# Profile and Influence of the
# Successful Fisher–Inventor of Marine Conservation Technology

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**Abstract**

Anecdotally it is often said that fishers are the best inventors of marine conservation technologies. In this paper I describe case studies of Turtle Excluder Devices (TEDs) and dolphin conservation technology, offering empirical evidence that fishers are successful inventors of marine conservation technology. I describe the Local Inventor Effect, in which adoption of a technology is disproportionately high in the geographic area near the inventor's home. In one case, the adoption of a local invention was 600% higher than that of the next most popular device. Further, I present the Successful Inventor Profile for inventors of marine conservation technologies. This profile consists of three characteristics (1) a successful conservation technology inventor will have extensive experience relevant to the problem and potential solutions, (2) he or she will have extensive experience in fabrication, and (3) he or she will have the ability and tendency to employ mental and/or physical models, to assemble and refine inventions.

**Keywords:** Turtle Excluder Device, sea turtle, tuna-dolphin, bycatch, inventor, invention, mental model, technology transfer, diffusion of innovations

## INTRODUCTION

'If any lesson was learned during the TED [Turtle Excluder Device] saga, it should have been that devices put in trawls must be simple and best designed by fishermen. The door to acceptance of TEDs by industry was opened when simple, shrimper designed devices were certified. All TEDs in use today are based on the original jellyball excluders, not one designed by non-fishermen.' – Dave Harrington, Georgia Sea Grant

As exemplified by this quote, in marine conservation and fisheries communities it is often said that fishers are the best inventors of marine conservation technologies (i.e., devices that protect organisms or habitat) (Hall *et al.* 2007). However, there have been no studies of the inventive power of fishers in general, or of the characteristics that help define what makes one fisher-inventor more successful than another. As sea turtle and other marine species populations continue to decline, in part due to bycatch (i.e., the incidental capture and/or harming of non-target species while fishing), and as calls for collaborative research and management increase, it is important to develop tools for identifying problem-solving partners who are most likely to succeed.

One of the most well-known examples of marine conservation technologies is the TED, which consists of a hard grid or mesh panel that is placed in a trawl net to direct sea turtles and other large objects out of an escape hole in the net. The federal government solicited the help of shrimp trawlers and others in the invention effort for TEDs. The initial recruitment techniques were broadcast methods, which allowed contact with the most—but not the best qualified—constituents. For example, government scientists requested the aid of personal contacts or made broadcast solicitations in public fora, such as shrimping industry association meetings and newspapers. As a result of these methods, many of the initial industry participants were industry leaders who were interested in the political and management aspects of the shrimp fishery and in some cases had not been active commercial fishers in years. These individuals could publicise the turtle bycatch problem to other shrimpers, but they did not have the expertise needed to solve the problem.

A profile of successful fisher–inventors would serve as a search tool to aid targeted recruitment of individuals with skills most pertinent to solving bycatch problems. In so doing, the

invention process would become more effective and efficient, possibly decreasing the time between problem identification and commercially practical solutions. In the case of sea turtle species—with some populations facing extinction in the near future—time is of the essence (Spotila *et al.* 2000).

In this paper, I examine the case study of TEDs and give evidence of the success of shrimpers as inventors and government scientists as modifiers of TEDs. I also discuss the positive influence shrimper–inventors have on local adoption of their TEDs. I support the findings in the TED case study by presenting a secondary case study of the invention of dolphin conservation technologies to reduce dolphin bycatch in the United States tuna purse seine fishery. Further, I will suggest that the key characteristics of successful fisher–inventors include their extensive experience with fishing and fabrication, and their ability to engage in mental modelling.

A mental model is a mental representation of a physical reality. These models can be used to run empirical mental simulations for the purposes of reasoning and problem-solving. For example, if one was trying to move a large piece of furniture through a doorway, one could mentally reconstruct the dimensions of the doorway (i.e., the parameters of the problem) and simulate different way of fitting the furniture through the door (Nersessian 2007). Mental modelling is a strategy used in successful technological inventions, such as Alexander Graham Bell's invention of the telephone and the Wright brothers' invention of the airplane (Gorman & Carlson 1990; Johnson-Laird 2005). In these case studies, the process of mental modelling allowed the examination of a mechanical representation and its variations, modifications, and flaws. I will give evidence that three of the most successful fisher–inventors in the TED and tuna–dolphin case studies used mental modelling as well.

## METHODS

This research focussed on the history of the TED in the years between 1976 (when US government research began to reduce sea turtle bycatch) and 1998 (the last year of TED development before major changes in TED regulations). The research also examined the history in the years 1964–1981 in the tuna–dolphin case study (dolphin bycatch was first brought to the government's attention in 1964, while 1981 was the last year that a dolphin conservation technology development programme existed within the United States government). Most of the major developments in dolphin conservation technology for the tuna industry occurred before 1981.

I gathered data for this study by examining inventions, conducting interviews, and analysing documents. I conducted 49 on-site semi-structured and unstructured personal interviews with key informants. I conducted interviews in all nine commercial shrimping states in south-eastern United States as well as California, the base of the tuna purse seine fishing fleet, and Washington, a centre for development of dolphin conservation technologies. These interviews mostly occurred during five, two-week long trips during June 2003 to January 2004.

The sample population consisted of representatives from stakeholder groups, including federal and state policy-makers and managers, scientists, inventors, change agents, as well as fishing industry and environmental organisation representatives. I initially established a sample frame using a purposive sample of prominent individuals frequently mentioned in the literature pertaining to the study (Coe *et al.* 1984; Durrenberger 1996; Joseph 1994; Joseph & Greenough 1979; Maiolo 2004; Margavio & Forsyth 1996; Maril 1983, 1995; National Research Council 1990, 1992; Orbach 1977). The purposive sample led to a snowball sample (Bernard 2002); informants were asked to name other individuals who were knowledgeable about the case study and as many as possible of these individuals were then interviewed as well.

I also collected hundreds of documents, including government reports, research records, workshop reports, panel reports, memos, personal letters, educational videos and pamphlets from the key informants' archives.[1] I analysed the text of the interviews and documents using a grounded theory approach, allowing theories to grow out of categories and concepts that initially emerged from the analysis of the texts of documents and interviews (Strauss & Corbin 1998).

In order to determine the characteristics of successful inventors of marine conservation technologies, I composed biographic profiles of inventors from each case study, using a convenience sample as determined by the availability of information. I examined the profiles for similarities in light of the varying success of the inventions. Further, I contrasted the inventive processes of these independent inventors with those used by government scientists.

For the purposes of this study, I needed to delineate between successful and unsuccessful technologies. The definition of success differed for each case study due to the difference in circumstances and goals of each invention programme. For the tuna–dolphin case study, I defined success as those technologies deemed worthy of implementing, in that the industry adopted them independently or that National Marine Fisheries Service (NMFS) recommended or mandated their use. I defined a successful TED as one that was government certified, that remained certified until the year 2002, and that commercial shrimpers widely adopted.[2] In order to assess adoption of individual TEDs at a state and county level, I analysed the distribution of TEDs by the Georgia and North Carolina State Governments in two free TED giveaway programmes. Because these state programmes gave shrimpers the TEDs of their choice, they yield important insight into the popularity of certain TEDs in North Carolina and Georgia in the late 1980s. I also re-analysed TED preference data from a survey conducted in North Carolina, South Carolina, Georgia, and Florida for the South Atlantic Fishery Management Council (Kitner 1987).[3]

## TED CASE STUDY

Sea turtle bycatch became a management issue for the

shrimp fishery after the listing of sea turtle species under the Endangered Species Act.[4] During the 1970s, the NMFS (the agency responsible for managing marine fisheries in the United States) listed as threatened or endangered all six species of sea turtles that occur in US waters. Shrimp and sea turtles share the same habitat—coastal waters along the south-eastern United States. Shrimpers tow large nets known as trawls for about three hours at a time. Sea turtles encountering these nets often attempt to escape but some are captured. Unable to surface to breathe, many turtles drown during these long tow times (National Research Council 1990). The NMFS has responsibility for managing marine fisheries and protecting sea turtles, and hence, to fulfil this responsibility, in 1976, it began research to invent a device to reduce sea turtle bycatch.

In 1980, the Georgia Sea Grant, a government agency charged with marine extension, sent the NMFS photos of a 'jellyball shooter' and suggested a similar approach could work for excluding turtles. The jellyball shooter had been used for decades, especially by shrimpers in South Carolina and Georgia, when cannonball jellyfish, S*tomolophus meleagris*, were so dense that shrimping could not otherwise occur. The jellyball shooter consists of a grid that is placed in the neck of the trawl to block large objects from entering the net bag and directs them out of a hole cut in the net. The first jellyball shooters were likely just grates from a charcoal grill. Based on these photographs, independently and simultaneously, Dr John Watson, head of the NMFS TED programme, and Eddie Toomer, a contract vessel captain from Winter Haven, Florida, conceived of placing the grid within a frame. Dr. Watson constructed his version from fragile plastic and Capt. Toomer constructed his from heavy steel. Though Toomer's original model was too heavy and Watson's too fragile to be practical, NMFS drew ideas from both to apply to a new design. NMFS called the resulting prototype the TED (Figure 1).

In 1986, Georgia Sea Grant realised that shrimpers might soon be required to use TEDs, and so reasoned that it would be best if they were given a choice among different TEDs. That year they sponsored a demonstration event comparing four different TEDs (1) a collapsible NMFS TED, (2) Georgia Jumper TED, (3) Cameron TED, and (4) the Matagorda TED. The three new TEDs were modified jellyball shooters invented by shrimpers from Darien, Georgia; Cameron, Louisiana; and Matagorda, Texas, respectively.

Based on the results of the turtle exclusion testing, NMFS announced the certification of all three new TEDs in the Federal Register in 1987. Later that year Georgia Sea Grant tested the Morrison Soft TED for certification. A soft TED uses a panel of mesh webbing instead of a hard grid to direct the turtle to the escape hole. The Morrison Soft TED created by Sonny Morrison of South Carolina excluded 100% of the turtles during testing, so NMFS certified it (52 FR 37152). In subsequent years NMFS continued to modify the NMFS TED and industry continued to develop new hard and soft TED prototypes. Over the course of this case study a total of 13[5] styles of TED were certified for use in the shrimp fishery, but the level of adoption of these devices varied greatly.

## Success of TEDs

The only large-scale observations of TED preferences during the time frame of this case study were the TED preference survey commissioned by the South Atlantic Fishery Management Council and the TED giveaway programmes in Georgia and North Carolina (Kitner 1987). At the time of these activities in the late 1980s, the only certified TEDs were the NMFS TED, Georgia Jumper, Cameron TED, Matagorda TED, Morrison Soft TED, and Parrish Soft TED. The Georgia TED giveaway programme distributed hundreds of Georgia Jumpers, a few NMFS and Morrison Soft TEDs, and one Matagorda TED. The North Carolina TED giveaway programme, which took place in 1988, gave away a total of 584 TEDs—65% of these were Georgia Jumpers, 28% were Parrish Soft TEDs, and 7% were Morrison Soft TEDs (Unpublished data). In both of these programmes, shrimpers requested the Georgia Jumper (Figure 2; invented by Sinkey Boone, a Georgia Shrimper) more frequently than any other TED.
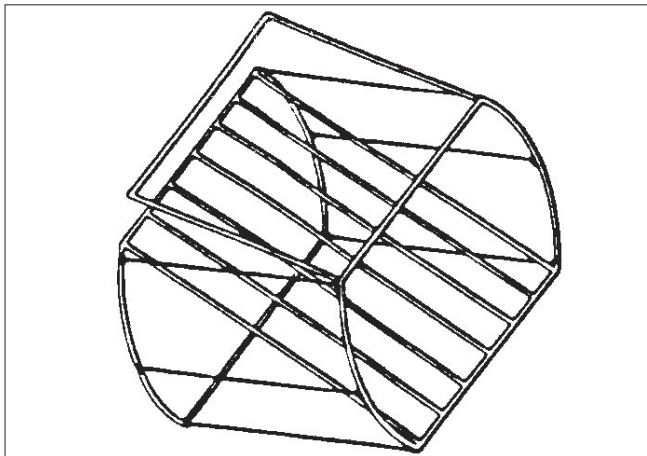


**Figure 1**
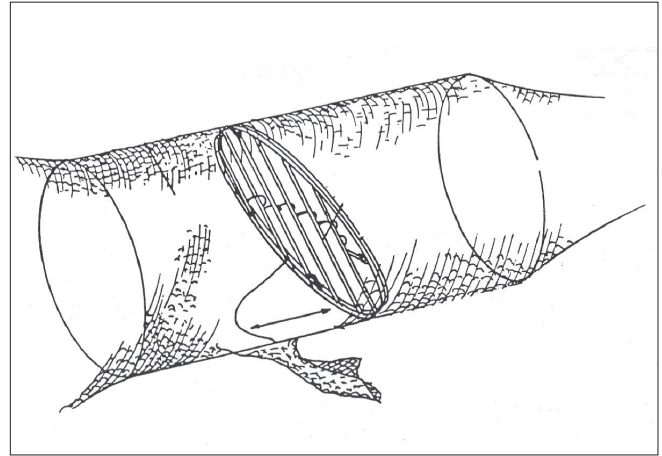*National Marine Fisheries Service Turtle Excluder Device*



**Figure 2**
*Georgia Jumper Turtle Excluder Device*

The popularity of the Georgia Jumper is consistent with opinions expressed in interviews, the TED preference survey, and in the TED giveaway programmes, but the popularity of the Parrish Soft TED in the North Carolina TED giveaway programme is surprising. The Parrish Soft TED had notoriously high shrimp loss rates; during documented tests, shrimp loss was as high as 54% and never lower than 14% (Berry 1987; Holland 1989; North Carolina Division of Marine Fisheries 1987; Pearce et al. 1989; Street 1990). In addition to high shrimp loss rates, opinions of the device were poor. In 1992, Dave Harrington, an influential Georgia Sea Grant agent, proposed that the Parrish Soft TED be decertified because 'No one is pulling them and most likely will not ' One would expect that the poor performance and opinions of the Parrish Soft TED would result in poor adoption rates. However, one might also hypothesise that the presence of a local inventor effect could drive adoption rates higher than expected. As corroborative evidence of this latter hypothesis, in 1988 Jim Bahen of North Carolina Sea Grant wrote, 'To date over 400 Parrish TEDs have been constructed and purchased by the shrimping industry.'

These contrasting statements by Harrington and Bahen can be reconciled by examining the location of Parrish Soft TED adopters. In the North Carolina TED giveaway programme, 84% of the 162 Parrish Soft TEDs were purchased by shrimpers in New Hanover County and neighbouring Brunswick County, which is the resident county of Steve Parrish, the inventor of the Parrish Soft TED. In Brunswick County, adoption of the Parrish Soft TED exceeded the adoption of the next most popular TED type by 45%. In New Hanover County, adoption of the Parrish Soft TED exceeded the adoption of the next most popular TED type by 140% (Unpublished data) . This shows that the popularity of the Parrish Soft TED was concentrated around the location of the inventor.

This concentration of TED popularity in correlation with the location of the inventor also held true in the South Atlantic Fishery Management Council survey. When this survey was conducted in 1987, all the previously listed TEDs were certified, except for the Parrish Soft TED. Overall, the survey found that the most popular TED was the Georgia Jumper (Kitner 1987). However reanalysis at the state-level reveals a connection between TED popularity and the location of the TED's invention. In South Carolina, of respondents with TED experience, 56% of them used the Morrison Soft TED that was invented by Sonny Morrison, a South Carolina shrimper. This exceeded the use of the next most popular TED by 200%. In Georgia, of respondents with TED experience, 78% of them used the Georgia Jumper. This exceeds the use of the next most popular TED by 600%. This high level of adoption supports the hypothesis that there is a Local Inventor Effect that can stimulate adoption of a device in the area surrounding the inventor's residence.

Shrimper–inventors were not just influential in promoting adoption of their TEDs, they also were the most successful at inventing TEDs. Table 1 features the thirteen TEDs certified for use during the timeframe of the case study and indicates the importance of shrimpers in inventing successful TEDs. The relative success (defined as being government certified and widely adopted by shrimpers) of TEDs decreased towards of bottom of the chart.

The TEDs in Group 4 were the least successful TEDs. Invented by NMFS and various gear manufacturers, most of

**Table 1**

*Comparative success of all certified Turtle Excluder Devices with level of industry adoption indicated by presence and size of star*

| Certified TED | Inventor | Success ★ Industry adopted ☆ Still certified as of 2002 | |
|---|---|---|---|
| **Group 1** | | | |
| Georgia Jumper | Shrimper | ★ | ☆ |
| Supershooter | Manufacturer & NMFS | ★ | ☆ |
| Anthony Weedless | Inventor | ★ | ☆ |
| Parker Soft | Sea Grant | ★ | ☆ |
| **Group 2** | | | |
| Matagorda | Shrimper | ★ | ☆ |
| Cameron | Shrimper | ★ | ☆ |
| **Group 3** | | | |
| Morrison Soft | Shrimper | ★ | |
| Andrews Soft | Manufacturer | ★ | |
| **Group 4** | | | |
| Jones | Manufacturer | | |
| NMFS | NMFS | | |
| Taylor Soft | NMFS | | |
| Parrish Soft | Manufacturer | | |
| Mississippi Hybrid | Manufacturer | | |

these TEDs were never widely used. Several hundred shrimpers did adopt the NMFS TEDs, but did so when this was the only TED available and received it for free (Watson 1985). In general, the shrimping industry did not accept the NMFS TED. According to Dave Harrington, a Sea Grant agent, 'The National Marine Fisheries Service… has developed a TED, but many fishermen [prefer] other devices.' The TEDs in Group 4 were eventually decertified, because of design flaws that caused the capture of sea turtles or—in the case of the Jones TED—because few shrimpers used it.

The TEDs in Group 3 are both devices that shrimpers accepted but that NMFS decertified. The Andrews Soft TED has a small star for adoption, because few shrimpers used the certified version of this TED, but many shrimpers illegally used versions of this TED with larger mesh sizes. Evidence of the popularity of the Morrison Soft TED was pervasive throughout the historical documents and interviews. In the late 1980s, a Georgia Sea Grant report stated that the Morrison Soft TED was one of two TEDs that 'had emerged as the most popular within the Atlantic Coast commercial shrimp fleet.' The TED preference survey conducted during that same time found that the Morrison Soft TED was the second most popular TED and 37% of respondents had used it (Kitner 1987). Further, Harrington wrote, 'As TED regulations were implemented into the Southeastern fisheries, this device became a commonly used turtle separator and is perhaps the most popular of the six certified excluders.' In 1996, NMFS decertified all soft TEDs, citing that soft TEDs had inherent design flaws that caused the entanglement of turtles (61 FR 66933). This was a controversial decision over which TED experts were divided. According to one net shop owner, 'In the 1980s, the Morrison TED was the most popular; the decertification of the soft TED forced the shrimpers to start using hard TEDs.'

In some areas the industry accepted the shrimper-invented TEDs in Group 2, but their popularity failed to spread throughout the fishery. The Louisiana Sea Grant estimated that by 1985, 300 shrimpers where using some type of excluder or cannonball shooter to exclude jellyfish in Cameron County (Weber 1995). The gross majority of these devices were Cameron TEDs, which were invented in Cameron County. Gary Graham, a Texas Sea Grant agent, reported that, in 1992, a single net shop in Texas sold over 200 Matagorda TEDs .

I found that the four most successful TEDs were Group 1 (1) the Georgia Jumper, (2) Super Shooter TED, (3) Anthony Weedless TED, and (4) the Parker Soft TED. Although only the Georgia Jumper is credited as being invented by a shrimper, shrimpers played crucial roles in the invention of all four TEDs. The Parker Soft TED is actually the original version of the Morrison Soft TED that was invented by Sonny Morrison, a shrimper. Earnest Anthony was not a shrimper, but his Anthony Weedless TED consists of an insightful modification to a Georgia Jumper-style TED, which was invented by Sinkey Boone, a shrimper. Finally, the Supershooter TED was invented by Noah Saunders, a fishing-gear manufacturer in collaboration with NMFS. Notably, Saunders' primary collaborator at NMFS was Dale Stevens, a highly respected and experienced

former shrimper. Arguably, without the expertise of shrimpers contributing to their invention, none of these devices would have been as successful.

The Georgia Jumper was popular on the East Coast and Gulf Coast even over time. The Georgia Jumper was the most purchased TED in both the North Carolina and Georgia TED giveaway programmes as well as the TED used by the most shrimpers (63%) in the TED preference survey[6] (Kitner 1987). Dave Harrington wrote that the Georgia Jumper 'has met with a high degree of acceptance along this [Atlantic] coast.' In 1996, a NMFS report states that the agency used the Georgia Jumper for special TED tests 'due to the preference on non-funnel straight-bar grids [description of the Georgia Jumper] by fishermen in the South Atlantic (Mitchell *et al.* 1996).' During interviews in 2003, a Louisiana Sea Grant agent said most shrimpers in Louisiana use the Georgia Jumper.

The Super Shooter TED and Anthony Weedless TEDs were not commercially available until around 1990, so they are not represented in the Kitner survey or state TED giveaway programmes, but many TED experts cited them as popular TEDs. In 1992, both the Super Shooter TED and Anthony Weedless TED were used in government TED research because of their 'increasing preference among US commercial shrimp fishermen' (Mitchell & Shah 1992). In the course of my research interviews, several people, including an industry leader and former NMFS policy-maker, named the Super Shooter as the most popular TED and an extension agent declared that the Anthony Weedless TED is popular along the Gulf Coast.

The Parker Soft Ted is a special case of popularity. Chuck Oravetz, a former NMFS policy-maker wrote, 'industry use of the Parker TED is extremely low'. This statement is true, but the commitment of some soft TED adopters to soft TEDs and the circumstances that led to this low adoption, warrant special consideration of the Parker Soft TED. This TED is the original version of the Morrison Soft TED. According to the owner of a popular net shop in Florida, in the 1980s, the Morrison TED was the most popular TED at the time. The decertification of the soft TED forced the soft TED users to start using hard TEDs. In 1997, Lindsey Parker, a Georgia Sea Grant agent, reintroduced this soft TED, because some members of the industry still wanted to use a soft TED, especially along the Atlantic coast for catching white shrimp during the winter. The Parker Soft TED warrants being labelled a successful TED, because it is used in a number of states and has been widely adopted by the target group—soft TED users—for which it was intended.

### Biographical profiles of TED inventors

Although only 15 TEDs were ever certified for use, there were at least 43 named varieties of TED prototypes or modifications with nearly as many inventors. In order to determine what characteristics defined successful inventors, I composed biographical profiles of TED inventors Sonny Morrison, Sinkey Boone, Earnest Anthony, Noah Saunders, John Lettich, and Nelson Paul. These profiles, which are summarised below,

reveal that successful inventors engaged in mental modelling, while unsuccessful inventors apparently did not.

Sonny Morrison, the inventor of the Morrison Soft TED, grew up in a shrimping community in South Carolina. He began fishing as a child and often helped out with this father's marine construction business. He learned basic net repairing out of necessity—he had only one cotton net as a boy and with little chance of replacement, it *had* to be maintained. Morrison continued in this self-efficient fashion, making and repairing his own nets, and building and repairing his own 67' steel haul boat (Morrison 2007).

Sinkey Boone, the inventor of the Georgia Jumper TED, grew up in a shrimping community in Georgia and had a career as a shrimper. Boone also worked as a machinist, enjoys working with his hands, and prides himself on his mechanical skills.

Ernest Anthony, the inventor of the Anthony Weedless TED, had no previous connection to any type of fishing industry. Anthony was a machinist by trade and lived in Louisiana. In retirement, he learned of the problems some shrimpers were having with TEDs getting clogged with debris and hence modified a Georgia Jumper-style TED that successfully reducing clogging.

Noah Saunders is a machinist who runs a family business that traditionally built and repaired parts for fishing boats in Mississippi. Although he grew up familiar with aspects of the fishing industry, he does not have any commercial fishing experience. With some advice from his customers, Saunders invented the Mississippi Hybrid TED and a version of the Georgia Jumper called the Saunders TED. He helped create the Super Shooter TED in conjunction with NMFS personnel, especially Dale Stevens, a former shrimper highly respected throughout the shrimping industry.

John Lettich created a greatly modified Lettich Soft TED that differs so much from the original Lettich Soft TED that it can be considered a new device. Lettich grew up shrimping and now participates in a family net-making business in South Carolina.

Nelson Paul, a self-described net-making hobbyist, is the inventor of the Paul Soft TED. He was never a commercial fisherman, but he grew up in a shrimping community, and helped with his family's shrimping and fish processing businesses in North Carolina. Paul took a series of net-making classes and later continued to study and refine his skills as a net-maker. He designed and built a variety of different net types for various fisheries.

Many of these men share two characteristics—a shrimping background and a mechanical inclination. The importance of these characteristics is highlighted by Table 1. Shrimpers invented more highly successful TEDs than any other group, but all of the inventors listed in the Table 1 had expertise fabricating devices and instruments. Being able to produce a physical prototype was a critical step, because a physical device was arguably more likely to gain attention and support than schematics alone. Those inventors who did not have shrimping experience, compensated by directly seeking the advice of shrimpers or basing their invention on a shrimper-invented TED.

These characteristics of a shrimping background and mechanical inclination are prominent among successful TED inventors. But these same characteristics can be found among unsuccessful TED inventors as well. Further examination of the biographical profiles reveals a third defining characteristic that helps delineate between successful and unsuccessful TED inventors, the ability to engage in mental modelling.

The inventors whose TEDs were most successful are Boone, Morrison, Saunders and NMFS with the Super Shooter TED, and Anthony (Table 1). I could not interview or even locate Anthony, the inventor of the Anthony Weedless TED, who may be deceased. What I know of him is based on his writings and the memories of those who met him. Unfortunately, neither of these sources describes the methods he used to invent his TED. Of the remaining three inventors, two strongly exhibited the same characteristic, the ability to engage in mental modelling. Boone and Morrison both spoke extensively of how they evaluated and refined their TED designs. Despite poor visibility in the murky waters where they tested their devices, both men confidently described the action of deployed gear and the effect that a gear modification would have on gear performance. They explained how they could imagine the gear in the water and how this process of imagining allowed them to identify potential problems with their design, which they could then correct without ever having built a physical prototype of that design.

In contrast, Saunders did not readily display this characteristic. In order to evaluate the TED design and make changes, he said he would build and show the prototype TED to shrimpers he knew for their insight. Further he had almost daily conversations with NMFS scientists and gear specialists about the designs and prototypes. Interviews and research reports showed no evidence that NMFS personnel employed mental modelling as an invention strategy; rather, NMFS personnel tended to build physical prototypes of modifications. In addition, the divers and underwater cameras available to NMFS were far more accurate than mental modelling for visualising deployed gear. This method of invention made NMFS a successful modifier of TEDs, because it is better suited for the level of detailed refinement needed for fine-tuning at the end of the development process.

Based on these findings, the profile of a successful marine conservation technology inventor includes at least three characteristics (1) They have extensive experience in commercial fishing, (2) They have extensive experience in fabrication, and (3) They have a means to visualise the action of deployed gear, either by mental modelling or using divers and cameras. Individuals such as Ernest Anthony and Noah Saunders, who did not have commercial fishing experience, drew on the knowledge of expert fishers by conferring with them directly or modifying their designs. In addition to the role of inventor, another key role was that of modifier. In general, fishers invented the most successful TEDs, but

NMFS played a key role in refining and further developing the TEDs.

## TUNA–DOLPHIN CASE STUDY

If the successful inventor profile is to be of practical value for identifying collaborative partners, it is essential to determine if the profile would hold true in other cases. The tuna–dolphin case study offers positive evidence that the profile does delineate successful inventors from other fishers and inventors.

Tuna fishing in the United States was largely based in San Diego. The early 1960s saw the introduction of a new fishing technique, pole and lines being replaced by nets called purse seines. The hundred or so boats fishing the Eastern Tropical Pacific quickly became the second most profitable fishery in the country. The purse seining process involved encircling tuna that are either swimming as a free school, as a school associated with floating debris, or as a school associated with dolphins (McNeely 1961; Orbach 1977). 'Fishing on dolphins' soon became the most popular method of tuna fishing, because it yields large yellowfin tuna, which were the size and species preferred by tuna processors, and because dolphins, which are frequently on the surface, were a good visual indicator of tuna. Unfortunately, this tuna fishing method can result in significant dolphin mortality. Even though dolphins are capable of jumping several feet above the water surface, when enclosed in a net they failed to do so and instead became passive. Thus, the dolphins tended to huddle together at the surface or lay submerged against the bottom of the net. Frequently, the dolphins would come in contact with the net and become entangled in it. Unable to surface to breathe, they drowned.

In 1964, a tuna fisher alerted California wildlife managers about the numbers of dolphins being accidentally killed in purse seines.[7] Subsequent estimates suggested that tuna fishers killed several hundred thousand dolphins each year (National Research Council 1992). In 1969, the U.S. Bureau of Commercial Fisheries—which soon became part of the newly established National Marine Fisheries Service—began a research project to investigate the problem.

Concurrently, in 1963, the feature film 'Flipper' and the subsequent television show, which aired from 1964–1967, sparked a nation-wide craze in the United States for dolphins and other marine mammals. The public came to view marine mammals—more so than many other animals—as uniquely intelligent, caring, and lovable. In the late 1960s, the first reports of the high dolphin mortality by the tuna fishery began to surface in the media. By 1971, articles in *Newsweek* and *Life* magazines firmly placed the tuna–dolphin issue on the national platform (Anon. 1971). The public, with its newfound love for marine mammals, was outraged. People from all walks of life, from scientists and environmentalists to housewives and school children, bombarded their Congressmen with letters decrying the slaughter of dolphins and demanding protective action. In 1972, Congress drafted and passed the Marine Mammal Protection Act. The Act protects all marine mammals and mandates that their populations be as large as the ecosystem can adequately support.

The Marine Mammal Protection Act drove both government and industry to solve the dolphin bycatch problem. With the passage of the Act, the tuna fishing industry felt compelled to solve the bycatch problem, because it feared the complete closure of the tuna fishery if dolphin mortality was not reduced. In addition, NMFS was required by law to reduce dolphin bycatch, in part through invention of dolphin conservation technologies.

Two of these technologies were the backdown method and the Medina panel. The backdown method is a dolphin rescue procedure, which involves reversing the boat so that part of the netting becomes submerged allowing the dolphins to escape to safety. The Medina panel is an area of smaller mesh-size netting which prevents dolphins becoming entangled as they escape the net. These two technologies are credited with making the most significant contribution to reducing dolphin bycatch in the tuna fishery. I examine their development and other dolphin conservation technologies herein.

The pattern of fishers inventing the most successful conservation technologies—while NMFS refined and further developed these technologies—is a pattern that is also evident in the tuna–dolphin case study. Of the over twenty conservation technologies explored in the tuna–dolphin case, Table 2 features the eight most successful (in that the industry adopted them independently or that NMFS recommended or mandated their use). The majority of the successful technologies originated from within the industry, but NMFS played an essential role as modifier of these technologies. This is supported by a comment by August Felando, president of the American Tunaboat Association, the primary tuna industry group. Felando said, 'the process was really about enhancing what people were already doing', i.e., the backdown method and the Medina panel. For example, with the backdown method, NMFS gear specialists developed an empirical net tie-down formula to increase the accuracy of the backdown channel alignment (National Marine Fisheries Service 1981). NMFS modified the porpoise grabber[8] so that it would not injure dolphins and could be used on all sizes of dolphins (Fox 1975a). NMFS also introduced the use of a face mask, snorkel, and raft to make hand rescue more effective and efficient (Fox 1975b). In addition, all the fine-mesh dolphin safety systems

**Table 2**
*The eight most successful technologies for dolphin conservation among tuna fishers*

| Invention | Origin | NMFS Modified |
|---|---|---|
| Backdown Method | Industry | ✓ |
| Medina Panel | Industry | ✓ |
| Dolphin Grabber | Industry | ✓ |
| Speedboat Rescue | Industry | ✓ |
| Hand Rescue | Industry | ✓ |
| Snap-on Purse Rings | Industry | |
| Large-volume Net | NMFS | |
| Net Towing | NMFS | |

NMFS invented were derived from the Medina panel. These numerous examples strongly illustrate the critical role of the NMFS as modifier of fisher-inventions.

Data of adoption of dolphin conservation technologies was extremely limited in the tuna–dolphin case. Adoption of the Medina panel, however, is widely acknowledged by the key informants to have been the most rapid and complete adoption of any of the dolphin conservation technologies. In 1972, a year after its invention, and before Congress passed the Marine Mammal Protection Act, 40–50% of the industry had voluntarily adopted the Medina panel. By 1973, 60–70% of industry had adopted it (Unpublished data). Harold Medina, the tuna fisherman who invented the device, facilitated this adoption by making available diagrams and instructions for the panel's installation and recommending it to other fishers (Barham *et al.* 1977). This strong example is in keeping with the pattern of local inventors positively influencing the adoption of their inventions.

### Biographical profiles of dolphin conservation technology inventors

Harold Medina and Richard McNeely are both credited with inventions that made a significant contribution to solving the dolphin bycatch problem. Medina's contribution of the Medina Panel is widely recognised. McNeely's contribution is less well known, but was greatly lauded at the time. Among McNeely's accolades were Man of the Year award from the American Cetacean Society, the United States Government Gold Medal, the highest honour given to federal employees, and various awards from environmental groups. McNeely systematically identified the causes of dolphin bycatch and invented or innovated solutions to many of these. These inventions and innovations included anti-torque cable, large volume net, porpoise apron, counter-balanced purse block, and modified Medina Panel.[9] Upon McNeely's retirement in 1977, NMFS praised his work, writing, 'The tuna industry, as well as the environmental community, are greatly indebted to McNeely for his perseverance and success in dealing with an extremely complex difficult, and challenging assignment' (National Marine Fisheries Service 1977).

Harold Medina grew up in a tuna fishing family. He served as a merchant marine before becoming a commercial tuna fisher and, quickly, captain of his own boat. Gaining a reputation as a highliner[10], Medina was admired by his peers for his fishing skill and his innovations were often imitated. He claimed to be the first tuna fisher to try sonar, the omega navigation system, and satellite navigation. He also asserted that he was responsible for increasing fishers' safety by moving the winch from the deck of the boat to the boom. He recounted that when he asked for this modification 'the boatyard gave me a hard time but now all boats are this way.' He further declared, 'I can do anything with my hands….I can do anything on a boat.' His talents include being a good carpenter, net man, engineer, and navigator.

Medina also knew how to overhaul boat engines as well as build and repair his own nets. Using his knowledge of nets and observation of how most dolphins were entangled in the net, Medina surmised that smaller-mesh in the backdown area would prevent dolphins from entangling their rostrums and flippers. He used mental modelling to visualise the design in operation, and determined that two-inch mesh would provide maximum protection for the dolphins without creating adverse drag on the net.

In contrast, Richard McNeely was not a commercial fisherman but he was an expert machinist. The son of a carpenter, McNeely attended a technical school in his home state of West Virginia after receiving the highest score ever on a mechanical aptitude entrance exam. He later worked as a machinist for General Electric, where he soon earned a reputation as a problem solver. As a recreational fisher, McNeely had a life-long interest in the water, so, he began to work for the Bureau of Commercial Fisheries, where his first assignment was to build a remote-controlled underwater camera. He eventually rose to head the gear research programme. In this position, McNeely was always looking for opportunities to go out on a boat. He claimed to have been on every type of fishing boat on both coasts of the United States and further claimed to be the only government scientist to do so. This experience included sailing on over a dozen tuna boats (McNeely 2002).

Thus, despite their differing backgrounds, both Medina and McNeely fit the Successful Inventor Profile. Medina had extensive mechanical and fishing experience. In addition, his own comments on the importance of imagination and his recollections on how he invented the Medina Panel showed that he used mental modelling. According to Medina, 'because you can't see what happens to the gear under water, you have to imagine it'.

McNeely also had an extensive mechanical background. He compensated for not having a background in commercial fishing by frequently riding aboard commercial vessels and observing commercial fishing practices in order to bolster his knowledge. His gregarious personality garnered the industry's trust and helped him mine their expertise. He had many novel ideas for conservation technologies, which may indicate that he had a good imagination. However, he did not seem to readily engage in mental modelling; instead he used divers and underwater cameras to observe the gear.

### DISCUSSION

### Local inventor effect

Both case studies indicate a link between the location of an inventor and the adoption of his device. For the Parrish Soft TED, there are several possible reasons for this concentration of popularity (1) a local inventor effect, involving familiarity with the inventor or his reputation, could influence adopters' decisions, (2) North Carolina Sea Grant found it easier to promote a local TED and so concentrated more effort on this TED than any other type, or, (3) a locally invented TED is best suited to the fishing condition of that area.

The third option is unlikely because of the poor shrimp retention of the Parrish Soft TED, although this option may hold some truth for other TEDs. As for the second option (easier promotion of a local TED), North Carolina Sea Grant did expend much time and money helping to develop the Parrish Soft TEDs. There was also special emphasis placed on promoting the Parrish Soft TED . However, various Sea Grant agents spread these extension efforts throughout the North Carolina coast, which would not explain the concentration of Parrish Soft TED adopters. Given all these considerations and the acute concentration of Parrish Soft TED adopters, I believe that familiarity with Steve Parrish and/or his reputation is the main reason for the high number of Parrish Soft TED purchases in Brunswick and New Hanover counties.

The rapid voluntary adoption of the Medina panel in comparison to later conservation technologies is also indicative of a local inventor effect. However, there are a number of other factors worth considering: (1) The local inventor effect could have been enhanced by Medina's influence as an opinion leader, because he was well-known in the fishery as a highliner; (2) The comparatively (to other dolphin conservation technologies) rapid adoption of the Medina panel could be due to the fact that in later years the tuna–dolphin problem became more adversarial and so fishers were less willing to voluntarily adopt technologies invented after the Medina panel. Further, the frequent changes in regulations and resulting financial and time investment to comply could have restricted fishers' willingness to voluntarily adopt new technologies; or (3) Alternatively, according to one NMFS manager, as the types of conservation technologies became more complex, captains may have felt the effort of keeping informed about the gear improvements was not worth the benefit, especially if the captain already had low mortality rates. There is not enough data to identify, which, if any, of these three explanations helped drive the comparatively rapid adoption of the Medina panel. However, Medina's reputation as an innovative fisher arguably figured into the successful adoption.

Diffusion studies also offer some insight into Medina's role. According to diffusion theory, opinion leadership (i.e., the ability to influence the views of one's peers) is earned and maintained by competence, accessibility, and conformity. When the social system is oriented to change, opinion leaders are quite innovative, but when the system's norms are opposed to change, opinion leaders are not very innovative (Rogers 1995). Because the tuna industry had experienced a major gear conversion just a decade earlier—when changing from pole and line gear to purse seines—it was oriented to change. Medina's highliner status spoke of his competence. As an active fisher in a rather small fishery, he was as accessible as any other fisher. As a member of an established family of tuna fishers he was part of the mainstream tuna fishing community, and thus conformed to the cultural norms. These qualities of competence, accessibility, and conformity made Medina an innovative opinion leader in an industry that valued innovation. This combination was likely very influential in the adoption of the Medina panel. Also, I believe the political climate with the passage of the Marine

Mammal Protection Act motivated the industry to try to deflect criticism. The adoption of the Medina panel helped them do so. Finally, the simplicity of the gear was such that it did not change the fishing process and most fishers could easily understand how it worked. All of these factors likely contributed to the successful adoption of the Medina Panel.

**Successful inventor profile**

From my case studies, I found that fishers invented the most successful conservation technology. Arguably fishers invented more successful devices, because their fishing experience provided them with the knowledge to create practical devices that were compatible with commercial fishing. Also it was to the fisher's benefit to invent practical devices that had limited effect on how they fished. This desire for practicality was balanced by conservation mandates in the Endangered Species Act and Marine Mammal Protection Act. Government scientists, on the other hand, had no practicality mandate to fulfil. So while they were concerned about practicality, they placed primacy on conservation. The fishers fishing knowledge coupled with the need to have practical and effective conservation technologies created invention parameters that facilitated their success.

The profile of a successful marine conservation technology inventor includes at least three characteristics. (1) They have extensive experience with commercial fishing. (2) They have extensive experience with fabrication. (3) They have a means to visualise the action of deployed gear, either by using mental modelling or divers and cameras.

Existing invention theory offers support that this profile can be expandable beyond marine fishing to create a more general profile of a successful conservation technology inventor. The critical feature of the first characteristic is experience. A successful conservation technology inventor will have extensive experience relevant to the problem and potential solutions. The successful conservation technology inventor will also have extensive experience in fabrication. Many world-class inventors present at a conference on invention linked their exceptional inventiveness to gaining considerable hands-on machine shop experience early in their careers. They believed that this distinguished them from their less inventive colleagues (Perkins & Weber 1992). Finally, successful conservation technology inventors have the ability and tendency to employ mental and/or physical models, to assemble and refine inventions. Eugene Ferguson (1977) argued this was a defining difference between technologists and scientists. He concluded that technologists and engineers create using non-verbal, visual thought, i.e., mental modelling. They mentally visualised and assembled the components of their inventions, before sketching or building the device. In contrast, scientists are more likely to manipulate concepts, mathematical expressions, and hypotheses (Ferguson 1977). Based on my case studies, I add to this that technologists will use mental and physical models to refine the technology before building a full prototype. Scientists, however, will build full

prototypes, test them, analyse the data, modify the technology and then test it again. Scientists tend to engage in a systematic and comparatively time-consuming physical refinement, while technologists successfully circumvent this through mental and physical modelling.

Researchers profiling successful inventors found that common characteristics are intelligence, ingenuity, and articulateness (Perkins & Weber 1992). Although my research did not attempt to assess the intelligence and ingenuity of inventors, the key informants in both case studies often describe successful inventors in these or similar terms. Thus I am inclined to agree with the first and second characteristics, but have reservations about articulateness fitting the profile. In the context of the traditional inventors that they study, the concept is sound. They note that inventors need to be articulate to convince others of the worth of their ideas. Among the inventors I interviewed, especially the fishers, their eloquence was not a shining feature, but all the inventors were very talkative. This was particularly true of one inventor who made up for lack of eloquence with persistence. Additionally, at least one inventor was not functionally literate and several did not complete high school. This could have posed a problem, because many shrimpers' TED ideas were submitted for consideration in writing. But the extensive verbal networks in fishing communities allowed another path for these ideas to reach Sea Grant or NMFS.

## CONCLUSION

Based on my case studies, the general profile of a successful inventor of conservation technology contains three characteristics (1) a successful conservation technology inventor will have extensive experience relevant to the problem and potential solutions, (2) he or she will have extensive experience in fabrication, and (3) he or she will have the ability and tendency to employ mental and/or physical models, to assemble and refine inventions. In keeping with Perkins' and Weber's profile of a successful inventor, successful inventors of conservation technology may also be intelligent and ingenious; this would be a topic worthy of future study.

In the case of successful fisher–inventors of marine conservation technology, they tend to engage in mental modelling. The act of mental modelling allows the fisher–inventors to create mental representation of devices and conduct simulated tests of their performance. In this way, fisher–inventors can sort through and identify the most promising designs without building timely and costly prototypes. Given the dire extinction timelines and limited conservation resources for sea turtles and other endangered species, mental modelling could be a cost-effective rapid assessment tool. In the case of successful scientist–inventors, they tend to employ physical prototypes and technology to visualise and test them. This process is more costly and time-consuming than mental modelling, but better suited for the fine-scale refinements needed towards the end of the development process.

For future efforts to invent marine conservation technologies, extension agents and government gear specialists should recruit specific individuals matching the Successful Inventor Profile. Individuals having the first characteristic can be identified in that they will readily express pride in their skill with and knowledge of boats, gear, and fish capture. They may have a reputation as a highliner or be well-respected for their fishing skill. Those having the second characteristic can be identified in that they have experience as a machinist or net-man, or they do their own major boat or gear repairs. They may have a reputation as a 'tinkerer', i.e., constantly seeking to improve performance by modifying gear. People who possess the third characteristic can readily describe the action of deployed gear and can mentally model the effect of modifications on gear performance.

Using the successful inventor profile would help create a more effective and efficient invention process for marine conservation technologies, by aiding the targeted recruitment of individuals not just willing to try to solve a problem but who also possess the skills and knowledge needed to do so. In addition, acknowledging the benefit of mental modelling and incorporating individuals with this skill would streamline the invention process. If these individuals were also fishers, their reputations in their local communities could help propel the adoption of conservation technologies by triggering the Local Inventor Effect.

## ACKNOWLEDGEMENTS

**Notes**

1. Unpublished reports, data, and quotes references in this article can be obtained from the author.

2. The year 2002 is the year when NMFS decertified many TEDs in accordance with new federal regulations requiring that TEDs be large enough to accommodate leatherback sea turtles. Because there are no statistically representative surveys of TED use, I have defined a 'widely adopted' TED as a TED that TED experts have said was used by a significant portion of the fishery in more than one state. By being used in more than one state, this demonstrates that the TED could be used in a variety of shrimping conditions. However, I have given special consideration to TEDs that were used in only one state, but where the majority of shrimpers in that area used that TED. One confounding factor in this analysis of success is the treatment of time. NMFS certified TEDs in different years. The differing socio-political landscape of the TED case during those years had an effect on what TEDs were adopted and to what extent. I accounted for this variable based on the information provided by informants as to their TED preference and the reasons and circumstance that drove their adoption decisions.

3. The South Atlantic Fisheries Management Council has authority to make regulatory recommendations to the United States government for

marine fisheries in the southeastern United States.

4. The Endangered Species Act is the primary law in the United States governing the protection of endangered species.

5. Some of these styles were certified in multiple sizes, being the total of distinct TEDs to fifteen.

6. Notably, the Super Shooter TED, Anthony Weedless TED, and Parker TED were not certified at the time of these programmes nor the survey.

7. At the time of the case study, dolphins were often referred to as porpoises.

8. The porpoise grabber is a type of shepherd's crook that aids in guiding dolphins out of the net.

9. For a description of these devices see Coe *et al.* 1984.

10. A highliner is a boat captain whose superior fishing skill yields major financial profit and a reputation as a master fisher.

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