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Journal cover photograph of vaquita provided by T. Jefferson.

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Editorial

The vaquita (*Phocoena sinus*) -Another species on the brink. A special issue of JMATE

The editors and staff of JMATE are pleased to dedicate this 2015 issue to a timely and impactful marine mammal crisis looming in the Gulf of California - namely the dire situation of the vaquita (*Phocoena sinus*). The sad plight of this little known species of porpoise, which only resides in a very specific and limited region in the northern Gulf of California, also called the Sea of Cortez, is such that the JMATE editorial staff thought it critical to dedicate the next issue exclusively to this marine mammal. The goal is to bring understanding and awareness regarding this mammal to our readership. It is truly sad to think that human activity has once again brought a species to the brink of extinction. The next generation may never have the opportunity to see a living example of this shy and beautiful creature.

We have tried to include the many aspects of this problem from the vaquita's unique biology, political history, and the 'human aspects', while including differing perspectives from various invested groups.

We begin with a poignant *Letter to the Editor*, which describes the concern and angst felt by our young generation of high school students who ask 'why' and beg that something be done.

Next, in the *Invited Commentary*, we see the issue through Tom's eyes, who has followed the vaquita situation for many years. His concern was so great that he established *¡VIVA Vaquita!* (VV), a coalition that includes a number of marine mammal research focused groups including the American Cetacean Society, Cetos Research Organization, Save the Whales and our parent organization, the Oceanographic Environmental Research Society (OERS), as well as student groups. VV was created to try to help bring public awareness to this issue and has done so for over six years now. This invited commentary not only serves to introduce the specific plight of the vaquita, but integrates this with other species, both present and past, that have found themselves in similar situations. The point that 'lessons learned' must be acted upon or dire scenarios are destined to repeat themselves, creating a highly undesirable precedent, is critical to the message!

The next, a *Review Article*, authored by Mike Belanger *et al.*, provides the reader with background regarding the basic biology and what is known about this rare species. It is humbling to realize that the species was initially scientifically described only in 1958 and that the first physical specimens were only recovered in 1985. Using the limited information available from published articles, this review presents what is known regarding their habitat, evolution, unique morphology/physiology and other characteristics. This shy and elusive creature is even more impressive once one realizes how special the vaquita is and the role it plays in that ecosystem!

This is followed by a focused historical *Review Article* by Cantú-Guzmán and co-authors, in which they provide an in-depth accounting, from the perspective of a Mexican NGO, on the history of what efforts have been made in Mexico throughout the years to remedy the decreasing vaquita numbers. In this paper, it becomes overwhelmingly obvious that politics, economy, and personalities can affect even the best and most well meaning efforts. It is also shocking and surprising that in truth this problem has existed for many more years than we realized.

Finally, this is followed by a *Scientific Article* written by Urrutia-Osorio and co-authors including the vaquita expert, Lorenzo Rojas-Bracho, who has for many years been involved scientifically and politically working on the vaquita's dilemma. In this work, the authors analyze the artisanal fisheries of San Felipe, Mexico, estimating incidental mortality

Editorial Cont'd

of the vaquita using data collected during one representative peak fishing season. Specifically, it explores the role of gillnets used by the shrimp fishers of Mexico, which has resulted in large numbers of vaquita trapped as by-catch. The data presented are solid evidence of the issue and identify that unless an immediate and thorough solution is implemented, we will shortly say good-bye to yet another marine mammal species.

So on behalf of the JMATE staff, we want to thank all the authors for providing the articles for this special JMATE issue and hope you, the reader, will appreciate their contributions and the message contained within.

We will be featuring any *Letters to the Editor* related to this issue in our subsequent issue of JMATE, should you feel compelled to voice your thoughts or want to add anything to this topic that you might feel was left out. This is one event that needs to be rapidly addressed and commentary from concerned individuals is one useful way to help accomplish that.

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ANNOUNCEMENT

JMATE launches new section featuring student manuscripts

JMATE is pleased to launch a new section under 'Original Manuscripts' specifically dedicated to encourage **current students** in the field of marine animal research to publish their work in a peer review journal. Though the manuscripts will undergo the same rigorous review afforded all submissions, consideration will be given that the first author is a student at the time of submission of the manuscript, and certain expectations will be adjusted. It is imperative that the work was done by a student under the supervision or mentorship of an active scientist in the field, who should be the senior author on the paper. Whenever possible, we hope to include at least one paper by a student with each issue, assuming the submission meets the appropriate criteria and standards of the journal.

We would like to encourage students at every level from undergraduate, masters or PhD training to consider submitting their work for review. It is our hope that supervisors/mentors of these future leaders in the marine animal field will support and promote this initiative; which will give students at all levels the opportunity to gain experience in publishing their research work.

Dr Carin Wittnich
Editor-in-Chief, JMATE

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Letter to the Editor

Why the Extinction of the Vaquita Should Matter to All of Us- A Teenager's Perspective

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The vaquita (*Phocoena sinus*) is a species on the extreme brink of extinction. It is found in the very northernmost part of the Gulf of California, Mexico, and its population now likely numbers fewer than 90 individuals (4). Bycatch in both legal and illegal fisheries has been its primary threat for as long as we have known about the species, and before we know it, the vaquita could be extinct. The only way to prevent the vaquita's extinction is to remove all gillnets from the vaquita's entire range immediately (12). Doing this will give the vaquita a chance to slowly begin to repopulate, but it could hurt the fishermen in the region (9). So why should we possibly sacrifice the well-being of a community for a seemingly invisible porpoise?

The vaquita is near the top of the food web in its northern Gulf of California ecosystem (8). It is extremely likely that the decline in the vaquita population has already had negative impacts on the other species of the Gulf. If there are no vaquitas, there will be fewer animals to prey upon small and medium-sized fish, as well as squid and crustaceans. Vaquitas are opportunistic feeders, and have been known to eat dozens of species of fish and other fauna (6). An increase in the species that are prey of the vaquita would therefore cause a decrease in other specis such as small animals and plants like plankton, which would then cause a decrease in species like baleen whales. The vaquita is also a food source for multiple shark species, such as the great white shark, and possibly killer whales, so therefore the absence of vaquitas would make it more difficult for these predatory species to locate prey (3). Many species have undergone miraculous population recoveries after being pushed to the edge of extinction, such as the gray whale, whooping crane, bald eagle, nene goose, and California condor (1). If the vaquita begins to increase, it will help stabilize the ecosystem and bring a once-diverse environment back to its natural and health state.

The vaquita is a clear symbol of Mexico's natural diversity. This cetacean is the only species endemic to Mexican waters (13). It is no secret that Mexico has a negative public image, thanks to drug cartels, kidnappings, and other unsavory activities (7). The last thing one would expect the government of a country like this to be worried about is a species of marine mammal that is almost never seen. However, if Mexico shows that they care about their ecology by creating one of our greatest conservation success stories, it will tremendously help their reputation. If the vaquita goes extinct, there will likely be massive public outcry towards the Mexican government and fishermen, which at this point could be devastating to Mexico's economy. A healthy population of vaquitas would be great incentive for ecotourism. Ecotourism, which is environmentally friendly tourism oriented around seeing wildlife, would be an ideal career option for the affected fishermen, due to their knowledge of the environment and boating experience (14). This would help diversify the local economy. Adoption of more sustainable fishing techniques would also improve the economics of the fishing industry itself. Some gillnets have a bycatch rate of almost 60%, which means that more than half of the animals caught are not what the fishermen are trying to catch, and part of this 60% is the vaquita (5). Thankfully, trawl nets have been developed that allow fishermen to catch what they want without having bycatch like vaquitas (4). Utilizing technology like this will allow fishermen to join front lines of modern sustainable fishing as well as keep the Gulf of California ecosystem healthy and productive. Thus, the survival of the vaquita would benefit Mexico's economy.

We have known the cause of the vaquita's decline for over 50 years now, and yet the problem has

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continued, if not intensified, to this day (4, 11). We have the moral duty to save the vaquita from a demise that is entirely anthropogenic in nature (12). In 2006, the extinction of the baiji river dolphin was announced, the first human-caused cetacean extinction (2). It was a wake-up call to conservationists all over the world. Now we are right on the cusp of losing another species only a few years later. As the most powerful species on the planet, we have the responsibility to protect all life, especially when it is because of us that they are in danger in the first place. Every organism has a fundamental right to exist, and our deprivation of this right is a moral crime. Killing an entire species is simply wrong. Furthermore, vaquitas are intelligent mammals, much like us (10). We simply cannot allow ourselves to kill off every last vaquita that will ever exist.

Lastly, saving the vaquita would have immeasurable global implications for other endangered species. The vaquita's situation mirrors that of countless other species that are losing the battle to human development and activities. If the vaquita is brought back from the absolute brink of extinction, it will show what can be done when humans work together towards a good cause. It will show that humans can bring a species back from the brink without the use of captive breeding, and that humans and animals can co-exist peacefully through the implementation of sustainable careers. The recovery of the vaquita would send a very strong message throughout the conservation community that we can save critically endangered species. The vaquita is the world's smallest and most endangered cetacean, and if we don't even have the will to save this cute little mammal, the future of generally less appealing animals like fish, insects, and reptiles does not look bright. Teenagers like William and me have to witness and live with the results of humanity's decisions for the rest of our lives. We do not want to live in a world without the irreplaceable creatures like elephants, tigers, pandas and vaquitas, and morale in the conservation community will dive to new depths if we let the vaquita slip away. We need the headlines to read "Vaquita Back from the Brink," and not "Vaquita Goes Down the Sink."

The vaquita is the most endangered marine mammal species on the planet, and will be extinct in the near future unless immediate, long-term action is taken to remove all gillnets in the species' entire range. We cannot afford to let the vaquita go extinct for the reasons outlined above. Environmentally, the vaquita is an important species, and its native ecosystem would be disrupted if the vaquita disappears. Economically, the loss of the vaquita would have a negative effect on Mexico. Furthermore, it is a moral crime to cause the extinction of an entire species. We have the power to save the vaquita, the same power that, until now, has been abused to such a degree that fewer than 90 vaquitas swim in the Gulf of California today. Finally, the vaquita's story will be heard around the world, regardless of it being a success or failure. If the vaquita is saved, it will inspire other conservationists to work to achieve similar results. We need to save the vaquita for the vaquita itself, for its ecosystem, for other endangered species, and for us. It is really not a question of if we can - the solution is plain, simple, and achievable. We just need to work together to make sure gillnets are out of the vaquita's range - for good.

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Commentary

A Bad Precedent: What the Loss of the Vaquita Would Mean to Marine Mammal Conservation

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Marine mammals have been exploited by humans for centuries. Many species have been driven to very low population levels by past hunting. But most of these have recovered. This was largely due to the fact that, as the species became rarer and rarer, it became less worthwhile to pursue them, and generally a more abundant species was turned to. This concept of a species being too rare to make it worth exploiting is known as "economic extinction." Luckily for the animals, and for those of us who care about them, economic extinction generally comes before biological extinction, and so therefore may give the species a second chance. It is probably the main reason we have only lost four species of marine mammals in centuries of killing them and chasing them to all corners of the Earth.

These four species consist of one sirenian, two pinnipeds, and one cetacean. If you consider the sea mink a marine mammal, then it would get added to the list. The Steller sea cow (*Hydrodamalis gigas*) was wiped out by fur hunters just 27 years after its discovery, a clear victim of ignorance and carelessness (9). The two pinnipeds, the West Indian monk seal (*Monachus tropicalis*) and Japanese sea lion (*Zalophus japonicus*), both went extinct most likely in the 1950s, both victims of hunting programs that pushed the point of economic extinction for these species too close to biological extinction for them to survive (5, 6). They were all victims of overhunting (the sea mink too). But the most recent marine mammal to go extinct, and so far the only cetacean, the baiji (*Lipotes vexillifer*) was never heavily hunted (10). It was a victim of accidental deaths in fishing gear and rampant destruction of its habitat.

The baiji represents the dawning of a new age of marine mammal endangerment. This is one in which the animals are not killed directly or intentionally, but rather the extinction risk is caused by incidental impacts of human activities like fishing, coastal development, agriculture, shipping, or minerals extraction. The animals simply get in the way of our ambitions to shape the world as we would like it to be.

The solutions to these new sets of problems are not so simple as just banning hunting and leaving the animals alone to recover. Generally, the problems are complex and involve many different activities that often do not have easily quantifiable impacts on marine mammal populations. This was certainly the case with the baiji, which suffered from accidental killing from rolling hook and dynamite/electric fishing, injury and death from vessel traffic, river modification schemes, and rampant pollution of its environment by countless toxic chemicals, not to mention sewage from something like 10% of the world's human population.

Despite decades of warnings from scientists that the baiji population was declining and heading toward extinction, the threats only got worse, and the species' numbers plummeted, reaching "functional extinction" in about 2006-2007. Presumably, the last baiji to inhabit the planet died sometime after that, with no ceremony or special attention. Perhaps this should not surprise anyone. China, where the baiji, lived, has a deplorable record of wildlife conservation, a totalitarian government determined on becoming a major economic powerhouse, the worst human overpopulation problem on the planet, not to mention that the threats to the species were so varied and difficult to quantify, much less control or eliminate. Maybe the baiji was doomed for a long time, and in truth it would have taken a monumental effort to save it (11).

However, the vaquita is different… quite different. It lives in a relatively "pristine" environment, with virtually no development, little ship traffic, and minimal water pollution. The surrounding region is sparsely populated, and the desert climate means that agriculture is barely present. The vaquita really only has one problem – a particular type of net called a gillnet. The number of boats setting these kinds of nets in the vaquita's range is only several hundred to maybe a thousand, and the range is a very small area – about

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a quarter the size of the Los Angeles metropolitan area. This sounds like a relatively easy problem to solve, especially when one considers that it has been understood that the vaquita was rare and endangered since the species was first discovered in the 1950s (7).

The vaquita's problems are imminently solvable – it is really simply a matter of replacing the several hundred gillnets in this area with an alternative type of fishing gear that is vaquita safe. And some progress has been made towards this goal. But, ultimately, it appears that the Mexican government, despite the claims that have been made over the years, does not have the political will to do what is needed to save the vaquita. Widespread corruption, and infighting between different departments that should be working together, have created an environment in which denial of facts, misuse of funds, planning for failure, and repeated delaying of needed measures have occurred. See the article by Cantu *et al* in this issue for more details on this sad, sad story.

Now, here in mid 2015, we have less than 80 vaquitas left on the planet, and they are declining at a rate of at least 18.5% annually and maybe faster (2). A breaking point, in which the species' numbers drop so low that even the elimination of the threats will be unlikely to save them, could happen as early as later this year. The situation is getting desperate and now is the time for the Mexican government to show the world that it is serious about saving the vaquita. There is still a chance!

If the vaquita were to go extinct in the next couple of years, we would have had two cetacean species lost in just a bit over a decade. This, despite the loss of not a single cetacean species in several hundred years of relentless hunting, using newly-developed technologies to make the hunt more efficient. So, what next?

After the vaquita, the world's most endangered cetacean species is undoubtedly the North Pacific right whale (*Eubalaena japonica*), which is currently listed as Endangered by IUCN. The Eastern North Pacific population is estimated at around 30 animals, with possibly several hundred found in a western Pacific population (though there is no reliable estimate for the western Pacific). The North Atlantic right whale (*Eubalaena glacialis*) is also listed as Endangered by IUCN, and is thought to number no more than 300-350 individuals in the western North Atlantic. The eastern North Atlantic stock is thought to be extirpated, or nearly so (4).

The Indus River dolphin (bhulan) is currently considered a subspecies of *Platanista gangetica*, which is listed as Endangered by IUCN. But recent studies strongly suggest that the bhulan should be considered a separate species. Its population is thought to number about 1,600-1,700 individuals. It lives in a war-torn part of the world, Pakistan, and clearly its prospects do not look bright (1).

Hector's dolphin (*Cephalorhynchus hectori*) is considered Endangered by IUCN, and the current estimate of abundance for the species is about 7,800. A subspecies, known as Maui's dolphin, is listed as Critically Endangered and only numbers approximately 55 individuals (8).

Two pinnipeds, the Mediterranean and Hawai'ian monk seals (*Monachus monachus* and *M. schauinslandi*, respectively), are listed by IUCN as Critically Endangered. The Hawai'ian monk seal's population is estimated at about 1,000 individuals, and the Mediterranean monk seal is in even worse shape at about 350-450 animals. The latter is the world's most-endangered pinniped species (3).

Any of these species, plus one or more of the sirenian species, could be facing extinction in the next 10-15 years. None of them are actively hunted, and the threats facing them are diverse, but always indirect, like those of the vaquita. We need to recognize that a failure to save the vaquita, when the threats to the species are so well-known and the conservation actions required to save it are so feasible, would have a very severe bearing on our ability to save these other species, for which our understanding of their threats are much less.

One way to look at this is in terms of what lawyers call a "precedent." Precedents have value and implications that go well beyond the merits of the specific case that they are based on, because they have a strong influence on the direction of future legal decisions. In a similar way, the success or failure of conservation efforts toward the vaquita can be viewed as a precedent in marine mammal conservation. The current precedent, the extinction of the baiji in the late 2000's, is obviously negative for marine mammal conservation. Our hope would be that we can save the

vaquita, not only for the value of maintaining the biological diversity of the species itself, but also to help reverse the negative precedent that is currently in place. If and when, in the future, we find ourselves in a situation where we are desperately trying to save one of the species listed above from extinction, having a positive precedent to lean on will be valuable in terms of trying to persuade governments, industry, and other stakeholders to change their behavior for the benefit of marine mammal conservation.

Going back to the baiji situation, the Chinese government's efforts to try to conserve the species had been almost completely aimed at developing a captive breeding colony and very little effort was put into trying to preserve habitat for the animals in nature, or in other words, almost all efforts were put into *ex-situ* approaches and very little was put into *in-situ* approaches. Even in the last decade or so of the baiji's existence, and despite strong recommendations from scientists and conservationists from around the globe, the Chinese government steadfastly maintained its course of only supporting *ex-situ* conservation. Even as the species was sliding into extinction, there was a strong refusal to accept that other approaches were needed. This stubbornness contributed to the extinction of the baiji (11).

We must be careful not to make the same mistake again with the vaquita. Efforts over the last several years by the Mexican government, and with support from outside of the country, have been well intentioned and made sense at the time. These efforts have primarily been directed towards voluntary buy-outs and switch-outs of fishing gear to more vaquita-friendly nets (7). However, we are now at a point where it is apparent that these approaches are simply not working. In order for the vaquita to survive even another few years we need to embrace new approaches. These new approaches will necessarily involve an immediate and complete elimination of all gillnets from the entire range of the vaquita, even if this cannot be done through a completely voluntary program. The vaquita just does not have time to wait anymore.

Now in mid 2015, there is new reason for optimism. The Mexican government has instituted a 2-year gillnet ban, and early indications are that it is being effectively enforced and may be working. However, it is still too early to tell, and everyone involved has emphasized that the gillnet ban needs to be permanent to have any chance to save this species. The president of Mexico appears to be serious about saving the vaquita, so there is good reason for hope. However, if the ban is not effectively enforced and made permanent, then economic sanctions against import of Mexican seafood products may be needed. Let's all hope we don't need to go there! We failed the baiji… we need to get this one right. We owe it not only to the vaquita, but also to all the other marine mammal species for which the threat of extinction lies looming, just around the corner.

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Figure 1: Vaquita mother and calf. Photograph reproduced with permission.

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Vaquita (*Phocoena sinus*) - The Little Known Porpoise

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Abstract

The vaquita (*Phocoena sinus*) is a small and very elusive porpoise that ranges in a limited geographical area in the Gulf of California, Mexico. Despite various efforts to conserve this critically endangered species, the latest research reveals that it may become extinct within a few years. Little is known of the vaquita as it was first scientifically described in 1958 and the first physical specimens were only recovered in 1985 when sighting surveys were also begun. A review of the little known and available knowledge on its biology, habitat, and physiology was compiled to better understand and recognise how truly unique this species is. After more than 5 decades since its discovery, if the current trends continue, it would seem that the only knowledge about the vaquita will be the very few photographs ever taken and some specimens recovered as bycatch. [JMATE. 2015;8(1):10-14]

Keywords: *Phocoena sinus*, Biology, Habitat, Physiology

Introduction

It is estimated that, if current trends continue, the vaquita (*Phocoena sinus*) will become extinct within the next 4-5 years (5). The vaquita was only 'discovered' less than 60 years ago and very little is directly known about this species and in fact there are a limited number of pictures of the vaquita in its natural habitat (4). The following article will describe its habitat, some unusual physiological traits, and general characteristics of this highly endangered and under studied porpoise.

The vaquita is a shy small porpoise of the family *Phocoenidae,* averaging 1.5 meters in length and weighing 45-50 kilograms (12). Figure 1a shows that its coloration varies from a dark grey dorsal surface which gets lighter along on its lateral sides and ending in a very light grey or white abdomen (12). There are no defined body stripes or color patches as seen in other species such as the Dall's porpoise (*Phocoenoides dalli*) (12). However, (Figure 1b), there are very well defined black patches that surround both the eyes and the lips (3). It is an elusive animal that avoids contact with boats, rarely congregates together in groups larger than 7 individuals, with a life span of approximately 21 years (3).

Habitat

The vaquita is endemic in the northwest region of the Gulf of California, also known as the Sea of Cortez, mainly between 30º45'N and 114°20'W flanked by the Mexican coastal regions of the Baja California Peninsula on the west and Mexican states along the northern and eastern coast line. (Figure 2a) The entire Gulf of California is a partially-enclosed sea measuring approximately 1,000 km long and averaging 150 km wide (19). In 1993, the Mexican government created the Upper Gulf of California and Colorado River Delta Biosphere Reserve (total size 12,000 km^2) of which approximately 8,000 km^2 is open water and coastline designated as a buffer region. (Figure 2b) The vaquita refuge or "core area" is an area of 2,500 km^2 and is approximately 40 km northeast of San Felipe, Baja California, Mexico, and is partially situated in this biosphere reserve (7) (Figure 2b).

The vaquita have been observed in waters as deep as 40 m (130 feet) and are most commonly found approximately 40 km (25 miles) off shore (12). Their distribution may be due to the warmer waters found near the coast: 30°C near the shore versus 26°C in deeper waters (3,10). The sea surface temperature ranges from 13-21°C in the winter, to 28-31°C in the summer (19).

The vaquita's aquatic environment is described as turbid and dynamic with various upwellings and tidal currents (7). The coastal environment is composed of mixed sands, silt, mud, with rocky reefs and rhodolith beds, coastal lagoons, seagrass beds, coral reefs, and hydrothermal vents (19). The high nutrient enrichment of the Gulf of California can be attributed to year-round tidal mixing and wind-driven coastal upwellings during the winter (8). This results in an increase in phytoplankton which becomes trapped on the inside of the basin. The gulf is also abundant in zooplankton which is a source of food for various fish larvae (8). As

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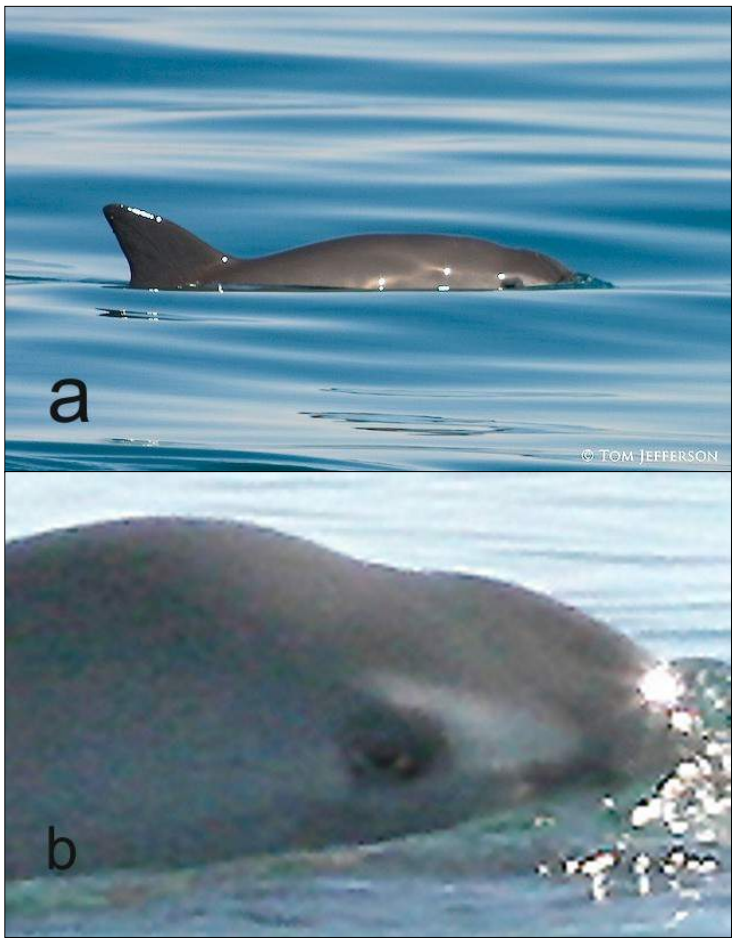

Figure 1: (a) Overall coloration of the vaquita. Photograph reproduced with permission (T. Jefferson); (b) Coloration around the vaquita eye. Photograph reproduced with permission (T. Kieckhefer).

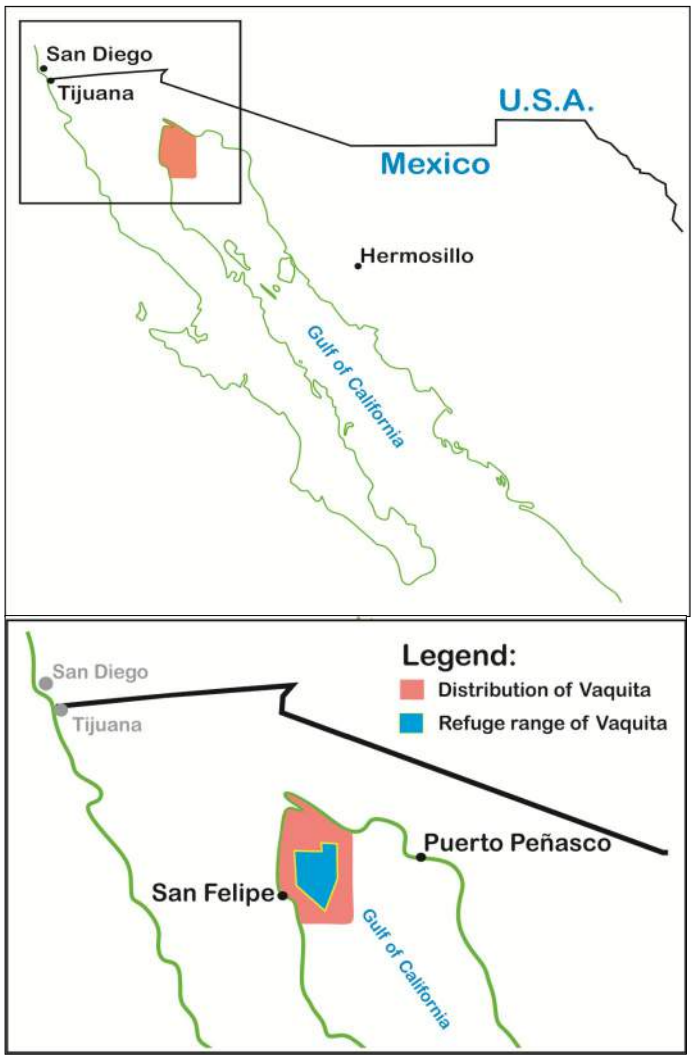

Figure 2: (a) The orange polygon represents the area encompassing the range of the vaquita located at the northern most area of the Gulf of California; (b) The vaquita current refuge area is depicted visually in blue.

such, the Gulf of California is rich in plankton which gives rise to an abundance of fish species that provides the vaquita with ample sources of food such as demersal or benthic fish, squid, and crustaceans (7). There are also a variety of large palegic fish such as tuna, billfish, approximately 40 elasmobranch species, and squid that live in the Gulf (8,19).

Other marine mammal species also flourish in the Gulf of California throughout the year, though they are usually found in deeper more oceanic waters south of the vaquita's range in the northern part of the gulf. There are in total 31 cetacean species such as blue (*Balaenoptera musculus*), humpback (*Megaptera novaeangliae*), gray (*Eschrichtius robustus*), sperm (*Physeter macrocephalus*), Baird's beaked (*Berardius bairdii*), and Bryde (*Balaenoptera edeni*) whales who utilize the gulf as a feeding and breeding area (8). Additionally, fin whales (*Balaenoptera psysalus*) are occasionally seen in the vaquita's range. The California sea lion (*Zalophus californianus*) is the only pinniped to breed in the Gulf, with over 13 breeding colonies reported (8). The Gulf is also a flourishing breeding ground for other seabirds and marine turtles species.

Evolution

It has been reported that the vaquita may have evolved from a population of animals, possibly related to Burmeister's porpoises, that moved up from the western coast of the South American continent to the Gulf of California as a result of numerous geological events that

started during the middle Miocene era (9,13). Its range has now become limited to the northern most area of that Gulf (Figure 1a). Despite having been a small isolated population, the vaquita has remained viable, and it has been speculated that this is because they were less susceptible to inbreeding. As a result, the vaquita has fared better than other species that have smaller populations (16).

Unique Physiology

Although related to several other species, the vaquita has a number of unique and unusual physiological traits. Compared to other *phocoena* species, it has a proportionally larger dorsal and pectoral fins and tail flukes in comparison to its body size. This is possibly to help optimize heat exchange as it lives in an area where there are higher water temperatures in summer versus other species that live in cooler waters (1,14).

The carpals, found in the pectoral fins of the vaquita are different from other *Odondocetes* in that they have only 3 proximal boney elements and one cartilaginous *accessorium*. As well, polydactyly or extra digits are present in both flippers which is not found in other closely related porpoises such as the harbour porpoise (*Phocoena phocoena*) (11). A sample skeleton is shown in Figure 3.

Figure 3: Skeleton of a Vaquita. Photograph reproduced with permission (T. Kieckhefer).

General Characteristics

Silber in 1991 discovered that the acoustic signals of the vaquita were similar to other *Phocoenidae* (ie. click duration, dominant frequency and bandwidth) however, their click structure differed from other species where the maximum frequency was greater and average bandwidth was slightly less (15). Samples of the skull structure is shown in Figure 4.

It has been reported that activities such as dive times, roll over intervals, surface times, and rolls per surfacing are lower in the vaquita when compared to other species such as the harbour porpoise (*Phocoena phocoena*) (14).

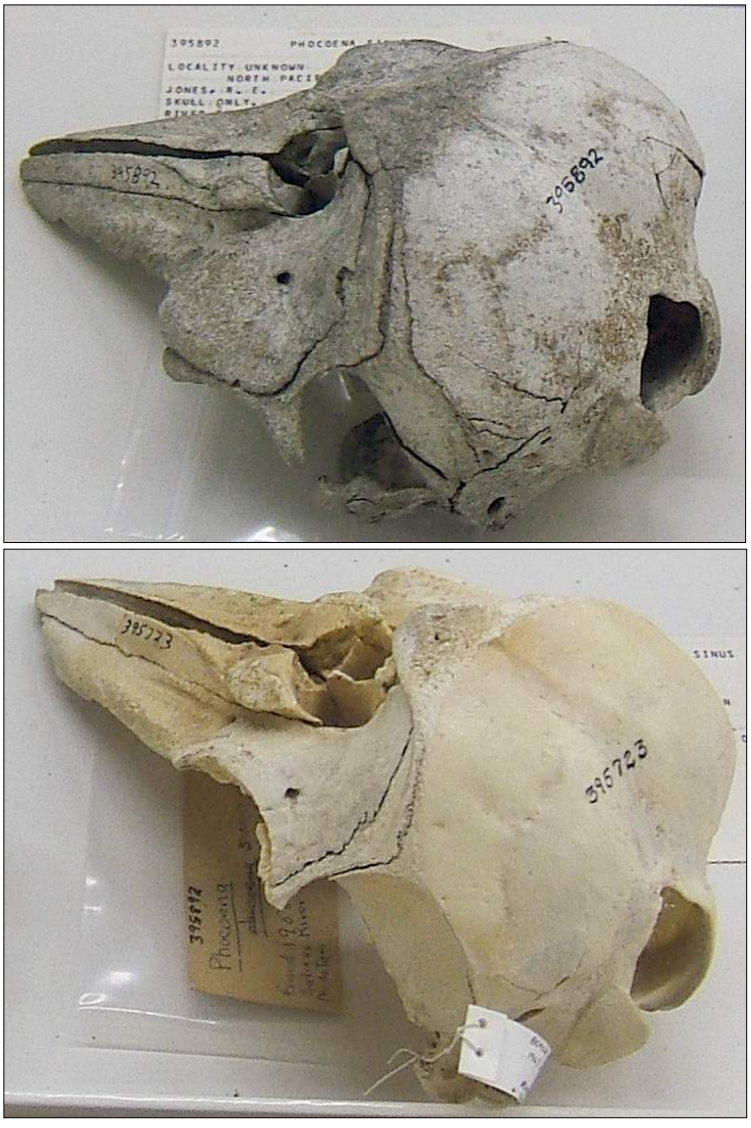

Figure 4: Samples of vaquita skull structures. Photograph reproduced with permission (T. Kieckhefer).

Conclusion

This small porpoise is highly endangered with only a few years left before it goes extinct (5). Due to the lack of concern and interest from the various political agencies and uncontrolled fishing practices, researchers have had few opportunities or specimens of this small porpoise to study which is reflected in the limited information available. The vaquita will soon be used as another example of a species that was not considered important enough to protect until it was too late. If current trends continue, in just over 5 decades, humans have directly caused another marine animal species to go extinct. How many more marine animals will future generations of humans only get to see and read about in books, the research literature, or on posters?

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A HISTORY (1990-2015) OF MISMANAGING THE VAQUITA INTO EXTINCTION- A MEXICAN NGO'S PERSPECTIVE

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Abstract

The population of the critically endangered vaquita has decreased alarmingly to less than 100 individuals due to by-catch in legal and illegal fisheries of totoaba, shrimp, shark, and others in the Upper Gulf of California. Mexico has implemented a series of conservation and fishery management measures to protect the vaquita since the early 1990's but to no avail. Most of these measures were put in place for political or economic reasons, and many were designed to fail. Fishery authorities worked for the benefit of fisheries and many times against environmental authorities. Two decades of lack of enforcement of weak and badly designed protection measures have doomed the vaquita to almost certain extinction. [JMATE. 2015;8(1):15-25]

Keywords: totoaba, fishery, panga, bycatch, embargo

Abbreviations Used:
CIRVA: International Committee for the Recovery of the Vaquita
CITES: Convention on International Trade in Endangered Species of Wild Fauna and Flora
CONAPESCA: National Commission of Fishery and Aquaculture
IUCN: International Union for Conservation of Nature
NAFTA: North American Free Trade Agreement (USA, Canada, and Mexico)
NGO: Non-Governmental Organization
PACE VAQUITA: recovery Plan for the Vaquita
PROFEPA: Environmental Enforcement Agency
SEMARNAP: Ministry of Environment Natural Resources and Fishery
SEMARNAT: Ministry of Environment and Natural Resources
TED: Turtle Excluder Device

The population of the Critically Endangered vaquita (*Phocoena sinus*) was estimated to be in July 2014 down to 97 individuals and it is expected to go extinct by 2018 (12). Mexico has implemented many conservation and fishery management measures to protect the vaquita since the early 90's (12), and it would appear that the Mexican government has been doing its upmost to save the vaquita from extinction but that is not the reality. Many of these conservation measures were put in place not to save the vaquita but for economic or political reasons, some were designed without using the best available information and some were designed to fail. We will present information of the legal measures taken by the Mexican government to protect the vaquita starting in 1990 until 2015, the way these measures were supposed to work, comments on how and why these measures were created or chosen, and their end result.

1990-1994 The NAFTA Years

Many of the conservation measures of the early 90s were the result of the Mexican government eagerness to demonstrate to detractors of the North American Free Trade Agreement negotiations (NAFTA) in the USA, that Mexico was really changing and trying to achieve similar levels of environmental standards as the rest of North America (13, 37). To attain this objective, Mexico's President pledged reforms to national and international policies, laws, environmental and enforcement institutions, government transparency and openness to the participation of society in environmental decisions (37).

The campaign to gain a quick signature of the NAFTA had immediate consequences for the conservation of the vaquita. In 1991 Mexico signed and ratified the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) without any reservations which included in its Appendix I the vaquita and totoaba (*Totoaba macdonaldii*) (3, 37, 43). This was unheard off given that Mexico had been unwilling to sign most international environmental treaties before the 90's (37). In fact, some authorities, like the Fishery Ministry, were totally against it.

In 1991, the first ever Mexican official list of endangered and threatened species was published with

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the vaquita and totoaba listed as endangered (17). Before that Mexico used international wildlife lists like the IUCN red list to identify which species were endangered or otherwise in the country, and this did not set well with fishery authorities.

Vaquitas were dying as by-catch of the totoaba fishery and for some time it was assumed that this was the main threat to the vaquita (56). In early 1992 the gillnets called "totoaberas" utilized to capture totoabas were banned (18). The fishery of this endangered species was banned in 1975 and it took the Fishery Ministry 18 years to ban the gillnets as well (20). This ban was significant for the conservation of the vaquita given that an important amount of legal and illegal bycatch continued to occur within this fishery (56). The Fishery Ministry allowed fishing of the banned totoaba under the form of "research" from 1983 to 1993 (56). This was done, even though they captured endangered vaquitas. This was frowned upon by the experts who said: "Given what was known already by the 1980s concerning the vaquita's endangered status and its susceptibility to entanglement in totoaba gill nets, it seems incredible that an 'experimental' fishery was allowed to proceed" (42).

The creation of the biosphere reserve of the Upper Gulf of California and Colorado River Delta in 1993 while the NAFTA negotiations were still going on was certainly the most important conservation action for this region. The decree established a total and indefinite ban in all of its area to the capture of vaquita and totoaba as well as several species of cetaceans, birds, reptiles, including all species identified as endemic, rare, threatened, or endangered (19). It established that the Fishery Ministry would define the areas and seasons for the bans on marine species not mentioned in the decree and that the management program of the biosphere should be published no later than one year after the decree entered into force.

1994- 2000 The Environment Fishery Ministry Years

The Fishery Ministry would not let environmental authorities tell them what they could and could not do to manage fisheries and published the Official Mexican Norm 012 that established measures for the protection of the totoaba and vaquita, which contained two dispositions, one was the unnecessary ban of the "totoaberas" gillnets since they were already banned and the other established a fishing ban in the core area of the biosphere reserve to stop the by-catch of the vaquita and totoaba (21). On first glance this would seem a good protection measure but it was not. The Fishery Ministry should have established indefinite or seasonal bans for other fisheries (shark, mackerel, shrimp, sierra, corvina, chano) within the reserve not only for the core area but for the buffer zone as well, and since they did not it meant that any fishery could work year round in the buffer zone. This would have a serious effect on the protection of the vaquita since essentially most of the sightings had been done outside of the core area, and thus the majority of its distribution area laid in the unprotected buffer zone and even outside of the reserve's boundaries (9).

This bickering between fishery and environmental authorities was just the first round of a very long fight which essentially has spelled the doom of the vaquita. The fishery authorities had their own agenda and it was not the conservation of a non-commercial species. Their objective has and will always be to ensure that the annual volume of capture of any commercial fishery does not drop. Even though they clearly stated in their fishery Norm 012 that by-catch was the problem the vaquita faced, they devoted their resources to prove otherwise by creating doubts in the recent classification of endangerment of the vaquita nationally and internationally, the mortality rates in fisheries and blaming the USA for cutting off the supply of fresh water from the Colorado River into the delta in the Upper Gulf of California and thus changing the whole marine ecosystem and decreasing nutrient inputs (31). In 1994, to the chagrin of those fishery authorities that refused to accept the vaquita's classification as endangered (30), the vaquita was again classified as endangered in the new format of Mexican Official Norms (known as NOM-059) which can only be reviewed and modified after 5 years of entering into force (22).

Later that year in December the Fishery Ministry received a serious slap in the face when the new President of Mexico, named a conservation biologist as head of the Fishery Ministry and a few weeks later dissolved the ministry and demoted it to a sub Ministry inside the newly formed Ministry of Environment Natural Resources and Fishery (SEMARNAP) again

with the conservation biologist heading it (7). In 1995, the Environmental Enforcement Agency (PROFEPA) created the office of natural resources within it. They would be in charge to enforce environmental laws including regulations to protect the vaquita and any other endangered species.

This change in the administration's institutions brought hope to the environmental sector that marine conservation issues would soon attain the importance they deserved but that hope was short lived. Although the fishery institution had suffered a severe blow, it was still too powerful and it became obvious that the management of fisheries would continue with business as usual, that is, paper thin measures favoring fisheries with no enforcement and no conservation.

The misgivings that the fishery authorities had created about the conservation status and threats to the vaquita only served to delay any real actions for its protection forcing all scientists to focus their research looking for documented proof that the vaquita was in real danger from fishery by-catch. Rojas *et al.* (2010) stated "Until the early 1990s there were disagreements on what were the most significant risk factors for vaquita survival (by-catch, lack of flow of the Colorado River and pollution). This controversy hindered management actions. Some authorities still believe today that by-catch is not the main threat to the vaquita." (41).

Probably the most damning affirmation from the fishery authorities was that the totoaba legal fishery only produced a by-catch of 4 vaquitas in ten years from 1983 to 1993 (30). Rojas *et al* (2006) questioned this affirmation: "It has proven impossible to determine how or why Fleischer (1996) reported only four vaquitas taken in the experimental fishery over the entire period from 1983 to 1993; in contrast, Robles *et al*. (1987) reported 3.5 times that number taken in the same fishery in one area (near El Golfo de Santa Clara) during the months of March and May 1985 and February 1986" (42). Additionally, Rojas *et al.* quoted that "Vidal (1995) listed 77 vaquitas definitely known to have been by-caught in totoaba gill nets during the period of the experimental fishery, 1983–93" (42). But we do know why Fleischer under reported the vaquita by-catch in the totoaba fishery. Specifically it was the result of a common used tactic by the fishery authorities to dismiss and discredit any by-catch information that could lead to an embargo.

This tactic of dismissal and discredit was used in the late 1980's during the tuna-dolphin dispute with the USA (32). Mexico was embargoed and had to change the way its tuna fleet operated (43). In the early 1990's they used the tactic again to avoid a shrimp embargo by manipulating the data of their sea turtle by-catch studies in the shrimp fleet (43). The embargo was avoided but they still had to change the way the fleet operated by making it mandatory to use Turtle Excluder Devices (TED) in trawl nets (20). In 2014, to avoid another embargo, the same tactic was used to dismiss decades of data of loggerhead sea turtle by-catch in the Gulf of Ulloa, BCS, including their own data (52). The decision of this embargo threat is still pending.

Vidal (1995) reported a bycatch of 128 vaquitas in several fisheries from 1985 to 1992: totoaba (68%), shark (28%) , mackerel and shrimp trawl fishery (7%) (56). D'grossa *et al.* (1995) confirmed that in 1993-1994 vaquitas were being caught in all kinds of nets for shark, ray, mackerel, chano, sierra and gill nets for shrimps used by small artisinal boats or pangas (14). This proof of by-catch occurring in many fisheries should have been enough to prove its threat to vaquitas and take measures to stop it or at least decrease it, but it was not.

In 1995 the Environmental and Fishery Ministry published the management plan for the biosphere reserve (46). However, it only described general dispositions that already existed in shrimp fishery regulations for the Pacific Ocean like using TEDs in trawl nets or trawling deeper than 10 meters (20). This does not help vaquitas since this depth puts the nets in direct contact with them (14,35). There was nothing in the management plan to address the by-catch of vaquitas in gill nets or shrimp trawls (35). It did not contain dispositions to reduce fishing effort of large vessels or pangas and only established that new studies needed to be made to mitigate the impact of fisheries in the buffer zone (35). Fishery authorities were able to block any language in the management program that would affect any fishery inside the biosphere reserve and still delay any future actions by demanding more research.

It was not until 1997 that something was done by the government that could have some impact in the conservation of the vaquita and that was the creation of the International Committee for the Recovery of the

Vaquita (CIRVA) (33). Finally there was an international task force that could work without most of the pressure from the fishery authorities to analyze data, focus research and give recommendations of what needed to be done to save the vaquita. Their first recommendations defined which risk factors were important (by-catch) and which were not (pollution, decrease of flow of Colorado river, nutrient decline, inbreeding). They found that regulations were not being enforced so they recommended enforcement be implemented. Their strongest recommendations was that "the Committee felt that existing mortality estimates strongly indicate actions to reduce by-catch be implemented at the soonest possible time" (9).

Fishery authorities disregarded the recommendations of CIRVA and continued to support fisheries and increase fishing effort n the Upper Gulf. As a result there was an increase in number of pangas fishing in the Upper Gulf. In 1995 it was estimated that there were 635 pangas working inside the reserve; 390 in Puerto Peñasco, 215 in Golfo de Santa Clara and 30 in San Felipe (1). Then in 1996 fishery authorities authorized the state of Sonora to increase their fleet by 41% in the Golfo de Santa Clara and 98% in Puerto Peñasco, and San Felipe in the state of California had an increase of almost 100% (39). By 1997, the number of pangas had doubled to 1269; 390 in Puerto Peñasco, 225 in Golfo de Santa Clara and 233 in San Felipe (1). Even fishers of the Upper Gulf were against the increase given that it meant more competition for them and they asked authorities to stop the increase in pangas (10).

During CIRVA's second meeting in 1999 they recognized problems that had been evident since 1993, the core area of the biosphere reserve did nothing for the conservation of the vaquita: "…the existing nuclear zone of the Reserve, designed primarily to protect totoaba spawning habitat, provides no meaningful protection to the vaquita." (10). The director of the biosphere reserve said: " …protection of vaquita from by-catch has probably not been significantly affected by the current boundary of the Reserve nor by the zones within it" and "the staff does not have punitive powers and, although they discourage illegal fishing activities, they are unable to prevent illegal fishing in even the nuclear zone of the Reserve" (10). We have to recall that the biosphere decree banned all fishing of vaquitas and totoabas, that norm 012 banned fishing in the core area, and the shrimp fishery regulation made it mandatory to trawl in depths where vaquitas live. So the only three existing fishing regulations were useless given they did not take into account the information on the distribution or habitat of the vaquita when they were drafted and could not be enforced inside the reserve. CIRVA recommended for the first time that the boundaries of the biosphere reserve needed to be expanded to encompass the real distribution area of the vaquita, along with a ban of gill nets and trawl nets, stop increase in number of pangas and increase enforcement of the regulations (10). None of this happened.

In 1999 Greenpeace Mexico launched a campaign to create a sanctuary for whales in all of the waters of Mexico. This proposal consisted of most of the large cetaceans that inhabit Mexican oceans but it also included the vaquita. At first SEMARNAP would not hear of it but by the end of 2000, the authorities of the National Institute of Fishery had come on board and supported it openly. Unfortunately in 2000 the administration ended and the campaign momentarily came to a halt.

Several law changes took place before the end of the administration, the National Fishery Charter was published in the Official Register which stated that the vaquita population consisted of 567 individuals in accordance to mortality estimations in gillnets. It also established that the bycatch limit for this species should be 0.2% per year (or zero rate) (24). The rules for Natural Protected Areas for the Law of Ecological Equilibrium and Protection of Environment were published (25). These rules brought with them the most strict dispositions regarding fishing inside reserves and basically they were the only real regulation that could stop by-catch of vaquitas. Article 81 established that during fishing activities inside reserves, by-catch could not exceed the volume of the object species and by-catch could not consist of species classified as at risk (endangered, threatened, under special protection) (25). No by-catch of vaquitas, totoabas, sea turtles or any other species at risk were allowed. Thus, there could not be any fishing for shrimp, since by-catch represented ten times more than shrimp in the Upper Gulf (50). This also applied to any fishery using gill nets since they capture incidentally several species at risk.

Another change was the creation of the Wildlife Law which established that all aquatic species that were classified in any category of risk such as extinct in the wild, endangered, threatened or especial protection (vaquita, totoaba, sea turtles, all marine mammals, among others) would be managed by this new law.

2001- 2006 The Hopeful and Dark Years
The Hopeful Period

A new Environment Ministry was created (SEMARNAT) and the sub Ministry of Fishery was once again demoted and became a mere commission, it was separated from the Environment Ministry and incorporated into the Agriculture Ministry where it is still today. This change would not solve the in-house bickering between fishery and environmental authorities. The new Wildlife Law was the domain of the Environment Ministry and thus, fishery authorities had no say in matters relating to the conservation or use of marine species classified as 'at risk'.

The campaign for the whale sanctuary started once again and was readily accepted by the environmental authorities. Nevertheless, most of the cetacean species in the proposal were not listed in categories of risk in norm NOM-059, so the norm was changed to include all marine mammals (22). This consequently gave the Environment Ministry the full decision in the creation of this refuge area. The campaign was successful and the whale refuge area was decreed in 2002 becoming the first ever refuge area under the new law. But before that happened there was an agreement from the NGOs supporting the campaign to drop the vaquita from the proposal, and seek a separate refuge area for the vaquita.

Fishery authorities refused to abide by the 2000 new rules for the natural protected areas and continued to issue permits for fishing inside the biosphere reserve, even though none of the shrimp trawlers or gillnetters could comply with the rules. So in September 23, 2002 the Environment Ministry issued an emergency norm (good for 6 months only) informing that the Agriculture Ministry (Fishery Commission) had lifted the ban on the shrimp fishery inside the biosphere reserve on September 6, 2002. However, this did not have any restrictions to said fishery to safeguard the species or habitats of the reserve (26). The emergency norm prohibited - any activity that used equipment to drag on the floor of the reserve (shrimp trawls), any fishing in the core area, any use of gill nets of more than 6 inches in the buffer zone, and any bottom gill nets. It only allowed 6-inch-mesh corvina nets and mesh shrimp nets under 200 meters in length, and only local fishers that inhabited the reserve when it was created could fish inside it (26).

The emergency norm would certainly stop any by-catch of vaquitas but it did not sit well with fishery authorities or fishers. It was recognized that: "… the problem when fishery authorities instead of working together with environmental authorities decide to be on the side of fishers, creates hard situations of conflict" (6). Most of the shrimp trawlers of the Upper Gulf have their port in Puerto Peñasco and fishers started protesting in front of governmental offices and blocked highways while federal police monitored the situation (53). After a series of negotiations and a month after the norm entered into force an agreement was reached between SEMARNAT and the shrimp trawling fleet, allowing only those from the region to enter the reserve with restrictions to avoid the vaquita distribution area. As well, they had to present an environmental impact assessment before the next shrimp season (53).

The Dark Period

The hopeful period only lasted two years when a new Environment Minister took over. In 2003 a group of NGOs decided to form a coalition to fight for the conservation of the vaquita and the Upper Gulf. The main objectives of this coalition were to get the Environment Ministry to decree a refuge area that would encompass all of the distribution of the vaquita and to ensure environmental law be complied with and enforced.

In September 5, 2003, an environmental impact assessment was presented by the shrimp trawler fleet of Puerto Peñasco to allow them to fish inside the biosphere reserve. Just 24 days later the Environment Ministry disregarding all the violations to the law, especially the rules for natural protected areas, resolved in favor of the shrimp trawlers (47). In October 2003, NGOs presented a legal recourse against this resolution and got a favorable sentence in November of 2004

annulling the Environment Ministry's resolution of the year before (48). The legal battle did not sit well with the new administration which took a different route of action with terrible consequences for the vaquita.

In 2004 during a meeting with the Commission of Natural Protected Areas, the NGO coalition was informed that for the conservation of the vaquita it would be either the refuge area or the law, not both. They said article 81 of the rules for natural protected areas was impossible to comply with and was causing conflict among fishers, governors, congressmen, and fishery authorities, so it would be modified, and it was in December 2004 (27). The modification allowed the authority to interpret the restrictions of article 81 as they wished. NGOs used all legal recourses against the illegal modification of the only existing rule that could stop by-catch of vaquitas, but to no avail.

In 2005, the President of Mexico announced the creation of the refuge area for the vaquita and the announcement immediately brought a flurry of protests from fishers, governors, fishery authorities, and congressmen. However, the Environment Minister who had the intention of running for the presidential ticket of his Party, refused to publish the decree not wanting to be stuck with the political scandal of it. The NGO community was fed up with him and his myriad of bad decisions on a whole range of environmental issues and decided to confront him through media pressure, he soon left without publishing the decree.

The third Environment Minister of this administration met with NGOs and accepted to take on any political costs from decreeing a refuge area, which he did in September 1995 (28). Later in December, the management program for the refuge area was published (29). Everyone was glad that the vaquita had its own protected area, but the area decreed was smaller than the distribution area and the management program did not clearly prohibit the use of gill or trawl nets inside it. It also established that fishery authorities should end the process of individualization of permits. The system allowed a fisher to have many different permits (8). Each permit was good for one panga or many (5). The fairly loose permit system made it impossible to know how many pangas existed in the Upper Gulf, with estimates contradicting each other (36).

The refuge area failed since it had no impact on the fisheries through lack of enforcement (5). Shrimp fishing went on unimpeded as "…75.72% of the shrimp artisanal catch is done in the Biosphere Reserve and inside 92.22% of the Vaquita Refuge" (39). Without any control, the number of pangas doubled from 2005-2007 (6). In fact the number of pangas has tripled since 1995 from 636 to 2070 by 2004 (1). The panga problem was much worse due to a high percentage of illegal pangas compared to legal ones working in the Upper Gulf. These were estimated by some to represent 40% (5). Others suggested it was 50% (8). There was controversy as still others claimed it to be >50% (50). At its worst, it was said that there were 3 illegal pangas for every legal panga (2). To the government, informal or independent fishers do not exist, they only recognize the permits issued (8).

2007-2012 The Buyout Years

A new administration took over in 2007, and a new management program for the biosphere reserve was published. It established the prohibition of commercial fisheries with any type of net inside the refuge area of the vaquita (50). Unfortunately this prohibition did not apply to the refuge area that lay outside of the biosphere reserve and fishing has concentrated in this area. Nevertheless it was apparent that the refuge area was not working and it was suggested that the problem was that fishers were not being compensated for their loss of income due to fishing restrictions and estimates of how much funding was needed for a buyout were being developed (57).

In 2008 the recovery Plan for the Vaquita (PACE Vaquita) was published and it determined that a compensation for fishers was needed (49). The compensation program is voluntary for fishers that can choose from 3 options: (a) Buy-out, fisher surrenders all fishing permits assigned to the boat, along with boat, motor and fishing gear (the number of permits surrendered determines the amount paid: 1 permit US$40, 000, 2 permits US$50,000 and 3 or more US$60,000); (b) Switch-out, fisher permanently uses alternative fishing gear for US$35,000; and (c) Rent-out, fisher stops fishing with gillnets inside the refuge area during the season for US$4,500 (4).

The results of this program were not what was expected. Participation decreased over time: in Buy-out, 153, 18 and 0 boats were turned in during 2008, 2009 and 2010 respectively; Switch-out was 51, 54 and 49;

and Rent-out was 542, 214 and 508 respectively (4). The sum of pangas being turned out permanently is 325 (Buy-out 171 and Switch-out 154). In 2014, after seven years of the program, the number of boats turned out permanently was only 247 (Buy-out) and 230 (Switched-out). Nevertheless there was no assurance that those fishers in the Switched-out option were really using the alternative gear (12).

The program has certainly not been a success mainly because the authorities did not take into account several factors including that most fishers don't want to stop fishing (40). As well, mostly older fishers about to retire were interested in the Buy-out and once all of these retire the Buy-out option would be useless and richer fishers are the only ones willing to risk a Buy-out. (4). Then there are those fishers that had enough permits and pangas to sell one and keep fishing, or those that cheat. Fishers are accustomed to receiving annual subsidies from fishery authorities worth millions in the form of pangas, outboard motors, fishing gear and fuel. The states of Sonora and Baja California in the Upper Gulf are number 1 and 3 respectively as the states who receive the most subsidies (44). As a result, fishers feel entitled to receiving government handouts so they can take or leave any program. But the real problem was that the program only worked for permit holders, thus disregarding half the fleet working in the area made up of illegal or independent fishers who don't have permits.

2013-2015 The Totoaba Embargo Years

Shrimp fishing efforts have increased dramatically in the past 20 years. In 1993 D'Agrosa *et al.* (2000) estimated 1358 fishing trips, while in 2006-2007 the estimate went up to 15,000 fishing trips (36). Then, in 2013-2014, it soared to 50,692 trips (55). In 2014 CIRVA announced that nothing had worked and the vaquita was heading for extinction in the next four years (12). The aerial survey showed no significant decrease of boats fishing inside the refuge area (12).

But most alarming was the increase in totoaba illegal fishing because the black market in China is paying more than US$8,000 for a kilo of swim bladder. It is assumed that most fishers in the area are now fishing illegally for totoaba and that organized crime is also involved.

International illegal trade of high value wildlife commodities cannot be stopped just from the supply end of the trade as it has been demonstrated with elephant ivory, rhino horn, tiger bone, bear gall bladder, rosewood, among many others (38, 54). Trying to restrict supply through law enforcement only increases the price of the commodity making it more desirable for criminals to participate in the trade. Trying to increase supply to lower the price through aquaculture will not work for two reasons: (a) Chinese don't value captive bred specimens and it only creates a new legal market for those willing to accept these specimens (34, 51); and (b) it does not account for the illegal fishing since their black market is not affected. The only measure that will work is decreasing demand in China to lower the price, but this takes time which the vaquita does not have.

Mexico announced a 2 year fishing ban along with a new compensation plan but has been delaying its entry into force while fishing inside the refuge area continues. This plan does not take into account the 50% of the fleet of illegal fishers without permits or the 20-30 years of recovery needed by the vaquita. It seems like another flawed measure which has come about for the wrong reasons as explained by Fishery authorities: "…if measures are not taken to mitigate the decrease of the vaquita population, the risk exists of an embargo to Mexican fishery products which will bring negative consequences to the national economy…"(45).

As long as environmental and fishery authorities keep working against each other and keep coming up with the same strategies that have not worked for the past two decades, the vaquita is doomed. This is the last opportunity to save the species so the authorities need to change the way they are addressing the problem. It is not a feud between fishery and environmental authorities or between fishermen and the vaquita. The solution is certainly not a stop measure for an embargo. It is only about using the best available information to develop correct protection measures and enforcing them to save a critically endangered species from extinction, just as Mexican laws mandate.

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Analysis of the artisanal fisheries of San Felipe, Mexico: Estimating incidental mortality of the vaquita (*Phocoena sinus)*

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Abstract

The vaquita (*Phocoena sinus*) is the most critically endangered cetacean species in the world and is a small porpoise endemic to the northern Gulf of California, Mexico. As fishing efforts increased greatly, over half of the species population was lost in 11 years. Gillnets for shrimp cause very high rates of by-catch, thus incidental mortality is the principal threat for vaquita survival. We estimated the current fishing effort in the Upper Gulf of California in order to estimate vaquita by-catch mortality. Fishing activities carried out by artisanal fishermen in the Port of San Felipe were monitored from September 15 - December 14, 2013 and from October 17 - October 21, 2013 in El Golfo de Santa Clara. Information on the number of pangas fishing was collected daily. Since every boat goes out and back once per day, we consider the number of trips as our measure of fishing effort. A total of 5,505 trips were observed during the sample period. Using Bayesian analysis, we estimated the fishing effort for the days that were not monitored to cover the entire shrimp season. A total of 50,692 trips were estimated using the Markov Chain Monte Carlo. We estimated the mortality rate per trip using the fishing effort estimation and available demographic information of the vaquita population. The mortality rate of the vaquita resulted in 3.15×10^{-6} trips^{-1}. By 2014, the estimate of current vaquita abundance was 97 individuals and using the number of fishing trips estimated per day, we estimated 28 vaquitas caught in artisanal nets for the 2013-2014 period. With this amount of fishing effort and lack of enforcement, unless drastic action is taken, the vaquita will be lost. [JMATE. 2015;8(1):26-35]

Keywords: *Phocoena sinus*, fishing effort, incidental mortality

Introduction

The vaquita (*Phocoena sinus*), a small porpoise endemic to the northern Gulf of California, is the most critically endangered cetacean species in the world. Their most concentrated distribution area is about 2,235 km^2, approximately 40 km east of San Felipe in Baja California, Mexico (26). Due to its capture in gillnets in a remote region where fishing has long been a primary economic activity, which provides the sole source of income for many people, this makes the vaquita uniquely vulnerable. As fishing efforts increased greatly in the past decades, over half of the species population was lost in 11 years, with only about 245 (95% C.I. 68–884) porpoises remaining in 2008 (13). The Vaquita Refuge protects only about half of the population and illegal gillnet fishing is still common inside and outside the Refuge. Gillnets for fish and shrimp cause very high rates of by-catch of vaquitas, thus incidental mortality in gillnet fisheries has been recognized as the principal threat for the vaquita (9, 18, 25-27).

In 1993, D'Agrosa *et al*. conducted the first and only study of vaquita by-catch (9). The study monitored the artisanal fisheries of El Golfo de Santa Clara through on-board observations and interviews with local fishermen as they returned from fishing. The by-catch mortality of the vaquitas was estimated to be 39 vaquitas per year (95% I.C. 14-93) in the El Golfo de Santa Clara. Assuming that in 1993 the artisanal fleet of San Felipe and the one in El Golfo de Santa Clara had the same fleet size, the incidental mortality of the vaquita population resulted in about 78 individuals for the upper Gulf of California (9, 26).

The estimations by D'Agrosa *et al*. have been used to estimate the abundance and the status of the vaquita population ever since (12, 16, 17). However, there is some uncertainty on the estimation of the vaquita by-catch due to the assumption that the fleet size was the same for both locations, the sampling period was not conducted during the most productive months of the shrimp season (October to December), and the artisanal shrimp fishery was going through an anomalous year during the study period (8, 26). All of these factors could have resulted in a subestimation of the fishing effort. On the other hand, the model used by D'Agrosa *et al*. could have been biased, because there was no monitoring of the shrimp fishery from

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September to December, probably resulting in an overestimation of incidental mortality.

In this paper we provide an updated estimation of the fishing efforts of the artisanal fleets of San Felipe and El Golfo de Santa Clara during shrimp fishing season in the upper Gulf of California (September to March) in order to improve vaquita by-catch mortality models to estimate population numbers and its trend and also provide further information on active number of artisanal boats in the upper Gulf of California. These two elements have been requested by the Mexican Ministry of Environment (SEMARNAT) in order to contribute to vaquita conservation actions.

Methods

Fishing activities carried out by artisanal fishermen in the Port of San Felipe (SF), Baja California, Mexico, were monitored from September 15th to December 14th 2013, covering the most productive months of the shrimp season (8). Information on the number of artisanal fishing boats or pangas leaving and returning to port was collected daily through direct observations using Fujinon 7X50 binoculars. In the morning, the number of pangas was documented from 4:30 to 7:30. In the evening, pangas were counted from 16:00 to 19:00 from the San Felipe Lighthouse using Big Eye 20x120 binoculars. This elevated location allowed to cover a more representative portion of the sites where fishermen go out to sea. Other than the number of pangas leaving and returning to shore, information was also collected on number of fishermen and nets per boat, outboard engine size, boat condition, and direction of navigation (as an index of apparent fishing ground to be approached). From October 17th to the 21st, the same methodology was used to monitor the fishing activities of El Golfo de Santa Clara (SC), the other small fishing town within the vaquita distribution area, in the east coast of the upper Gulf of California in the State of Sonora, Mexico. Since every boat goes out and back once per day, making only one trip per day, we consider the number of trips as our measure of fishing effort.

Estimation of fishing effort

To estimate the fishing effort for the days that were not monitored and to cover the entire shrimp season, which was not done by D'Agrosa *et al*., it was necessary to address the different factors that could affect the number of trips conducted on a given day such as (9):

Tidal amplitude. Fishermen of the upper Gulf of California did not go out fishing when the difference between high tide and low tide on a given day is smaller than 2 m (9). Thus, the difference between high and low tide for the days of the study represented the tidal amplitude measure and data was collected using sea level data of Centro de Investigacion Cientifica y de Educacion Superior de Ensenada;

Wind speed. Fishermen did not go out to fish if the wind conditions represent a risk while fishing. Wind speed data was collected from the San Felipe meteorological station (Estacion Sinoptica Meteorologica) of the Mexican Meteorological System;

Day of the week. In the study by D'Agrosa *et al*., fishermen of El Golfo de Santa Clara did not go out fishing on Sundays (9). Thus, the number of trips conducted on a given day can be unpredictable due to the fact that fishermen don't go fishing during festivities, weekends, etc;

Date. As per CONAPESCA, shrimp productivity is higher during the first three months of the shrimp season (8). Catches decrease by the end of the season, assuming that the same occurs to the fishing effort;

Fishing town. Due to the fact that there was not enough data to incorporate into the model on the fishing effort monitored in El Golfo de Santa Clara, both towns (SF or SC) were considered as a factor.

To estimate the number of trips (λ) for the days that were not monitored, the factors influencing fishing effort were analyzed within the framework of a Generalized Linear Model (GLM), assuming a negative binomial distribution. That is we assumed that:

$$\lambda = e^{\beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_{31} X_{31} + \beta_{32} X_{32} + \beta_4 X_4 + \beta_5 X_5}$$

Where e denotes the exponential function of the independent variables, X_1, X_2, X_4 y X_5 represented tidal amplitude, wind speed, town and date respectively, X_{31}

represented the rest of the days of the week and β_0, β_1, β_2, β_{31}, β_{32}, β_4 y β_5 states the estimated coefficients.

Four models with different combinations of the factors influencing fishing effort were essayed in order to select the best model, based on variance-covariance matrix as computed by the optimization routine of package AD Model Builder (10). Once the model was selected, a Bayesian Analysis approach was used to obtain posterior distributions of its parameters (11). Monte Carlo Markov Chain routine (MCMC) in ADMB was used for this purpose, which is based on an implementation of the Metropolis-Hastings algorithm (11).

There was no previous information on the parameters of the models, therefore we used uniform, semi-informative prior distributions. Every parameter was started at zero and 500,000 MCMC steps were used to construct posterior distributions. Convergence problems were inspected by plotting moving average and standard deviations against MCMC steps (requiring average and standard deviation to stabilize), MCMC run (showing a random walk instead of deviations to certain values), and histogram form of posterior distributions (showing well-formed tails and smooth contour).

Medians of every posterior distribution were used as point estimators of parameters. Percentiles were used to construct credibility intervals. MCMC chain was used to obtain posterior distributions of estimated number of trips for days with no monitoring effort, using observed values for variables as described before. The total fishing effort was then calculated as the sum of observed plus the estimated trips per day.

Mortality rates

There are only two specifically designed estimations of the vaquita abundance available in the literature. In 1997, the abundance of vaquitas was estimated to be 567 individuals and later in 2008, the abundance was estimated to be 245 vaquitas (13, 18). Using the point estimates, it means a 56.79% percent decline in 11 years, which translates to an average annual decline of about 7.36%. Using this average we constructed a table of expected vaquita abundances from 1997 to 2008, assuming the population was decreasing at a similar average annual rate prior to 1997 (Table 1). Also, in order to compare the results of this study and those of D'Agrosa *et al.*, the abundance and captured vaquitas were also estimated from 1992 to 1997 assuming the population was decreasing at a similar average annual rate (Table 1) (9).

During the last meeting of the Comite Internacional para la Recuperacion de la Vaquita (CIRVA), the vaquita abundance was estimated to be 97 individuals by 2014 (7). Using the same procedure as above, we estimated abundances from 2009 to 2013 with the average annual decrease rate calculated from 2008 and 2014 estimates. Based on the following demographic model the number of vaquitas that should have been captured (V_c) from 1997 to 2014 was estimated (Table 1).

$$Vc = N_t + \left[N_t * r\ (1 - \frac{N_t}{K})\right] - N_{t+1}$$

Where N_t stated the estimated abundance on a given year, N_{t+1} represented the estimated abundance the following year, K represented the carrying capacity of 5,015 vaquitas and r the intrinsic growth rate of the vaquita estimated to be 0.038 (13, 16). Subsequently, data in Table 1 was used to estimate mortality rates using the following equations:

$$M_{i(2013-2014)} = \frac{V_{c(2013-2014)}}{ET * (3/2)}$$

$$Mc = \frac{M_i}{V_{2013}}$$

Where *Mi* denotes the instant mortality rate (vaq/trip), which is defined for the period of study (2013-2014); *Mc* is the mortality rate *per capita* (trips^{-1}), *Vc* denotes the number of vaquitas that should have been captured during the period 2013-2014, *V* is the abundance of the vaquita population by 2013 and *ET* is the total fishing effort estimated. The latter is multiplied by 3/2 because the data obtained for the model only represents nine months of the year (2/3 of the fishing season) and assuming that from March to June the same number of trips are conducted by the fishermen the rest of the season.

Year	Abundance	Captured vaquitas
1992	830	87
1993	769	81
1994	713	76
1995	660	70
1996	612	65
1997	567	61
1998	525	56
1999	487	52
2000	451	49
2001	418	45
2002	387	42
2003	359	39
2004	332	36
2005	308	34
2006	285	31
2007	264	29
2008	245	27
2009	227	25
2010	210	39
2011	179	40
2012	146	32
2013	119	26
2014	97	UNK

Table 1: Abundance and captured vaquitas from 1992 to 2014. UNK= unknown.

Results

The artisanal fisheries of San Felipe were monitored from September 15 - December 14, 2013. In 72 monitored days, 4,079 trips were conducted by the artisanal fleet. In El Golfo de Santa Clara, the artisanal fisheries were monitored from October 17 - October 21, 2013 and 1,426 trips were conducted by the artisanal fleet in 5 days of observations.

Factors influencing fishing effort

Tidal amplitude was visually the main factor influencing fishing effort on a given day, followed by wind speed (Figure 1). When tidal amplitude increased, the number of trips conducted by the fishermen was greater and when wind speed decreased, a greater number of trips were observed. There were no significant differences between the day of the week and the number of trips conducted by the artisanal fleet (Figure 2).

Estimation of fishing effort for the days that were not monitored

Based on the variance-covariance matrix results, the model with tidal amplitude, wind speed, and day of the week was not selected because the variance of the parameters was above 32 million, therefore, the model with tidal amplitude, wind speed and town was selected as the best model. The link function of number of trips given the variables included in the selected model is:

$$\lambda = e^{\beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3}$$

Where e denotes the exponential function of the independent variables, X_1, X_2 y X_3 represent tidal amplitude, wind speed, and town effect and $\beta_0, \beta_1, \beta_2, \beta_3$ are the estimated coefficients.

There were no apparent problems of convergence after running the MCMC chain 500,000 times. The moving standard deviation and average stabilized since early in the chain and the run looks to travel in the sample space randomly along the walk. Figure 3 shows the posterior distributions of the coefficients of the parameters obtained after running the MCMC chain and Table 2 shows the point estimate (median of MCMC chain) of the coefficient for each parameter. The posterior distributions were symmetrical, with a similar form of a normal distribution.

For the days that were not monitored from September 15th 2013 to March 14th 2014, a total of 5,366 trips were estimated to be conducted by the artisanal fleet of San Felipe and 39,821 trips by the fishermen of El Golfo de Santa Clara (Table 3). Figure 4 shows the posterior distributions for the days with more and less number of estimated trips for both towns.

The total fishing effort estimated for the Upper Gulf, represented as the number of trips for the 2013-2014 fishing shrimp fishing season resulted in 50,693 trips (Figure 5). The fleet size at the beginning of the shrimp season of 2013 was assumed to be of 908 pangas (6). Thus, each panga made in average 51 trips per

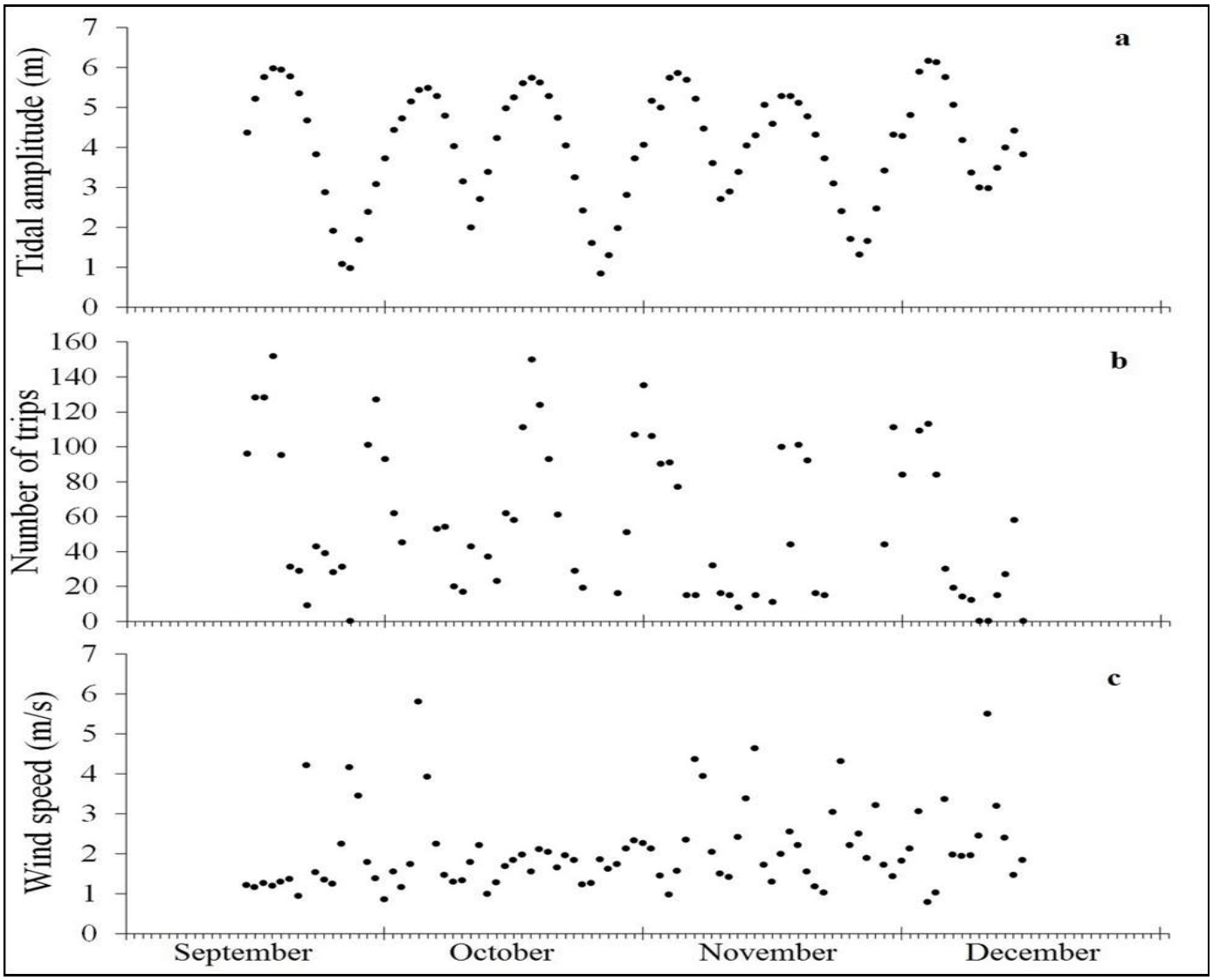

Figure 1: Daily raw datae regarding conditions and trips taken. Datae collected from September 15th to December 14th 2013 (a) tidal amplitude; (b): fishing effort; (c): wind speed. Each unit on the horizontal axis represents one day.

season.

The instantaneous mortality rate estimated for the 2013-2014 period was 0.00038 (95% I.C. 0.00036-0.00039) vaquitas/trip and the *per capita* mortality rate estimated was 0.00000315 trips^{-1} (95% I.C. 0.0000031-0.0000033).

Discussion

Incidental mortality, especially in gillnets, has been responsible for the decrease of the abundance of several porpoise species worldwide (14, 19, 22-24). Fishing effort represents a parameter that has made possible the quantification of the impact of fisheries in certain cetacean species (15). The information presented in this study represents the first update in twenty years documenting the dynamics and behavior of the Upper Gulf of California artisanal fishing activities to measure and describe the fishing effort impacting the vaquita population. The present study estimated only the fishing effort for the shrimp fishery and did not include the effort and mortality in illegal nets set for totoaba, an illegal fishery that has risen in the last couple of years.

Dynamic of the shrimp fishery

As seen in Figure 1, although the factors that define whether the artisanal fleet goes out fishing on a given day are clearly tidal amplitude and wind speed, we cannot disregard the fact that the behavior of the fishermen often determines the dynamic of the fishery on a given day. That is, in some occasions, the decision

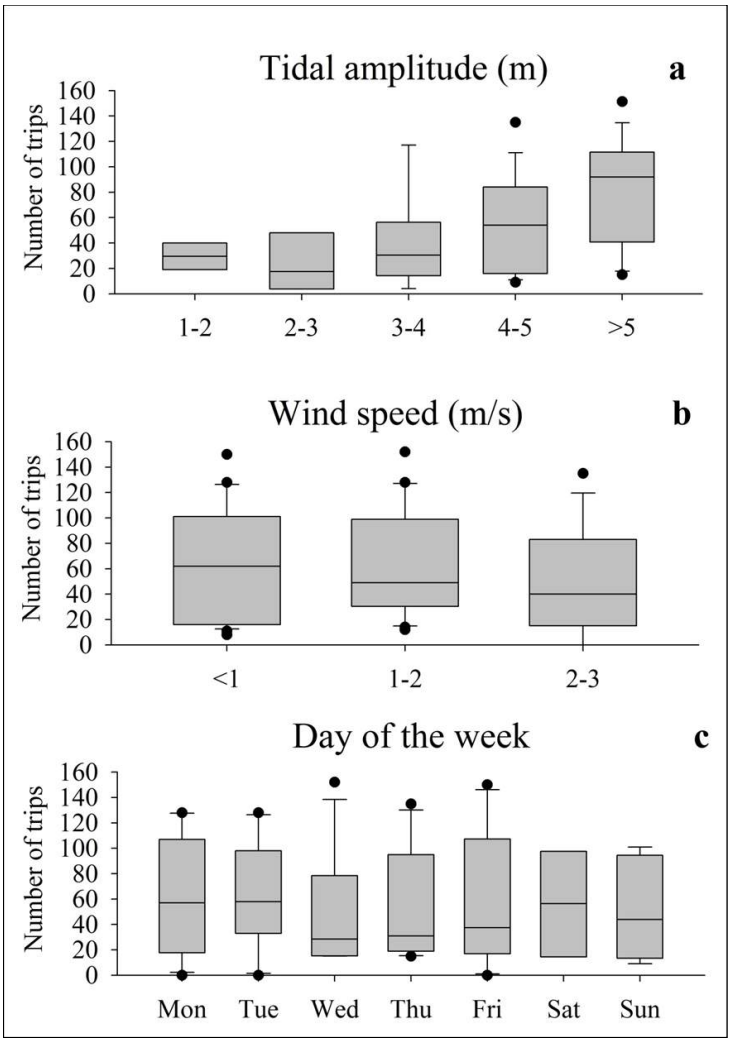

Figure 2. Distribution of the datae collected based on trips observed in San Felipe from September 15th to December 14th 2013 and its relationship with: (a) tidal amplitude; (b) wind speed and (c) day of the week.

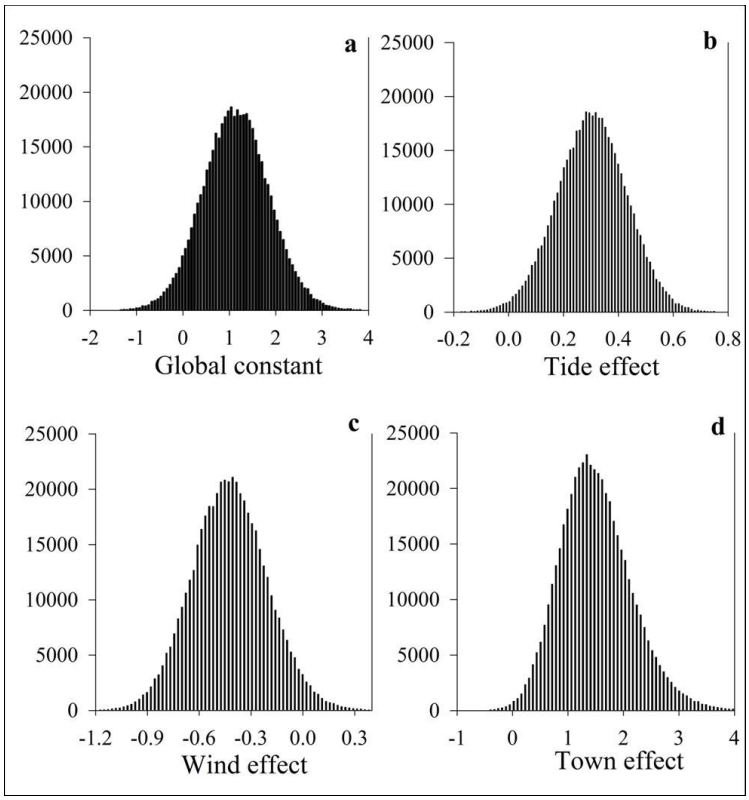

Figure 3. Posterior distributions of the estimated coefficients: (a) global constant, (b) tidal amplitude, (c) wind speed and (d) town. The median of each distribution represented the punctual value for each coefficient.

to go out or to return early from fishing is not a mechanic decision, but a subjective one, far from the environmental factors that determine a work day, such as sport events, local or religious festivities, etc. There is also a strong communication between fishermen in San Felipe, regardless of the cooperative in which they worked. One fishermen once said that after two or three days of fishing, the word spreads around that the shrimp has been harvested and then they rest the next two or three days. Also when wind speed was strong, fishermen stayed on their pangas at the FONATUR Marina and waited until wind conditions changed or until other fishermen said the conditions were appropriate to go out fishing.

By December, fishermen changed the direction of navigation. Specifically, during September and October they were observed coming back from the North. By late October fishermen would come back from the east and by late November and early December from the south. This could be due to the following factors; (a) the predominant wind circulation of the Upper Gulf has southeast winds during summer and northwest winds during winter. In the present study, the months of the sampling period covered both patterns (2); (b) shrimp tend to move to deeper water which transports the shrimp towards the south (4); (c) all reported that shrimp depletion often occurs when there are high levels of fishing effort (1). Thus, the mobility of the fishermen to the south by the end of November could have occurred because of the depletion of shrimp during the first months of the season or because of the empirical knowledge that has been gathered by the fishermen that the shrimp moves to the south.

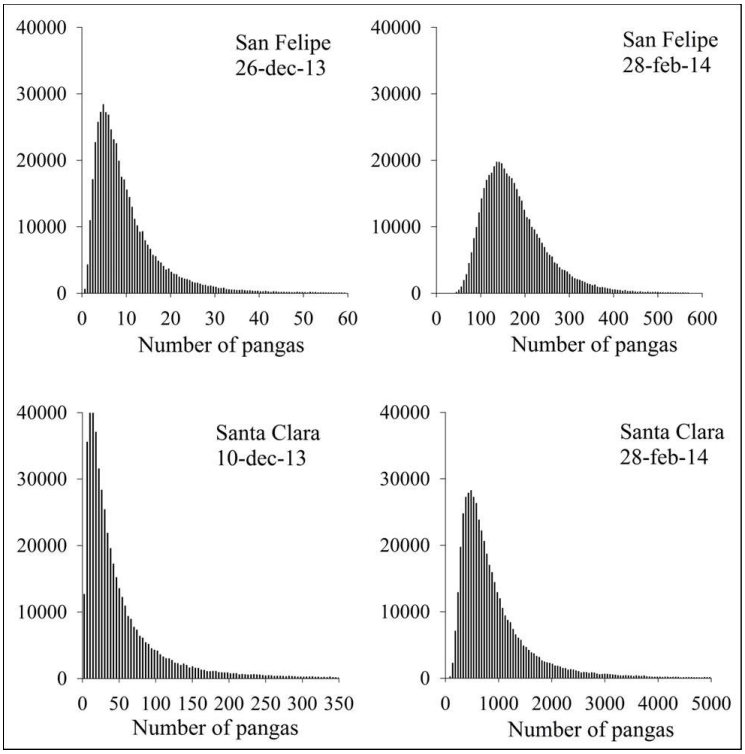

Figure 4. Posterior distributions of the fishing effort for the days with less (left) and most (right) number of trips estimated for San Felipe and El Golfo de Santa Clara.

Estimation of fishing effort

In 1995, D'Agrosa *et al*. reported that there were almost no fishing trips on Sundays while the present study demonstrated that fishing now does indeed occur on Sundays (Figure 2). This could represent a change in the artisanal fishermen behavior over the last twenty years. In 1993 the resource competition between fishermen was almost not existent, or maybe there were less cooperatives, resulting in lower rates of fishing effort. All this has changed and fishermen now use every opportunity to go out fishing, regardless of the day of the week.

The number of trips as a fishing effort measure has been acknowledged to be an important constituent to describe the interactions between the different components of the artisanal fisheries and a good indicator in places where there is lack of information and enforcement of fishing activities (19). As well, many authors have estimated the number of vaquitas that could have been captured on a given year, based on the size of the artisanal fleet under different scenarios (12, 17).

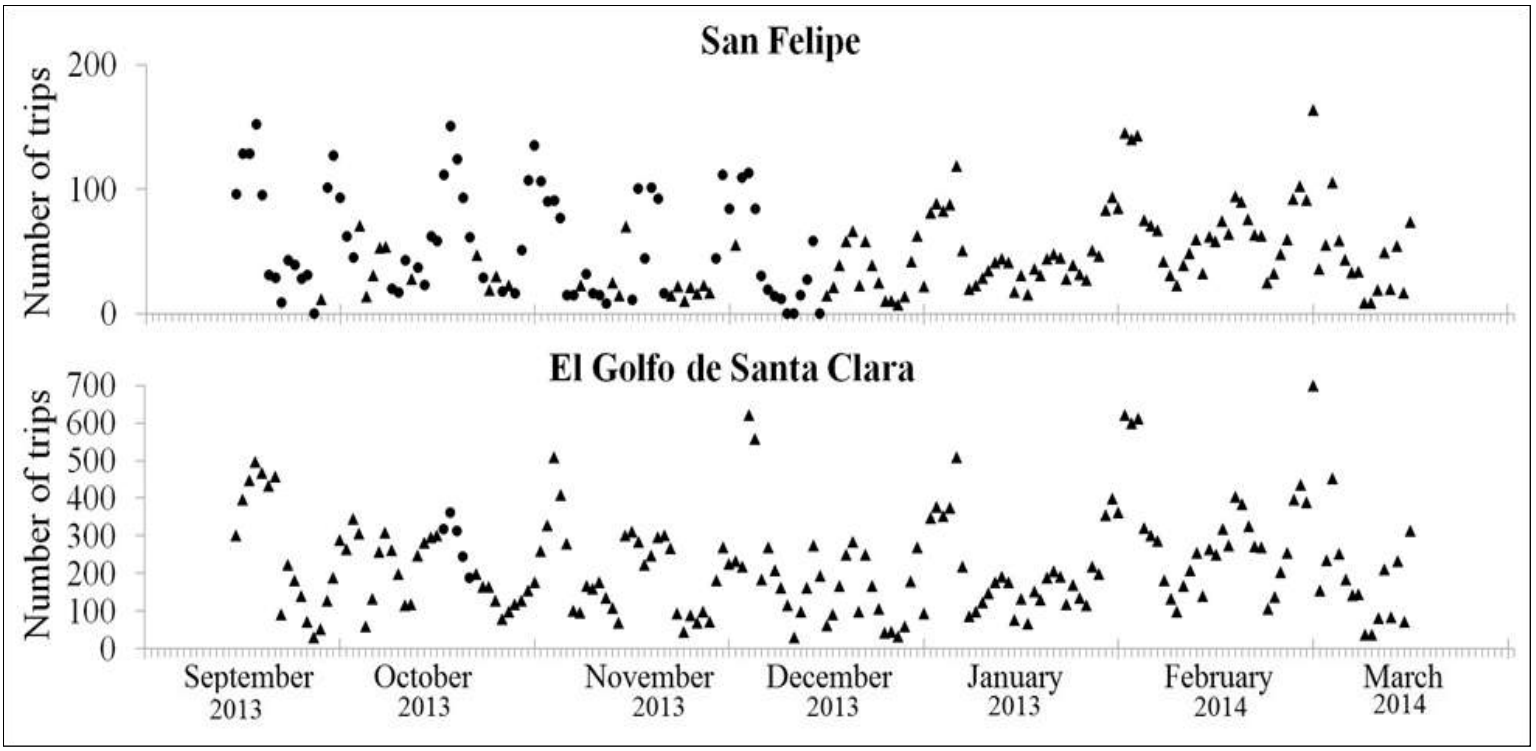

Figure 5. Observed (●) and estimated (▲) fishing effort for the 2013-2014 shrimp season of San Felipe and El Golfo de Santa Clara. In the horizontal axis, each unit represents one day.

Parameter coefficient	Point estimate	Credibility interval
β_0	1.1415	- 0.23791 , 2.56138
β_1	0.3040	0.05390 , 0.55020
β_2	0.4261	- 0.84226 , 0.01646
β_3	1.4527	0.37143 , 2.90951
r	0.6505	0.52632 , 0.78859

Table 2. Estimated coefficients for the parameters of the model.

	Point estimate	Credibility interval
San Felipe	5,366	3,164 - 9,991
El Golfo de Santa Clara	39,821	13,151 - 177,062
TOTAL	45,187	315 - 187,053

Table 3. Number of trips estimated for the Upper Gulf of California.

Morality rates

For the 1992-1995 period study by D'Agrosa *et al*., the vaquita population was estimated to be 830 individuals, resulting in a mortality rate of 1.19×10^{-5} trips^{-1} (9). There is a difference of one order in magnitude between the *per capita* mortality rate estimated in this study and the one estimated by D'Agrosa *et al*. in which the latter is higher (9).

These authors estimated that during the 1993-1994 period, around 9,000 trips were conducted by the artisanal fleet of the Upper Gulf, which could be an underestimation due to several factors. First, the *in situ* observations made in the study were conducted from February to August 1993. The shrimp fishery was the first to be monitored from late January to mid-March, resulting in the only fishery that was monitored intermittently. Thus, the fishery that was mostly represented in the model was sampled during the less productive months of the season, probably resulting in a underestimation of the fishing effort in El Golfo de Santa Clara.

In 1995 and later in 2012, the Scientific Committee of the International Whaling Commission (IWC) recommended that the incidental mortality of a porpoise such as *P. sinus* should not be greater than one-fourth of the potential rate of increase. This estimation has been used primarily with harbour porpoise (*Phocoena phocoena)* since this species has a similar growth rate to the vaquita. Therefore, the rate of increase of the harbour porpoise can be used to make mortality rate estimations for the vaquita (5, 13, 21).

Although the mortality rate estimated in the present study is nearly zero per set, when the number of trips estimated in more than 50,000 is taken into account, the mortality rate of almost zero becomes relevant. This is, if the number of vaquitas captured in a year is divided by the population size of that year the result is the mortality rate per year (5). Thus, for the 2013-2014 period, the number of captured vaquitas is calculated using the estimated mortality rate *per capita* (3.15×10^{-6} trips^{-1}), the estimated total number of trips for the 2013-2014 season (50,692 trips times 3/2 to estimate the number of trips for the entire year), and the vaquita abundance (119 individuals). Assuming that the vaquita mortality rate of 7.36% annual stayed the same from 1997 to 2008, the *P. sinus* abundance for the 2013-2014 period is 119 vaquitas. Thus, the number of captured vaquitas for the 2013-2014 period was estimated at 28 individuals. If this estimation is divided by the 119 estimated vaquitas, the result is an annual mortality rate of 24% of the population.

According to the last meeting of the Comité Internacional para la Recuperación de la Vaquita (CIRVA), held in July 2014, the best estimate of current abundance was 97 vaquitas, with an annual population decline of 18.5% from 2012 to 2014 (7). Therefore, the number of captured vaquitas in 2014 is 24 individuals.

Dividing this estimation by the 97 vaquitas estimated by CIRVA resulted in an annual mortality rate of 24%.

For both estimations, the vaquita mortality rate of 24% per year is six times its potential rate of increase (3.98%). The minimum viable population estimates the minimum number of individuals a population needs in order to be able to persist for a certain period in the future (3). A mortality rate of this magnitude suggests that the vaquita population could soon reach its minimum viable population size, decreasing any possibility of recovery. An immediate solution is to have the Mexican Government increase enforcement resources to ban gillnets and eliminate illegal fishing in the vaquita refuge. It is necessary to implement an alternative fishing gear that could benefit the local fishermen. Training and environmental education programs are required to teach local communities conservation strategies involving recovery. Vaquita population increase can only be achieved if all the involved organizations enforce strict conservation measures in collaboration with the government. The vaquita will soon be lost if by-catch is not eliminated immediately.

Less than 100 vaquitas now remain (7). Approximately 51,000 trips by the artisanal fleet were conducted, resulting on a mortality rate of more than 25 vaquitas per year. With a population growth rate of only 4%, the vaquita population is not capable of sustaining the current amount of fishing effort, particularly if the skiffs continue using gillnets as fishing gear. The vaquita can only recover if all gillnet fishing within its range is eliminated.

Acknowledgements

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