


# Depredation: An old conflict with the sea

James Marcus Drymon<sup>1,2</sup>  | Amanda E. Jargowsky<sup>1,2</sup> | Evan G. Prasky<sup>3</sup> |  
Edward V. Camp<sup>4</sup> | Ashley Oliphant<sup>5</sup> | Sean P. Powers<sup>6,7</sup> | Steven B. Scyphers<sup>6,7,8</sup>

<sup>1</sup>Coastal Research and Extension Center,  
Mississippi State University, Biloxi,  
Mississippi, USA

<sup>2</sup>Mississippi-Alabama Sea Grant  
Consortium, Ocean Springs, Mississippi,  
USA

<sup>3</sup>Department of Environmental  
Conservation, University of  
Massachusetts Amherst, Amherst,  
Massachusetts, USA

<sup>4</sup>Fisheries and Aquatic Sciences  
Program, School of Forest, Fisheries, and  
Geomatic Sciences, University of Florida,  
Gainesville, Florida, USA

<sup>5</sup>Unaffiliated Hemingway Researcher,  
Denver, North Carolina, USA

<sup>6</sup>Stokes School of Marine & Environmental  
Sciences, University of South Alabama,  
Mobile, Alabama, USA

<sup>7</sup>Dauphin Island Sea Lab, Dauphin Island,  
Alabama, USA

<sup>8</sup>Department of Sociology, Anthropology,  
and Social Work, University of South  
Alabama, Mobile, Alabama, USA

## Correspondence

James Marcus Drymon, Coastal Research  
and Extension Center, Mississippi State  
University, 1815 Popps Ferry Road, Biloxi,  
MS 39532, USA.

Email: [marcus.drymon@msstate.edu](mailto:marcus.drymon@msstate.edu)

## Abstract

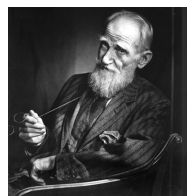
Depredation (the partial or complete removal of a hooked species by a non-target species) is a human–wildlife conflict as old as humans and the sea. In some ways, depredation is no different today than it was a century ago. But in many ways, this conflict has become more complicated. Following three decades of successful management, some US shark populations have begun to rebuild. However, many anglers attribute perceived increases in shark depredation to management measures, claiming they have led to ‘overpopulation’ of sharks and/or learned behaviour by sharks. We investigated whether these factors could explain the reported increases in depredation. Based on fishery-independent surveys, neither shark population increases nor learned behaviour by sharks is evident. However, increases in angler effort provide an alternative explanation that is not often considered. While far from a smoking gun, at least four themes emerge from this thought exercise. First, it is important to understand historical predator baselines. Second, it is important to acknowledge lifting baselines, that is, instances where previously depleted populations are recovering. Third, it is important to remember that there are many instances when stakeholder observations were initially misaligned with traditional scientific observations but were ultimately recognized as pivotal for filling data gaps. Finally, and perhaps most important, is the acknowledgement that perceived conflict is as potent as real conflict. Arguably, it may not matter if depredation has increased or decreased; the overwhelming perception from stakeholders is an increase in depredation, and this is the perceived (or real) conflict that must be addressed.

## KEYWORDS

human–wildlife conflict, lifting baseline, shark, shifting baseline

In the early 1930s, two anglers were lamenting a seemingly impossible task. Despite numerous attempts since discovering the seasonal presence of bluefin tuna (*Thunnus thynnus*) in the area 3 years prior, not a single unutilized tuna had yet been landed in the waters of

Bimini, the Bahamas. The problem was sharks. In the classic book *Atlantic Game Fishing*, Kip Farrington writes that ‘none of these magnificent fish have ever been boated near Bimini unmarked by sharks’ (Farrington, 1937). Rather, tunas were often ‘apple-cored’,



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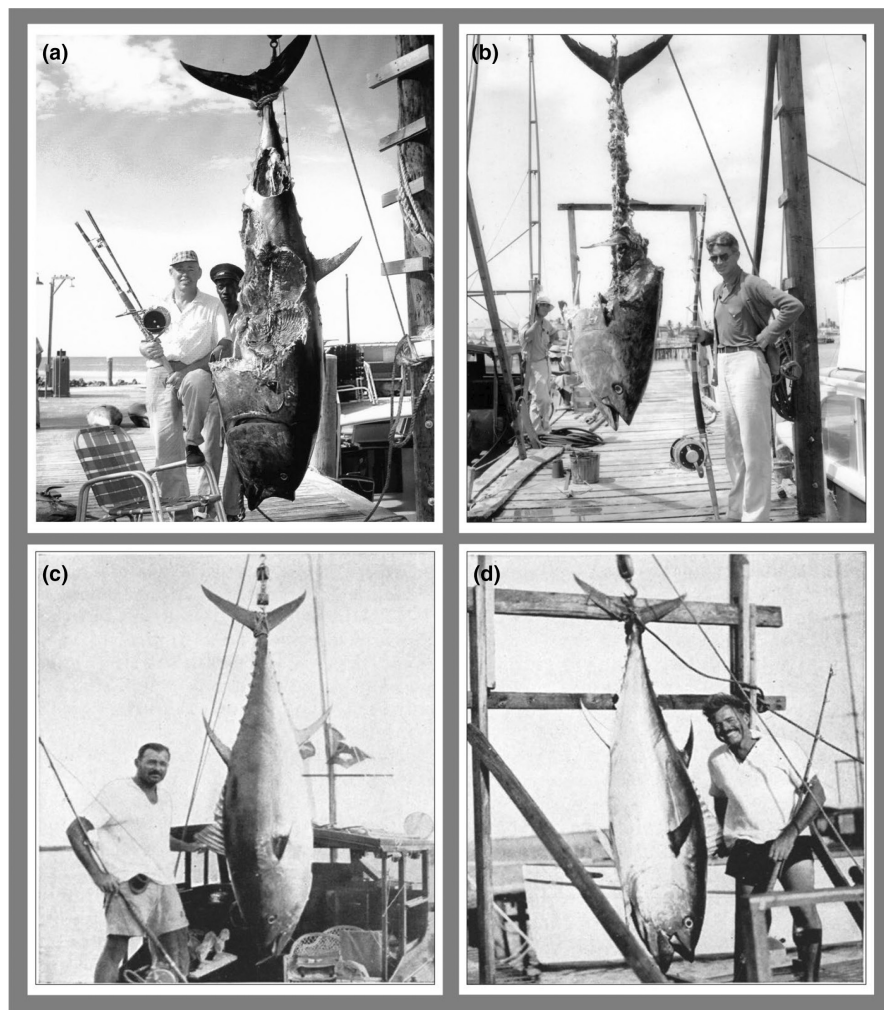
**Etymology of Ghoti:** George Bernard Shaw (1856–1950), polymath, playwright, Nobel Prize winner, and the most prolific letter writer in history, was an advocate of English spelling reform. He was reportedly fond of pointing out its absurdities by proving that ‘fish’ could be spelt ‘ghoti’. That is: ‘gh’ as in ‘rough’, ‘o’ as in ‘women’ and ‘ti’ as in palatial.

that is, landed with minimal flesh remaining around a gruesomely exposed vertebral column that connected an intact head and tail (Figure 1a,b). By 1935, these two highly skilled anglers had spent several years pondering the conflict between anglers and sharks. One of these anglers was Michael Lerner, who would go on to make numerous early contributions to fisheries science, including the establishment of the Lerner Marine Laboratory in Bimini. Lerner also co-founded the International Game Fish Association (IGFA) in partnership with the other angler, famed author and Nobel-laureate Ernest Hemingway. A renowned sportsman, Hemingway meticulously documented specific obstacles to landing whole fishes, including necessary modifications to fishing tackle and techniques. As a result of these innovations, Hemingway landed the first intact bluefin tuna documented in Bahamian waters on 21 May 1935, thus ending the 3-year drought. Two days later, he landed another (Oliphant, 2017) (Figure 1c,d). As these modifications proved successful, fishes caught by other anglers using his approach were said to be 'Hemingwayed'. These trials and tribulations ultimately shaped how Hemingway viewed, and interacted with, sharks.

Nearly a century after Hemingway landed his first Bahamian bluefin tuna, depredation (the partial or complete removal of a hooked species by a non-target species) has re-emerged as a contentious topic

among anglers (Mitchell et al., 2023). In some ways, depredation is no different today than it was for Lerner and Hemingway. But in many ways, this conflict has become more complicated. In Hemingway's time, sharks were at best a nuisance, and at worst a danger. The modern shark conservation ethos did not yet exist because none was needed. At the time, sharks were considered an 'underutilized resource', and attempts to develop and incentivize US shark fisheries were underway (Ottwell et al., 1985). Shark fishing expanded throughout the 1970s and 1980s, and shark conservation efforts did not begin in earnest until the early 1990s, after several shark populations had already been overfished (Pacoureau et al., 2023). These efforts included the first fishery management plan for sharks in the US Atlantic, which was enacted in 1993 (NMFS, 1993). As a result of that initial management plan, many US shark populations have begun to rebuild (Pacoureau et al., 2023; Peterson et al., 2017), which is generally viewed as a conservation success. However, many anglers attribute shark depredation to regulations enacted over the past 30 years to protect shark populations (Prasky et al., 2023), as these regulations were intended to rebuild populations relative to their levels during the 1990s.

Just as Lerner and Hemingway devised new fishing gear and modified their fishing practices to land Bimini tunas in the 1930s, today's anglers are poised to intuit solutions to depredation. Indeed,



**FIGURE 1** (a, b) Two depredated, or 'apple-cored', bluefin tuna caught off Bimini, the Bahamas (images from Ed Pritchard, [antiquefishingreels.com](http://antiquefishingreels.com)); (c, d) Hemingway stands proudly next to the (c) first and (d) second documented intact bluefin tuna caught off Bimini, the Bahamas as a result of his successful modifications to fishing tackle and techniques (images from Hemingway, 1935).

efforts to co-produce a shared understanding of this conflict in the US Gulf of Mexico (GoM) have advanced our understanding of depredation. On 04 April 2022, a group of charter-for-hire captains (expert anglers with deep local ecological knowledge) from across the GoM gathered at a workshop designed to characterize depredation (Drymon et al., 2022). As part of this characterization, the anglers were asked to draw trendlines illustrating how they perceive depredation has changed over time. These trendlines were used to reconstruct and digitize a time series using the R package 'digitize' (Poisot, 2011). Complete details of this process are provided in Gervasi et al. (2023). Collectively, the anglers perceived a clear increase in depredation over the past 10 years (i.e. from 2012 to 2022) (Figure 2a). While several explanations were offered, when asked which factors were primarily driving this increase, the anglers most often expressed two sentiments: 'overpopulation' of sharks and learned behaviour by sharks. Using data collected from the northern GoM, we can investigate whether 'overpopulation' of sharks (i.e. shark population increase) and/or learned behaviour by sharks could explain the recent increase in depredation reported by anglers.

## 1 | HAVE SHARK POPULATIONS INCREASED?

More specifically, does an increase in shark populations provide a likely explanation for the increase in depredation indicated by the anglers? To examine this, let us consider the case of the sandbar shark (*Carcharhinus plumbeus*) population off the coast of Alabama. Although this species was once the dominant component of the large coastal shark fishery in the GoM, a 2006 stock assessment determined the stock was overfished and experiencing overfishing (SEDAR, 2006), which led to a total harvest moratorium in 2008 that is still in effect today. In the absence of fishing pressure, sandbar shark has shown signs of population recovery (Pacoureau

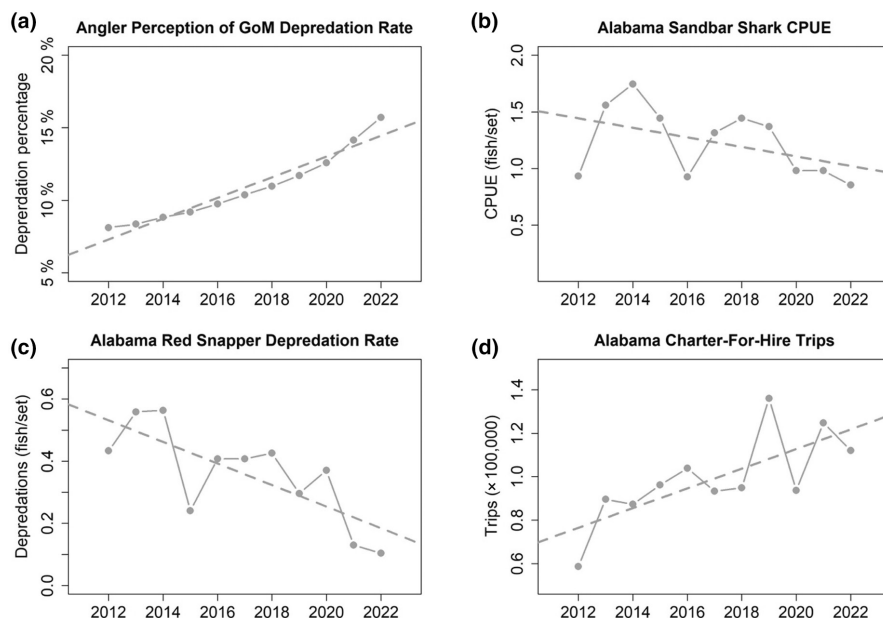
et al., 2023; Peterson et al., 2017). In addition, depredation by sandbar sharks is well documented in this region (Drymon et al., 2019). Based on a time series of sandbar shark catch-per-unit-effort from a fishery-independent bottom longline survey off the coast of Alabama (Drymon et al., 2020), the relative abundance of sandbar shark varies from year to year (Figure 2b). Seeing as this metric has not increased over time, the increase in depredation noted by the anglers does not appear to be caused by an increase in sandbar shark populations.

## 2 | ARE SHARKS LEARNING TO DEPREDATE?

More specifically, does an increase in learned behaviour by sharks provide a likely explanation for the increase in depredation described by the anglers? To examine this, let us consider the case of red snapper (*Lutjanus campechanus*) using the same fishery-independent bottom longline data mentioned above. Red snapper are commonly caught on bottom longline and are often subject to depredation by sharks (Drymon et al., 2019). Based on a time series of red snapper depredation by sharks off the coast of Alabama, a pattern of yearly variability is evident, like that of sandbar shark relative abundance (Figure 2c). If sharks were learning to depredate, we would expect an increase in the rate of red snapper depredation by sharks over time as more sharks learned the behaviour. However, the declining trend in red snapper depredation does not appear to support the idea that an increase in learned behaviour among sharks can explain the increase in depredation perceived by anglers.

The trends detailed above suggest that increases in shark populations and/or learned behaviour by sharks do not fully explain the increase in depredation documented by anglers. Something else may be contributing to the increased conflict. While sharks are one side of depredation, humans represent the other side of this human-wildlife

**FIGURE 2** (a) Anglers' perceptions of the rate of depredation in the Gulf of Mexico (GoM) from 2012 to 2022; (b) Catch-per-unit-effort (CPUE) of sandbar shark off Alabama based on fishery-independent bottom longline data from 2012 to 2022; (c) The depredation rate of red snapper by sharks off Alabama based on fishery-independent bottom longline data from 2012 to 2022; (d) The number of charter-for-hire trips off Alabama based on NOAA's Marine Recreational Information Program angler effort data from 2012 to 2022.



conflict. Accordingly, perhaps an increase in the number of anglers on the water may provide a likely explanation for the increase in depredation indicated by the anglers. Using angler effort data collected through NOAA's Marine Recreational Information Program, we can see a clear increase in the number of charter-for-hire fishing trips off Alabama in recent years (personal communication from the National Marine Fisheries Service, Fisheries Statistics Division, 25 August 2023, Figure 2d).

While far from a smoking gun, the above exercise highlights the complexities of this human–wildlife conflict. In 1935, Hemingway was one of a small group of anglers fishing a virgin stock of bluefin tuna in Bimini. Today, there are more anglers on the water than any time in history (Arlinghaus et al., 2019), and the stocks they target are far from virgin biomass. Are there more sharks in the GoM today than there were 20 years ago? Very likely. Are there more sharks in the GoM than there were in Hemingway's time? Likely not. Following the peak of shark fishing in the 1970s–1990s, US shark populations have slowly started to recover (Pacoureaux et al., 2023; Peterson et al., 2017), a product of 30 years of successful management efforts. Yet, for many anglers, the recovery of these shark populations is not cause for celebration. Just as for other taxa (e.g. marine mammals, Schakner et al., 2019), addressing shark depredation will require acknowledging that, while shark population recovery represents conservation success for sharks, the recovery of these shark populations has cascading (and often adverse) impacts on fisheries stakeholders (Carlson et al., 2019).

### 3 | WHAT LESSONS CAN WE TAKE FROM THIS CASE STUDY?

Drawing on the example above, at least four themes emerge related to depredation. First, it is important to understand historical predator baselines (Cammen et al., 2019). For example, Powers et al. (2013) used angler-documented accounts of tournament-landed sharks to reconstruct a 70-year time series of shark sizes in the northern GoM. Interestingly, there was clear evidence of shifting baselines; that is, the gradual acceptance of a reduction in the abundance or size of species (Pauly, 1995). Older anglers viewed changes in shark sizes more accurately than younger anglers; specifically, only individuals over 60 years of age remembered a time when larger sharks were more common. Second, it is important to acknowledge lifting baselines; that is, instances where previously depleted populations are recovering after decades of decline (Roman et al., 2015). For example, Pacoureaux et al. (2023) attributed increases in population trajectory for several US coastal shark species to the successful implementation of science-based management measures. It is vital that these success stories are celebrated. Third, it is important to remember that there are many instances when stakeholder observations were initially misaligned with traditional scientific observations, but were ultimately recognized as more accurate, or pivotal for filling data gaps (e.g. Scyphers et al., 2015). Finally, and perhaps

most important, is the acknowledgement that perceived conflict is as potent as real conflict (Cammen et al., 2019; Guerra, 2019). Arguably, it may not matter if depredation in the GoM has increased or decreased; the overwhelming perception from stakeholders is an increase in depredation, and this is the perceived (or real) conflict that must be addressed.

### 4 | WHAT LESSONS SHOULD (AND SHOULDN'T) WE TAKE FROM HEMINGWAY?

After carefully documenting his 'apple-cored' catches, Hemingway realized that the secret to landing intact fishes involved modifications to both behaviour and gear (i.e. landing the fishes faster using heavier tackle). While the seascape has undoubtedly changed since the 1930s, managing modern-day depredation will require similar behaviour and gear modifications. Despite Hemingway's successes in landing unmutated bluefin tuna, his antagonism towards sharks never subsided. Over a 3-month period from June to August of 1935, Hemingway penned three articles for *Esquire*, each of which mentioned his struggles with sharks. In his August 1935 article entitled 'He Who Gets Slap Happy', Hemingway elaborates on the struggle between tuna and sharks in Bimini:

So now the great myth that you cannot catch them in a half mile or a mile of deep water is dispelled... Lately we have been using a tommy gun on sharks when they come after a hooked fish. Sharks who are going to hit a fish usually show up first close to the boat. They will make a couple of circles before they go down. We bait them up with small pieces of fish to keep them to the top of the water, then throw out a big bait fish tied to a line and as the shark sticks his head out to take it someone gives him a burst. It works beautifully.

(Hemingway, 1935)

More than a decade after leaving Bimini, Hemingway's visceral reaction to sharks was immortalized as Santiago's prized marlin was repeatedly attacked in the Pulitzer prize-winning novella *The Old Man and the Sea* (Hemingway, 1952). It is impossible to know what Hemingway would think of modern-day shark depredation; based on his writings from 1935, he may empathize with anglers who suggest lethal retaliation as a 'solution' to depredation (Casselberry et al., 2022). But just as in Hemingway's day, angler-derived, non-lethal solutions like gear modifications and behavioural changes offer the most promise for innovating solutions to an old conflict with the sea.

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## ORCID

James Marcus Drymon  <https://orcid.org/0000-0002-2104-004X>

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