Arizona-Sonora Desert Museum Studies in Natural History

SERIES EDITOR

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Sea Turtles of the Eastern Pacific
Advances in Research and Conservation

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THE UNIVERSITY OF ARIZONA PRESS
TUCSON

THE UNIVERSITY OF
ARIZONA PRESS

www.uapress.arizona.edu

Library of Congress Cataloging-in-Publication Data
Sea turtles of the eastern Pacific : advances in research and conservation / edited by Jeffrey A. Seminoff and Bryan P. Wallace ; foreword by Peter C. H. Pritchard.
p. cm. — (Arizona-sonora desert museum studies in natural history)
Includes bibliographical references and index.
ISBN 978-0-8165-1158-7 (cloth :alk. paper) 1. Sea turtles—Pacific Ocean. 2. Sea turtles—Conservation—Pacific Ocean.3. Sea turtles—Research—Pacific Ocean. I. Seminoff, Jeffrey A. (Jeffrey Aleksandr) II. Wallace, Bryan P.
QL666.C536S44 2012
597.92'809164—dc23
2011051602

Publication of this book is made possible in part by a grant from NOAA—National Marine Fisheries Service.

Manufactured in the United States of America on acid-free, archival-quality paper containing a minimum of 30 percent post-consumer waste and processed chlorine free.

17 16 15 14 13 12 6 5 4 3 2 1

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No "Silver Bullets" but Plenty of Options

Working with Artisanal Fishers in the Eastern Pacific to Reduce Incidental Sea Turtle Mortality in Longline Fisheries

MARTIN HALL, YONAT SWIMMER,
AND MARILUZ PARGA

Summary

Sea turtles are vulnerable to capture in a variety of fishing gears, including nets, trawls, purse seines, and longlines. Sea turtle bycatch is significant in the eastern Pacific Ocean, an area of heavy fishing pressure because of high biological productivity and the resulting dual presence of numerous sea turtle and target fish species. Injuries and mortality related to bycatch can have significant negative impacts on the region's sea turtle populations.

Ideally, to optimize available resources to reduce the incidental mortality of sea turtles, fisheries managers must identify which fisheries or fishing methods have the most significant impacts on sea turtle populations. This involves determining, with an acceptable level of precision, the level of incidental mortality in all relevant fisheries. In this chapter, we discuss the challenges to achieve this objective and identify opportunities for reducing fishery impacts to sea turtles in the eastern Pacific and beyond, focused primarily on longline fisheries. Specifically, we describe the concept of "lines of defense" for sea turtle fisheries interactions, which can be envisioned as layers of risk or opportunity that are unique for each fishery, with the idea that efforts must be taken to prevent turtles from interacting with fishing gear initially, to ultimately ensuring that an animal has the highest chance of surviving with minimal damage. We strongly promote the training and use

of at-sea fisheries observers as well as cooperation with fishing communities to increase chances of long-term sustainability of conservation efforts.

Introduction

From the moment hatchlings emerge from their nests, sea turtles are exposed to a variety of hazards (see plates 11 and 12). One of these is the incidental capture in fisheries. Turtles are vulnerable to capture in fishing gear for a variety of reasons, including chance encounters with gill nets, trawls, purse seines, and longlines, many times because they are drawn near the fishing gear by either bait or catches as they search for food (plate 11). Depending on numerous factors associated with the fishing operation, this incidental capture can lead to mortality. We define bycatch as the individuals discarded dead or likely to die as a result of the fishing operations, which can have significant impacts for some of the sea turtle populations in the eastern Pacific Ocean. This region is an area of heavy fishing pressure because of high biological productivity and shared presence of numerous sea turtle and target fish species. Moreover, the continental shelf that lines the eastern Pacific Ocean is extremely narrow, and because much of the productivity occurs over the shelf and the shelf break, extensive fishing grounds are within close range of the artisanal and industrial fishing fleets operating out of eastern Pacific ports. Just as this region is a haven for productive fisheries, the adjacent coasts of the eastern Pacific from México to Perú host numerous large congregations of nesting sea turtles. For this reason, high turtle densities overlap with intense coastal and pelagic fishing effort, leading to unavoidable interactions.

Ideally, to optimize available resources to reduce the incidental mortality of sea turtles, fisheries managers must identify which fisheries or fishing methods have the most significant impacts on sea turtle populations. The answer is a question not simply of numbers of turtles affected, but also of which sex and age (or size) classes are most vulnerable to which types of gear. Clearly, a primary goal of sea turtle conservation is to reduce incidental capture and mortality to sustainable levels. However, we must first achieve the monumental task of determining, with an acceptable level of precision, the level of incidental mortality in all relevant fisheries. In this chapter, we discuss the challenges to achieve this objective and identify opportunities for reducing fishery impacts to sea turtles in the eastern Pacific and beyond, particularly as they relate to longline fisheries.

Fisheries of the Eastern Pacific

In the eastern Pacific, the nutrient- and biologically-rich continental shelf is very narrow (for example, compared with the Gulf of México, or the Southwestern Atlantic coasts). Even small vessels can easily reach areas with characteristics of open ocean, and a relatively benign climate in parts of the regions (fewer hurricanes or large storms than other ocean basins) allows them to venture offshore in search of pelagic species such as tunas (*Thunnus* spp., *Katsuwonus pelamis*), swordfish (*Xiphias gladius)*, and sharks (e.g., *Prionace glauca*, *Sphyrna lewini*, *Alopias* spp.). Both artisanal and industrial fisheries are an important source of employment for the nations of the region, and their catch constitutes an indispensable source of protein for local consumption as well as important exports to foreign markets.

Fisheries operating from different ports or countries may share a fishing ground, and their gear technology can be similar. However, artisanal fisheries exhibit a bewildering array of modes of operation. Some boats fish most of the year with the same gear, while others change seasonally, and yet others use more than one type of gear in the same fishing trip (e.g., switch from setting longlines at the surface and bottom in successive sets, or even from longlining to gill netting). Most of the small boats (<10 m in length) operate their lines or nets manually and therefore have limitations in the amount of gear they can deploy. They also tend to deploy their gear at shallow depths, frequently less than 30 m.

On the other hand, industrial-scale longline fishing vessels, generally larger in size, deploy their lines much deeper, from approximately 100 to 400 m, to catch species such as bigeye tuna (*Thunnus obesus*). Because sea turtles spend most of their time in the upper layers (frequently at <30 m; Polovina et al. 2002; Swimmer et al. 2006; Seminoff et al. 2008), turtle bycatch rates are orders of magnitude lower in deep-set gear than in shallow-set gear. Inversely, the probability of surviving a net entanglement or longline hooking is much higher for shallow gear because the turtles have a greater chance of reaching the surface to breathe than they do in deep-set gear (Gilman et al. 2006).

Quantifying Sea Turtle Bycatch and Bycatch-Related Mortality

Despite many researchers' assertions that fisheries are a driving force in the decline of some sea turtle populations, we still are very far from having reliable estimates of the mortality caused by the different fisheries (Lewison et al. 2004) or by other factors. Similar to such estimation for any pelagic species, the range of methods available to estimate sea turtle mortality is quite limited because of costs and logistical constraints. In some populations, with knowledge of the age structure, or a series of abundance data, it is possible to estimate the total mortality and then, based on some reasonable assumption for natural mortality, to separate the component caused by the fishing operations (which can then be useful for understanding impacts at the population level). However, age determination of sea turtles has proven to be a fairly complex process (e.g., Bjorndal et al. 1998). In the future, use of electronic tags, such as passive integrated transponder (PIT) tags, which can be used on hatchlings (Rowe and Kelly 2005), may increase the accuracy of the process and greatly facilitate more accurate estimations.

Strandings of sea turtles have been used as a proxy for mortality (Epperly et al. 1996; Alava et al. 2005). However, strandings reflect only a sample of dead turtles within reach of the coasts, subject to oceanographic and atmospheric variability, and if the causes of mortality are not easy to identify (e.g., turtles washing ashore without clear hook or net scars), strandings do not allow a clear distinction between natural and fishing mortality (Epperly et al. 1996). Stranding studies could provide some valuable information on the species and sizes present in an area, but not reliable estimates of mortality, or in some cases of the causes of mortality.

These limitations bring us to the estimation of incidental mortality through sampling of fishing activities of fleets. This can be obtained through the use of fishers' logbooks, observers, or fisher surveys. Fishers' logbooks can provide valuable data on the distribution of effort and operational modes (e.g., day or night sets), but the fishers are usually dedicated to the fishing

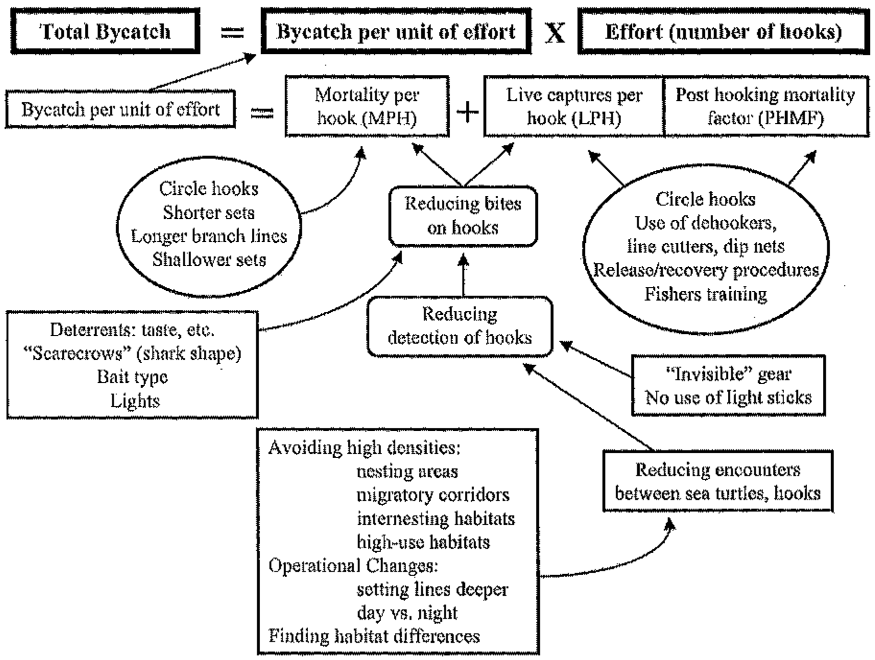

FIGURE 6.1. Components of sea turtle mortality.

operations and are not likely to keep complete records of the incidental captures. We believe that, in most cases, fisher surveys have little or no quantitative value, because the questions are never perceived in a neutral way, and answers reflect biases from either fishers or researchers. Thus, in order to effectively manage sea turtle bycatch in fisheries, it is important that efforts are undertaken to directly observe, through time and space, the extent to which gear types are more prone to interact with sea turtles (fig. 6.1).

Observer Programs

The use of observers is critical to gather the type of detailed data necessary to pinpoint seasonality, geographic range, fishing techniques, and species most associated with sea turtle bycatch. Observer programs can produce a vast amount of information that can be used to understand why bycatch happens and what affects its magnitude. If observers are well trained and collect data on a series of variables that are known or expected to affect the bycatch rates, they can be used to generate databases that have proven

invaluable to reduce bycatch in many cases (e.g., Hall et al. 2001). We believe that observers are a valuable tool for the scientists searching for solutions, and they are also very important in creating and maintaining open communication links with fishers and in bringing their knowledge and feedback to scientists and managers.

Once the existence of a problem has been identified, the first step is to develop a research program to identify the technological or operational changes that could reduce bycatch mortality, while at the same time allowing fishers to continue to practice a sustainable fishery by improving the selectivity of the gear and minimizing the impact on other species, the habitat, and so on. This type of program addresses a wide range of issues, from understanding how turtles and target species sense their environment in order to devise ways to attract or reject them from fishing gear, to behavioral and ecological studies that can help us understand why bycatch happens and how to avoid it. By ensuring the participation of the fishing community in the development of the solutions (Campbell and Cornwell 2008), we ensure that the solutions will be effective and practical and will increase the chances of adoption by the fishers themselves, reducing problems of rejection or noncompliance that could later deter full use of the bycatch reduction strategy.

The Lines of Defense in Longline Fisheries

A reasonable way to approach a sea turtle bycatch mitigation program is the concept of "lines of defense" (Hall 1996), which can be envisioned as layers of risk or opportunity that are unique for each fishery. In the case of a longline, which we will use as the main example, the six lines of defense are sequential and involve preventing turtles from, first, encountering the fishing gear; second, detecting or approaching the bait; and third, biting the bait. Subsequently, efforts must be taken to, fourth, minimize the number of hookings (i.e., use hooks that slide off the mouth without setting); fifth, use hooks that are less harmful (i.e., with higher posthooking survival probability) and are easier to remove; and sixth, use the best dehooking and resuscitation techniques to improve the turtles' chances of surviving the encounter.

While the specifics of these lines of defense differ for each fishery, the sequence is generally similar. Stopping the problem in the initial lines of defense is better, because it decreases the risk of mortality. However, the problem of mortality reduction should not be seen as an all-or-nothing battle to win at any given line of defense. Rather, it should be seen as a gradual process of containment, where reductions in successive lines lead to a sustainable level of mortality based on a precautionary approach that would allow all populations to persist. Research efforts should be accompanied by programs to implement effective mitigation methods and to work with the communities to obtain their authentic support for the program and its objectives. However, it is important to note that a bycatch reduction strategy proven successful in one area or one fishery may not be universally so for all regions and fisheries. This variability calls for rigorous regional verification of what constitutes a "successful" bycatch reduction strategy.

One solution is to reduce or eliminate the fishing effort that results in the mortality. This heavy-handed approach may be impossible to enact, given the social and economic burdens it would cause in most fisheries; thus, we concentrate our attention on the ways to minimize the impacts while allowing fishing activities to continue.

First Line of Defense: Separating Sea Turtles and Fishing Gear

VERTICAL SEPARATION. Because most pelagic-stage turtles spend most of their time near the surface (with the exception of olive ridley turtles), deeper gear will have fewer interactions than shallower gear. For instance, in longline gear, deeper hooks have lower hooking rates. The Japanese industrial longline fishery targeting tunas in the eastern tropical Pacific deploys its hooks at 100–400 m of depth, and their hooking rates (in turtles per 1,000 hooks) are a fraction of those observed in shallow sets in the coastal zone (Gilman et al. 2007). In some cases, the shallower hooks from a deep-set longline may be removed to reduce encounters (Beverly et al. 2009). In other cases, bottom longlines or nets may have more interactions with benthic foraging turtles.

HORIZONTAL SEPARATION. If it were possible to define (or predict with high levels of accuracy) the route and timing of turtle migration toward the breeding and nesting areas, it may be possible to establish spatial-temporal closures to reduce gear interactions with migrating turtles. The existence of "migratory corridors" has been postulated (Morreale et al. 1996), but more recent tagging studies have shown more diffuse patterns of movement (Seminoff et al. 2008; Shillinger et al. 2008). The oceanographic correlates of the movements add a component of spatial variability (Polovina et al. 2004; Shillinger et al. 2008). When the density of sea turtles is very high, such as in the vicinity of nesting beaches, the most sensible solution is to avoid hooking and entanglement by establishing temporary fishing closures. This type of mitigation method is most likely to succeed if the closures are temporary and agreed upon by the fishing community, or if they are heavily enforced, which is rarely a viable option. Oftentimes, ambitious attempts to create marine parks and protected areas end up becoming "paper victories" without real means of enforcement or a steady stream of funding to finance them. An alternative way to identify and avoid high risk areas is the use of fleet communication among fishing vessels (Gilman et al. 2006), which we believe has great promise as a conservation tool.

HABITAT SEPARATION. When turtles and target species have different habitat preferences, it may be possible to constrain fishing operations to the target species habitat (Plotkin 2003; Canadas et al. 2005; Sasso and Epperly 2007; Kobayashi et al. 2008; Seminoff et al. 2008). This is more difficult when sea turtles and targeted fish species are associated with the same oceanographic features, such as sea surface temperatures or oceanic fronts (Polovina et al. 2000; Swimmer et al. 2010a). Attempts to delineate the habitats of both target and protected species are fraught with difficulty, yet efforts are under way to achieve this using TurtleWatch, a real-time, online system using satellite imagery to guide fishers away from predicted locations of sea turtles based on their habitat preferences (Howell et al. 2008). This represents yet another conservation tool that would be especially valuable to fishers operating in regulatory regimes with hard caps, such that successfully avoiding turtles could result in fewer fishing restrictions.

Second Line of Defense: Prevent Turtles from Detecting the Bait

Physiological and behavioral research has helped to identify the sensory mechanisms used by target fish species and sea turtles to draw them into the vicinity of the fishing gear. By understanding how animals sense their environment, we can modify fishing gear or bait so that it is less attractive to turtles (e.g., reduce its visibility via camouflaging in water, make floats transparent, mask the smell of bait) but still attractive to the target species. We can also use the information to attract turtles away from the nets or lines, to prevent them from approaching the gear. Primarily visual senses, and secondarily olfactory senses, are believed to play stronger roles than auditory senses in attracting turtles to fishing gear or bait (Constantino and Salmon 2003; Swimmer and Brill 2006; Southwood et al. 2008).

Third Line of Defense: Prevent Turtles from Biting the Bait

This approach aims to render bait unattractive or even repellent to the turtles without affecting its attraction to the target species. Bait can be presoaked in different chemicals and used the regular way, without causing additional work to fishers, which would facilitate adoption. Unfortunately, attempts to date to develop repellent scents for the turtles have not been successful (Swimmer and Brill 2006).

Another approach is to use a visual "deterrent" based on a predator–prey relationship. This model assumes that prey such as sea turtles would flee upon sight of a predator, such as a shark. Efforts are under way to test this idea, with preliminary success (Wang et al. 2010). Additionally, trials in a gill net fishery in Baja, México, have also shown that illuminating fishing gear in nighttime fisheries by adding LEDs or light sticks reduces sea turtle capture (Wang et al. 2010). A theoretical, as yet untested idea for a visual deterrent is a blinking light that relies on differences in the speed of vision between turtles and fish to repel turtles from the fishing gear.

Fourth Line of Defense: Reduce the Number of Turtles Hooked

Use of different hook sizes and shapes have been used to achieve a reduction in the number of animals that become hooked or entangled in the gear. Laboratory experiments with captive sea turtles and a variety of tested hook sizes suggest that using wider hooks could reduce the number of hooking events (Watson et al. 2005; Gilman et al. 2007; Read 2007; Piovano et al.

2009). Relatively wider circle hooks can be used instead of the straight J or Japanese-style tuna hook (fig. 6.2), which are commonly used in most longline fisheries. It is believed that circle hooks are effective for two reasons: (1) the increased width makes it more difficult to hook a turtle's mouth in the first place, and (2) because of the hook's shape, it should slide along the mouth while the fish or turtle takes the bait and lodge externally in the jaw, rather than being swallowed for a deep hooking, with a higher assumed probability of mortality (Cooke and Suski 2004). Fishing experiments have produced essentially two types of outcomes: either (1) the hooking rates of sea turtles are reduced and fewer deep hookings occur, or (2) the hooking rates remain the same but fewer deep hookings occur, so the effectiveness is essentially related to severity of injury and likelihood of surviving the encounter, and not whether turtles were caught on the line. Recent reviews of circle hooks (Gilman et al. 2006; Read 2007) reach the general conclusion that they seem to reduce bycatch of some species, including turtles. Furthermore, use of circle hooks has not shown to decrease catch rates of target

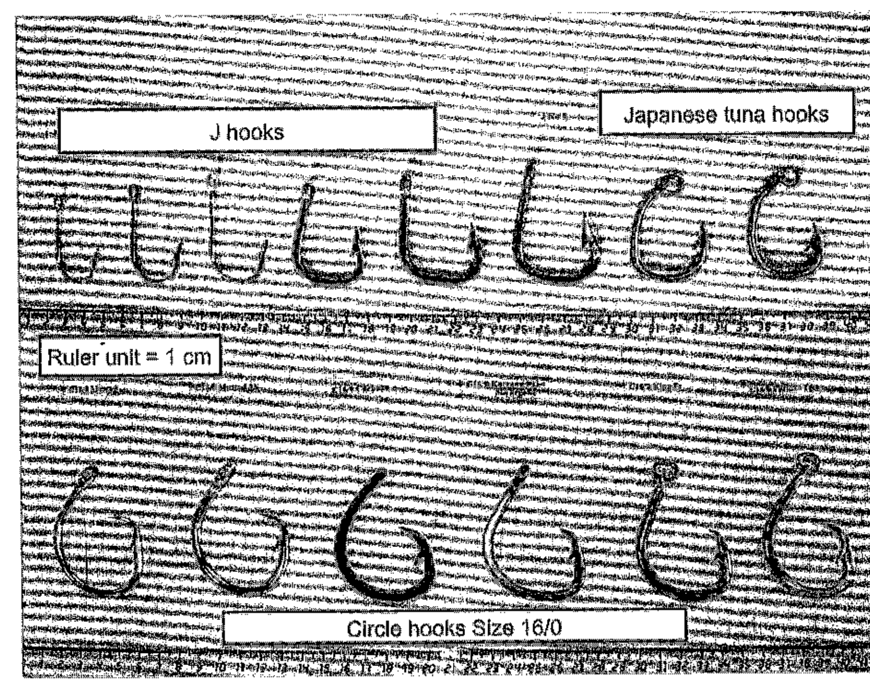

FIGURE 6.2. Different hook types typically used in longline fishing.

species, thereby improving the chances that the hooks will be more easily adopted by the fishing industry. An exception is the fishery targeting mahimahi (*Coryphaena hippurus*) in the Pacific off the coast of South America, which catches smaller fishes at the beginning of the season. For this range of sizes, circle hooks do not produce at the same level as the traditional J hooks. However, one could argue that the capture of a large number of small fishes is not a desirable outcome of the fishery, and the selectivity of the circle hook in this case could also be beneficial to the sustainability of the target species fishery.

Different bait types also have an impact on the hooking rates of turtles (Watson et al. 2005). Fish bait (e.g., mackerel) results in fewer hookings than does squid bait, probably because of how the turtle removes the bait from the hook. Because of the sucking action of the turtle, the squid bait plus hook is generally brought deeper into the turtle's digestive tract. In contrast, the turtle likely takes smaller bites of bait fish and thus avoids biting the metallic hook. The combination of fish bait plus circle hooks has the highest reduction of sea turtle hooking rates of all hook/bait combinations (Watson et al. 2005).

Fifth Line of Defense: Use Hooks that are Less Harmful

If the turtle is going to be hooked, a number of factors and actions can play a significant role in determining the fate of the animal. The special shape and the usually larger size of circle hooks tend to affect turtles in the mouth, as opposed to J and tuna hooks, which usually hook turtles in the esophagus and stomach. Many scientists assume that hooks left in the esophagus have a high percentage of mortality, but several authors question this belief (Tomás et al. 2001; Alegre et al. 2006; Valente et al. 2007), at least for smaller hooks. The esophagus in turtles is strong and very muscular, and in many occasions the hooks that pass through cause only local scarring that does not affect the long-term health of the animal. There is also an erroneous assumption that hookings in the mouth are generally benign. In fact, mortality resulting from hookings in the mouth most likely depends on the exact location of the hooking. For example, based on observations, a hook affecting the epiglottis will probably lead to mortality due to aspiration pneumonia, and a hook that has fractured a jawbone or is affecting the mandibular joint might stop a turtle from eating or cause a severe infection. Tests of hooks with wires attached to the shank ("appendage hooks") suggest that they could in theory be used to reduce rates of turtle capture, but they also resulted in significant declines of target species catch rates, so this method would not be acceptable to fisheries (Swimmer et al. 2010b). One should also consider that, if a sea turtle swallows this type of hook, the related mortality would increase because of the larger size of the complete hook and the transverse wire crossing the esophagus.

The importance of the location of the hook depends very much on the attitude of the fishers when they incidentally catch a turtle, and their level of desire to recover the hook. For example, Mediterranean surface longline fishers do not attempt to recover the hooks from captured turtles. Rather, even when turtles have the hook lodged externally (e.g., jaw), fishermen cut the line and let the animal go with the hook still lodged. In this case, especially if the hooks are small, it might be better for the animal to swallow the hook than to have it hooked in the mouth. However, concerns remain regarding the influence of the hooks lower in the gastrointestinal tract. Mainly for economical reasons, fishers in some regions of the eastern tropical Pacific tend to remove every hook from these animals, so the more external the hook and easier it is to remove, the better for the fishers and the turtles—removal of deeper hooks may result in mortality.

Sixth Line of Defense: Use the Best Dehooking and Resuscitation Techniques

Although the location of hooking may be the most important factor affecting the posthooking mortality of incidentally captured turtles (Ryder et al. 2006), we feel strongly that the actions taken after the hooking event to ensure a safe release to the sea may be the most critical. In most cases, the correct handling of a captured turtle coupled with a good hook-removal technique can greatly increase the probability of that animal surviving the encounter. Here are some recommendations arising from our recent experience on the subject:

1. Reduce to a minimum the pressure caused by pulling on the line with the hook lodged in a turtle; this will reduce the possibility of tears and larger lesions in the mouth or esophagus.
2. If the crew and boat can accommodate bringing the turtle on board, make sure that is done with the use of a dip net. Alternatively, hold the turtle's shell and bring it on board, if possible. Avoid grabbing the animal only by the flippers, because this can damage the tendons and ligaments of the joints, reducing the mobility of that flipper for some weeks.
3. If a turtle is very weak or appears to have drowned, never put it on its back, which restricts the animal's breathing as all the organs in the coelomic cavity push on the lungs, which are located in the dorsal area.
4. If the animal is strong and lively, and you put it on its back for easier handling, be careful when you return it to its original position. The stomach and intestines in these animals are very loose in the coelomic cavity, and it is easy to cause them to twist, which always leads to death.
5. If you cannot remove a hook, always cut the line as short as possible. Long pieces of line can get tangled up in the animal's flippers, causing constriction and eventually necrosis of that limb. If the animal swallows the line, then it will cause severe damage to both the stomach and the intestines, leading in all cases to the turtle's death after a long agony.
6. Hook removal is complicated and in many cases determines the chances of the animal surviving after release. It should only be carried out by well-trained observers, who can then train the fishers. They should have the right equipment for this job and proper protocols describing how to proceed in the different cases. Among other things, they should know the different anatomical parts of the mouth, to assess the severity of the lesions caused by the hook; how much tension to put on a line in order to remove a swallowed hook; how to use the different dehookers; and when it is best to leave a hook inside the turtle.
7. If the boat and crew are not prepared to bring the turtle on board, use a line cutter to cut as much line off the turtle while it is still in the water. This may require a line cutter with an extension. Once again, this should be done with caution so as not to add further injury to the turtle.

Conclusion

The ideal bycatch reduction strategy is one that uses all opportunities available to reduce capture, and to improve survival if capture happens. It promotes technological or operational changes that could reduce bycatch mortality, while at the same time allowing fishers to continue to practice sustainable fishing by improving the selectivity of the gear and minimizing the impacts on other species, the habitat, and so forth. Such a program would touch on a wide range of issues, from understanding how turtles and target species sense their environment, in order to devise ways to repel or attract them to fishing gear, to behavioral and ecological studies that can help us understand why bycatch happens and how to avoid it. There should also be an exploration of sensible and effective management options that can help in the process. And of course, the practicality of implementation should also be taken into account, to maximize successful adoption and compliance. By ensuring participation of the fishing community in the development of solutions, we ensure that solutions will be effective and practical and increase chances of adoption. Achieving this goal would reduce problems of rejection or noncompliance that could later plague full use of the bycatch reduction strategy.

Perhaps the main lesson that researchers involved in bycatch reduction programs have learned is that successful programs require the full participation and engagement of the fishing communities (Hall et al. 2007; Campbell and Cornwell 2008). Success stories come from cases where scientists and managers learned to communicate and fully collaborate with fishers in the search for solutions. The time is ripe for the development of academic programs that include, in addition to biological and ecological components, exposure to social sciences that could facilitate understanding the structure and function of fishing communities, their decision-making processes, and especially some real-world experience with these communities to prepare new cohorts of scientists to address bycatch issues successfully. In the eastern Pacific Ocean, the fishing sector ranges from highly advanced industrial fleets to pirogues and numbers in the hundreds of thousands of fishers. More resources should be dedicated to understanding how these communities function (Campbell and Cornwell 2008).

Success ultimately hinges on fishers' willingness to adhere to whatever bycatch reduction strategies are promoted by shore-bound fishery managers and sea turtle conservationists. The engagement of fishers in the reduction of mortality will play a crucial role, and interaction with the fishing community is perhaps the most significant component in the process. If fishers are aware of the vulnerable condition of sea turtle populations and are willing to help mitigate fishery impacts, then putting the best technology available in their boats (e.g., hooks, and instruments to handle the turtles and remove the hooks) and teaching them the best mitigation techniques will be the best approach.

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