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SEDAR99-WP-14

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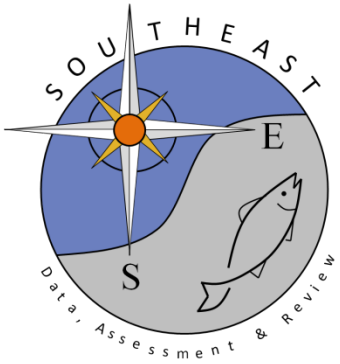

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**SEDAR 99 Working Paper**

# Estimation of King Mackerel Bycatch from Gulf of America Shrimp Trawls

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## Introduction

Bycatch of non-target species in Gulf of America (formerly Gulf of Mexico, hereafter Gulf) shrimp trawls has been a pressing management concern for several decades. During the 1990s, devices installed on shrimp nets to limit bycatch of fishes and protected species (bycatch reduction devices, turtle excluder devices) were developed and implemented fleet-wide. Procedures for estimating bycatch from shrimp fleet landings and effort, and catch-effort data from observer and Southeast Area Monitoring and Assessment Program (SEAMAP) sampling, were developed in the 2000s (Nichols 2004ab) and routinely applied for stock assessments of Red Snapper (Isely 2017) and other bycatch species like King Mackerel (Zhang and Isely 2020).

To address concerns about the reliability of shrimp bycatch estimates, an improved estimation process was developed that was subsequently reviewed and approved by the Council of Independent Experts (CIE) (Smith et al. 2023). The improved methodology was applied to the 2014 to 2020 period. The SEDAR 98 Red Snapper bycatch estimates incorporated CIE recommendations and extended the analysis to a longer time series spanning 1984 to 2023 (Smith et al. 2025). This working paper applies the Smith et al. (2025) methodology for estimating bycatch of King Mackerel from Gulf shrimp trawls.

## Data Sources

Penaeid shrimp effort in the Gulf has non-universal coverage of the fleet. Therefore, trawling effort is derived from two sources (1) captain interviews collected by National Marine Fisheries Service (NMFS) port agents from 1984 to 2014 and (2) GPS tracklog or electronic logbook (ELB) data collected by LGL Ecological Research Associates or the Southeast Fisheries Science Center (SEFSC). Total trawling effort used for shrimp bycatch estimation were initially developed for SEDAR 87 (Dettloff 2024) and updated for SEDAR 98 (Atkinson et al. 2025) to include key stratification variables.

The improved methodology relies exclusively on catch-per-unit-effort (CPUE) data from the SEFSC Shrimp Observer Program, which began mandatory coverage of shrimp vessels in the Gulf of Mexico in 2007 (Decossas & Atkinson 2026). While these data provide net-level information for sampled tows, their utility is limited to species consistently reported according to the sampling protocol. Because King Mackerel is included on the species characterization list, bycatch estimation for this species is feasible. For further details on survey design, sampling protocol, or temporal coverage, refer to Decossas & Atkinson (2026).

## Methods

*General Approach*

The general approach for estimating bycatch entails two catch rate expansion estimates, one to estimate total fleet effort (*f*) and one to estimate total fleet catch/bycatch (*C*). Fleet effort was estimated using shrimp catch and effort data for a subset of vessels interviewed by port agents or equipped with ELB devices (Atkinson et al. 2025). The main assumption is that the sample catch and effort is representative with shrimp fleet catch and effort,

$$\frac{C_{ELB}}{f_{ELB}} = \frac{C_{fleet}}{f_{fleet}} \quad . \qquad (1)$$

This relationship was then used to estimate shrimp fleet effort (tow hours),

$$\hat{f}_{fleet} = \frac{C_{fleet} \times f_{ELB}}{C_{ELB}} \quad , \qquad (2)$$

where the respective fleet and sampled catches are obtained from reported shrimp landings. Fleet catch of non-target species (discarded as bycatch) was estimated using onboard observer catch and effort data for a subset of vessel trips, again assuming representativeness with fleet catch and effort,

$$\frac{C_{obs}}{f_{obs}} = \frac{C_{fleet}}{f_{fleet}} \quad . \qquad (3)$$

Fleet effort from Eq. (2) was used to estimate fleet bycatch,

$$\hat{C}_{fleet} = \frac{C_{obs} \times \hat{f}_{fleet}}{f_{obs}} \quad . \qquad (4)$$

*Observer catch-per-unit-effort (CPUE) estimation*

Bycatch estimation using observer catch rates (Eq. 4) was carried out using a Horvitz-Thompson ratio-of-means estimator for a stratified sample frame (Lohr 2022), which accommodated varying levels of fishing effort among observer samples. Computational details are provided in Smith et al. 2023.

*GLM analysis of stratification variables*

Historical estimation procedures employed a space-time stratification scheme within years: geographical area, depth, and season (Nichols 2004ab, Isely 2017). A general linear regression analysis was used to evaluate relationships between catch and effort and between CPUE and additional stratification variables. Regression models were developed of the general form,

$$Catch = f(effort, addtl.covariates) + \varepsilon \quad .$$

Results confirmed that season (3 quadrimesters: Jan-Apr, May-Aug, Sep-Dec), geographical area (Figure 1), and depth (<10 fathoms, 10-30 fathoms, > 30 fathoms) were important variables for partitioning mean and variance of penaeid shrimp and King Mackerel catch rates. This analysis also identified two additional variables, trawl configuration (2-nets or 4-nets) and diurnal period (daytime, nighttime), that further improved estimation of mean and variance of CPUE. Combinations of trawl configuration and diurnal period were used to designate gear types: D2, daytime 2-net trawls; D4, daytime 4-net trawls; N2, nighttime 2-net trawls; and N4, nighttime 4-net trawls.

*Imputation of data for strata*

Commercial shrimp trips sampled by observers in a given year included most season-area-depth-gear strata, but not all. Stratification analysis of interannual variability showed that combining data across years for the same trawl configuration and diurnal period within area-depth-season strata did not introduce any systematic bias in CPUE estimates. Year strata were subsequently grouped into time periods of years to mitigate observer sampling issues. The two time periods were 2007-2014 and 2015-2024 to correspond with changes in effort data collection over time. Variance of mean CPUE was computed using the average annual stratum sample size to avoid inflating the precision (i.e., treating the combined years as a single survey). A GLM imputation procedure was developed for remaining sparsely-sampled gear types (N2, N4, D2, D4) within specific season-area-depth strata, which accounted for 11% of fleet effort. These GLM estimates were then used to develop a ratio of catch to the most common gear type, N4 and the subsequent trip catch scaled to the N4 value of the same strata when missing.

*Hindcasting*

Bycatch estimation for the pre-observer time period 1984-2006 followed previously established procedures in hindcasting reef fish discards outlined in Smith et al. 2019. The hindcasting procedure used observer data for 2007-2013 to estimate the stratum-specific ratio of King Mackerel CPUE to penaeid shrimp CPUE. This ratio was applied to historical penaeid strata CPUEs from captain interviews to estimate historical King Mackerel strata CPUEs. These were multiplied by strata fleet effort to obtain strata bycatch (Eq.4). In order to obtain stratum CPUE estimates, the sparse sampling imputation procedure was conducted for each shrimp species (brown, pink, white) and King Mackerel.

Another consideration in these analyses is the requirement to install bycatch reduction devices (BRDs) on shrimp nets that was implemented in 1998. To account for the pre-BRD era (1984–1997), King Mackerel CPUE estimates were adjusted using a GLM analysis of paired-net experiments conducted by the Shrimp Observer Program. Because annual sampling from port

agent interviews was sparse, years were combined into two broader time periods (1984-1997 and 1998-2006) to align with BRD regulations.

*Adjusting for King Mackerel Fishing Year*

King Mackerel is managed by fishing year (July 1-June 31), therefore, for this assessment, all data inputs were provided by fishing year. As such, the annual King Mackerel bycatch estimates from quadrimester 2 (May-Aug) were apportioned to fishing year based on the annual proportion of shrimp landings in May-June and July-August by area. For these results then, 1984 refers to the July 1984-June 1985 fishing year and the terminal year of 2023 is July 2023-June 2024.

**Results and Discussion**

Observer sample sizes from 2007-2024 are provided in Table 1. Trips observing King Mackerel were relatively low with an occurrence rate of less than 10% and in many years much lower. GLM predicted catches differed with respect to net configuration and diurnal period for King Mackerel and the ratios used to scale other gear and time combinations when missing in strata are shown in Table 2. King Mackerel mean catch per tow was twice as much in nets without a BRD to those with a BRD (Table 3). This difference was used to adjust bycatch observations for the pre-BRD time period of 1984-1997 in the hindcasting procedure.

Estimates of King Mackerel bycatch from commercial shrimp trawls for the Gulf regions from 1984-2024 are provided in Table 4 and illustrated in Figure 2. Gulf-wide King Mackerel bycatch peaked in the late 1980s at over 1.25 million fish, and has been generally declining through time with recent years bycatch estimates below a half a million fish (Fig. 2). Bycatch estimates provided for SEDAR 38U using the previous methodology (Zhang & Isely 2020) showed much higher estimates of bycatch, particularly in the earlier portion of the time series (Fig. 3). This pattern was also seen in Red Snapper when the methodology was updated from the SEAMAP approach as well (Smith et al. 2025).

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**Table 1.** Annual observer sampled tows and nets and numbers with observed King Mackerel.

| YEAR | N Tows | Tows with King Mackerel | N Nets | Nets with King Mackerel |
|---|---|---|---|---|
| 2007 | 755 | 61 | 1,361 | 67 |
| 2008 | 1,585 | 96 | 2,789 | 111 |
| 2009 | 1,551 | 50 | 2,447 | 59 |
| 2010 | 1,448 | 35 | 2,287 | 39 |
| 2011 | 1,519 | 39 | 2,311 | 41 |
| 2012 | 1,625 | 92 | 2,695 | 109 |
| 2013 | 2,041 | 134 | 3,253 | 166 |
| 2014 | 2,371 | 36 | 3,845 | 42 |
| 2015 | 1,861 | 75 | 2,974 | 85 |
| 2016 | 2,417 | 84 | 4,084 | 102 |
| 2017 | 2,667 | 77 | 4,390 | 95 |
| 2018 | 2,096 | 92 | 3,521 | 105 |
| 2019 | 1,164 | 24 | 1,823 | 29 |
| 2020 | 863 | 9 | 1,428 | 9 |
| 2021 | 2,121 | 18 | 3,481 | 18 |
| 2022 | 1,835 | 65 | 2,901 | 73 |
| 2023 | 1,375 | 57 | 2,275 | 68 |
| 2024 | 1,002 | 15 | 1,588 | 18 |

**Table 2.** Conversion factors to scale King Mackerel catch as a ratio to N4 catches to impute missing levels from strata for the different time of day and gear configurations.

| Gear Category | Conversion Factor to N4 |
|---|---|
| D2 | 0.7077 |
| D4 | 0.5922 |
| N2 | 0.6021 |

**Table 3.** GLM analysis results used to adjust King Mackerel bycatch estimates for the pre-BRD time period (1984-1997).

| | | GLM Estimates | |
|---|---|---|---|
| Paired-Net Tows | Net Type | Mean Catch | SE |
| 44 | No BRD | 4.59 | 0.48 |
| | BRD | 2.18 | 0.48 |

**Table 4.** Time-series (1984-2024) of annual King Mackerel bycatch in numbers and associated CVs the Gulf of America. Year is fishing year as defined by the assessment parameters.

| YEAR | Bycatch N (millions of fish) | SE (millions of fish) | CV |
|---|---|---|---|
| 1984 | 1.220 | 0.438 | 0.359 |
| 1985 | 1.329 | 0.472 | 0.355 |
| 1986 | 1.380 | 0.501 | 0.363 |
| 1987 | 1.395 | 0.461 | 0.330 |
| 1988 | 1.374 | 0.493 | 0.359 |
| 1989 | 1.297 | 0.484 | 0.374 |
| 1990 | 1.274 | 0.421 | 0.330 |
| 1991 | 1.157 | 0.338 | 0.292 |
| 1992 | 1.224 | 0.339 | 0.277 |
| 1993 | 1.056 | 0.320 | 0.303 |
| 1994 | 0.871 | 0.238 | 0.274 |
| 1995 | 0.724 | 0.161 | 0.222 |
| 1996 | 0.773 | 0.166 | 0.215 |
| 1997 | 0.787 | 0.181 | 0.230 |
| 1998 | 0.722 | 0.176 | 0.243 |
| 1999 | 0.700 | 0.175 | 0.250 |
| 2000 | 0.619 | 0.146 | 0.236 |
| 2001 | 0.544 | 0.137 | 0.252 |
| 2002 | 0.553 | 0.138 | 0.250 |
| 2003 | 0.443 | 0.108 | 0.245 |
| 2004 | 0.382 | 0.091 | 0.239 |
| 2005 | 0.303 | 0.072 | 0.238 |
| 2006 | 0.318 | 0.074 | 0.231 |
| 2007 | 0.256 | 0.068 | 0.266 |
| 2008 | 0.446 | 0.114 | 0.256 |
| 2009 | 0.429 | 0.089 | 0.206 |
| 2010 | 0.275 | 0.083 | 0.301 |
| 2011 | 0.414 | 0.099 | 0.239 |
| 2012 | 0.383 | 0.099 | 0.258 |
| 2013 | 0.531 | 0.138 | 0.261 |
| 2014 | 0.509 | 0.113 | 0.222 |
| 2015 | 0.384 | 0.111 | 0.290 |
| 2016 | 0.332 | 0.098 | 0.295 |
| 2017 | 0.355 | 0.098 | 0.275 |
| 2018 | 0.357 | 0.102 | 0.287 |
| 2019 | 0.335 | 0.099 | 0.295 |
| 2020 | 0.290 | 0.077 | 0.267 |

| | | | |
|---|---|---|---|
| 2021 | 0.319 | 0.086 | 0.269 |
| 2022 | 0.233 | 0.080 | 0.343 |
| 2023 | 0.205 | 0.059 | 0.287 |
| 2024 | 0.124 | 0.038 | 0.307 |

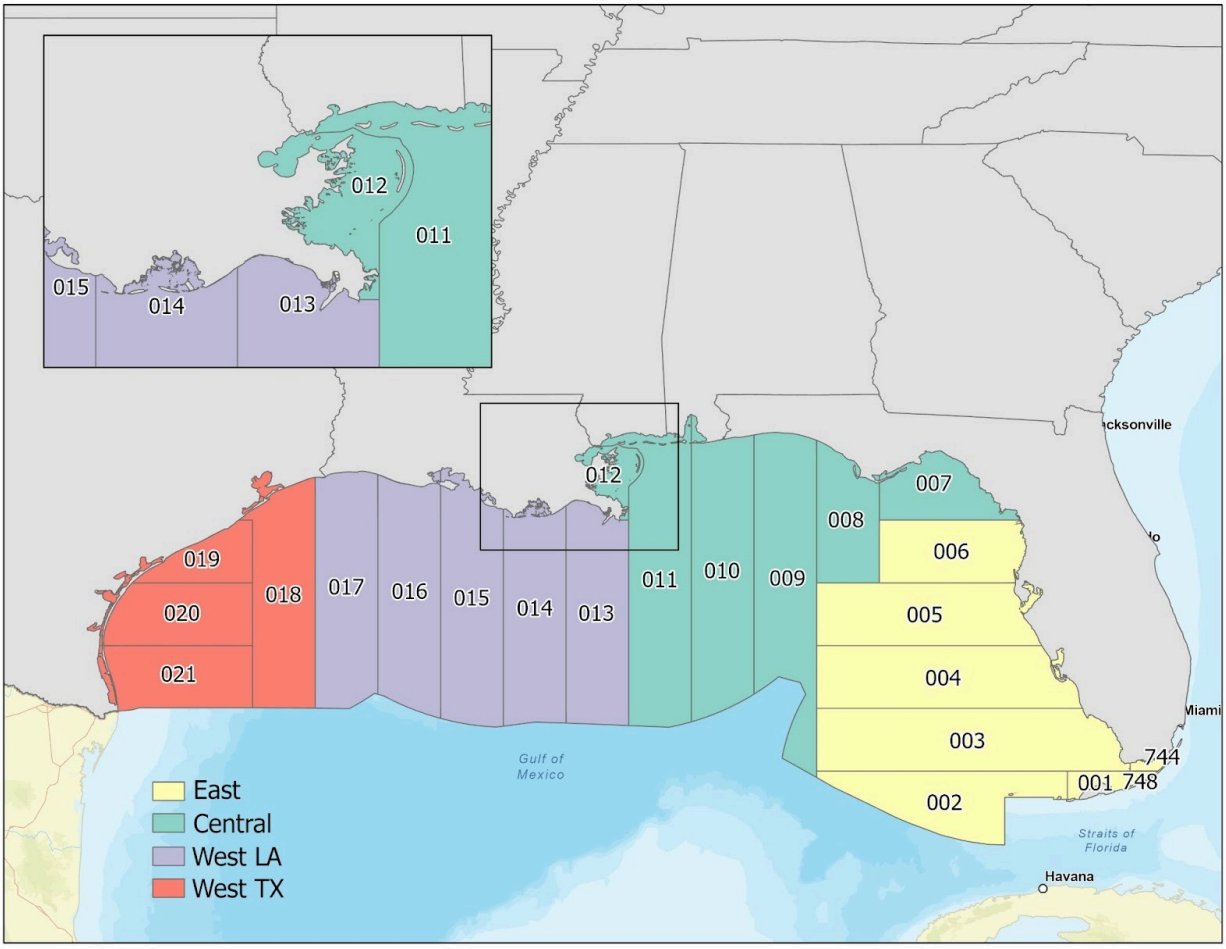


**Figure 1.** Map of aggregated areas used for King Mackerel shrimp bycatch estimation.

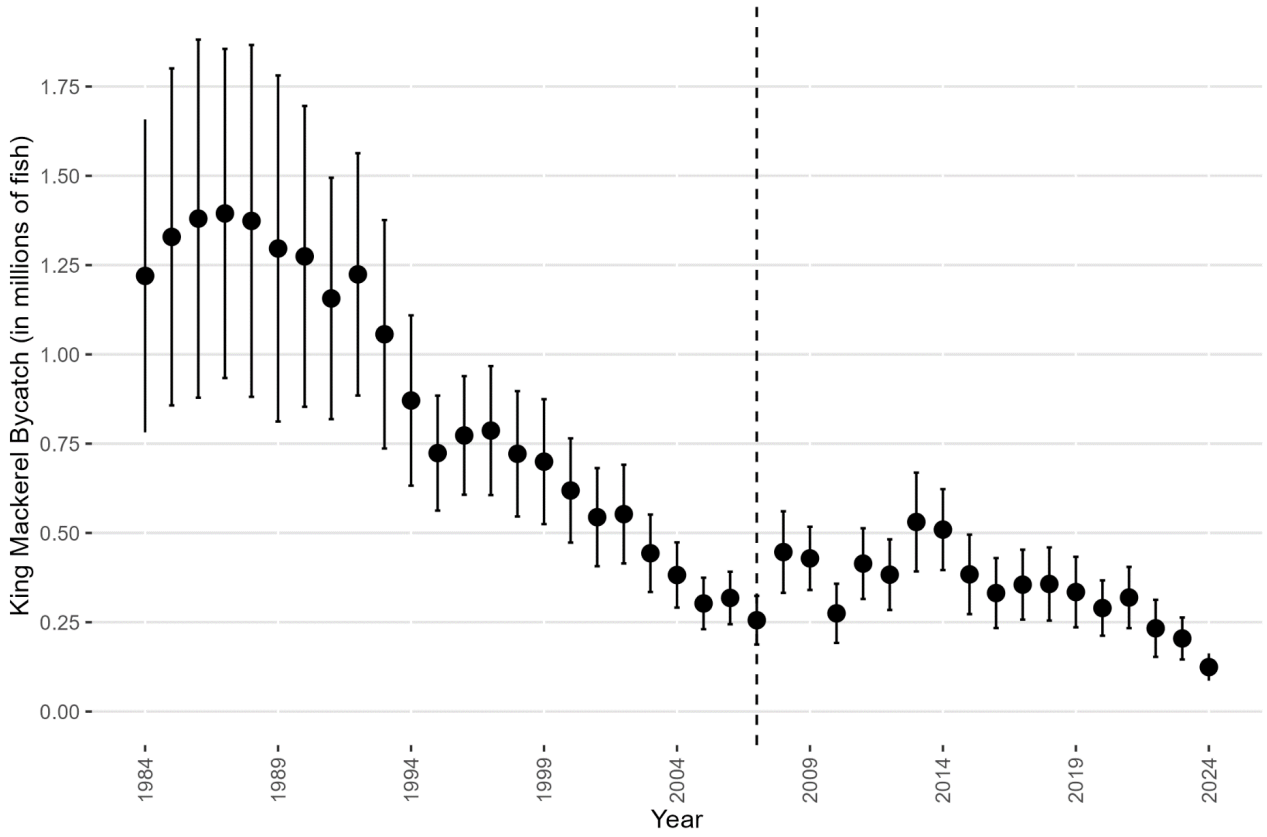


**Figure 2.** King Mackerel bycatch time-series (1984-2024) and associated standard errors for the Gulf of America. Note year is the fishing year as defined by the assessment parameters. Horizontal dashed line represents the beginning of the observer time period.


**Figure 3.** Comparison of Gulf-wide King Mackerel bycatch time-series for SEDAR 99 (triangles) and SEDAR 38U (circles).