from the Expert Committee of Fishing Technologies (ECOFT) on recommended actions towards developing alternative fishing methods to gillnets for catching finfish WWF Mexico funded a project developing fish pots and testing different bait to attract fish. The projects had two main objectives. First, to compare how different locale commonly used bait and light stimuli could attract fish- both in terms of number of fish but also with respect to fish arrival time and time the bait could attract and retain fish in the close proximity of a pot. Second, the aim of was to study the catch efficiency of different fish pots for commercial fish species. This was done by using statistical modelling determining which predictors such as different pot types, fishing areas and soaktime that significally affect the pots´catch efficiency.
The results from the study will be an important progress with regards to developing the optimal pot and use of bait for finfish pot fisheries in the UGC. The results will be set in an economical viable perspective, discussing the potential future of pot fisheries in the area.

Methods

Bait trials

Experiment setup

The study was carried out in the protected bay of Bahia de San Luis de Gonzaga from the 12th of April to the 20th of April. To measure the presence and abundance of fish attracted to different stimuli, different bait and visual stimuli stations were set up with cameras filming the fish attracted. The bait stations were set both on sandy and rocky bottoms and the depth ranged between 5 to 15 meters (fig. 1).

The bait stations were constructed, using concrete blocks as base and weight (fig. 2). A water-sealed custom-made camera house made out of stainless steel and plexiglass were placed so that the camera placed inside the camera-house would point around 20 degrees upwards towards a bait bag. A steel rod was attached to the camera house. The purpose of the steel rod was to have a point on which to secure the bait bags position, approximately one meter in front of the camera, and to ensure that the bait bag was in the middle top of the frame when recording video, to ensure full visibility of the fish approaching. The cameras were GoPro cameras set on the lowest resolution (720), with at least a 64GB sd-card. In the camera house we put two additional power banks in order to keep recording for at least 24 hours. Approximately 400g of bait was inserted in the bait bag in an ordinary tennis sock to keep fish from eating the bait as the fish couldn't access the bait inside the sock. To be able to register fish approaching the bait bag, underwater lights was attached to the bait stations during night time. The underwater lights were fisheye fix Neo DX 800/1200 allowing around 12 hours of light, enough for a full night.

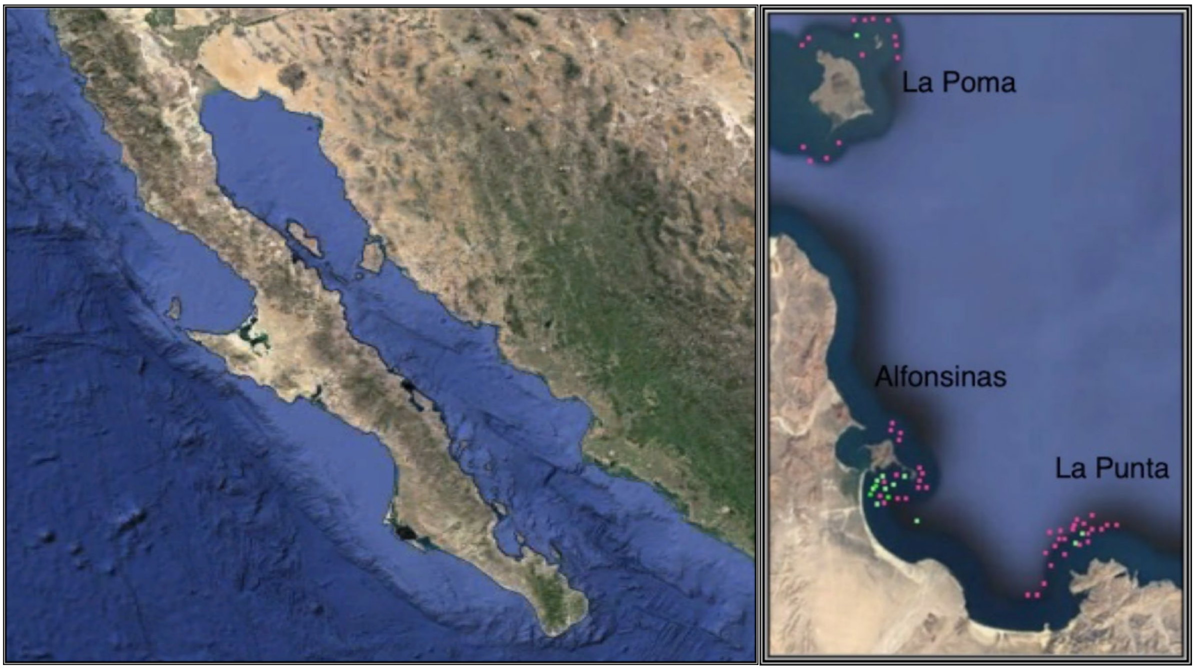


Figure 1. Green dots indicate approximate placement of video bait traps and magenta dots indicate the approximate placements of pots from the pot trial. A purple dot can be both a single pot or a pot string of five pots. The areas of interest is divided in Alfonsinas, La Punta and La Poma

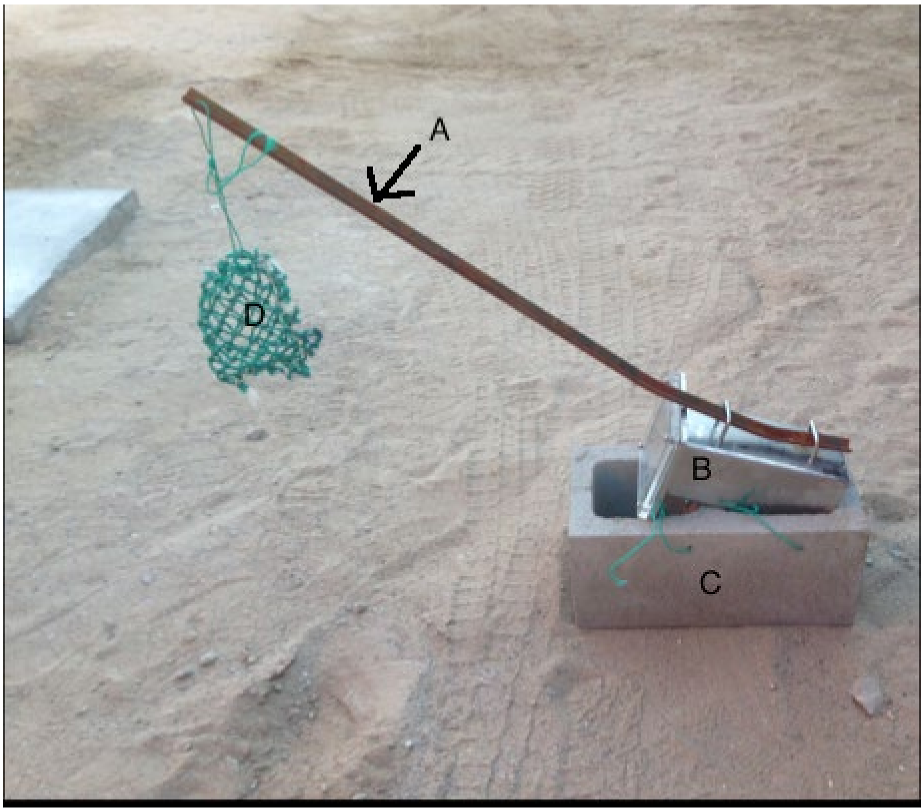


Figure 2. The bait stations constructed for the purpose of attracting fish to the bait bag while filming them. Note that the bait was put in a tennis sock to last the longest and keep fish from eating the bait. Steel rod (A) Steel and plexiglas cage (B) brick (C) Bait bag(D)

Three types of baits were based on what the fishers had previously used. Sierra mackerel *(Scomberomorus sierra),* an oily fish with an oil content usually between 2-4 % (Murillo and others 2014), Flat-iron herring *(Harengula thrissina)*, found throughout the Sea of Cortez with a peak oil content in average at around 21%. (Iverson and others 2002) and Monterrey sardine *(Sardinops sagax caeruleais),* the preferred bait of the fishers and the most expensive and with an oil content of 8,4 to 11.1% (Ramirez-suarez & Mazorramanzano, 2000).

Data collection - Video analysis

The recorded video was analyzed using the program Quicktime player with playback speeds between 1x –30 times the normal speed. Playback speed was dependent on the fish present. Size of fish is not possible to determine from the recordings as no scale was present and no stereo frames could be taken. Various species were observed but the main focus was the commercial species, thus a frame with more commercial species (cabrilla, croaker, corvina, flounder, triggerfish) was selected over a frame with equally or more non-commercial species (pufferfish, cinto, ray, angelfish, catfish) (see fish list in Appendix I) (fig. 3).
To estimate the effectiveness of Sierra mackerel, Flat-iron Herring and Monterey Sardine as bait, we measured the attraction as MaxN. MaxN is the maximum number of fish present and counted in a single frame per every 30 minutes, similar to the work of Cundy and others (2017).

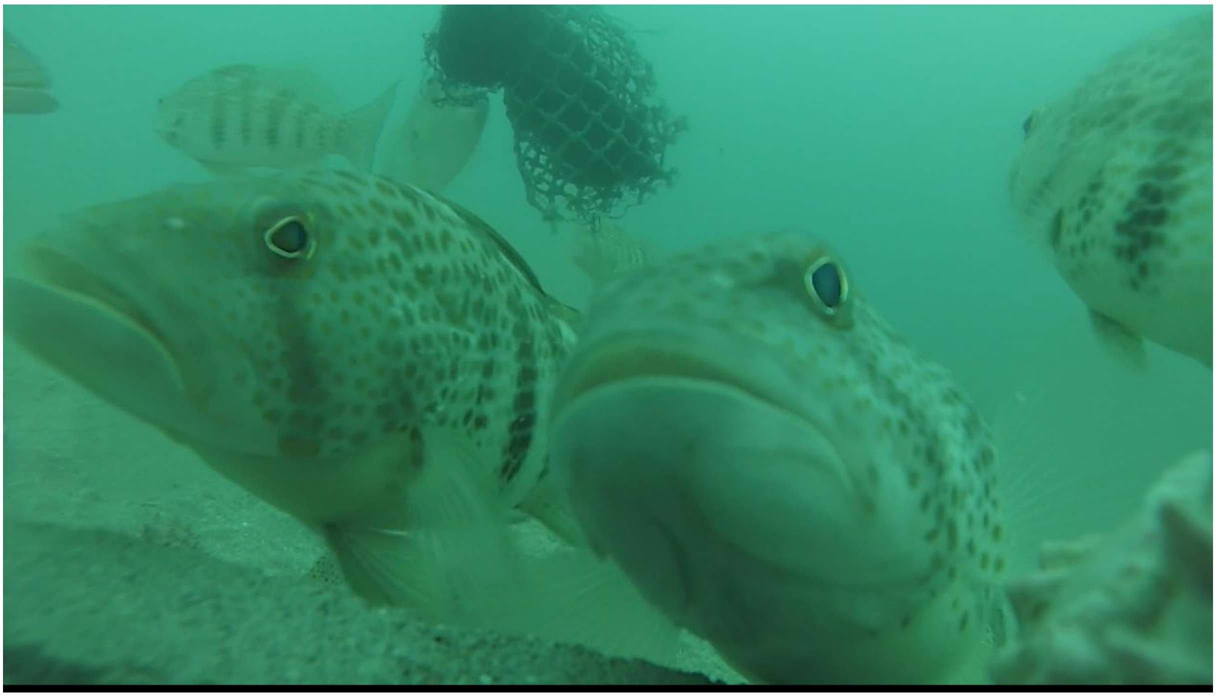


Fig. 3. Frame captured from one of the bait trap samples. Cabrillas (*Paralabrax maculatofasciatus)* inspecting the bait station.

Statistical analysis

A GAMM (Generalised additive mixed model) approach was chosen to analyse which predictors (explanatory variables) could explain the response variables (MaxN) in the bait trials. The statistic modeling software R was used to compute the model. A GAMM is a non-parametric method to analyze data, that utilize smoothers to smooth the curves of the data, approximating a mean function of the data, which is used to determine which predictors affect the response variable (Beck & Jackman, 2016). To build the final model the statistical significance and the deviance is analysed for the predictors. Stepwise removing the least significant predictor one by one until the remaining predictors are statistically significant resulting in the final model.

A GAMM analysis was performed with MaxN as the response variable and bait type (Monterrey Sardine, herring, Sierra or "no bait"), time (time and date of deployed bait station) and soak time (time the bait station was submerged) as predictors. One analysis for daytime and one analysis for night. An AIC (Akaike information criterion) analysis was performed on the suggested models and showed that on both models the Poisson distribution was the best fit.

Pot trials

Pot trials were carried out in collaboration with three local fishermen during two periods. Trial 1 was conducted from the 10th to the 18th of April 2018 in the area around San Luis de Gonzaga. In trial 1, soak time and area of fishing was decided by fishers and researchers. Trial 2 started on the 19th of April and ended the 15th of May. In trial 2 soak time and area of fishing was decided by the fishers based on experiences and catches from trial 1. Fishing grounds for both trials were approximately from lat. 30.002715 long: 114.380032 to lat: 29.781343 long: 114.284123 (fig. 1). The depth was between 10 and 110 meters.

Experiment setup

The fishermen went fishing with 2 strings of pots per panga for each fishing event. In every string, five pots were set randomly. The pots were spaced with 50 meters distance in the string. Each pots were baited with around 400 gr of monterrey sardines and soak times varied between 2 to 26 hours.

In trial 1, three different pot designs were tested (fig. 4, 5 & table 1). (A) A floating pot with one entrance and one chamber , (B) a sinking type pot with two entrances and one chamber and (C) a floating pot with one entrance but with two chambers and without funnel in the entrance. In trial 2, after consultation from active fishermen, all the pots were made bottom standing pots with either one or two monofilament entrances with funnels. See table 1 for description of the different pot types. The pots were made of stainless steel rods welded together to a cube (approx. 0,8 mm thickness) whereas the bottom, top and sides were green polyethylene (2.5mm twine and 30 mm mesh size). A selection panel allowing undersized fish to escape was sowed in each pot with square mesh and with 5 cm distance knot to knot. Approximately 400g of bait was stuffed in a water bottle with multiple small holes in and then inserted in the bait bag. This was done to keep caught fish from eating the bait and thereby maintain attraction.

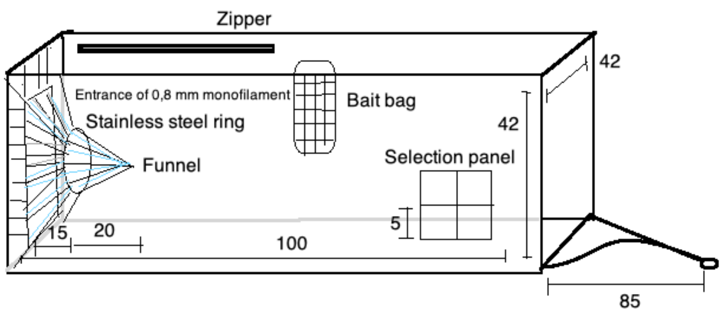


Figure 4. Sketch of the basic pot design we used for the trial. The features depicted (except funnel) are common for the three different types we used. You open the zipper to empty the pot. The bait bag was centered in front of the entrance. All measures are in centimeters(cm).

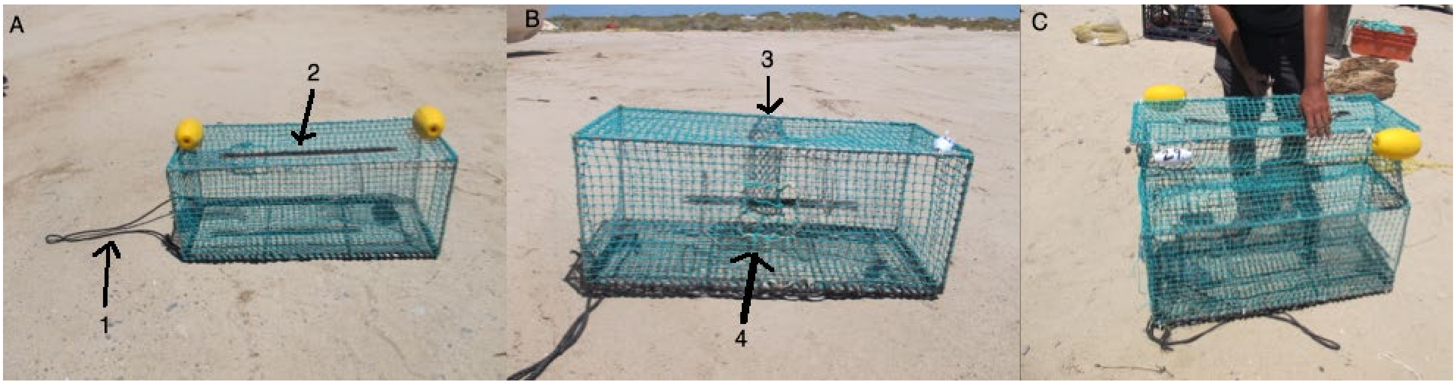


Figure 5. A floating type pot with one entrance and one chamber. B: Sinking type pot with two entrances and one chamber. C: A floating type pot with one entrance but with two chambers, no funnel. NB: On the floating pots, weight is attached to the bridle in order to keep them fixed at one point at the bottom. The current will swing the pot around so that the entrance is oriented away from the current. 1. The bridle that is attaching the pot to the mainline. 2. The zipper for emptying the pot. 3. Baitbag compartment. 4. Selection panel to avoid undersized fish.

Table 1. The different characteristics of type of pots used in trial 1 and 2.

Pot type Id	*Trial*	*Used period*	*Description*	*No of entrances*	*Type of entrance*	*Depth of entrance before funnel*	*No of Chambers*	*Length (cm)*	*Width (cm)*	*Height (cm)*
A	1	10-18th April	Floating	1	Funnel	~30	1	100	42	42
B	1 & 2	10th of April-15th of May (Entire period)	Bottom standing	2	Funnel	~14	2	100	42	42
C	1	10-18th April	Floating	1	Open	~30	2	100	72	42
D	2	19th of April-15th of May	Bottom standing	1	Funnel	~30	1	100	42	42
E	2	19th of April-15th of May	Bottom standing	1	Funnel	~30	2	100	42	72

Data collection

During trial 1 all data was collected by an onboard observer. The observer recorded date, time soak time, position of the fishing event, species, weight and length of the catch.

During trial 2, the data was collected by the fishers. The fishers noted number of each fish species in each pot, pot type, position of the pot, date and time, and depth. An observer joined the fishers on random occasions to check the quality of the reports. Only during trial 1, subsamples were taken to generate length-weight relations for the different species. Catch and weight per unit effort (CPUE) was calculated for every pot at every fishing occasion. CPUE equals catch in numbers of commercial fish per pot hauled and WPUE equals catch in kilo of commercial fish per pot hauled.

Statistical analysis

In both trial 1 and 2, The GAMM analysis was performed on both of the two response variables CPUE and weight per unit effort (WPUE) separately to evaluate which predictors could affect the catch. Predictors included were ”Soaktime”, ”Location”, ”Fisherman”, ”Date & Time”, ”Depth”, ”Entrances”, and ”Bait” (table 2).
As the response variable was count data the distributions selected reflect this. A Poisson distribution was selected for the model of the WPUE and a negative binomial distribution proved a better fit for the model of the CPUE. This was determined from running AIC analysis. This was the case in both trial 1 and trial 2.

Table 2. Predictors used in the GAMM model, explaining the variation in numbers and weight of the catch.

Predictors	*Description*
Soaktime	For how long have the pots been submerged before hauling.
Location	The three main locations where we fished. Alfonsinas, La Punta, and La Poma
Date&Time	Date and time for setting and hauling.
Fisherman	Which fisherman is fishing. Javier, Will or Armando.
Depth	At which depth are the pots deployed
Entrances	Number of entrances of the pot
Bait	What type of bait. Monterrey Sardine, Herring, Innapesca Cookie, or Sierra
String	String Id and Date in one predictor to account for spatial and temporal fish abundance.

Results

Bait trials

A total of 114 hours of video footage constituted the final database for the bait trials (table 3). The species recorded were also reflected in the species composition observed from the pot trials in the area (fig. 9 and 12)

Table 3. Hours of filming with each type of bait in the bait trials, for nighttime and daylight.

	Hours filmed Sierra	*Hours filmed Herring*	*Hours filmed Monterrey Sardine*	*Hours filmed no bait*
Day	18	21	6	-
Night	14	33	11	11

GAMM model analysis found differences between the three bait types in daylight. In the night trials, the statistical difference is inconclusive with regards to which bait attracted most fish. Soak time was not significant. The final model for both the bait trials – day and night:

$$MaxN \sim Baittype + s(Time)$$

The ”Bait type” predictor is a three level factor for the day trials and 4 levels for the night trials due to tests of only light, described in the model as ”no bait”. The statistical model for the bait trial during daytime showed a significant difference between Flat-Iron Herring and the other two types of bait: Sierra Mackerel and Monterrey Sardine (fig. 6). MaxN is significantly higher when Flat-iron herring is used as bait than when sierra Mackerel and Monterrey sardine.

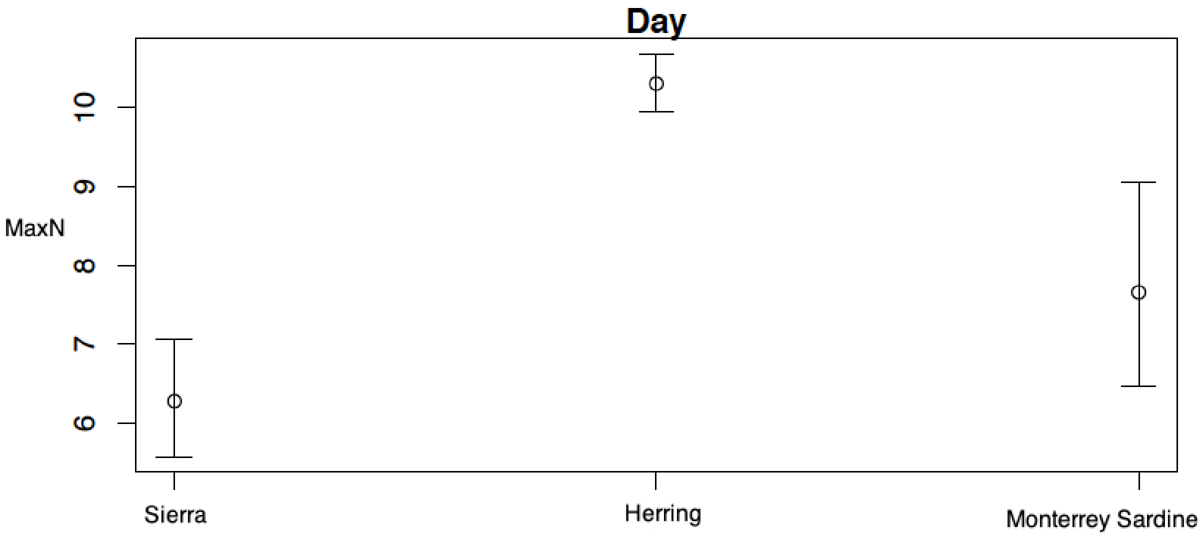


Figure 6. Graphical illustration of the difference in the estimate of MaxN (no. of fish) in daylight with 95% Confidence intervals.

Plotting the MaxN over time, the fish activity is constant over the span of a day (fig. 7). The gap in the late afternoon data corresponds with the time the bait stations were taken out of the water to replace, battery, SD-cards and light. . Even when the bait had been soaked for over 12 hours there was still activity around the bait station and at no time do we see a drop from measured activity to zero activity.

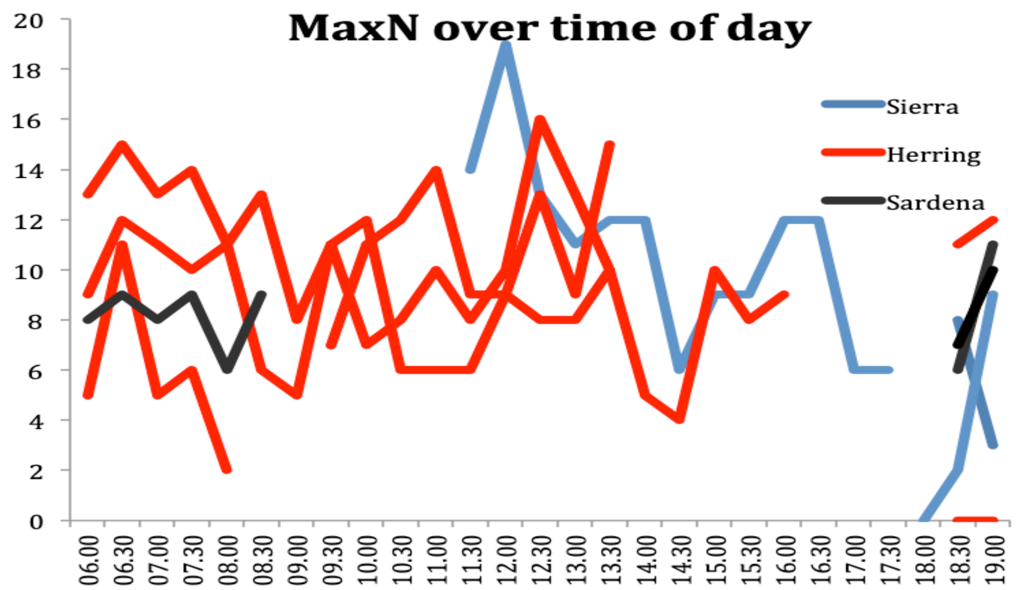


Figure 7. The MaxN (no. Of fish) over time of day fra raw data. No real pattern is visible. The bait stations continue to attract fish a long time after being set.

The model estimates of the average MaxN revealed that when Monterrey Sardine was used as bait MaxN was the highest average of 7.2 (C.I -1.9+4.1), whereas when Herring was used as bait MaxN had an average of 3 (C.I. ± 0.5). The MaxN of “No bait” is just as high as every other bait tested at night based on the results from the model, the average and the confidence intervals. Monterrey Sardine is statistically different from Flat-iron Herring at the 5% significance level (fig. 8)

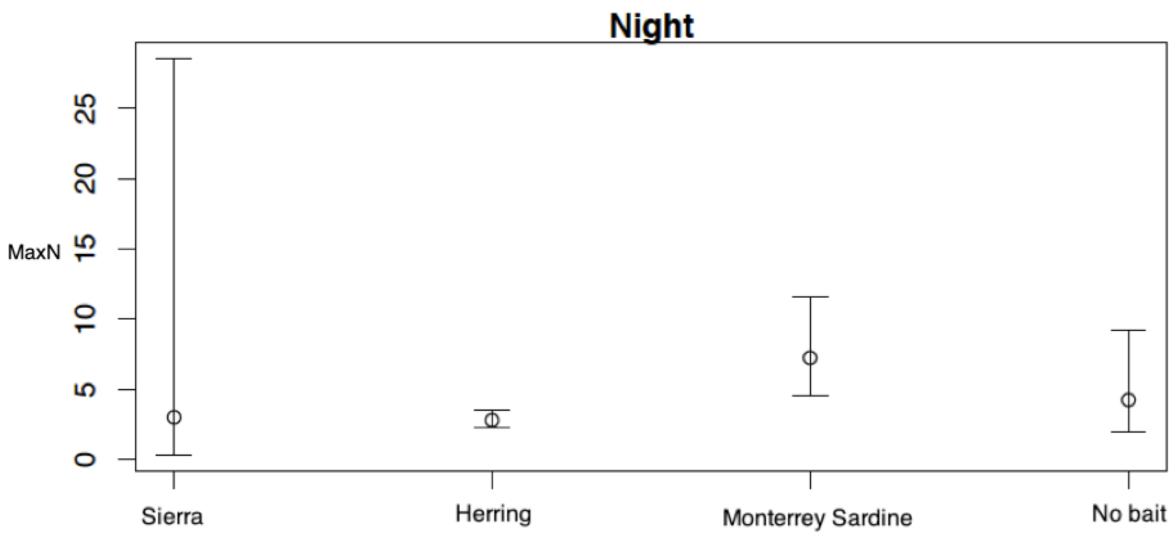


Figure 8. Difference in MaxN for the three bait types during night time trials with 95% Confidence intervals. Monterrey Sardine is statistically different from Flat-iron Herring at the 5% significance level. Other than that confidence intervals are overlapping among the other types of bait, including ”no bait”

A total of 196 hours of filming revealed 13 species attracted by 3 different baits or ”No bait”. For a distribution of the species for night and day (fig. 9). No corvinas were recorded during the daytime despite being the most abundant species at night. Cabrillas (*Paralabrax maculatofasciatus)* were the most abundant species during daytime followed by fine-scale triggerfish (*Balistes polylepis)*.

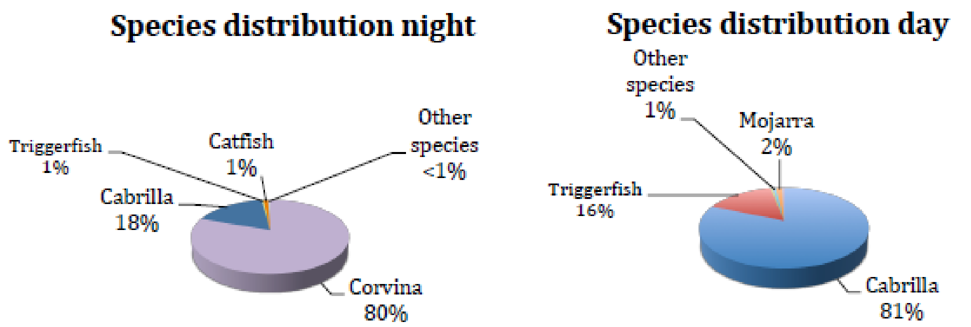


Figure 9. Distribution of species presence during day and night. See fish list App I.

Pot Trials

During trial 1 and trial 2, a total of 673 pots were emptied. The mean number of fish per pot and the mean weight per pot can be seen in table 7. A twofold increase in mean CPUE and WPUE is observed from trial 1 to trial 2 (table 7).

Table 4.

	Sample size/ Number of pots emptied	*Mean number of fish per pot (Mean CPUE)*	*Mean weight of fish per pot in (kg) (Mean WPUE)*
Trial 1	199	2,23	0,63
Trial 2	474	4,69	1,67
Total	673	4	1.4

Trial 1

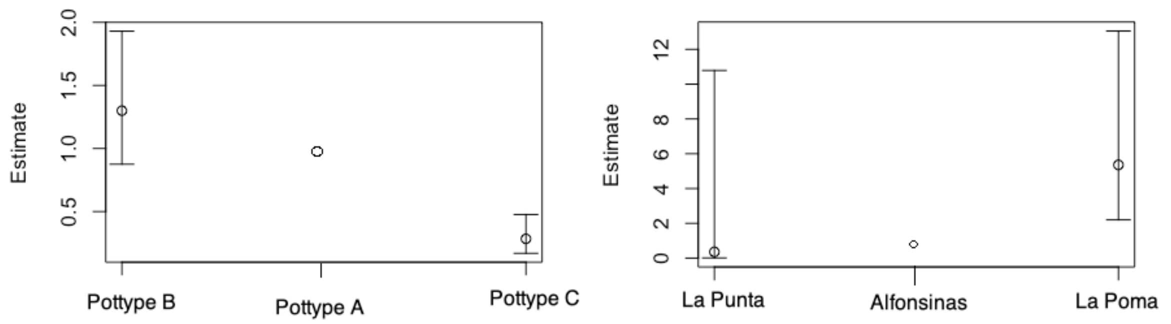
The GAMM model analysis revealed that in trial 1, the predictors: string, location and pottype significantly explained the variation in CPUE and WPUE. Deviance explained for WPUE was 57,5% and 67,5% for CPUE (n=160). String is used to account for spatial and temporal variations in abundance of fish and thereby the catch. It is a combination of the date and string number. The final models for CPUE and WPUE trial 1:

*GAMM(WPUE~ **s**(String, bs=”re”)+offsetlog(Soaktime) + Location + Pottype)*

*GAMM(CPUE~ **s**(String, bs=”re”)+offsetlog(Soaktime) + Location + Pottype)*

The predictor soak time is not significant, however it is important to keep soak time in the model to account for hours of fishing. If not present it would be difficult to assess the actual effect of the pots as the single pot/observation would have no reported fishing time. The assumption is that catch is proportional to soaktime. This assumption was also statistically tested for and direct proportionality couldn't be refused. CPUE and WPUE is a log link and to match "Soaktime" linearly with the response variable it is with a log function in the model. The offset function in R simply offsets the estimation of the predictor even though it is present as data in the model.

There is no statistical difference in CPUE and WPUE between pot type B and A, whereas pot type C had a significant lower catch rate than pot type B and A (fig. 10A).
The location had a significant effect on CPUE and WPUE, similar catches were observed in La Punta and Alfonsinas whereas La Poma showed a significant higher catch rate (fig. 10B).



A. B.
Figure 10. Model estimates of the partial effect of pot types (A) and location (B) on WPUE in trial 1. Error bars show 95% confidence intervals.

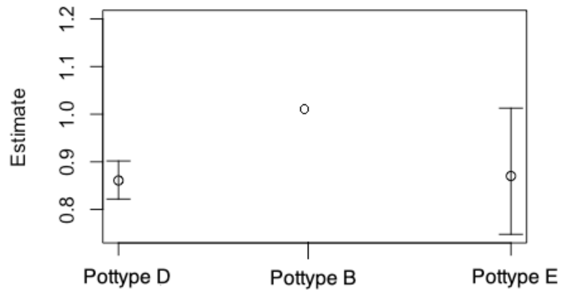
Trial 2

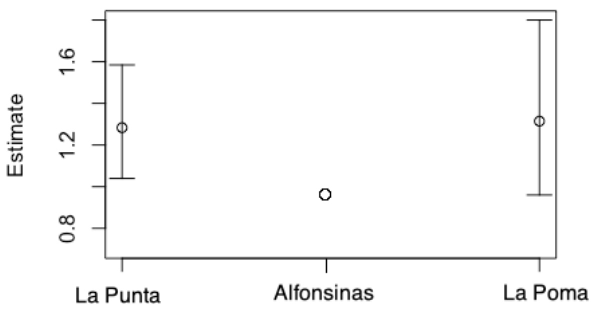
The GAMM model revealed that the only significant predictor that had an impact on CPUE and WPUE was string, accounting for spatial and temporal fluctuations of fish abundance. Deviance explained for WPUE was 74,4% and for CPUE 76,2% (n=474). The final model is shown below:

GAMM(CWUE ~ s(Link3, bs = "re" + offset(log Soaktime))

GAMM(CPUE ~ s(Link3, bs = "re" + offset(log Soaktime))

Even though pot type is not a predictor in the model that significant affect the catch when combined with the other predictors, there is a difference in catch between the three pottypes. Pottype B has a higher catch rate than Pottype B and E (fig. 11 A). Separating the predictor location shows that the highest catch rates are at the location La Punta and la Poma (Fig 10 B.).





A. B.

Figure 11. Model estimates on the partial effect of pot types (A) and location (B) on the WPUE from trial 2. Error bars show 95% Confidence intervals.

Calculations of total catches

As the catch rate in pot fisheries are dependent on many factors such as pot type and location calculating the mean CPUE or WPUE for all pots in all areas can be misleading. The average catch rate (CPUE or WPUE) for all pot types in all areas is much lower than the catch rates of the most effective pots in certain areas with a high abundance of fish. Therefore, to be able to estimate a potential daily catch, the mean WPUE was calculated for the most effective pots (bottom standing pots) in the area with the highest catches. Thereby, using this WPUE to estimate the potential daily catches, the daily catches when only 10 pots are in average 90 kg (Table 5).

Table 5. The mean fishing time per journey, total number of journeys and total catch as well as mean catch per journey and WPUE. The mean WPUE per non-floating pots and the calculated mean daily catch for non-floating pots fished in La Poma are also shown.

Trial	*Mean Fishing time pr. journey (hours)*	*No. of journeys*	*Total catch (kg)*	*Mean catch per journey (kg)*	*Mean WPUE (kg/h)*	*Mean WPUE for non-floating pots (kg/h) at La Poma*	*Mean Daily catch (8 hours of fishing) using 10 pots at La Poma*
Trial 1	5,6	18	126	7	0,15	1,4	110,2
Trial 2	6,7	32	793	24,8	0,73	0,7	56,5
Trial 1 & 2	6,3	50	919	18.4	0,55	1,1	90,1

Species composition

The species composition for trial 1 and trial 2 in the pot trials shows that 59% of the total catch numbers were cabrilla followed by extranjera (32%). With regards to, weight, cabrilla constitutes the majority of the catch (54% of the catch), thereafter extranjera (40% of the catch). Triggerfish, Chano, Pargo, Corvina, Mojarra and Cinto were only caught in smaller numbers. An overview of the species caught in the three areas was derived from the total catch data (Trial 1 & 2). The higher priced extranjera, a nickname given to both the gold-spotted sand bass (*Paralabrax auroguttatus)* and parrot sand bass *(Paralabrax loro)*(Aburto-Oropeza & Erisman, 2008)*,* is almost exclusively found in the open waters of La Punta and La Poma. On the other hand, the lower priced cabrillas are notably fewer in La Punta and La Poma than in the bay of Alfonsinas, where they dominates catches.

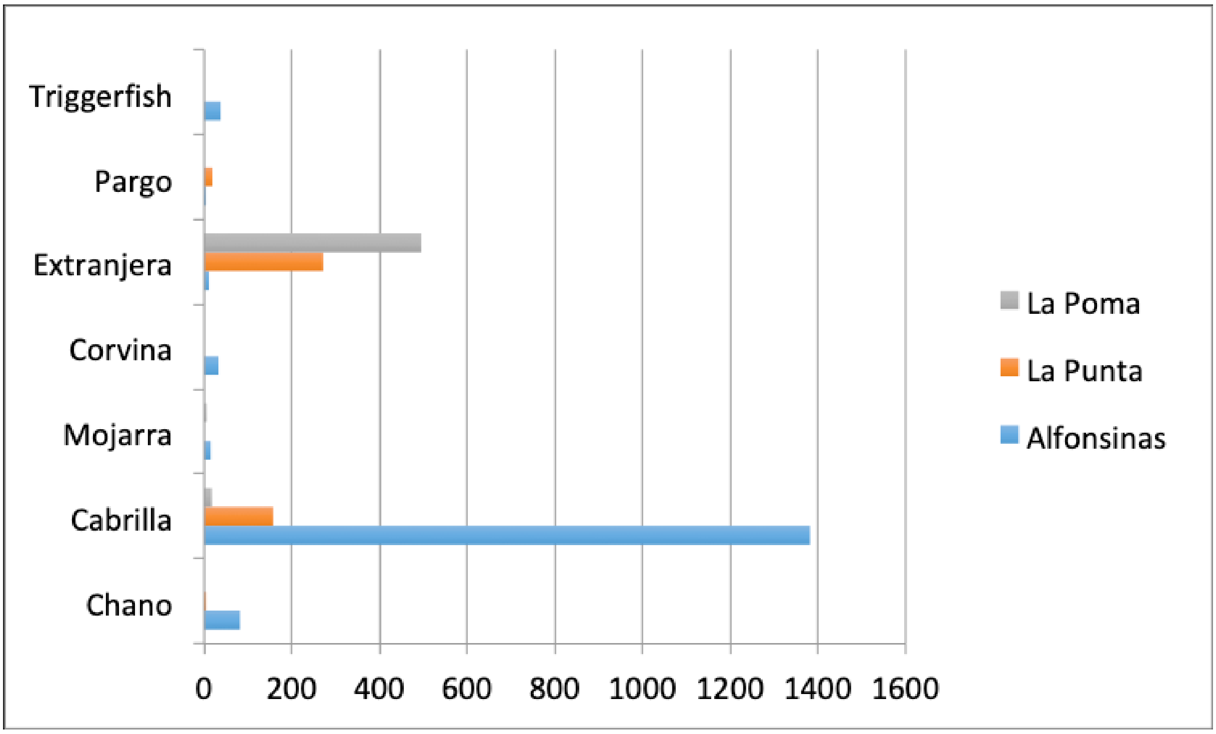


Figure 12. Species composition by area. The higher value species (Extranjera) is almost exclusively found in open waters of La Punta and La Poma.

Discussion

In the daylight trial, flat-iron herring proved to be the choice of bait. This could be due to the fact that the oil content, is seasonally higher in flat-iron herring than Monterrey sardine could have an impact. Monterrey sardines are considered by the fishermen to be the most effective bait, however our findings show that flat-iron herring attract fish more effective than monterrey sardines. Therefore fishers should consider changing to a bait more easily available in their local waters, namely the flat-iron herring, rather than transporting Monterrey sardine from Ensenada at higher prices.

The optimal experimental design would include all three baits tested on the same days to observe a possible difference under the same environmental circumstances. However, this was not a possibility, due to a shortage of bait from the fishers. Furthermore, to strengthen the

result of flat-iron Herring, more replicates in the areas of La Poma and La Punta should have been conducted to test how the bait attract other species.
The night trial results with regards to bait as stimuli proved to be inconclusive. We observe the MaxN for "no bait" has a similar average including confidence intervals than both the baits; Sierra mackerel and Flat-iron herring. On the other hand, it gave important insights in light as a stimuli to attract different fish species. The videos from the bait stations set out at night showed corvinas and cabrillas gathering to feed on the fry and small fish attracted to the light, rather than feeding on the bait in the bait bag. When daylight comes and the fry and small fish disperse, interest is again directed at the bait bag but then mainly by cabrillas. Light has been shown to be an effective attractant in other fisheries (Bryhn and others 2014; Humborstad and others 2018) and the reason to be that it attracts small prey that in turn attract larger fish. The results also indicate that measuring the attraction of different types of bait at night, is heavily biased by the artificial light mounted on the bait stations.

In trial 1 three different pots were tested, different number of entrances and chambers.
The results from the GAMM model showed that the bottom standing pots were more efficient than the floating pots. The pot type C (the one without a funnel in the entrance, but with an extra chamber) caught noticeably and statistically significantly less than pot type A and B. Pot type C had an open entrance in contrast with pot type A and B. (Ljungberg and others 2016). Having an open entrance allow for a higher proportion of entering cod but also to a larger extent allow cod to exit pots. Pots with funnels decrease the escape rate and thereby increasing the pots capability to retain the catch (Ljungberg and others 2016).

In cooperation with the fishers and their observations along with preliminary results from trial 1, the pot design was changed prior to trial 2. All pots in trial 2 had funnels and were bottom standing, resulting in the design of pot type D pot type E. Pot type turned out to not be a significant predictor affecting the pots catch rate most likely due to the fact that in trial 2 the characteristics in the pot affecting the catch rate the most was the same for all pots. All pots were of the same size and had funnels on the entrances. However, the model showed that pot type B, the only pot with two entrances, has the highest model estimates in both trial 1 and 2. The positive model estimates of pot type B, with two entrances, is in line with similar pot trials where the effect of the entrance design on the pots catch rate was evaluated (D. M. Furevik & Løkkeborg, 1994; Hedgärde and others 2016). A single entrance is mostly used in floating pots, where the pot entrance is in line with the direction of the current and thereby also in line with the odour plume of the bait (Jørgensen and others 2017). If the extra entrance doesn't increase the exit rate more than the rate of ingress, it makes sense that a higher catch can be expected with more than one entrance (Meintzer and others 2017). This could hold true in reefy areas such as "La Poma" and "La Punta" where an entrance could be partially blocked by a boulder or if the pot was set in between rocks.

In trial 1 the "Location" predictor proved significant from the model. The area La Poma had significantly higher catch rates than both Alfonsinas and La Punta. The results also showed that there are different fish in the different areas. The fish that are abundant at the fishing

location that was more in the open waters was the high priced extranjera compared to the fishing locations inside the bay where cabrillas were more abundant. Even though the predictor “Location” was not significant in trial 2 a clear difference between the areas with regards to catch rate were found. Also in trial 2 La Poma had the highest catches. However, it is possible that soak time is a factor affecting the catches in the different areas. In La Poma pots were set for a short time (1-2 hours), whereas longer soak times (more than 2 hours) were the norm in the Alfonsinas Bay. In trial 1, the pots were set as often as possible to gather most possible information. This meant going out fishing even though it was not possible to get out of the bay due to windy conditions. For this reason, the pots were often in the water during night and day, which increased soak time but this was not reflected in the catches. In trial 2, the fishers controlled the fishing themselves meaning they did not go fishing in unfavourable conditions or have the pots out for extended periods.
In trial 2, the predictor ”string” was significant. This indicate most of the variance seen in the single pot was connected to the string, where it was attached. The single catch of one pot in a string could be partly explained from the total catch of the string.

Setting the results in an economic viability perspective, there is a possibility that if the fishery is conducted in open water areas, where there is more fish abundant, with the bottom standing pots one would get 90 kg of fish per day in average using 10 pots. Using only ten pots per day will not give a viable daily catch; the fishers must use at least 20 to 30 pots per boat. In 2015, Inapesca carried out a pot study in the waters outside San Felipe ans Santa Clara. Their daily catches were 34.3 and 7.3 kg of fish per day. However, no information on what species and soaktime or number of pots are given (Herrera, Y and others 2017). It is difficult to know what daily catches would account as a viable economic daily compensation. As the fisheries are set up for many fishermen in the UGC is that it is one person who is owning a number of pangas. Then fishermen are hired to fish. Thereby the daily catches don’t only need to cover the fishermens salary and expenses for the boat and gear but also the boat owners part. Comparing the pot fisheries to the g fisheries in the area, such as small-scale purse seines which can be used for catching corvina, pot catches are not comparable. Purse seine fishing for corvine can give around 2 tons of corvine in one day. It is not possible for pot fisheries to get as high catches in one day.
However if the number of pots used by fishermen is increased, by for example using collapsible pots or modifying the pangas so that more pots can be effectively stored on the boat, the daily catches would increase and can potentially be a viable option. If pots were to be left in the water over longer time periods the catches would likewise increase. There is a concern that the gears will be stolen if left in the water, however by using for example zink anods the bouys of the gears can be hidden below the surface. Another factor increasing daily catch is the fact that the fishermens daily working hours were only in average 6-7 hours. Since the weather is extremely variable and many days you are not even able to get out at sea when the weather is good you need to at least have a 10 to 12 hours day of fishing.

Conclusions

The conclusions of the study are the following bullet points.

- When fishing with pots, the locale bait flat-iron herring do attract fish more effective than Monterrey sardines and sierra. Thereby using flat-iron herring as bait in a pot fishery is a viable option.
- Light attracts a large amount of fish at night. The main species attracted by light is corvine. These results implies the possibility to catch corvine at night using light as an attractant.
- Pot catch rates are the highest in bottom standing pots with funnels in the entrance opening. Having pots placed on the bottom, not floating in line with the current, pots should have at least two entrances to get increase catch rates.
- Pot catches are dependent of many factors including soak-time, pot-type and location.
- Pot fishing should be conducted in areas with high abundance of target species (in this case in open waters).
- Increasing soak-time, daily fishing time and the number of pots used will increase daily catches.

Future recommendations

This study gave valuable insights in what affects the pots catch rate, which is important knowledge for future development of the pot fisheries in the Upper Gulf of California. The results showed that pots do actually catch fish, however the few amount of pots used by the fishermen do not give a viable economic alternative to gillnet fisheries. If the fishermen would need to use at least 30 pots to have enough catch and thus see pots as a potential alternative. When the weather allows full days of fishing or more must be carried out, with at least 8-9 working hours at sea. Being able to use flat-iron herring lower costs due to its lower price. Therefore, it is recommended for future studies to have a minimum of 30 pots per panga and increase the pots soak-time significantly. This could be done for example by using collapsible pots or storing the pots more effective on the boat. The soaking time should be increased by for example hiding the pots by using zink-anod submerging bouys for a certain time. Light should also be further investigated as the light attracted a large amount of corvina at night indicating potential in attracting potential catch.

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Appendix I

List of fish that were caught in pots and that have a commercial value.

Local name	English name	Scientific name	Family	Commercial Value
Sierra Mackerel	Sierra	*Scomberomorus sierra*	Scombridae	Yes
Cabrilla arenera	Spotted Sand Bass	*Paralabrax maculatofasciatus*	Serranidae	Yes
Extranjera	gold-spotted sandbass	*Paralabrax auroguttatus*	Serranidae	Yes
Extranjera	parrot sand bass	*Paralabrax loro*	Serranidae	Yes
Baqueta	Gulf Coney	*Hyporthodus acanthistius*	Serranidae	Yes

Corvina	Gulf Corvina	*Cynoscion othonopterus*	Sciaenidae	Yes
Cochito or Bota	Fine-scale triggerfish	*Balistes polylepis*	Balistidae	Yes
Bagres	Cominate Sea Catfish	Occidentarius platypogon	Ariidae	No
Mojarra	Mojarra	*Diapterus ?*		Yes
Totoaba	Totoaba	*Totoaba macnoldi*	Scianidae	No
Chano	Slender Croaker	*Micropogonias ectenes*.	Scianidae	Yes
Lenguado	*Cortez flounder*	*Paralichthys aestuarius*	Paralichthyidae	Yes
Cinto	*Pacific Cutlassfish*	Trichiurus nitens	Trichiuridae	No
Botete	*Pufferfish*	-	Tetraodontidae	No
-	King Angelfish	Holacanthus passer	Pomacanthidae	No
Pargo	*Snapper*	Lutjanus ?	Lutjanidae	Yes