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Tropical shrimp trawl fisheries: Fishers' knowledge of and attitudes about a doomed fishery

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ABSTRACT

Tropical shrimp trawl fisheries are unsustainable, and similar sets of management measures are used globally to address the direct and indirect costs of their practices. Yet little is known about shrimp fishers' perceptions, despite the clear importance of human behaviour in determining the success of fisheries management. This article presents the results of interviews with industrial shrimp trawl fishers from the southern Gulf of California, Mexico, and reveals fishers' knowledge and attitudes that should be considered when developing management plans for industrial shrimp trawl fisheries. Fishers were asked to comment on problems facing the fishery, management options to address the issues, and the future of the fishery in general. The interviews also elicited new knowledge on effort and valuable components of bycatch, useful to the management process. Among the problems facing the Gulf of California fishery, fishers tended to identify those generated externally—fluctuations in shrimp populations, increases in fishing effort, decreases in shrimp prices and increasing overheads—and thus distance themselves from responsibility for management options. The successes of any mitigation measures for the fishery are likely to depend on proper enforcement and reliable governance, as our study indicates. Should strong enforcement be put in place, then trawl free areas seem to be the most pragmatic way to alleviate problems associated with the fishery; our effort data point to areas that might have greatest acceptance among fishers. A reduction in capacity would clearly complement marine zoning for trawl free areas. In the long run, however, it may be economic extinction of the fishery that reduces pressure on the marine ecosystem.

1. Introduction

Tropical shrimp trawl fisheries are unsustainable in economic, environmental, and social terms. Economically, declining catch per unit effort (CPUE) combined with rising overhead costs (mainly fuel) and falling shrimp prices (due to world wide competition with lower-cost farmed shrimp) have reduced profitability for most of the worlds commercial shrimp trawl fisheries [1]. As a consequence, half of all shrimp landings presently come from countries that subsidise fuel for such fisheries [2]. Environmentally, the gear used in most large-scale operations is known to be destructive to marine habitats [3,4], as well as highly non-selective, catching many million tonnes of non-target species each year [5]. In the tropics, this bycatch is composed of (i) species of conservation concern, (ii) commercially important species targeted by other fisheries, and (iii) oft-forgotten small fish of considerable ecological, thought not economic, value [5,6]. Socially, conflict among the industrial shrimp fishing sector and other, smaller-scale, fishing sectors is a common concern (e.g. [1,7]). The conflicts mainly arise where the industrial shrimp fishery catches species of economic importance to other fisheries and/or displaces fishers that use static gears.

Tropical shrimp trawl fisheries around the world employ similar sets of mitigation measures to address the direct and indirect costs of their practices. The most common management measures to improve the status of shrimp stocks include controlling fishing effort through permit requirements, vessel buy-back programs, mesh size regulations, and closed seasons and/or areas [1]. In addressing the indirect impacts of shrimp trawling, managers commonly try to reduce overall fishing effort, promote modifications to fishing gear—mainly through the use of turtle excluder devices (TEDs) and bycatch reduction devices (BRDs)—and ban fishing in areas of critical habitat or species of conservation concern [8]. Although many of these technical measures are useful [9,10], trawl closures are likely to be most effective in reducing fishing mortality and habitat impacts [10]. Retention of bycatch, often promoted as a mitigation measure for tropical shrimp trawl fisheries, does not reduce environmental impact [11]. Social concerns can, however, be reduced by moving larger boats offshore, in order to reduce physical conflict with smaller-scale operations [1].

Successful implementation of any management or mitigation measure requires information. An understanding of effort distribution in space and time is needed to plan for spatial/temporal

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management, but also to understand sector overlap and so potential for fisheries conflicts. Assessing BRDs for effectiveness requires an understanding of relative values of different components of the catch, including bycatch. Although gear modifications and changes to fishing techniques have proven successful at reducing bycatch in some fisheries, failure to consider the regulatory and social systems in which the gear modifications are being implemented has resulted in considerable resistance to their introduction [12].

Little is known about shrimp fishers' knowledge and attitudes, despite the large number of scientific papers, technical manuals and management briefs on tropical shrimp trawl fisheries, especially with respect to bycatch (e.g. [1,7,10,13–15]). The available literature considers the biological elements of managing tropical shrimp trawl fisheries but pays little attention to social acceptance of such protocols, despite the clear importance of human behaviour in determining the success of fisheries management. As just one example, the US government mandate to use TEDs and BRDs, although biologically reasonable, met considerable resistance from shrimp trawl fishers in the Gulf of Mexico because they perceived a loss of independence and control over the circumstances of their work [16].

Fishers' knowledge can be useful in both biological and management contexts (e.g. [17]). They know a lot about marine life because their livelihoods depend on maximising catch while minimising effort [18]. Tapping into stakeholder knowledge should increase greater acceptability of the results of the research, and resulting recommendations [18]. In a review of marine conservation planning initiatives, those that were most successful seemed to include more stakeholder groups [19]. In spite of this, past practices in fisheries management have generally involved only biologists and economists, attention turning to fishers' perceptions only in the last two decades or so [20].

The industrial shrimp trawl fishery in the Gulf of California, Mexico, provides a useful model for the challenges of managing tropical shrimp trawl fisheries, not least because of its perceived great economic and social importance [21]. Despite its prominence, the fishery suffers the same problems as other tropical shrimp exploitation. Reported management issues include declining catches and overcapacity, unprofitability (government subsidies are presently needed to maintain an otherwise unviable fishery), conflict between it and small-scale fisheries, and environmental impacts [1,21–23]. Current management includes a seasonal closure (April–September, to protect commercial shrimp species), permit requirements, depth restrictions (<10 m), area closures (bays, estuaries, and a few marine protected areas (MPAs)) and gear requirements (minimum mesh size and TED) [24]. Enforcement of fishing laws is the responsibility of federal government through CONAPESCA, with little room for local governments to manage fisheries resources [1].

Ours is the first study on industrial shrimp trawl fishers' perceptions and/or attitudes in the Gulf, and complements previous studies on the direct and indirect issues associated with the fishery (e.g. [21,23,25]), and the technical solutions to these problems (e.g. [26]). In this paper, we use interviews with fishers from the industrial shrimp trawl fishery of the Gulf of California to shed light on the social dimensions of tropical shrimp fisheries management. Specifically, we wished to obtain fishers' views on direct and indirect problems facing the fishery, proposed and potential management options to address the issues, and the future of the fishery in general. We also wanted to obtain new knowledge on effort and valuable components of bycatch to feed into the management process. We focus our work on fishers from the southern Gulf of California, the area of the Gulf with greatest intensity of anthropogenic pressure, and greatest increasing trend of such pressure [27].

2. Materials and methods

2.1. Interviews

We interviewed shrimp trawl fishers from the two main fishing ports in the southern Gulf of California: Mazatlan, Sinaloa and San Blas, Nayarit (Fig. 1). Limiting interviews to the southern Gulf (also know as Lower Gulf), one of the three biogeographic regions of the sea [28], avoided results being influenced by biogeographic differences in species composition and abundance. Interviews took place in March 2006 (Mazatlan only) and January–March 2007 (Mazatlan and San Blas). We intentionally directed our interviews at more experienced fishers, in a non-random fashion. Selection of fishers was done either by word of mouth, asking one candidate to suggest other experienced fishers to talk to (i.e. snowball sampling [29,30]), or by direct interception [31]. Where we used the interception method to find fishers, we sought out individuals whom we guessed to be older.

Interviews followed a semi-structured multi-purpose questionnaire that was designed to yield information on the fishery, catches, changes over time (in catches and fishing practices), issues facing the fishery and potential options for addressing the problems. During the interviews, participants were guided in the discussion by the interviewer based on a predetermined list of questions (Table 1), but the direction and scope of the interview were allowed to follow the participant's train of thought. This provided opportunity for novel information to come up in the conversation [29]. As a result of this flexibility, the number of responses varied for each question (as indicated in the results), and the interviews varied in length (although most were around 30 min). Interviews were conducted by S.J.F. with the help of a local Mexican research assistant. S.J.F. relied on the assistant for interpretation in the first year and then drew on him more for validation during the second year, when her own Spanish was better. Responses were noted but not tape recorded. This research was given ethics clearance by The University of British Columbia.

We asked fishers who reported changes in catch rates (increasing or decreasing) to quantify the change. We then converted their responses to % change per year in order to make individual responses comparable. When fishers did not provide a time frame for a reported change, we used the number of years the fisher had participated in the fishery as the maximum time frame over which the change had occurred. This would result in conservative decline rates if fishers were actually reporting declines that had occurred over a shorter period of time than their time in the fishery. All statistical analyses were conducted with GraphPad Prism, version 5.02 (GraphPad Software Inc., 2008).

During interviews, fishers identified taxa by their local common names. The local names were then translated to scientific names by the research assistant. The final list was verified by an independent researcher, a trained taxonomist with extensive experience working with bycatch from the shrimp trawlers in our study area. Most reported declines in specific taxa were not quantified by fishers. Where fishers did quantify declines, the units were variable such that we could not compare, nor deduce, mean rates, and thus we present individual fisher comments. We should note that fish catches are variable in space and time, so when fishers reported catching tonnes of big fish per tow they would not mean every tow, but when they happened to catch them.

2.2. Respondents

We interviewed a total of 52 fishers for the study: 20 fishers in Mazatlan in 2006; 17 fishers in Mazatlan in 2007; and 15 fishers in San Blas in 2007. Fishers worked aboard 34 different trawl

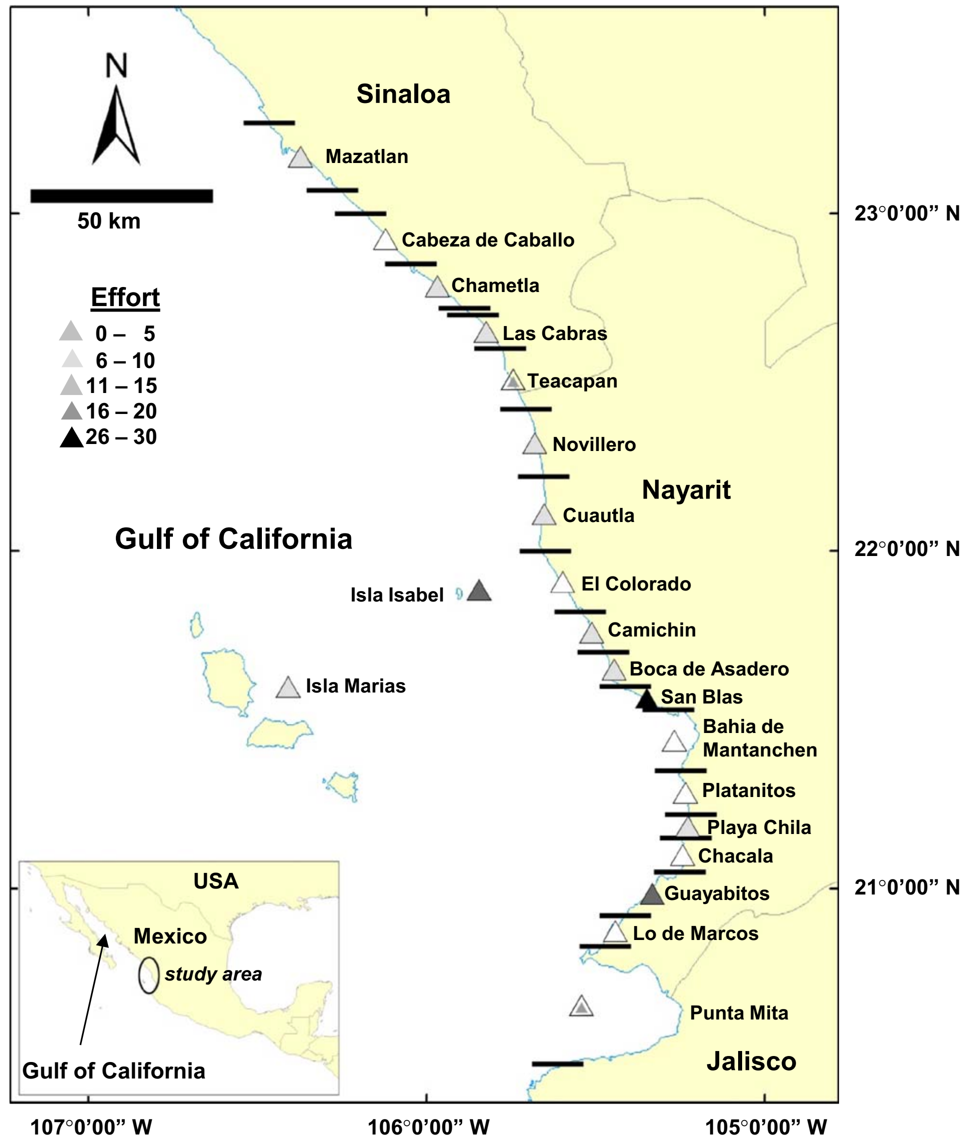

Fig. 1. Industrial shrimp trawl effort across fishing grounds of the southern Gulf of California, Mexico. Relative effort was determined from interviews with fishers from the ports of Mazatlan, Sinaloa and San Blas, Nayarit (N=46), and was measured as the number of respondents to report an area as having a high concentration of trawlers, year to year. Bars along coast delineate fishing areas.

vessels: we interviewed one fisher from each of 25 trawlers, two fishers from each of seven trawlers, six fishers from one trawler, and seven from another. All fishers were interviewed alone, including those that worked on the same boat.

Interviewed fishers had spent a mean of 20 ± 11 years participating in the fishery (N=52). The majority of the fishers could be considered experienced as the commercial shrimp trawl fishery in the Gulf only started 60 years ago; only seven had spent less than 10 years fishing, and 15 had spent 30 or more seasons on the boats. The majority of fishers interviewed were captains, mechanics or sailors. The number of fishers interviewed by position, in order of rank importance, was (Spanish name in parentheses): captain (capitán, N=17), mechanic (motorista, N=15), cook (cocinero, N=6), sailor (marinero, N=12) and deck hand (pavo, N=1).

The majority of respondents (N=33) worked in other fisheries-related jobs during the closed season for shrimp trawling. The most common source of income during the closed season was a small-scale fishery called *escama* (scale), where fishers reported targeting *inter alia* barracuda, dorado, mackerel and shark (N=15). Eight and four fishers were active in shark and tuna fishing, respectively. Two respondents worked as fisheries observers on tuna boats, and one respondent was active in each of the following fisheries related jobs: beach seine fisher, breath-hold diver (oysters and lobsters), buyer/seller, processor, tuna mariculture. Reported non-fisheries related jobs included maintenance of the shrimp trawlers (N=4), farmer (N=3), security guard (N=2), carpenter, hotel cook, electrician, and mechanic (each with N=1). The rest of the fishers claimed they only rested during the closed season (N=6).

3. Results

The following sections synthesise responding fishers' views on direct and indirect problems facing the fishery (Sections 3.1 and 3.2, respectively), potential management options to address the issues (Section 3.3), and the future of the fishery in general (Section 3.4). We also present new knowledge on effort and valuable components of bycatch to feed into the management process (Section 3.5). Fisher's views on problems and management options were either *prompted* by researchers during the

Table 1
Questions used to guide semi-structured interviews with industrial shrimp trawl fishers from the southern Gulf of California, Mexico.

1. Information on fishery:
a. Can you identify areas you believe experience a high concentration of fishing boats, every year?
b. Has your fishing practice changed over time?

2. Information on bycatch:
a. Does bycatch affect the location of your fishing?
b. Do you keep any of the bycatch? Which species?

3. Changes in catch over time
a. Has the total weight of your catch changed over time? Please quantify.
b. Have shrimp catches changed over time? Please quantify.
c. Has the amount of fauna in the catches changed over time? Please quantify.
d. Has the amount of valuable fishes in the catches changed over time? Please quantify.
e. Have there been any changes in the specific fish species you catch over time?

4. Issues with the fishery (asked in 2007 only)
a. In your opinion are the shrimp stocks you catch stable, decreasing, or increasing?
b. What do think might be the primary cause(s) for your observations?
c. How do you see the future of the shrimp trawl fishery in Mexico?

5. Possible solutions (asked in 2007 only)
a. What solutions do you propose for the problems facing the shrimp trawl fishery?
b. What do you think about the following possible solutions:
Bycatch excluder devices
Reducing the number of boats
Reducing the length of the season
Closing areas to trawling

interview, or volunteered (*unprompted*) by respondents during our discussions.

3.1. Direct problems

3.1.1. Prompted

Approximately half of fishers who commented on the status of commercial shrimp populations considered them stable (N=13/27), while the other half considered them to have declined over time (N=14/27). None of the respondents thought the Gulf's shrimp populations had increased over time. In a clearer verdict, the majority of fishers who commented on shrimp yields had experienced a decline in catches over time (N=31/35), with a mean reported decline rate of $4\% \pm 2\%\,\text{year}^{-1}$ (N=11). Very few respondents reported stable shrimp catches (N=4/35), and none reported increases.

The majority of respondents reported declines in total catch (shrimp plus bycatch) over time (N=24/29), while only five reported catches as stable, and none reported an increase. The mean reported decline in total catch was $4 \pm 2\%\,\text{year}^{-1}$ (N=15). Seven fishers commented that the shrimp to bycatch ratio had not changed over time, supported by the fact that mean reported decline rates for total catch and shrimp catch were the same.

3.1.2. Unprompted

All 32 fishers interviewed in 2007 commented on problems (direct and indirect: Table 2), with individual fishers reporting an average of 4 ± 2 problems (range 1–7). The number of problems reported by an individual fisher was not related to their time in the fishery (P=0.15), nor their position within the fishery (P=0.18). Similarly, there was no apparent correlation with years nor position in the fishery and each problem individually (results not shown). The most commonly reported concern (89% of respondents) was too many industrial trawl boats, resulting in a decrease in catch per boat. This was followed by decreasing shrimp prices and increasing overhead costs, with 41% and 34% of fishers citing these issues, respectively (Table 2).

Table 2
Unprompted direct and indirect problems facing the industrial shrimp trawl fishery in the Gulf of California, Mexico, as volunteered by participating fishers (total N=32).

ISSUE	# respondents	REASONS (based on fisher interviews)
DIRECT		
Too many industrial trawl boats	29	Has resulted in a decrease in catch per boat
Declining shrimp prices	13	Due to large amounts of shrimp entering the market from aquaculture and small-scale shrimp trawl fishing operations (pangas), and at half the price as those from industrial fishing operations
Increasing overheads	11	Due to the rising costs of oil and age of the fishing vessels, as old boats require more of maintenance and cost more to run that younger boats
Bigger, more efficient, gears	4	Heavier wood doors cause more damage to the bottom; more efficient gears catch more of everything
Illegal mesh size	1	Fishers used 1.5 in mesh in the past, until the law mandated 2.25 in, but now boats were again using 1.5 in to catch as many shrimp as possible
Improved technology	1	Fishers can find the shrimp faster, and fish more of the Gulf than they used to
INDIRECT		
Small-scale shrimp trawl fishers affect industrial shrimp catches	26	Pangas impact the catches of industrial fishers because they fish illegally in the closed season and in shallow waters, and start fishing first (their season opens a couple of weeks before the industrial season)
Poor governance	15	The government does a poor job enforcing laws, especially when it comes to small-scale shrimp trawl fishers who are considered to fish illegally in the closed season and areas without penalty
Aquaculture	11	Take larvae from the bays and estuaries, thereby reducing the number of mature shrimp available to industrial shrimp fishers
Contamination/garbage	5	Fishers throw garbage overboard, including engine oil and old nets
Industrial shrimp fishers impact catches of (non-shrimp) small scale fishers	1	Trawlers catch fishes that are important to small-scale fishers
Climate change	1	Climate change is changing currents and therefore locations of shrimp and fish

3.2. Indirect problems

3.2.1. Prompted

Approximately half of fishers who commented on trends in bycatch (the incidental portion of their catch) considered it stable (N=18/32), while the other half considered it to have declined over time (N=14/32). None of the respondents thought the amount of bycatch in their catches had increased over time.

Table 3
Fish taxa reported by industrial shrimp trawl fishers from the southern Gulf of California, Mexico, as having declined over time.

Common name (Spanish)	N	Kept[a]	Family	Genus/species	Max size (cm)[b]	Habitat[b]	Form	Diet[b]	Common name (English)[b]	Fishers' comments[c]
Robalo	26	Yes	Centropomidae	Centropomus nigrescens, C. viridis	123, 112	Demersal	Elongated and slender	Zoobenthos (including shrimps), nekton	Snook (Black/White)	40 bags to less than 1 bag per trip (26 years); 300 kg to 1 individual per season (20 years); 750 kg first trip, now a few individuals all season (3 years)
Constantino	2	Yes	Centropomidae	Centropomus robalito	35	Pelagic-neritic	Elongated and slender	Zoobenthos (including shrimps), nekton	Yellowfin snook	
Pargo	24	Yes	Lutjanidae	Lutjanus colorado	91	Reef-associated	Oblong, moderately laterally compressed	Zoobenthos	Colorado snapper	70–9 individuals per trip (16 years); used to catch 6–10 kg individuals, but not anymore (25 years);
Huachinango	4	Yes	Lutjanidae	Lutjanus peru	95	Reef-associated	Oblong, moderately laterally compressed	Zoobenthos, nekton	Pacific red snapper	300–25 kg per season (10 years); could catch 7000 kg in 3 days, but not anymore (5 years)
Caballo del mar	10	?	Syngnathidae	Hippocampus ingens	31	Demersal, reef-associated	Swims upright	Zooplankton	Seahorse	
Mero	9	Yes	Serranidae	Epinephelus spp.			Oblong, moderately laterally compressed		Grouper	Caught 10–80 kg individuals in past, but now only 15 kg when catch at all (25 years)
Botete	9	Yes	Tetraodontidae	Sphoeroides annulatus	44	Demersal	Round	Zoobenthos, plants	Bullseye puffer	
Mojarra	7	Yes	Gerreidae	Eucinostomus spp./ Diapterus spp.		Demersal	Laterally compressed		Mojarra	Would catch 300 kg in a 2 h tow, now get 100 kg in a 4 h tow (% years)
Burro	6	Yes	Haemulidae	Pomadasys panamensis	39	Demersal	Oblong, moderately laterally compressed	Zoobenthos, nekton	Panama grunt	500–45 kg per town (6 years)
Chivito	5	No	Mullidae	Pseudupeneus grandisquamis	30	Demersal	Flat on ventral surface, moderately laterally compressed	Zoobenthos	Bigscale goatfish	
Chihüil	3	Yes	Arridae	Bagre pinnimaculatus	95	Demersal	Robust, flat on ventral surface, spines	Nekton	Red sea catfish	
Lenguado	3	Yes	Paralichthyidae	Cyclopsetta panamensis, C. querna	35, 39	Demersal	Flattened dorso-ventrally	Zoobenthos, nekton	God's, Toothed flounder	
Corvina, Corvina chana	3	Yes	Scianidae	Cynoscion phoxocephalus, C. stolzmanni, C. reticulatus	60, 115, 90	Demersal	Flatter on dorsal surface, moderately laterally compressed	Zoobenthos, nekton (including shrimps)	Cachema, Stolzmann's, Striped weakfish	
Baqueta	3	Yes	Serranidae	Epinephelus acanthistius	100	Demersal	Oblong, moderately laterally compressed		Rooster hind	80–3 individuals per haul (35 years)
Chile	2	?	Synodontidae	Synodus spp.		Demersal	Elongated and rounded		Lizardfish	
Tiburón	2	Yes	Sphyrnidae/ Carcharhinidae	Sphyrna lewini/ Rhizoprionodon longurio	430/ 110	Pelagic-oceanic/ bentho-pelagic	Elongated, thick	Zoobenthos, nekton (including shrimps)	Shark (Scalloped hammerhead/Pacific sharpnose)	
Dorado	1	Yes	Coryphaenidae	Coryphaena hippurus	210	Pelagic-neritic	Elongated, thick	Nekton	Common dolphinfish	
Chabela	1	Yes	Stromatidae		25, 30		Compressed laterally			

Table 3 (continued)

Common name (Spanish)	N	Kept[a]	Family	Genus/species	Max size (cm)[b]	Habitat[b]	Form	Diet[b]	Common name (English)[b]	Fishers' comments[c]
				Peprilus medius, P. snyderi		Bentho-pelagic			Pacific harvestfish, Salema butterfish	
Liceta	1	Yes	Mugilidae	Mugil curema	90	Reef-associated	Elongated, rounded on ventral surface	Zooplankton, zoobenthos, nekton, plants	White mullet	
Mantarraya	1	Yes	Gymnuridae/ Dasyatidae	Gymnura marmorata/ Dasyatis brevis, D. longus	100/ 187, 260	Demersal	Flattened dorso-ventrally	Zoobenthos, nekton	California butterfly ray/ Whiptail, Longtail stingrays	
Berugatta	1	Yes	Scianidae	Micropogonias altipinnis	90	Bentho-pelagic	Oblong, rounded on dorsal surface	Zoobenthos (including shrimp), nekton	Tallfin croaker	
Sierra	1	Yes	Scombridae	Scomberomorus sierra	99	Pelagic-neritic	Elongated, moderately laterally compressed	Zoobenthos, nekton	Pacific sierra	

Fishers were asked to comment on observed declines in fishes in general, but specific fish taxa were unprompted.

[a] Yes=mentioned by fishers in interviews as species they keep, *yes*=not mentioned in interviews but are know to be retained, and ?=unclear if retained.

[b] Data from references in Fishbase [32].

[c] Years in parentheses are either the number of years over which the decline had occurred as reported by the fisher, or when this information was missing, the number of years the fisher had participated in the fishery.

When fishers were asked to comment specifically on large fishes (we did not define large for them), almost all respondents reported declines in this part of the bycatch ($N=33/35$). Only two reported large fish catches as stable, and none reported them as having increased over time. Several specific taxa were reported by fishers (unprompted by us) as having declined over time (Table 3).

Ten fishers commented on whether the amount or types of bycatch affected where they chose to fish. Of these the majority said they would avoid fishing an area if there was a lot of bycatch compared to shrimp ($N=6$). Three respondents reported targeting large fishes at the end of the season when shrimp catches were low; one even commented that he used a larger mesh size at the end of the season so as to target larger fishes. Only two respondents claimed that the fauna does not affect where they fish, and one mentioned keeping the small fish component of the bycatch to sell for fish meal.

3.2.2. *Unprompted*

The most commonly reported indirect problem was small-scale shrimp trawl fishers (81%, Table 2). Respondents commented that human population growth along the coast had resulted in an increased number of small-scale shrimp fishers, many of which are in direct competition with industrial boats as they can fish the same depths (up to 40 m) and with similar gears (nets up to 18 m). Poor governance and aquaculture operations were the next most commonly reported problems, with 47% and 34% of responding fishers citing these issues, respectively (Table 2).

3.3. *Management options*

3.3.1. *Prompted*

Three-quarters of fishers who commented on trawl free zones (MPAs) considered them a good idea (77%), but only if adequate enforcement was put in place (Table 4). One respondent even remarked that MPAs would be respected only if the Mexican president himself was sitting in the middle. Those against MPAs did not perceive benefits from them. Two respondents commented that existing zones closed to trawling—bays and estuaries, and any water shallower than 10 m—were trawled anyway.

Almost all fishers who commented on reducing fleet size considered it a good idea (91%, Table 4). Three respondents commented that the fleet size was decreasing anyway, as old boats stopped working, but also as overhead costs rose and fishers could not afford to go out. However, one respondent commented that reducing fleet size would change the problem from an ecological one to a social one, as there would be people out of work. Another respondent commented that all trawlers should be eliminated, large and small scale, and be replaced with alternative fishing methods that are not as harmful to the environment.

Shortening the fishing season was supported by 65% of fishers who commented on this management option (Table 4). Most respondents felt it should close earlier, as shrimp yields are not profitable after January/February, but several others felt the season should start later, as shrimp populations are still reproducing and/or too small in September (Table 4). Two respondents suggested a mid season break, as they believe that shrimp have a second reductive period around February. One respondent suggested spatio-temporal restrictions that were planned around target shrimp species. Fishers first target shallow and then deep water shrimp species during the first and second halves of the fishing season, respectively. The fisher proposed, therefore, that deeper waters be closed to fishing in the first half of the season, and shallow waters in the second half.

Table 4
Industrial shrimp trawl fishers' views on potential management options for their fishery in the Gulf of California, Mexico.

Management option	For	Against	N	Reasons (based on fishers interviews)
PROMPTED				
MPAs	20	6	26	For: would only work with adequate enforcement Against: would limit the availability of fishing grounds, further reducing shrimp yields
Reduce fleet size	20	2	22	For: government buy-back program best way to achieve this (n=10) Against: would put people out of jobs
Shorten trawl season	17	9	26	For: should end earlier (n=8), start later (n=4) against: would result in less employment (n=6)
TEDs	7	21	28	For: does not affect catches Against: affects shrimp catches, prevent large fish from entering the nets, are dangerous
UNPROMPTED				
Better governance (increased vigilance)	16			Government does not care about fisheries resources—evidenced by the fact they allowed small-scale fishers to trawl in the closed season, and inside estuaries
Temporary trawl moratorium	6			Average suggested length of 3.25 years, but government would have to help find alternative sources of income for displaced fishers—whether from other employment, or government assistance
Spectra nets/regulate mesh size	3			Considered to catch less fauna and reduce fuel consumption
Standardise gears	2			All boats have to be the same size, and use the same sized gears—thereby reducing competitive advantage of some larger boats
Eliminate small-scale shrimp trawlers	2			
Zoning of fishing grounds	2			Fishers would be restricted to fishing in their home state
Ban all trawling	1			

Management options were either prompted by the researcher, or volunteered by participating fishers during discussions (unprompted). N=number of respondents who commented on the management option; n=sample size where a further breakdown of overall result is reported.

It was clear from the interviews that fishers considered TEDs a problem, and not a solution; 75% of fishers who commented on the device were against it (Table 4). The main reasons were that they (i) frequently get clogged (with garbage, sticks, mud, etc.) and thus prevent shrimp from passing into the cod end, (ii) exclude large fish, which supplement fishers income, and (iii) are dangerous to handle due to their weight. Though we did not ask about problems and management options in 2006, dissatisfaction with the TED was the only unprompted issue discussed by respondents at that time (N=7/20).

3.3.2. Unprompted

Nearly all fishers interviewed in 2007 commented on management options other than those prompted by the interviewer, with individual respondents suggesting an average of 2 ± 1 options (range 1–3) (Table 4). The number of management options suggested by an individual fisher was not related to their time in the fishery (P=0.07), nor their position within the fishery (P=0.58). Similarly, there was no apparent correlation with years or position in the fishery and each option individually (results not shown).

The most common unprompted management option was better governance, especially increased vigilance of the small-scale shrimp trawl fishers (64% of respondents, Table 4). Two respondents suggested the enforcement system to be corrupt, such that for a fee small-scale fishers are warned ahead of time that authorities are paying an enforcement visit. In San Blas only, a common unprompted management option was a temporary trawl moratorium (N=6/15 San Blas fishers, Table 4). Two respondents, one from Mazatlan and one from San Blas, also suggested zoning of fishing grounds (Table 4).

3.4. Future of the fishery

Most fishers who commented felt that the fishery had no future (N=27/30). Specific stated reasons for the eventual demise of the fishery included collapsed shrimp populations (N=6), the destruction of the marine environment (N=3), and a loss of economic viability as increasing overheads combine with decreasing shrimp prices (N=7). Two of the three fishers who considered the fishery to have a future said it would continue only if the government started to take better care of fisheries resources, if no one fished when the shrimp were reproducing, and if the fleet size was maintained or (better) reduced.

3.5. Information to support management

3.5.1. Effort

Almost all respondents were willing and able to describe the main fishing grounds in the southern Gulf of California (between Mazatlan, Sinaloa and Cancun, Jalisco) (N=46/52). A query as to where they fished elicited a usual response of "everywhere". We therefore asked respondents where, year to year, they expected to find a large concentration of trawlers, and defined fishing effort as the number of individuals who cited the fishing ground as having a high concentration of trawlers (Fig. 1).

About half of fishers interviewed commented on what makes a good fishing ground (N=23). Spatial variables included areas in front of lagoons (N=2) and rivers (N=6). Temporal factors included temperature (N=11), presence of a full moon (N=6), and rain (N=6).

3.5.2. Important bycatch species

Several bycatch species were reported as being retained by fishers (Table 3). These taxa range in maximum sizes from 25 to almost 500 cm, in habitat (although the majority are demersal), and in shape (from elongate and rounded to dorso-ventrally flattened) (Table 3). In addition, the majority of these taxa relied on the shrimp grounds for their food source, some including shrimps as a targeted part of their diets (Table 3).

4. Discussion

Our study reveals fishers' knowledge and attitudes that should be considered when developing management plans for industrial shrimp trawl fisheries. It is notable that among the problems facing the Gulf of California fishery, fishers tended to identify those generated externally—fluctuations in availability of the resource, increases in fishing effort, decreases in international price of shrimp and increases in operation costs—and thus distance themselves from responsibility for management options. In such a climate, any solutions to the fishery are likely to depend on proper enforcement and reliable governance, as our study indicates. Should strong enforcement be put in place, then trawl free areas seem to be the most pragmatic way to alleviate problems associated with the fishery; our effort data point to areas that might have greatest acceptance among fishers.

The Gulf's industrial trawl fishers agreed with official reports that the fishery is suffering overcapacity, which depletes both the targeted shrimps and the ecosystem in general. Our respondents and official statistics have reported declines in catch per vessel over time [33], although fishers perceived the rate of decline to be more drastic (4% versus 1% per year, respectively [34]). A similar discrepancy in perceived decline rates was found in the northern Gulf, where fishers reported a much steeper decline in shrimp biomass than official records [35]. The fishers rightly blamed excessive fishing effort for decreased catches—the onset of declines in catch rates coincided with a significant increase in the number and size of fishing vessels [33]. Fishers did not agree as to whether reduced shrimp catches also meant declines in shrimp biomass, though reports suggested that most shrimp stocks in the Gulf of California are fully or over-fished (e.g. [36]). Our study adds to existing anecdotal evidence of reductions in the Gulf's overall biomass (e.g. [35,37,38]).

In our interviews, respondents recognised that even if effort were reduced, and catch per vessel increased, shrimp trawl industries might still be unprofitable because of declining shrimp prices and increasing overheads. As industrial shrimp catches in the Gulf failed to keep up with demand, Mexico's shrimp aquaculture grew rapidly to compensate [21], such that current production is now almost equal to wild capture [1]. Low prices for aquaculture shrimp and shrimp from small-scale fisheries have forced industrial shrimp trawling operations to sell their product at a loss [21]. Declining shrimp prices combined with the rising price of oil and an ageing fleet—in 2006, 82% of the Gulf's vessels were older than 20 years [39]—means that the fleet is generally unprofitable, with 93% of vessels registering a loss in 2000 [21].

Fisher interviews were only somewhat useful for increasing our understanding of the indirect impacts of shrimp trawl fisheries, especially with respect to the issue of bycatch. Fishers suggested several larger fish species for which incidental capture in shrimp trawl nets might be a problem; some of which other Gulf fishers had previously identified as depleted through fishing [37]. It is notable that most fishers reported declines in total catch (bycatch plus shrimp) without any change in bycatch to shrimp ratio yet, oddly, failed to recognise that bycatch species must therefore have declined with shrimp; only half reported a decline in bycatch over time. Even fishers who noted a decline in bycatch volume regarded it as an undifferentiated whole, overlooking any shifts in species composition in the bycatch. Such discrepancies suggest that fishers' knowledge may be most confidently embraced for species that they value (as per [35,37,40]). The corollary is that alternate assessment methods will be needed for the small fish component of bycatch, which constitutes most incidental catch in shrimp trawl fisheries [5].

Our study shows that a lack of understanding of the value fishers place on bycatch will limit the utility of bycatch reduction devices and other remedial action. Fishers value the very species which such devices serve to exclude. For example, the TEDs are unpopular because they allow mobile fish—of great value to the fishers—to escape along with the turtles. Ironically, such TEDs do little to exclude the small fish bycatch that fishers would be happy to reduce. The situation is similar in Indonesia, where compliance with the government mandated use of TEDs is very low, with the main reason being that they reduce fish bycatch which generate income higher than monthly wages [41]. Studies on TED performance have, therefore, failed in focusing only on their effects on shrimp catch and not on mobile or larger fish. This challenge to BRDs emphasises the need for management ventures to consider socioeconomic impacts and not just ecological goals. In general, research needs to refocus on assessing impacts and limiting unsustainable bycatch rather than only eliminating certain components of it [42].

The fishers we interviewed placed most blame for the problems facing their fishery on sectors other than their own, suggesting low levels of ownership for the current situation. The fishers blamed small-scale shrimp trawl fishers, the government and aquaculture ventures. Placing the blame on the small scale shrimp trawl fishery suggests that industrial shrimp fishers will not likely respect management or mitigation measures directed at the industrial fleet until the government has regulated the small-scale fishery. Indeed, restructuring of the small-scale fishery has been identified as a necessary step towards improving the shrimp industry in Mexico [24]. Tightly tied to the issue of the small scale trawl fishery is that of poor governance. Small-scale fishers fish illegally, in both space and time, and some fishers we interviewed suggested this happens without penalty, even considering the fisheries management system in Mexico to be corrupt. Aquaculture operations also bore fishers' blame, as they are perceived to steal larvae and thus decrease the number of mature shrimps available to industrial fishers, although it is more likely that aquaculture affects the industry by lowering market prices for shrimp (as discussed above).

Although fishers indicated support for several commonly employed shrimp trawl fisheries management options, it is clear from our study that improved governance and effective enforcement are vital for such options to be successful. Fishers generally supported three of the common management measures employed in tropical shrimp fisheries worldwide, professing willingness to reduce effort (a) spatially with trawl free zones, (b) overall by reducing fleet size, and (c) temporally with a limited fishing season. Regardless, the perceived lack of effective governance means that even mitigation measures supported by fishers would fall short of achieving their goals. A review of the world's shrimp fisheries suggest management is complex where it involves small-scale fishers, is open access, or occurs in a poor country with weak institutional arrangements for management [1]. The Gulf's shrimp fishery suffers all three of these, and all three need to be addressed before hope for a better future is returned to its fishers. Though revealed to be an important issue for the fishers, poor governance is not explicitly mentioned in existing literature addressing the management of the Gulf's shrimp fishery (e.g. [1,24]).

Of the three proposed options for reducing overall trawl effort, we suggest that trawl free areas are the most pragmatic way forward with shrimp fisheries management in the Gulf of California (and indeed shrimp fisheries in general). First, the number of fishing vessels is likely to decline without intervention, as the boats age and become prohibitively costly to run. Second, shortening the fishing season would have relatively little impact on catch (including bycatch), given diminishing returns with time [21]. And third, unless fishers have other sustainable ways to earn an income, reductions in shrimp exploitation (through a reduction in fishing vessels, or a shortening of the fishing season) would probably just redirect fishing effort onto other marine resources [43].

Trawl free areas would probably achieve levels of protection far beyond those of any BRD [10]. They would mitigate many of both the direct and indirect issues associated with the fishery, and fishers would generally support them as long as the government enforces them. Moreover, it is unlikely that any BRD or other technical solution will provide effective support for the bycatch species, given their very diverse sizes, shapes and habitats [44,45]. There are presently 11 MPAs in the Gulf, some of which have displaced trawlers, but none has been put in place as an explicit part of the shrimp fishery management plan. Instead, most were aimed at protecting charismatic species or specific high-profile areas [27], or managing and enhancing small-scale fisheries while conserving marine ecosystems [46]. The success of the restricted areas will depend on proper enforcement—it is helpful that electronic vessel monitoring (VMS) is already in place for all the Gulf's industrial trawlers [1]—and on exclusion of small-scale fishers.

Our effort data, while limited, shed light on the potential placement of trawl free areas in the southern Gulf of California. Although VMS monitoring of all industrial shrimp trawlers has been underway since 2004, the information gathered is not made readily available, even to in-country researchers. The effort data we obtained through fisher interviews is, therefore, important despite its uncertain and patchy nature. We were able to get the names of the fishing grounds between Mazatlan and Puerto Vallarta and an indication of which may be more important to fishers, although all information could do with further verification. In the meantime, our data may help to place trawl free zones where they might be accepted. For example, our findings suggest that trawl free areas should not be placed in front of lagoons and river outputs, areas identified by fishers as important for shrimp populations.

5. Conclusions

Our study revealed that fishers lack hope for a better future for the industrial shrimp trawl fishery in the Gulf of California. Indeed, decreasing shrimp prices and increasing overheads may lead to eventual economic extinction of the fishery, even if shrimp stocks remain stable. It is estimated that these fisheries are highly subsidised, with a cost of 1.6 pesos to generate one peso of income from shrimp trawling in the Gulf [21]. This social cost is likely to have increased since time of publication given subsequent decreases in shrimp prices and the rising price of oil. Elimination of subsidies could reduce capacity by eliminating older vessels that operate at a loss each year (approximately 600 boats, and 3500–4000 jobs [21]). A reduction in capacity would clearly complement marine zoning for trawl free areas. In the long run, however, it may be decreasing shrimp prices and increasing operation costs that drive the fishery to economic extinction, and so reduce pressure on bycatch species.

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