North American Journal of Fisheries Management

ISSN: 0275-5947 (Print) 1548-8675 (Online) Journal homepage: http://www.tandfonline.com/loi/ujfm20

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North American Journal of Fisheries Management 2:414–419, 2017

ISSN: 0275-5947 print / 1548-8675 online
DOI: 10.1080/02755947.2016.1271842

MANAGEMENT BRIEF

An Updated Description of the Benefits and Consequences of Red Snapper Shrimp Trawl Bycatch Management Actions in the Gulf of Mexico

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Abstract
Populations of Red Snapper *Lutjanus campechanus* in the Gulf of Mexico remain overfished, but overfishing has been ended. Historically, rebuilding plans were based almost entirely on the reduction of shrimp trawl bycatch mortality, which was believed to account for 80% of the total juvenile Red Snapper mortality. This estimate was based on the assumption that juvenile Red Snapper had low rates of natural mortality. Bycatch reduction devices were believed to be capable of reducing bycatch mortality by more than 50%, which would enable the stock to rebuild without any other management actions. Over the years, new information has shown that natural mortality rates of juvenile Red Snapper are four times higher than originally estimated, and bycatch mortality is presently estimated to comprise only about 4% of the total juvenile mortality. Hence, bycatch reduction, regardless of the means by which it is achieved, will not be very effective for rebuilding the Red Snapper stock. Limits on the harvest of adult Red Snapper beginning in 2007 have put this species on the road to recovery, but care must be taken to maintain a conservative harvest if full recovery goals are to be met on schedule.

The penaeid shrimp fishery in the Gulf of Mexico is one of the nation's most valuable fisheries (National Marine Fisheries Service [NMFS] 2016). The shrimp species harvested are capable of withstanding high levels of fishing pressure, but some of the nonshrimp species taken as bycatch in the trawl fishery are overfished or are subject to overfishing. One such species is the Red Snapper *Lutjanus campechanus*, and efforts to rebuild this stock have historically focused on the reduction of shrimp trawl bycatch mortality. Age-0 and age-1 Red Snapper are abundant on the shrimp grounds of the western Gulf of Mexico, especially within the 10- to 30-fathom (1 fathom = 6 ft) depth zone (Gallaway et al. 1999, 2009). Young Red Snapper enter the shrimp fishery at about 50-mm TL during July–August of their first year, and they remain vulnerable to trawls over an 18-month period through December of the second year (Gallaway et al. 2009). Historically, stock assessment scientists believed that juvenile Red Snapper were characterized by low natural mortality rates. For example, in the Goodyear (1995) stock assessment, the instantaneous rate of natural mortality (M) was set at 0.5/year for age-0 and 0.3/year for age-1 Red Snapper.

Fishing mortality attributable to shrimp trawls was believed to dominate the total mortality for juvenile Red Snapper over the first 18 months of life. Based on the terminal years (1992 to 1994) included in the Goodyear (1995, Table 98) stock assessment, the 1992 year-class started with 47,104,948 individuals, of which 1,723,872 were estimated to be alive at the end of the 18-month period. Thus, the survival rate (S) was estimated to be S = 0.036, which equates to an instantaneous rate of total mortality (Z) of 3.30. The instantaneous rate of natural mortality over the first 18 months of life was assumed to be on the order of M = 0.65 (1 year at 0.5/year + 0.5 year at 0.3/year). Given this, the instantaneous rate of fishing mortality (F) was estimated at 2.65. Thus,

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Received June 15, 2016; accepted December 8, 2016

80% of the total mortality over the period was thought to be attributable to shrimp trawl bycatch. Reducing this major source of mortality was believed to be critical to rebuilding the overfished Red Snapper stock.

With this understanding, the reduction of juvenile Red Snapper bycatch in the Gulf of Mexico penaeid shrimp fishery became a cornerstone of the Gulf of Mexico Fishery Management Council's (GMFMC) rebuilding plan for this overfished species (SEDAR 2013). Reducing shrimp trawl bycatch of juveniles was thought to be adequate for recovering the stock, and this assumption was used to justify continuing to harvest adult Red Snapper at historic levels. The direct commercial and recreational harvest of adult Red Snapper was 9.12 million pounds (mp).

Below, we outline a history of Red Snapper shrimp trawl bycatch management in the Gulf of Mexico, building on the previous descriptions of Cowan (2007) and Hood et al. (2007). After a description of management actions and the rationale for early management actions based on the Goodyear (1995) and SEDAR (2005) stock assessments for Red Snapper, we describe the outcome of the harvest reductions in the directed fishery and other changes in Red Snapper management that have occurred since 2007. We then discuss the overall consequences of historical and recent management actions.

BYCATCH MANAGEMENT HISTORY

Based on the Goodyear (1995) stock assessment, the GMFMC (1997) amended the Shrimp Management Plan (Amendment 9) with a strategy that required shrimp trawl bycatch mortality of juvenile Red Snapper to be reduced by 50%. It was believed that this action would achieve rebuilding goals for Red Snapper and that, given this, it would not be necessary to reduce the harvest of 9.12 million pounds (mp) of adults taken by the directed fishery. It was also determined by GMFMC (1997) that the use of bycatch reduction devices (BRDs) would reduce Red Snapper bycatch mortality by 50% or more (see Appendix A in GMFMC 1997). Federal regulations mandated the use of specific BRDs in the western Gulf of Mexico shrimp fishery beginning in May 1998 (NOAA 1998). As described in Appendix A of GMFMC (1997), the two BRDs initially certified for use were the midsize "fisheye" BRD in the 30-mesh position, and the extended funnel BRD. The midsize fisheye BRD reduced shrimp trawl bycatch mortality by 58 to 61%, and had an associated shrimp loss of only 3% (GMFMC 1997, Appendix A). Overall, the extended funnel reduced juvenile Red Snapper mortality by 32% but had little or no shrimp loss. However, Gallaway and Cole (1999) provided evidence that the preferred fisheye BRD in the 30-mesh position reduced mortality by only 25 to 27%, not 58 to 61% total as had been previously estimated.

The recreational and commercial harvest of adult Red Snapper remained at 9.12 mp from 1998 into 2006, based on the assumption that the bycatch reduction goals were being met in the shrimp fishery. In 2005, a new stock assessment (SEDAR 2005) determined that Red Snapper remained overfished, mainly because (1) the BRDs had failed to meet the target mortality reduction, and (2) the harvest for the directed fishery had been maintained at a level that was based on the erroneous assumption that the bycatch reduction goal was being met. Based on new evidence (Gazey et al. 2008), age-0 and age-1 instantaneous natural mortality rates were revised upward to 0.98/year and 0.6/year, double the rates assumed by Goodyear (1995).

The final outcome of the SEDAR (2005) assessment was reported in "Section 5 Addenda and Errata" published in May 2005. Based on the terminal years of this assessment (2001–2003), the 2001 year-class had an initial stock size of 27,170,000 individuals, and 4,020,000 of these were still alive at the start of 2003. This yielded a survival of $S = 0.14$ and a corresponding Z of 1.91. Total M over the same period was 1.28 based on 12 months at $M = 0.98$ and 6 months at $M = 0.60$. Based on the new assessment, juvenile fishing mortality from shrimp trawls was now estimated at 33% of the total mortality (not 80% as formerly believed), and 67% of the total juvenile mortality was attributed to natural mortality. In spite of new data suggesting that the linkage between Red Snapper population dynamics and shrimp trawl bycatch was weaker than originally believed, the GMFMC's strategy for increasing Red Snapper populations was to continue the focus on reducing juvenile mortality from shrimping. The Red Snapper allowable harvest for the directed fishery was maintained at 9.12 mp while new requirements were put in place to further reduce shrimp bycatch mortality.

To achieve the needed bycatch reduction goals, GMFMC (2006) first changed the BRD certification criteria in the western Gulf of Mexico. The requirement for a reduction of Red Snapper mortality was deleted and replaced with the requirement that, to be certified for use, a BRD must provide a 30% reduction in finfish biomass. Next, in 2007, shrimp trawl fishing effort in the western Gulf of Mexico (Statistical Areas 10–21) between depths of 10 and 30 fathoms was selected as a proxy for juvenile Red Snapper shrimp trawl mortality. As noted above, the 10- to 30-fathom depth zone is characterized by high juvenile Red Snapper abundance. Amendment 14 of the Shrimp Fishery Management Plan (GMFMC 2007) required shrimping effort in this zone to be reduced by 74% of the baseline effort observed for 2001 to 2003. To complement this action, the harvest for the directed fishery was reduced to 6.5 mp in 2007, and was further lowered to 5.0 mp in 2008 and 2009. This was the beginning of change in the Red Snapper stock rebuilding strategy. Harvest of adults was curtailed in addition to shrimp trawl bycatch reduction requirements.

Shrimp trawl effort reduction from the baseline years began immediately (Table 1). Reductions were 39.8% (2004), 59.2% (2005), and 65.6% (2006) due mainly to adverse economic conditions (LGL Ecological Research Associates 2013). Effort reductions have exceeded the target each year since 2008 (J. M. Nance,

TABLE 1. Shrimp effort reductions (target and actual), total allowable catch (TAC, mp), allowable biological catch (ABC, mp), and Red Snapper landings (mp), 2008 to 2014. (Source: Table 3.1.2 in GMFMC 2015).

Year	Target reduction (%)	Actual reduction (%)	TAC/ ABC	Landings
2008	74.0	83.6	5.0	6.5
2009	74.0	77.0	5.0	8.1
2010	74.0	80.7	7.0	6.0
2011	67.0	67.8	7.5	10.3
2012	67.0	77.8	8.1	11.5
2013	67.0	73.1	11.0	14.8
2014	67.0	67.1	11.0	

NMFS, Galveston Laboratories, personal communication). Total allowable harvest in the directed fishery was increased from a low of 5.0 mp in 2008 and 2009, to 11.0 mp in 2013 and 2014 (Table 1). Increases in catch in 2013 and 2014 were allowed because it appeared that the Red Snapper population was increasing.

The SEDAR (2013) Red Snapper stock assessment was initially published in 2013 and was then updated in 2015. Based on new information, the natural mortality rates for juvenile Red Snapper were again doubled, as compared with the rates used in the previous SEDAR (2005) stock assessment. The new rates that were used were M = 2.0 for age-0 and M = 1.2 for age-1 fish. Thus, the most recent estimates of juvenile Red Snapper mortality were four times higher than originally assumed in the Goodyear (1995) stock assessments.

Based on Table 4.3 in Cass-Calay et al. (2015), the 2011 year-class began with 160,942,100 fish, of which 10,774,630 fish were alive at the start of age 2. This yields a survival rate of S = 0.06, which equates to Z = 2.70. Natural mortality over the 18-month period was 2.60. Thus, F = 0.10, only 4% of the total mortality, not 80% as originally assumed.

DISCUSSION

If Goodyear (1995) had used estimates of natural mortality from the most recent stock assessment, fishing mortality on juvenile Red Snapper in 1995 would have been about 0.71, or 21% of the total mortality, not 80%. The early estimates of natural mortality rates for juvenile Red Snapper were based on the best available data available at the time, but in retrospect, those estimates proved to be too low. Based on this underestimate of juvenile natural mortality, harvest reductions in the directed fishery taking adult Red Snapper were minimized in favor of reducing shrimp trawl bycatch mortality. The reduction of shrimp trawl bycatch mortality did not have the anticipated level of impact on rebuilding the Red Snapper stock because, as suspected by Cowan (2007), the natural mortality of juvenile Red Snapper is much higher than originally assumed.

Cowan (2007) suggested that BRDs did not appear to be attaining mortality reduction goals and, if natural mortality rates of juvenile Red Snapper were higher than previously thought, further attempts to reduce shrimp trawl bycatch would result in diminishing returns. Cowan (2007) also expressed concerns about selecting harvest levels for the directed fishery from the "high-risk range" based on the notion that bycatch reduction would occur and stated that, because of political pressure, fisheries governance had failed all users of the Red Snapper resource by acting in a risk-prone manner with respect to controls on fishing mortality of adult Red Snapper. Hood et al. (2007) also noted that reductions in fishing mortality were needed in both the directed and shrimp trawl fisheries for rebuilding to occur. Subsequent to these papers and others of the time (see Patterson et al. 2007), it has been learned that practicable BRDs are not capable of reducing shrimp trawl mortality of juvenile Red Snapper by the required amount because natural mortality rates are much higher than was thought, even as late as 2007. However, when harvest reductions were initiated in the Red Snapper directed fishery in 2007, recovery rates of the Gulf of Mexico Red Snapper population accelerated.

Further, evidence that the reduction of shrimp trawl mortality of juvenile Red Snapper did not have the anticipated impact on rebuilding the Red Snapper population (e.g., Goodyear 1995) is provided by plots of juvenile Red Snapper abundance trends in the Gulf of Mexico in SEDAR (2013). As an example, annual indices of juvenile Red Snapper abundance in the western Gulf of Mexico in summer (1982–2011) and fall (1972–2011), while variable, reflect no dramatic or even discernable trend (Figure 1). If shrimp trawl mortality was as important as once believed, a dramatic increase in juvenile snapper abundance would have been expected as shrimping effort plummeted over the period 2002 to 2008 (see Figure 2.1.1 in GMFMC 2015). This increase has not occurred. Shrimp effort from 2008 to 2015 has remained at low levels not seen since before the 1960s (see Figure 1 in Gallaway et al. 2003).

Red Snapper biomass levels reflected little response over the period from the mid-1990s to 2003, when BRDs were required but the harvest in the directed fishery taking adult Red Snapper was maintained at 9.12 mp (Figure 2). A small increase in biomass was estimated over the period 2004 to 2006, when BRDs were in place and shrimping effort in high-value juvenile Red Snapper habitat had declined by 40 to 66% from the baseline years. The harvest in the directed fishery remained at 9.12 mp. A dramatic increase in biomass was estimated for the period 2007 to 2012, when shrimping effort reduction ranged from 67.8% to 83.1% and the harvest in the directed fishery was reduced to 5.0 to 8.1 mp. However, the rate of biomass increase in the Red Snapper population appeared to decline somewhat in 2013 and 2014, as compared

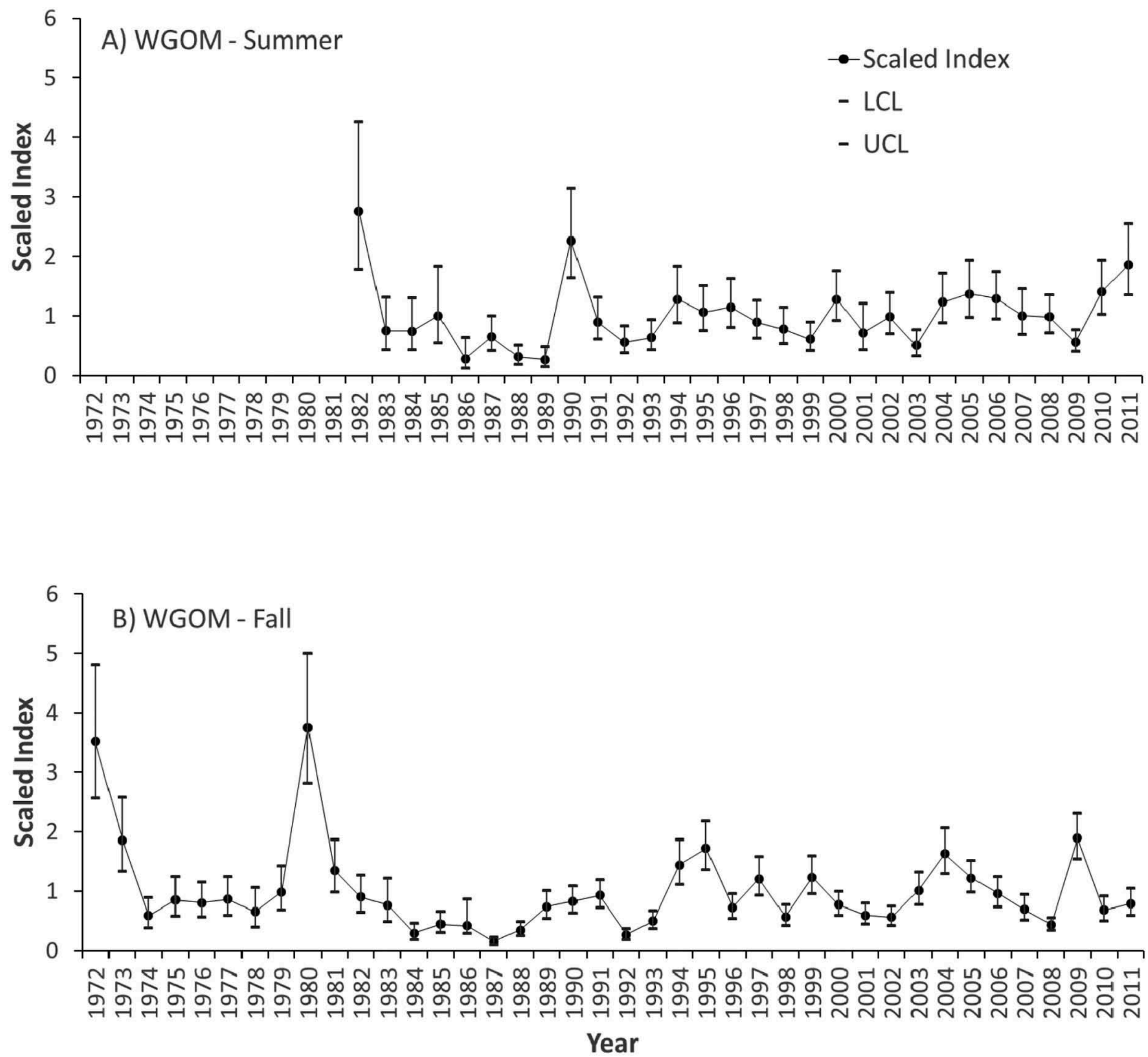

FIGURE 1. Annual indices of abundance for juvenile Red Snapper in the western Gulf of Mexico (WGOM) for **(A)** summer and **(B)** fall as reported by the GMFMC (2015). LCL = lower 95% confidence limit; UCL = upper 95% confidence limit.

with the rate increases that occurred between 2007 and 2012 (Figure 2). Shrimp effort reduction remained high in 2013 (73.1%) and 2014 (67.4%), but the harvest in the directed fishery was increased to 11.0 mp in both years. Further, actual landings ranged up to near 15 mp in 2013 (see Table 1).

While controlling Red Snapper shrimp trawl bycatch does not appear to provide much effect on rebuilding the Red Snapper population, there are valid reasons for controlling shrimp effort at or near present levels, and maintaining the BRD requirements. The effort reductions that have occurred have been mainly due to economic aspects of the shrimp fishery. In 2001, the GMFMC established a federal commercial permit for all vessels harvesting shrimp from federal waters of the Gulf of Mexico (Amendment 11 to the Shrimp Fishery Management Plan), and approximately 2,951 permits had been issued by 2006. However, the shrimp fishery began to experience heavy economic losses due to a combination of high fuel costs and reduced shrimp price caused by competition from imports (GMFMC 2015). These economic losses resulted in an exodus of vessels from the fishery and, consequently, the observed reduction of effort. The GMFMC determined that the number of vessels in the offshore fleet would likely decline to a point where fishing became profitable again for the remaining participants. New vessels would then want to enter the fishery, which would threaten the profitability of the fleet as a whole. To avoid this outcome, the GMFMC (2006) established a 10-year moratorium on the issuance of new permits (Amendment 13 to the Shrimp Fishery Management Plan).

There is little doubt that reduced effort has resulted in higher shrimp catch rates than before, and this has increased the profitability of this fishery. The primary motivation for

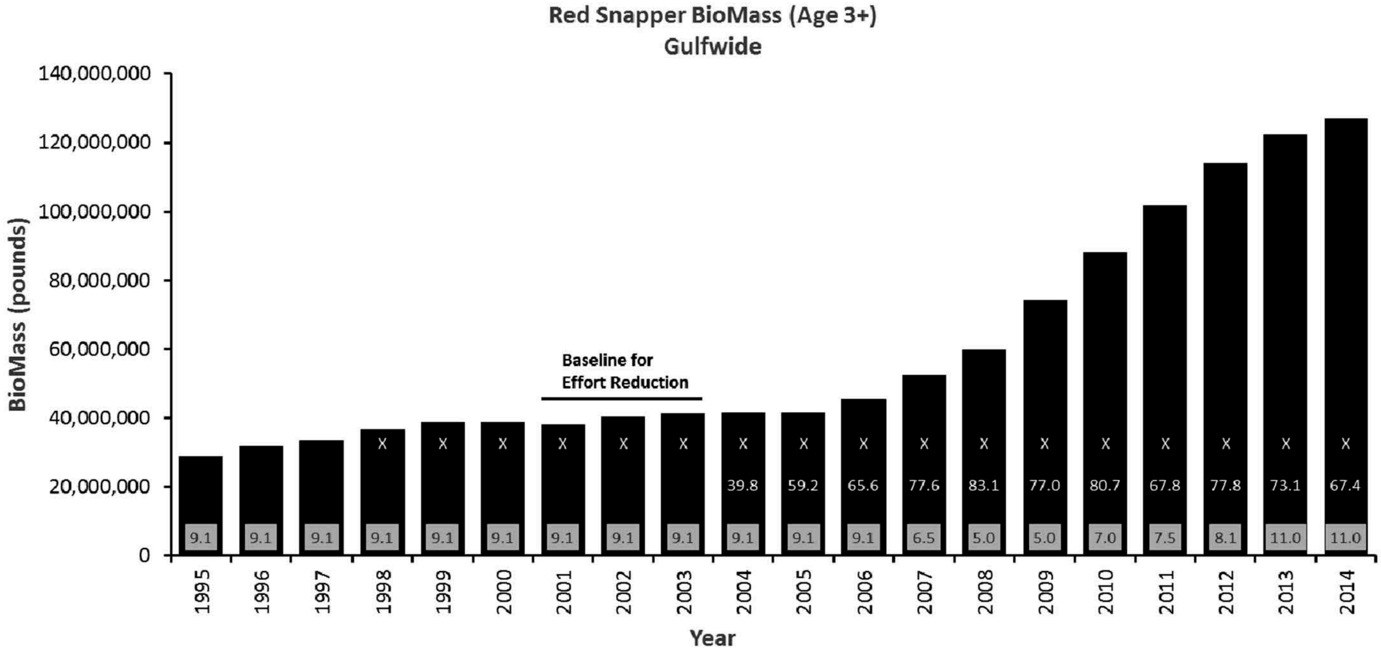

FIGURE 2. Response of Red Snapper biomass levels in the western Gulf of Mexico to management actions; biomass levels (black bars) are from Cass-Calay et al. (2015). Bycatch reduction devices have been required since 1998, as shown by the X on the black bars. Substantial shrimp effort reductions began in high-value juvenile Red Snapper habitat in 2004, and the percent reduction for each year is shown by the number below the Xs. Total allowable catch for each year (mp) is shown by the number in the shaded insets on the black bars; TAC was reduced below 9.12 mp in 2007.

managing shrimp effort should relate more to management of the shrimp fishery than to Red Snapper management. While Red Snapper may benefit to some degree by reduced shrimping effort and this source of mortality should continue to be evaluated, shrimp trawl mortality is clearly not the “driver” of the Gulf of Mexico Red Snapper populations as was previously estimated.

When harvest reduction was finally imposed on the directed fishery as an additional management measure in 2007, biomass of the Red Snapper stock in the Gulf of Mexico began to dramatically increase. However, when allowable harvest was raised to 11 mp in 2013 and 2014, the rate of increase in the Red Snapper population appeared to decline (Figure 2). Care must be taken to maintain the harvest at levels that will ensure rebuilding goals are met on schedule, and not repeat the mistakes of the past.

It is clear that the effectiveness of reducing juvenile bycatch as a management measure for a species is highly dependent on the level of natural mortality associated with the juvenile stages of the target species. If natural mortality rates of juveniles are high, reducing bycatch of these stages will not have much impact on the rate of population increase. In contrast, for species having low rates of juvenile mortality, bycatch reduction is an effective way to increase the population. For example, turtle excluder devices effectively exclude both juvenile and adult sea turtles (order Testudines; each of which has a low rate of natural mortality), and their use has made a major contribution to the rebuilding of sea turtle populations (e.g., Turtle Expert Working Group [TEWG] 1998, 2000). The lesson here is that assessing the effects of bycatch reduction is not straightforward, and that the population effects resulting from the reduction of fishing mortality of juveniles depend heavily on the rates of natural mortality. Accurate estimates of vital rates (e.g., natural mortality by life stage) are critical to good management.

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