ICES Journal of Marine Science, 2022, **0**, 1–10
DOI: 10.1093/icesjms/fsac062
Original Article

The role of fisher engagement in the acceptance of turtle excluder devices in Georgia's shrimping industry

Jennifer Sweeney Tookes [1,*], Tracy Yandle[2] and Bryan Fluech[3]

[1]Department of Sociology and Anthropology, Georgia Southern University, Statesboro, GA 30460, USA
[2]Department of Environmental Sciences, Emory University, Atlanta, GA 30322, USA
[3]University of Georgia Marine Extension and Georgia Sea Grant, Athens, GA 30602, USA

[*] *Corresponding author: tel: +912-478-6587; fax: +912-478-0703; e-mail:*jtookes@georgiasouthern.edu
[†]Jennifer Sweeney Tookes and Tracy Yandle should be considered joint senior authors. The authors have no competing interests.

The "Georgia Jumper" turtle excluder device (TED) is a rare example of a well-accepted conservation tool required by regulation. Mediated by the UGA Marine Extension and Georgia Sea Grant, Georgia's shrimping industry was integral to the design, revision, and implementation of excluder devices, since the earliest "jellyball shooter" proposed to NMFS in 1980. This paper highlights fisher involvement in the creation of the popular "Georgia Jumper" TED. Both the Diffusion of Innovation and the Traditional Ecological Knowledge literatures stress the importance of meaningful engagement of user communities in the development of new management approaches, and make specific recommendations for improving uptake of new methods. Consistent with literature expectations, fisher and industry participation in the development, testing, and implementation of TEDs has been key to the general acceptance of TEDs in Georgia. This paper illustrates the importance of fisher participation in conservation efforts such as these.

Keywords: bycatch reduction devices, Diffusion of Innovation, fisher engagement, Georgia, Marine Extension/Sea Grant, outreach, regulation, shrimpers, Traditional Ecological Knowledge, turtle excluder devices (TEDs).

Introduction

Commercial fishers are directly impacted by gear regulations, yet often feel that their perspectives are not valued and that they are not authentically included in management (Pita *et al.*, 2010; Yates, 2014). Simultaneously, fisher involvement positively influences sustainable fisheries management (Pitcher *et al.*, 2009; Yates and Schoeman, 2015).

Fishers' engagement in sustainable fisheries management is not new to this journal. In a 2015 review article, Hind argued that fishers' knowledge of ecosystems and species are often not incorporated into fisheries management because mainstream fisheries scientists often do not look outside their disciplines, and data highlighting fisher knowledge are not often disseminated in mainstream fisheries science venues (Hind, 2015). Simultaneously, Eayrs and Pol argue that fishers are "steeped in tradition and reluctant to voluntarily change their fishing activity", and resistant to adopting "fishing gear proven to increase catching efficiency, gear selectivity, or reduce fuel costs" (2019, p. 392). The question of *how* to effectively engage fishers—whether voluntary or in response to regulation—remains.

To address this question, we present the history of the mandatory adoption of the turtle excluder device (TED) gear in Georgia, and demonstrate fisher perspectives on why this technology was accepted by shrimpers. Georgia shrimpers' relatively uncontested adoption of TEDs illustrates the willingness of fishers to accept new technology and fishing practices, when they are included in the development process and their knowledge is respected. This case illustrates that insights from the "Diffusion of Innovation" and "Traditional Ecological Knowledge" literatures can be applied to fisheries management practices. We demonstrate that the extension and outreach practices of University of Georgia Marine Extension/Georgia Sea Grant (MarEx/GSG) resulted in greater acceptance of new conservation practices by the fishing community.

Theoretical background

We draw on two literatures that address engaging fishers: Diffusion of Innovation examines drivers of adopting new technologies or practices, while Traditional Ecological Knowledge explores the value of fisher knowledge and its incorporation into regulatory practice. Together, these literatures offer a guide to better practices.

Diffusion of Innovation

Across settings, how and why new ideas and practices are adopted at varying speeds is an important question explored by the Diffusion of Innovation literature popularized by Rogers (1962/1995), 1962/1995). Innovation is different from invention, which is the creation of new ideas. Innovation is "an idea, procedure, thing, or system that is perceived as new by the people who are adopting it" (Rogers, 1962/1995); and Diffusion of Innovation is "the adoption and implementation of innovations within and across organizations" (Lunblad, 2003). This theory is used in many settings including organizational theory (Lunblad, 2003; Yoshikawa et. al, 2007); healthcare (Dingfelder and Mandell, 2011; Iqbal and Zahidie, 2021); agriculture (Simin and Janković, 2014; Levy and Lubell, 2018); and technology (Quinlan *et al.*, 2018; Min *et al.*, 2019). Within fisheries management, Diffusion of Innovation theory examines adoption of fisheries management poli-

Received: August 30, 2021. **Revised:** February 11, 2022. **Accepted:** February 17, 2022

cies (Song *et al.*, 2019) and fishing technology (Acheson and Reidman, 1982; Dewees and Hawkes, 1988).

Early research into diffusion of fishing technological innovations found the process idiosyncratic. While personal attributes of fishers and nature of the innovation (e.g. complexity) are associated with adoption of specific innovations, statistical analyses showed no consistent pattern of characteristics that consistently explained diffusion. Researchers called for more ethnographic and longitudinal studies to understand the dynamics behind fishing innovation (Acheson and Reidman, 1982; Dewees and Hawkes, 1988). Some research into Diffusion of Innovation in fishing continues (e.g. McBain-Riggs *et al.*, 2017; MacKeracher *et al.*, 2019), but the sector is not a primary focus.

Conservation is an active stream of innovation research. Researchers examine how innovations spread between and within conservation organizations, regions, and ecosystems (Fisher *et al.*, 2018; Macia and Mills, 2018; Romero-de-Diego *et al.*, 2021) but may take the form of rapidly discarded fads (Mascia and Mills, 2018). Meta-analysis shows that insights from this literature apply to conservation. Diffusion is most likely when interventions are simple, readily observable, and consistent with social beliefs and values, which can be tried and tweaked to fit local context, and with few barriers and costs to participation. Moreover, diffusion is more likely where implementers target adopters who have high social status, are well-connected to the outside world and each other, have autonomy to innovate, and are competing with others. Last, diffusion is most likely where implementers seek out suitable geographic, cultural, and policy contexts—and create an enabling policy environment (Mascia and Mills, 2018, p. 7).

These findings, particularly the importance of usability and social context, place those adopting at the centre of the process, rather than the external authorities or funders. This theme has since been developed further in the conservation context (Nilsson *et al.*, 2020; Mahajan *et al.*, 2021) focusing on the human components. This fits insights from our second literature stream: Traditional Ecological Knowledge.

Traditional Ecological Knowledge

Many themes in the Diffusion of Innovation literature are discussed in Traditional Ecological Knowledge, which identifies fisher knowledge as "Traditional" or "Local" Ecological Knowledge (TEK or LEK). Rooted in anthropology (Conklin, 1957) and first applied to resource management (Klee, 1980), and fisheries (Johannes, 1993), TEK focuses on the "cumulative body of knowledge and beliefs, handed down through generations by cultural transmission, about the relationship of living beings (including humans) with one another and their environment" (Berkes, 1993, p. 3). TEK is connected to a specific place, and is the product of processes of formation and dissemination of knowledge, based on personal and shared experience (Martin *et al.*, 2007). TEK is used to understand bycatch and discards (Damalas *et al.*, 2015), to assist in conservation planning (Silvano and Valbo-Jørgensen, 2008; Thornton and Scheer, 2012), and to add to fisheries science knowledge of a species (Marin *et al.*, 2017; Chan *et al.*, 2019).

Early TEK research focused on "historical continuity in resource-use practices" among mostly "non-industrial" societies, many of which were "indigenous or tribal" (Berkes, 1993, p. 3). Subsequent research expanded this definition to include relationships between people and place. TEK is characterized by local wisdom and practical skills developed in a particular environment over generations (diachronic); intuitive, lived experiences, and long-term empirical observations rather than systematic, deliberate accrual of facts (synchronic); and qualitative expertise rather than abstract quantitative data (Berkes, 1993). Scholars suggest that TEK should be incorporated into development (Johannes, 1993), and local populations can best assess true costs and benefits of development using TEK (Berkes, 1993).

TEK is also useful to inform fisheries management by filling information gaps or highlighting local management strategies (Schafer and Reis, 2008; Rist *et al.*, 2010; Espinoza-Tenorio *et al.*, 2013; Figus *et al.*, 2017) and by providing diverse perspectives with which to solve problems (Haggen *et al.*, 2007; Butler *et al.*, 2012). Incorporating TEK may increase regulatory compliance (Martin , 2007).

Case background and context

We examine the TEDs adoption in the Georgia shrimping industry during the 1980s. First, we provide information about bycatch, and the regulatory and social conditions of the Georgia shrimping industry during this time.

Bycatch

The unintended catching of not targeted species ("bycatch") is a well-documented issue in fisheries. Examples include seabirds (Clay *et al.*, 2019; Dias *et al.*, 2019), marine mammals (Verutes *et al.*, 2020), sharks (Silva and Ellis, 2019), turtles (Virgili *et al.*, 2018), and other fish species (Hazen *et al.*, 2018). Sea turtle entrapment in shrimping gear is a well-known example of bycatch in the United States.

Turtle bycatch has been a Federal regulation issue since the 1970s, when the species was first regulated under the Endangered Species Act (ESA) of 1973 (Jenkins, 2012). The ESA forbids the "taking" (or killing) of any species that is "listed" as an endangered species and requires regulation to minimize the taking of endangered species (EPA, 2022). TEDs are an important bycatch reduction tool. TEDs are a metal device attached to the inside of the neck of a shrimp net that blocks turtles from entering the larger "bag" end of the net, and detours them out of the net via a flap (Figures 1 and 2).

Regulatory and social context

Shrimp is harvested by bottom trawling, a process that is an iconic image of the coastal southeastern United States (Figure 3). In Georgia, artisanal shrimping dates back to the 1700s, and was dominated by enslaved and free African American fishers (Bell, 2010; Hoskins-Brown, 2020). Industrial shrimping began in the 1920s, and commercial shrimping peaked in 1976 with over 1500 commercial shrimping boats registered in Georgia (Blount and Pitchon, 2007). Georgia's commercial fishing industry declined in the late 20th century, caused by factors such as environmental protections, fuel costs, and competition from imported shrimp (Blount, 2003, 2007).

TEDs were crafted and adopted during the 1980s, following significant changes in commercial fishing regulation. The Magnuson-Stevens Fishery Conservation and Management Act of 1976 (MSA) extended US jurisdiction to 200 miles offshore and created the Regional Council System (Crosson, 2013). Historically, most US fisheries were regulated by state

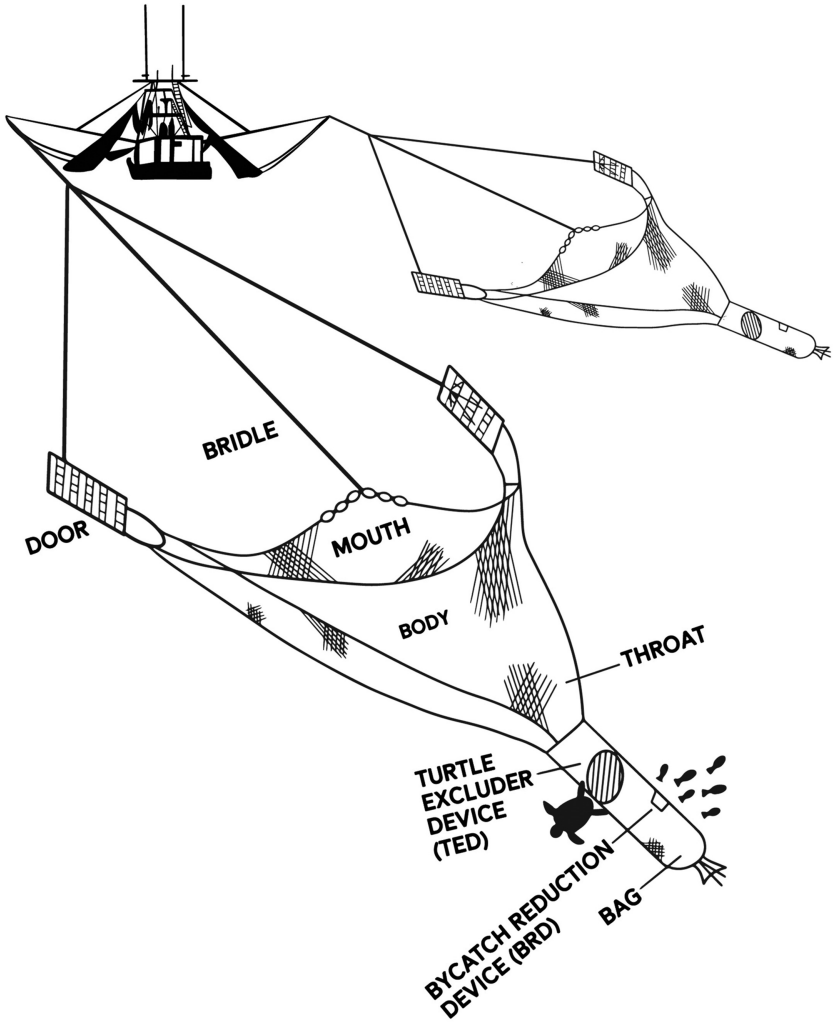

Figure 1. Diagram of shrimp boat towing trawl nets equipped with TEDs (image created by Tammy Fluech).

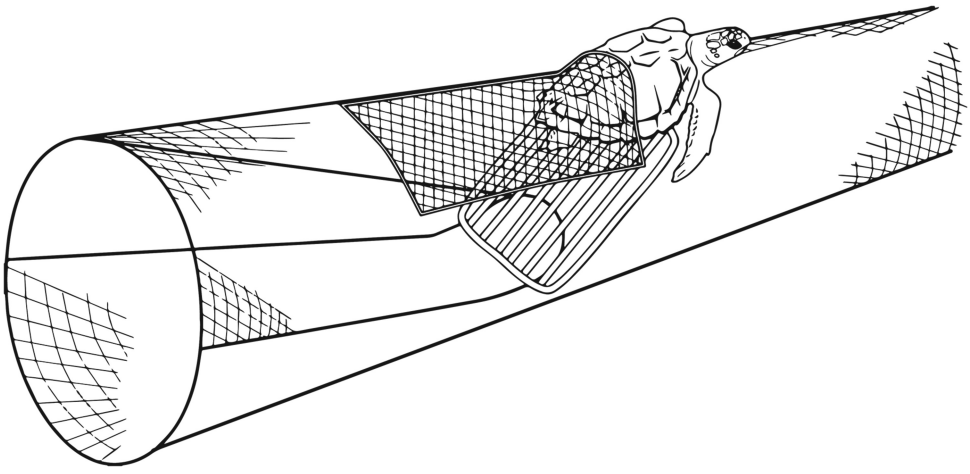

Figure 2. Turtle being excluded from a shrimp net by a TED (image courtesy of Texas Sea Grant, 2020).

and Federal agencies (Crosson, 2013), with shrimping regulated solely by state agencies. However, the Federal government interacted with the shrimping industry much earlier regarding bycatch regulation, which is often driven by the Endangered Species Act.

Methods

We use institutional records from UGA MarEx/GSG; publicly available oral history data from the National Oceanic and Atmospheric Administration's website *Voices: Oral History Archives* (NOAA, n.d.); and data gathered by the authors dur-

Figure 3. Shrimp boat deploying gear (image courtesy of UGA MarEx/GSG).

ing field research in fishing communities along Georgia's coast during 2013–2020 field research seasons. Research included participant observation on fishing docks and in fishhouses, in fishers' homes and backyard seafood processing operations, in the seafood processing facilities of small and large distribution companies, on a shrimp research vessel, in oyster flats on an oyster skiff, and in retail and wholesale seafood spaces across the six coastal counties for over 7 years. We conducted numerous unstructured interviews with a variety of fishing community members throughout the study periods, which frame and contextualize the data drawn from in-depth interviews with 12 commercial fishing industry members discussed in this paper.

Sampling and recruitment

Recruitment used purposive sampling (Bernard, 2002, p. 182) of knowledgeable individuals, followed by snowball sampling (Bernard, 2002, p. 185) from those contacts to others the participants thought would be informative. We used multiple recruitment strategies including identifying participants via the regional management council and local extension agents and publicly listed fishing licence data. Snowball sampling continued from each participant, and through overlapping research projects, as we built relationships with the majority of Georgia's fishing industry members.

Interviews

Data in this paper come from semi-structured, qualitative interviews conducted at a location the participant chose. Interviews followed a general script to ensure topic coverage, but were open-ended and followed grounded theory (Glaser and Strauss, 1967) so new information could emerge. While demographic data about Georgia's fishing communities is not available, the age and gender of this sample echoed the age, gender, and fishery trends that we observed; thus, we believe our sample captures the Georgia fishing industry. Notes and audio recordings were made during all interviews, and recordings were transcribed verbatim by the researchers and student volunteers. These comprise the data set for analysis.

Analysis

The researchers carefully read and re-read field notes, interview transcripts, and oral history transcripts, looking for themes, patterns, and variations in the data related to TEDs. Recurring ideas emerged, prompting the beginning of open coding (Emerson, Fretz, and Shaw, 2011) to note these ideas in the margins of the text and identify analytic categories that appeared repeatedly. Next, the researchers identified the overlap between categories, reviewed them to identify the most common themes, then identified fisher statements that captured the commonalities. These direct quotes from Georgia commercial fishers illustrate the foundational qualitative data, and are presented in Tables 1–3.

Case study: TED acceptance in Georgia

Shrimping and the development of TEDs

Commercial shrimp trawlers pull nets behind motorized boats to scoop shrimp from the water. Since the mid-20th century, shrimp boats have been similar in design: They are equipped with outriggers that sit upright until needed, when they are lowered to hang over the water. Each outrigger drags one or two nets equipped with two wooden doors, ~3–10 feet long (Figure 1). These doors slide on their edges along the seabed, where water pressure and a connecting chain keep them apart with the net between (Jenkins, 2012). After dragging for a period of time (2–3 h), the nets are winched onboard, and emptied on the deck. Shrimpers hope to find an abundance of

Table 1. Shrimper responses to the "Lifetime Change" question.

What are some positive changes you have seen in commercial fishing over your life?	…Years ago we didn't pull the turtle shooters… But now we have to pull them, the turtle shooter and the fish eye…
	Positive in the shrimping industry?…Well, I guess some things are positive, like nowadays, we have to pull…them TEDs…and it saves the turtles and stuff …
	I think the willingness for government agencies to get our input has grown, has gotten better over the years. Allowing us to try everything, taking our … suggestions on the TEDs… Actually having commercial fishermen test them.
	…We never thought that we'd think they [TEDs] were a good thing. But they've deleted a lot of the unnecessary stuff that we'd catch, a lot of trash, dead wood, chunks of old, rotten tree and stuff …stuff that just … crushes the shrimp all up and … mutilate them…

Table 2. Shrimper responses to the "Effective Fishery Management" question.

What *is* working and *not* working with fisheries regulation right now?	What they have works, and … the turtle shooter's a great thing. The fish eye *does* work.
	We"ve pretty much handled everything that's come down the pipe …We"ve worked and tested with turtle excluders where they"re a thousand percent effective, and then they do not … affect production too much… You know, I feel like the gear we"re pulling now is very effective.
	The regulations, the gear, we"ve pretty much gotten used to. [We've] learned how to deal with the TEDs and make them work efficiently… Actually, they"ve helped improve the quality of the catch because they don't get mutilated by the bycatch which is too heavy…. [It] has improved the quality of the shrimp. I don't know that you could tow out there today without turtle shooters.
	I was one of the first one to pull TEDs, you know, to get the right angle set on them…It worked. When we first started pulling them things… you would lose ninety percent of the shrimp that came through it. And then we got it down to about fifteen percent by adjusting and working back and forth. So I knew that [TED mandate] was coming so I figured… let's embrace it and try to work together because … the only thing constant is change…You can either resist it or try to make the best out of it.

Table 3. Positive comments about TEDs.

I wouldn't take it out. You don't catch near the damn junk you used to catch. Used to catch all kinds of horseshoe crabs and turtles and stuff. But, it saves on a lot of stuff now.
I used to …be resentful that you had to have these turtle excluders,… but …you just had a lot more fish that you had to deal with to get your shrimp because you catch a lot more. And most of that wouldn't be stuff you'd want to keep. That's good.
…trawl shooters have … helped a lot. It makes your shrimp a lot more marketable. You don't get the big horseshoe crabs and a whole bunch of crabs biting them. It shoots them out …keeps stuff from compacting everything in the bag.
A lot of shrimpers might hate the price of what [TED] costs, but it has helped them when it comes to catch… knocking a lot of that bycatch out. I would be willing to bet 95%, if not more than 95% of the shrimpers would still pull that device if they said, "hey, you don't have to do it anymore," because it helps them…
Shrimpers were at first hesitant … but before they made it mandatory, shrimpers, including my grandfather, were pulling devices very similar to that for bycatch reduction… so that the crews didn't have to spend so much time on the deck, digging through all that stuff.
Back then we didn't have no turtle shooters or nothing and you had jellyballs …We had to get them to help to pick the shrimp up out of those fish, that's how bad it was.

shrimp, with minimal other species, such as small fish, horseshoe crabs, cannonball jellyfish ("jellyballs"), or sea turtles. When sea turtles were placed on the Endangered Species list, there was regulatory pressure to prevent sea turtle deaths. In Georgia, MarEx/GSG sought solutions.

In 1971, Dr Ed Chin, the founder of UGA MarEx/GSG, recruited Dave Harrington from Texas A&M University to support the seafood industry. Harrington's experiences as a commercial fisher and researcher were key to his ability to effectively communicate and collaborate with fishers about new gear rules regarding sea turtles.

Georgia's commercial shrimpers faced numerous problems in the early 1970s: fuel shortages, high fuel prices, competition from imported shrimp, overcapitalization, price fixing in the seafood supply chain, and bycatch. To help with these issues, MarEx/GSG established a fisheries gear research program similar to that at the National Marine Fisheries Service (NMFS). NMFS had carried out gear research for years, but worked on their own research vessels, which were larger and used technology not common in shrimping. MarEx/GSG purchased a research vessel similar to those used by industry.

In 1979, MarEx/GSG acquired the Research Vessel (R/V) Georgia Bulldog, a 73-foot DESCO shrimp boat (Chin, 2007). Harrington solicited ideas from fishing industry members to combine with MarEx/GSG ideas to build and test gear. He involved industry in all steps of designing, testing, refining, and re-testing the gear. This collaborative process of industry involvement became a hallmark of the program.

In the mid-1980s, NMFS developed a TED intended to reduce or eliminate turtle mortality in shrimp trawls. Georgia shrimpers were frustrated with this TED—which was the only NMFS-approved TED at the time. While it successfully excluded turtles, former MarEx/GSG staff member Lindsey Parker explained that shrimpers considered it "expensive,

cumbersome, impractical, and potentially dangerous to the crew" (Parker, 2021). Parker elaborated that "Dave [Harrington] used to call it… 'a Swiss watch.' … Highly engineered, very highly tuned. Basically, everybody who has ever pulled a shrimp net and torn up a shrimp net, or hung up a shrimp net, knew that you don't put a Swiss watch in the ocean" (Parker, 2010). MarEx/GSG's involvement developed out of the shrimp industry's frustration with this NMFS TED, when NMFS consulted with MarEx/GSG because of their reputation for collaborative work, asking for assistance in developing TEDs that would be effective, less expensive, and more acceptable to shrimpers.

Two Georgia-based shrimpers played a central role in this collaboration: Sinkey Boone and Kenny Atwood. One of the first products of this collaboration was the "Georgia Jumper" TED. Excluder devices were familiar to Georgia shrimpers, as they had designed their own gear to exclude jellyfish from their nets for years. Parker (2010) explained:

> The gentleman that invented the oval-type TED, Sinkey Boone, the Georgia Jumper, developed the TED not only to save sea turtles, but to improve the quality of his catch. One of the buyers of their shrimp complained about cut shrimp, pieces of shrimp, and the processors didn't want them. So …Sinkey designed his TED to keep other bycatch out of the net so that the quality of the shrimp was better.

In 1986, Harrington invited NOAA, state agencies, Sea Grant agents, and environmental groups to observe this gear. They held a demonstration to compare the NMFS-designed TED to the Georgia Jumper in the sea turtle rich waters off of Cape Canaveral, Florida. The shrimper-based design proved effective and more affordable than the NMFS design, and it was approved for use by NMFS in 1987 (NOAA, 2021).

Shrimper perspectives on TEDs

Chin argues that Georgia shrimpers' lower hostility to TED requirements (compared to their Gulf counterparts discussed below) was "a direct result of the conciliatory influence of Marine Extension Staff" (Chin, 2007), and, as Blount argues, NMFS's willingness to allow some degree of choice in which TED a shrimper used (2003). Parker concurred, explaining "on our coast, there really haven't been any organized protests" (2010). He credits Harrington's collaboration with shrimpers, saying "the work that Dave did in opening up the rapport with fishermen about turtles and TEDs paid off" (2010).

Parker acknowledged that Harrington's style contributed to TEDs acceptance among Georgia shrimpers (Parker, 2021). Parker explained that Harrington spelled it out to the fishermen. "This [is the] problem. We got a shrimp net and we got sea turtles in the water. We got to be able to put this shrimp net out in the Canaveral channel – where turtles are thick as fleas on a dog's back… and it's got to come up with no turtles in it" (Parker, 2017). He believes that because fishers were treated as valuable collaborators, they found the implementation less offensive.

Parker's comments were echoed by many contemporary shrimpers who are still fishing. During 2017 interviews, shrimpers were asked about changes they had seen over their lifetimes. Several spontaneously responded that the TED mandate was a positive change (Table 1). While some simply cited TEDs, or "turtle shooters" (in local vernacular), as generally beneficial, others mentioned the collaboration between MarEx/GSG and fishers as a positive experience.

Another question asked participants (shrimping in both state and Federal waters) about fisheries regulation. Many cited TEDs as evidence of what was working well in regulation, explaining that TEDs and other bycatch reduction devices ("fish eyes") are beneficial (Table 2).

The qualitative data above, came from shrimper responses to specific questions about management, regulation, and lifetime changes. However, the final qualitative data set (Table 3) contains volunteered statements made by shrimpers during interviews. These were not responses to questions, but spontaneously shared information about how TEDs improved shrimping. Many noted that, while the TEDs were designed to exclude turtles, they resulted in a "cleaner" catch—meaning less heavy bycatch to strain the winch, drag on engines, or to be tossed out by the crew.

Discussion

The history of the development and adoption of TEDs, and recent oral histories and interviews, can be used to understand the drivers behind the acceptance of TED requirements on Georgia shrimping boats.

Analysis of congruence with literature insights

Our analysis shows that TED introduction was consistent with many insights from the Diffusion of Innovation and TEK literatures (summarized in Table 4), and the success of this bycatch reduction gear reflects arguments made in the literature. Almost all insights of the Diffusion of Innovation literature described by Mascia and Mills (2018) are congruent at a medium or high level, with exceptions being low barriers to entry not applying, and cost of innovation being low congruence. Similarly, the narrative of TEDs development by Georgia shrimpers in collaboration with UGA MarEx/GSG is highly congruent with the key features of the TEK literature.

Comparison with the Gulf of Mexico

The introduction of TEDs in the Gulf of Mexico, offers an interesting contrast to the relatively smooth acceptance of TEDs in Georgia. In the Gulf, TEDs met fierce opposition including a 6-week-long blockade of shipping channels in Louisiana and Texas, and heated statements such as "I'll set my boat on fire before I pull a TED" (NYT, 1989). These protests, which peaked in July 1989, involved up to 200 shrimping vessels blockading ports in southeastern Texas and Louisiana (see Figure 4).

It appears that in contrast to the conditions present in Georgia, Gulf of Mexico shrimpers were not involved in the development or adaptation of TEDs to the same extent. Although localized TEDs were developed in Gulf-adjacent states, there does not seem to have been the same concerted effort to incorporate fisher TEK or support localized innovation. Other factors may have influenced this resistance, such as relationships amongst harvesters, buyers, and brokers, or larger political forces. Furthermore, we were unable to find historical evidence of a collaborative relationship for engaging shrimpers in TED development in the Gulf. Teasing out which of these factors is most important in explaining the acceptance of TEDs in Georgia, and clarifying the differences in acceptance between

Table 4. Insights from Diffusion of Innovation and TEK literatures.

Insight	Congruence of insight and case study
Diffusion of Innovation: Innovation is most likely to diffuse when:	
Innovation consistent with social beliefs and values	Medium: Some shrimpers were already using similar devices to reduce unwanted catch of jellyfish and other species
Innovation can be tweaked to local conditions	High: Two different types of TEDs were both tweaked to local conditions. Fishers have some autonomy to improve efficiency.
Innovation has few barriers to entry	N/A: Innovation is required, thus criteria does not apply. But materials used in TEDs are common and locally available to shrimp industry.
Innovation is low cost	Low: TEDs are expensive in terms of materials and deployment effort. However, the Georgia TEDs are lower cost than other TEDs in terms of lost target species.
Early adopters are high status	High: The two earliest adopters were both high status shrimpers
Early adopters are well connected to outside world	Medium: Early adopters were well connected with Sea Grant. Connections beyond unclear.
Early adopters are well connected to each other	High: Early adopter worked together to develop Georgia TEDS, and are well connected to the rest of the shrimping community
Early adopters have autonomy to innovate	High: Early adopters were deeply involved in development of TEDs in Georgia, however, not all adopters had this level of autonomy
Early adopters are in competition with each other	High: Shrimping is a highly competitive industry. Ability of TEDs to reduce unwanted catch increased attractiveness
The innovation is introduced into a suitable context	High: Innovation leadership in Georgia (Harrington) worked extensively on context and appropriateness of TEDs
Incorporating TEK into regulation improves acceptance of new regulatory approach by:	
Using qualitative expertise rather than abstract quantitative data	High: Shrimpers were interested in real life TED usage rather than repeated statistical testing by NMFS.
Focusing on an intuitive rather than rational component	Medium: Shrimpers rational observations identified the problem. Intuitive understanding of gear capabilities and underwater effects of towing nets led to development of a completely different style of TED to contrast the NMFS TED.
Prioritizing empirical observations and accumulation of facts by trial-and-error	High: Boone had experience with crafting gear to exclude other types of bycatch even though not assessed by scientists; based on empirical observations of type and size of bycatch commonly showing up in local shrimp nets.
Incorporating data generated by resource users	High: Boone crafted TED in response to resource user observations of bycatch, and desire for cleaner catch.
Understanding and utilizing diachronic data	High: Resource user observations over many years (sometimes generations) exclusively in the South Atlantic off Georgia.
Not prioritizing principles of general interest and applicability	Medium: Original TED development in response to user need; only considered other applicability in response to impending regulations.
Assessing the true costs and benefits of development better than outside evaluators are able to do	High: NMFS costs and benefits focused on turtle mortality; Resource user costs and benefits included gas cost to tow heavy gear, cost in time lost to repositioning poor TEDs, cost in repairing, and maintaining TEDs too delicate for practical use.
Effectively incorporating TEK throughout the development process	Medium: Parallel development processes in Georgia by resource users in collaboration with local agencies vs. in Florida by NMFS resulted in better gear in Georgia/. Leadership by MarEx/GSG incorporated TEK into the development and NMFS approval process.

the Gulf states and Georgia, is a promising avenue for future research.

Conclusion

Changes in gear and regulation are difficult for commercial fishers. Often fishers feel excluded from meaningful roles in decision-making, despite evidence that fisher participation supports sustainable fisheries management (Pita *et al.*, 2010; Yates and Schoeman, 2015). This exclusion of fishers can be attributed in part to the disconnect between (1) the types of research that investigate fisher viewpoints; (2) the places where this research is published; (3) the types of publications that fisheries scientists most often read; and (4) the venues wherein this type of research is published (Hind, 2015).

Similarly, while fishers argue that they are not heard, fisheries scientists and gear developers also question why their research is not welcomed and readily adopted widely by commercial fishers (Eayrs and Pol, 2019). We offer literatures on Diffusion of Innovation and TEK as a partial answer. We bring together these literatures using the case of TEDs in Georgia. Analysing records from UGA MarEx/GSG, publicly available oral history data, and our research in these communities from 2013 to 2021, we articulate the connections between the literature and the relatively smooth uptake of TEDs in Georgia. In addition, we incorporate contemporary perspectives on TEDs to highlight current acceptance of, and preference for gear that was far more controversial in other parts of the country, specifically the Gulf of Mexico.

Georgia shrimpers' recollections show that Chin and Harrington's collaborative approach led to widespread acceptance. Chin and Harrington provided early adopters with the autonomy and support to innovate TEDS, and modify them to suit local conditions. They also ensured that early adopters were high status and well connected within the fishing community. Under their guidance, MarEx/GSG's extension approach, which reflects the values advocated by the Diffusion of Innovation and TEK literatures, was fundamental to the success of TEDs in Georgia. Pairing historical records and fishers' perspectives illustrates that the best practices identified in the literature were indeed present in this case. When contemplating bycatch reduction gear requirements, meaningfully engag-

Figure 4. News coverage of shrimpers' blockade of Galveston Ship Channel, Gulf of Mexico, July 1989 (photo credit: AP Photo/Gaylon Wampler).

ing fishers in development and testing of technology is essential. Our understanding of how to increase fisher buy-in and effective gear uptake would benefit from focused research as new regulations are developed, in addition to this retrospective analysis. In the interim, this paper provides a blueprint for collaboration with commercial industry for successful gear uptake and cooperative regulatory management.

Data availability statement

The data underlying this article cannot be shared publicly due to the privacy of individuals who participated in the study, and in accordance with Institutional Review Board policies.Data will be shared on reasonable request to the corresponding author.

Funding

This project was supported in part under grant award #NA17NOS4190164 to the Georgia Department of Natural Resources from the Office for Coastal Management, National Oceanic and Atmospheric Administration. The statements, findings, conclusions, and recommendations are those of the author(s), and do not reflect the views of DNR, OCM or NOAA.

Research was supported in part by Institutional Grants (#NA10OAR4170098 and #NA18OAR4170084) to the Georgia Sea Grant College Program from the National Sea Grant OfficeNational Oceanic and Atmospheric Administration, U.S. Department of Commerce. All views, opinions, findings, conclusions, and recommendations expressed in this material are those of the authors and do not necessarily reflect the opinions of the Georgia Sea Grant College Program or NOAA.

Conflict of Interest statement

The authors have no competing interests.

Acknowledgements

The authors are grateful to students of the 2018 "Fishing Traditions and Fishing Futures" field research project; graduate student Project Manager Ahmauri Williams-Alford; and Molly Graham of NOAA's *Voices: Oral History Archives*. All views, opinions, findings, conclusions, and recommendations expressed in this material are those of the authors, and do not necessarily reflect the opinions of the Georgia Sea Grant College Program or NOAA.

References

Acheson, J. M., and Reidman, R. 1982. Technical innovation in the New England fin-fishing industry: an examination of the downs and mohr hypothesis. American Ethnologist, 9: 538–558.

Bell, K. B. 2010. Rice, resistance, and forced transatlantic communities:(re) envisioning the african diaspora in low country Georgia, 1750-1800. The Journal of African American History, 95: 157–182.

Berkes, F. 1993. Traditional ecological knowledge in perspective. In Traditional Ecological Knowledge: Concepts and Cases. International Program on Traditional Ecological Knowledge and International Development Research Centre, Ottawa, Canada.

Bernard, H. R. 2002. Research Methods in Anthropology: Qualitative and Quantitative Methods. AltaMira Press, Walnut Creek, California.

Blount, B. G. 2003. Perceptions of legitimacy between commercial fishermen and regulatory agencies: some ethical concerns. *In* Values at Sea: Ethics for the Marine Environment, pp. 127–146. Ed. by Dallmeyer Dorinda G.. University of Georgia Press, Athens, GA.

Blount, B. G. 2007. Culture and resilience among shrimpers on the Georgia coast (USA): responses to globalization. MAST (Maritime Studies), 5: 5–26.

Blount, B. G., and Pitchon, A. 2007. An anthropological research protocol for marine protected areas: creating a niche in a multidisciplinary cultural hierarchy. Human Organization, 66: 103–111.

Butler, J. R. A. 2012. Integrating Traditional Ecological Knowledge and Fisheries Management in the Torres Strait, Australia: The Catalytic Role of Turtles and Dugong as Cultural Keystone Species. Ecology and Society, 17: 34.

Chan, M., Beaudreau, A. H., and Loring, P. A. 2019. Exploring diversity in expert knowledge: variation in local ecological knowledge of alaskan recreational and subsistence fishers. ICES Journal of Marine Science, 76: 913–924.

Chin, E. 2007. A History and Some Personal Reflections.University of Georgia Marine Extension, Athens, Georgia.

Clay, T. A., Small, C., Tuck, G. N., Pardo, D., Carneiro, A. P., Wood, A. G., and Phillips, R. A. 2019. A comprehensive large-scale assessment of fisheries bycatch risk to threatened seabird populations. Journal of Applied Ecology, 56: 1882–1893.

Conklin, H. C. 1957. Hanunoo agriculture. A report on an integral system of shifting cultivation in the Philippines. FAO Forestry Development Papers, 12. 209pp.

Crosson, S. 2013. The impact of empowering scientific advisory committees to constrain catch limits in US fisheries. Science and Public Policy, 40: 261–273.

Damalas, D., Maravelias, C., Osio, G., Maynou, F., Sbrana, M., Sartor, P., and Casey, J. 2015. Historical discarding in Mediterranean fisheries: a fishers' perception. ICES Journal of Marine Science, 72: 2600–2608.

Dewees, C., and Hawkes, G. 1988. Technical innovation in the Pacific Coast trawl fishery: the effects of fishermen's characteristics and perceptions on adoption behavior. Human Organization, 47: 224–234.

Dias, M. P., Martin, R., Pearmain, E. J., Burfield, I. J., Small, C., Phillips, R. A., and Croxall, J. P. 2019. Threats to seabirds: a global assessment. Biological Conservation, 237: 525–537.

Dingfelder, H. E., and Mandell, D. S. 2011. Bridging the research-to-practice gap in autism intervention: an application of diffusion of innovation theory. Journal of Autism and Developmental Disorders, 41: 597–609.

Eayrs, S., and Pol, M. 2019. The myth of voluntary uptake of proven fishing gear: investigations into the challenges inspiring change in fisheries. ICES Journal of Marine Science, 76: 392–401.

Emerson, R., Fretz, R., and Shaw, L. 2011. Writing Ethnographic Fieldnotes, 2nd edn. University of Chicago Press, Chicago, IL.

Environmental Protection Agency (EPA). 2022. Summary of the Endangered Species Act. https://www.epa.gov/laws-regulations/summary-endangered-species-act.

Espinoza-Tenorio, A., Wolff, M., Espejel, I., and Montaño-Moctezuma, G., 2013. Using traditional ecological knowledge to improve holistic fisheries management: transdisciplinary modeling of a lagoon ecosystem of southern mexico. Ecology and Society, 18: 6.

Figus, E., Carothers, C., and Beaudreau, A. H. 2017. Using local ecological knowledge to inform fisheries assessment: measuring agreement among Polish fishermen about the abundance and condition of Baltic cod (*Gadus morhua*). ICES Journal of Marine Science, 74: 2213–2222.

Fisher, J. R., Montambault, J., Burford, K. P., Gopalakrishna, T., Masuda, Y. J., Reddy, S. M., and Salcedo, A. I. 2018. Knowledge diffusion within a large conservation organization and beyond. PLoS One, 13: e0193716.

Glaser, B., and Strauss, A. 1967. Glaser and Strauss: Developing Grounded Theory. Aldine Publishing Company, Chicago, IL.

Haggen, N., Neis, B., and Baird, I. G. 2007. Fishers' Knowledge in Fisheries Science and Management|United Nations Educational, Scientific and Cultural Organization. Coastal Management Sourcebooks series. UNESCO, Paris, France.

Hazen, E. L., Scales, K. L., Maxwell, S. M., Briscoe, D. K., Welch, H., Bograd, S. J., Bailey, H. *et al.* 2018. A dynamic ocean management tool to reduce bycatch and support sustainable fisheries. Science Advances, 4: eaar3001.

Hind, E. J. 2015. A review of the past, the present, and the future of fishers' knowledge research: a challenge to established fisheries science. ICES Journal of Marine Science, 72: 341–358.

Hoskins-Brown, D. L. 2020. Tales of landings and legacies: African Americans in Georgia's coastal fisheries. Culture, Agriculture, Food and Environment, 42: 36–50.

Iqbal, M., and Zahidie, A. 2021. Diffusion of innovations: a guiding framework for public health. Scandinavian Journal of Public Health, https://doi.org/10.1177/14034948211014104

Jenkins, L. 2012. Reducing sea turtle bycatch in trawl nets: a history of NMFS turtle excluder device (TED) research. Marine Fisheries Review, 74: 26–44.

Johannes, R. E. 1993. Integrating traditional ecological knowledge and management with environmental impact assessment. In *Traditional Ecological Knowledge Concepts and Cases*, pp. 33–41. Ed. byJulian T. Inglis International Program on Traditional Ecological Knowledge and International Development Research Centre, Ottawa, Canada.

Klee, G. A. 1980. World Systems of Traditional Resource Management, 1st edn. Edward Arnold, London.

Levy, M. A., and Lubell, M. N. 2018. Innovation, cooperation, and the structure of three regional sustainable agriculture networks in California. Regional Environmental Change, 18: 1235–1246.

Lunblad, J. 2003. A review and critique of rogers' diffusion of innovation theory as it applies to organizations. Organization Development Journal, 21: 50–64.

MacKeracher, T., Foale, S. J., Gurney, G. G., and Purcell, S. W. 2019. Adoption and diffusion of technical capacity-building innovations by small-scale artisanal fishers in Fiji. Ecology and Society, 24: 3.

Mahajan, S. L., Jagadish, A., Glew, L., Ahmadia, G., Becker, H., Fidler, R. Y., and Mascia, M. B. 2021. A theory-based framework for understanding the establishment, persistence, and diffusion of community-based conservation. Conservation Science and Practice, 3: e299.

Marin, K., Coon, A., and Fraser, D. J. 2017. Traditional ecological knowledge reveals the extent of sympatric lake trout diversity and habitat preferences. Ecology and Society, 22: 2.

Martin, K., McCay, B., Murray, G., Johnson, T., and Oles, B. 2007. Communities, knowledge and fisheries of the future. International Journal of Global Environmental Issues, 7: 221–239.

Mascia, M. B., and Mills, M. 2018. When conservation goes viral: the diffusion of innovative biodiversity conservation policies and practices. Conservation Letters, 11: e12442.

McBain-Rigg, K. E., Franklin, R. C., King, J. C., and Lower, T. 2017. Influencing safety in Australian agriculture and fisheries. Journal of Agromedicine, 22: 347–357.

Min, S., So, K. K. F., and Jeong, M. 2019. Consumer adoption of the uber mobile application: insights from diffusion of innovation theory and technology acceptance model. Journal of Travel & Tourism Marketing, 36: 770–783.

New York Times (NYT). 1989. Shrimpers grudgingly obey turtle protection rules. In The New York Times, p. 24. September 9. (last accessed 4 August 2021).

Nilsson, D., Fielding, K., and Dean, A. J. 2020. Achieving conservation impact by shifting focus from human attitudes to behaviors. Conservation Biology, 34: 93–102.

NOAA. 2021. History of turtle excluder devices. https://www.fisheries.noaa.gov/southeast/bycatch/history-turtle-excluder-devices (last accessed 19 January 2022)

NOAA . https://voices.nmfs.noaa.gov/collection/turtle-excluder-device-oral-histories Voices: Oral History Archives. (Accessed 25 May 2021).

Parker, L. 2010. Oral history interview conducted by stephanie Scull-dearmey as part of the turtle excluder device oral histories collection. Interview hosted by NOAA Fisheries at https://voices.nmfs.noaa.gov/index.php/collection/turtle-excluder-device-oral-histories.

Parker, L. 2017. Oral history interview conducted by Kendra Cooper and Alexis McGhee, under the supervision of the authors for "fishing traditions and fishing futures" project. Project PI: Jennifer Sweeney Tookes. Project Funded by Georgia Department of Natural Resources Coastal Resources Division.

Parker, L. 2021.Personal communication. June 22

Pita, C., Pierce, G. J., and Theodossiou, I. 2010. Stakeholders' participation in the fisheries management decision-making process: fishers' perceptions of participation. Marine Policy, 34: 1093–1102.

Quinlan, S., Gummer, T., Roßmann, J., and Wolf, C. 2018. 'Show me the money and the party!'–variation in facebook and twitter adoption by politicians. Information, communication & society. Information, Communication & Society, 21: 1031–1049.

Rist, L., Uma Shaanker, R., Milner-Gulland, E. J., and Ghazoul, J. 2010. The use of traditional ecological knowledge in forest management: an example from india. Ecology and Society, 15: 3. https://doi.org/10.5751/ES-03290-150103

Rogers, Everett M. 1962/1995. Diffusion of Innovations, 4th ed., pp. The Free Press, New York.

Romero-de-Diego, C., Dean, A., Jagadish, A., Witt, B., Mascia, M. B., and Mills, M. 2021. Drivers of adoption and spread of wildlife management initiatives in mexico. Conservation Science and Practice, 3: e438.

Schafer, A. G., and Reis, E. G. 2008. Artisanal fishing areas and traditional ecological knowledge: the case study of the artisanal fisheries of the Patos Lagoon estuary (Brazil). Marine Policy, 32: 283–292.

Silva, J. F., and Ellis, J. R. 2019. Bycatch and discarding patterns of dogfish and sharks taken in English and Welsh commercial fisheries. Journal of Fish Biology, 94: 966–980.

Silvano, R. A. M., and Valbo-Jørgensen, J. 2008. Beyond fishermen's tales: contributions of fishers' local ecological knowledge to fish ecology and fisheries management. Environment, Development and Sustainability, 10: 657. https://doi.org/10.1007/s10668-008-9149-0

Simin, M.T. and Janković, D. 2014. Applicability of diffusion of innovation theory in organic agriculture. Economics of Agriculture, 61: 517–529.

Song, A. M., Cohen, P. J., Hanich, Q., Morrison, T. H., and Andrew, N. 2019. Multi-scale policy diffusion and translation in Pacific Island coastal fisheries. Ocean & Coastal Management, 168: 139–149.

Texas Sea Grant. 2020. Texas Shrimp Sustainability: How the Shrimp Industry Operates Sustainably in Texas. Texas A&M University and Texas Sea Grant College Program.

Thornton, T., and Scheer, A. 2012. Collaborative engagement of local and traditional knowledge and science in marine environments: a review. Ecology and Society, 17: 8. https://doi.org/10.5751/ES-04714-170308

Verutes, G. M., Johnson, A. F., Caillat, M., Ponnampalam, L. S., Peter, C., Vu, L., and Hines, E. M. 2020. Using GIS and stakeholder involvement to innovate marine mammal bycatch risk assessment in data-limited fisheries. PLoS One, 15: e0237835.

Virgili, M., Vasapollo, C., and Lucchetti, A. 2018. Can ultraviolet illumination reduce sea turtle bycatch in mediterranean set net fisheries? Fisheries Research, 199: 1–7.

Yates, K. L., and Schoeman, D. S. 2015. Incorporating the spatial access priorities of fishers into strategic conservation planning and marine protected area design: reducing cost and increasing transparency. ICES Journal of Marine Science, 72: 587–594.

Yoshikawa, T., Tsui-Auch, L. S., and McGuire, J. 2007. Corporate governance reform as institutional innovation: the case of japan. Organization Science, 18: 973–988.

Handling Editor: Yinji Li