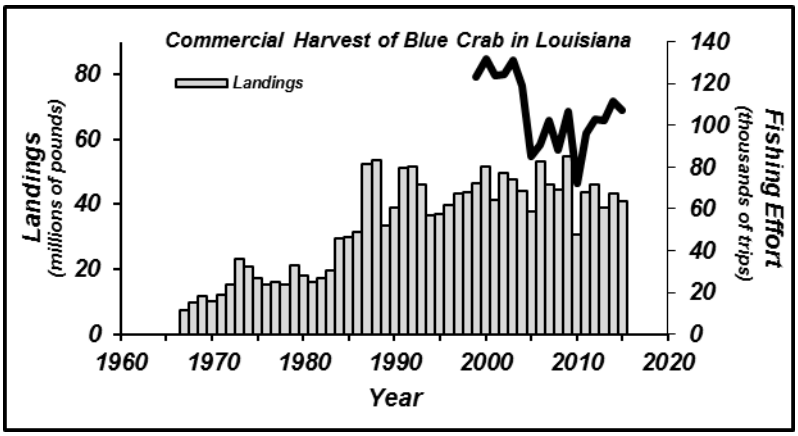
Update Assessment of Blue Crab in Louisiana Waters
2016 Report

Executive Summary

- Commercial landings of blue crab in Louisiana have remained above 40 million pounds per year since 1997 with the exception of 2005, 2010, and 2013. The highest reported landings were 53.5 and 54.7 million pounds harvested in 1988 and 2009, respectively.



- This assessment update is based on a Collie-Sissenwine or catch-survey analysis and results in estimates of exploitable biomass and recruitment of the Louisiana blue crab stock, 1968-2015. Annual fishing mortality is estimated, but is not available for the last year of the time-series. This assessment model has been extensively used in crustacean stock assessments. Data requirements include a time-series of observed landings and corresponding abundance indices for juvenile and exploitable life stages. Indices of abundance are derived from the Louisiana Department of Wildlife and Fisheries fishery-independent marine inshore trawl survey. Landings are taken from National Marine Fisheries Service statistical records, 1968-1998, and the Louisiana Department of Wildlife and Fisheries Trip Ticket Program, 1999-2015.

- In an earlier assessment (West et al. 2011), explicit limits and targets of fishing were proposed as conservation standards to ensure sustainability of the Louisiana blue crab resource. The Louisiana Wildlife and Fisheries Commission adopted a resolution on February 6, 2014 establishing the following policy based on the proposed limits and targets of fishing: "Should the fishing mortality or exploitable biomass exceed the overfished or overfishing limits, or exceed the targets for three consecutive years, as defined in the most current Louisiana blue crab stock assessment, LDWF shall come before the Commission with an updated assessment and a series of management options for the Commission to review and act upon, intended to keep the fishery from becoming overfished, and that management options for review and action shall include provisions for emergency closures, time based closures, and spatial closures." This assessment update constitutes the updated assessment in the resolution above for the Louisiana Wildlife and Fisheries Commission to review and act upon.

- Based on results of this assessment update, the Louisiana blue crab stock is currently overfished and was also considered overfished in 2013. Further, the 2014 and 2012 fishing mortality rate estimates exceeded their targets and were extremely close to their limits.

Summary of Changes from Previous Assessment

- Assessment model inputs have been updated through 2015. No changes have been made to the assessment model itself.

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Table of Contents

Executive Summary 1
1. Introduction 3
1.1Regulations 3
1.2 Trends in Harvest 3
2. Data Sources 3
2.1 Fishery Dependent 3
2.2 Fishery Independent 3
3. Life History Information 4
3.1 Unit Stock Definition 4
3.2 Maturity 5
3.3 Growth 5
3.4 Morphometrics 5
3.5 Natural Mortality 6
3.6 Relative Productivity/Resilience 6
4. Assessment Model 6
4.1 Catch-Survey Model Configuration 6
4.2 Fishing Mortality Estimation 7
4.3 Biomass Conversions 8
4.4 Model Inputs / Assumptions 8
4.5 Model Results 9
4.6 Management Benchmarks 10
5. Stock Status 11
7. Research and Data Needs 11

8. Literature Cited 13

10. Tables 16

11. Figures 25

1. Introduction

A catch-survey or Collie and Sissenwine analysis (Collie and Sissenwine, 1983) is applied to the Louisiana (LA) blue crab *Callinectes sapidus* stock. This model balances the number of individuals from one life stage to the next (i.e., juveniles to exploitable sizes) given constant natural mortality, while scaling these values to harvest. Data requirements are moderate: a time series of observed landings and corresponding abundance indices for juvenile and adult life stages. Indices of abundance are derived from the Louisiana Department of Wildlife and Fisheries (LDWF) fishery-independent marine inshore trawl survey. Landings are taken from National Marine Fisheries Service (NMFS) statistical records, 1968-1998, and the LDWF Trip Ticket Program, 1999-2015.

1.1Regulations

The Louisiana blue crab fishery and its industry are governed by the Louisiana State Legislature, the Wildlife and Fisheries Commission, and the Department of Wildlife and Fisheries. The Louisiana commercial blue crab fishery is currently regulated with a minimum size limit (i.e., a minimum carapace width of 5 inches) in addition to gear restrictions. Recreationally caught blue crabs are not subject to a minimum size limit. No bag and possession limits exist for the recreational and commercial fisheries.

1.2 Trends in Harvest

Trends in harvest were reviewed in the earlier assessment report (West et al. 2011). The current time-series of annual LA commercial hard crab landings (1950-2015) is presented (Table 1, Figure 1).

2. Data Sources

2.1 Fishery Dependent

Louisiana blue crab commercial harvest is derived from NMFS statistical records, 1968-1998, and the LDWF Trip Ticket program, 1999-2015 (Table 1). A time-series of recreational harvest records currently does not exist. Guillory (1999b) estimates the recreational harvest rate as 4.1% of the reported commercial harvest in a survey of the recreational blue crab fishery in Terrebonne Parish, LA.

2.2 Fishery Independent

Blue crab abundance indices are derived from the LDWF fishery-independent marine inshore 16-foot trawl survey. This survey is primarily used to sample peniad shrimp, blue crabs, and bottomfish in inshore bays and lakes. Sampling gear is a 4.9m flat otter trawl with a body and cod-end consisting of 19mm and 6.4mm bar meshes, respectively. Samples are 10 minute tows. All captured crabs are enumerated and a maximum of 50 randomly selected crabs per sample are measured (in 5mm CW bins). When more than 50 crabs are captured, catch-at-size is derived as the product of total catch and proportional subsample-at-size.

The survey has been conducted from 1967 to present at fixed sampling locations. In October of 2010, additional fixed sampling locations were added to this survey. To alleviate time-series bias associated with addition of these new stations, relative abundance time-series used in this assessment are constructed by retaining only the long-term stations for analysis.

Abundance indices are developed for life stages relative to the fishery. These include: 1) adult or exploitable crabs (i.e., ≥125mm CW), 2) juveniles or crabs that will recruit to the fishery during the survey year (i.e., by December 31st), and 3) young-of-the year or crabs that will not recruit to the fishery during the survey year (Tables 2-4). Due to size selectivity of the survey gear, crabs <25mm CW are excluded from index development. Crabs that will not recruit to the fishery during the survey year are identified by seasonal growth functions (see *Growth* section).

Mean catch per tow and its variance are calculated by assuming a delta-lognormal distribution. This method is appropriate for lognormally distributed survey datasets when a proportion of zero catches occur (Pennington, 1983; Pennington, 1996). In this case, the means are the product of the proportion of positive catches (assuming a binomial error structure) and the geometric mean catch-per-unit effort of successful trips (assuming a lognormal error structure). Its variance is approximated as:

$$Var(XY) \approx \mu_Y^2\sigma_X^2 + \mu_X^2\sigma_Y^2 + 2\mu_X\mu_Y\rho\sigma_X\sigma_Y \quad [1]$$

where μ_Y is the binomial mean proportion of positive catches, μ_X is the geometric mean catch-per-unit-effort of successful tows, σ_Y^2 and σ_X^2 are the respective variances, and ρ is the correlation between X and Y.

3. Life History Information

Guillory et al. (1996) summarized literature and data on the biology and ecology of blue crabs in a source document for the management of the Louisiana blue crab fishery. In addition to describing the fishery and commenting on research needs, the authors described blue crab taxonomy and nomenclature; larval, juvenile and adult morphology; distribution and abundance; habitat utilization; reproduction; age and growth; trophic relationships; behavior; movement and migration; pathology and parasitology; environmental tolerances; recruitment mechanisms; and mortality.

In "The Blue Crab Fishery of the Gulf of Mexico, United States: A Regional Management Plan", Guillory et al. (2001) developed a broad and comprehensive document addressing all relevant aspects of blue crab biology and the fishery. In addition to describing stock habitat, fishery management jurisdiction, economic and sociocultural characteristics of the fishery, management considerations/recommendations, and research needs, the authors provided detailed information on blue crab life history, including: geographic distribution; classification, morphology and genetic characterization; age, growth and maturation; reproduction; stock-recruitment relationship; larval development, distribution and abundance; megalopal settlement and recruitment; juvenile development, distribution and abundance; seasonal and areal distribution; factors influencing survival; parasites and diseases; food habits; predator/prey relationships; interspecific and intraspecific predation; foraging behavior; larval, juvenile and adult behavior; autonomy; and movements/migrations. This document was updated in 2015 by the Blue Crab Technical Task Force of the Gulf States Marine Fisheries Commission.

3.1 Unit Stock Definition

Adult blue crabs in the northern Gulf of Mexico (GOM) generally remain within one estuary for life. Females, however, migrate to higher salinity nearshore waters to spawn, where larvae are then dispersed offshore via tidal transport (Guillory et al. 2001). Recruitment and settlement of larvae into northern GOM estuaries as megalopae is likely influenced by wind and tidal circulation processes (Perry et al. 1995). Stock mixing between estuaries (and states) is very probable given these larval transport mechanisms. Nonetheless, blue crab landings from the northern Gulf of Mexico (GOM) are primarily of Louisiana origin.

For purposes of this assessment the blue crab unit stock is defined as those crabs occurring in LA waters. This is consistent with the current non-regional or statewide management strategy.

3.2 Maturity

Carapace width (CW) at maturity is reported by Guillory and Hein (1997a) for blue crabs from the Terrebonne Basin, LA. Males and females reached 50% sexual maturity at 110mm and 125mm CW, respectively. The CW-at-50% sexual maturity for female crabs corresponds with the minimum size limit of the LA commercial blue crab fishery (i.e., 127mm CW). Males and females reached 100% sexual maturity at 130mm and 160mm CW, respectively.

3.3 Growth

Blue crabs exhibit a discontinuous growth pattern; where growth occurs during the molting process (Guillory et al., 2001). Continuous growth models, however, are used to describe blue crab growth (Helser and Kahn, 2001; Pellegrin et al., 2001; Rugolo et al., 1998; Smith, 1997). In this assessment, Gompertz growth functions developed in the earlier LDWF crab assessment (West et al. 2011) are used to describe LA blue crab growth. The Gompertz model is configured as:

$$CW_t = CW_\infty e^{\alpha(e^{\beta t})} \quad [2]$$

where CW_t is CW-at-age, CW_∞ is the asymptotic average maximum CW, and α and β are constant growth coefficients. The seasonal and non-seasonal parameter estimates are presented in Table 5.

A monthly size-at-capture matrix is developed from the seasonal growth functions (Table 6) to identify crabs that will not recruit to the fishery during the survey year (i.e., by December 31st). This matrix represents CW-at-capture of monthly crab cohorts and implies variation in CW-at-age is primarily due to time of hatching. Carapace widths of crabs not fully-recruited to the trawl gear (i.e., < 25mm CW) are excluded. Rows represent monthly cohorts (or seasonal growth trajectories), with the current year-class above the diagonal and the previous year-class below the diagonal. Columns represent months of the LDWF fishery independent trawl survey. As an example, blue crabs captured by the trawl survey in August that are ≤63mm CW (or the current year's March-August cohorts) are considered young-of-the year crabs. An obvious discrepancy exists for the survey month of June, where the previous years' December cohort is approximately the same size as the current years' March cohort. To account for this, young-of-the-year are only identified from July-December captures.

3.4 Morphometrics

Carapace width-weight regressions were developed by Guillory and Hein (1997a) for blue crabs from the Terrebonne Basin, LA. For the purpose of this assessment, only the pooled (or non-sex specific) model is used. Blue crab weight at CW is calculated from:

$$W = 8.26\times10^{-4}CW^{2.446} \quad [3]$$

where W is weight in grams and CW is carapace width in mm.

3.5 Natural Mortality

Due to the difficulty of directly estimating instantaneous natural mortality (M) of blue crab, M is estimated based on assumptions of maximum age. Reported maximum age of blue crab along the Atlantic Coast range from 3-6 years (Kahn and Helser, 2005; Miller et al., 2005; Murphy et al. 2007). There are no longevity estimates for blue crab in the GOM (Guillory et al., 2001). Instantaneous natural mortality in this assessment is estimated as M=1.0, based on a stock where approximately 5% of the stock remains alive to 3 years of age (Hewitt and Hoenig 2005).

3.6 Relative Productivity/Resilience

Productivity is a function of fecundity, growth rates, natural mortality, age of maturity, and longevity and can be a reasonable proxy for resilience. We characterize the relative productivity of GOM blue crab based on life-history characteristics, following methods described in SEDAR 9 (SEDAR, 2006), with a classification scheme developed at the FAO second technical consultation on the suitability of the CITES criteria for listing commercially-exploited aquatic species (FAO 2001; Table 7). Each life history characteristic (von Bertalanffy growth rate, age at maturity, longevity, and natural mortality rate) was assigned a rank (low=1, medium=2, and high=3) and then averaged to compute an overall productivity score. Parameter estimates are taken from West et al. (2011) and VanderKooy (2013). In this case, the overall productivity score is 3.0 for GOM blue crab indicating high productivity and resilience.

4. Assessment Model

A catch-survey (CS) or Collie-Sissenwine analysis (Collie and Sissenwine, 1983) is used in this assessment to describe the dynamics of the LA blue crab stock. The CS modeling approach is intended for data moderate situations where a full age structure is lacking. Model requirements include: 1) annual abundance indices for juvenile and adult life stages, 2) annual harvest estimates as individuals, 3) an estimate of instantaneous natural mortality, and 4) the relative selectivity of the juvenile and adult life stages to the survey gear.

4.1 Catch-Survey Model Configuration

The CS model is based on the modified Delury discrete difference equation (Collie and Sissenwine, 1983):

$$N_{y+1} = (N_y + R_y - C_y)e^{-M} \quad [4]$$

where y is the fishing and survey year (i.e., January 1st through December 31st), N_y is the abundance of adult crabs in that year, N_{y+1} is the abundance of adult crabs in the following year, R_y is the abundance

of juveniles, C_y is harvest as individuals, and M is the constant natural mortality rate. To approximate landings occurring throughout the year, the model equation is reconfigured as:

$$N_{y+1} = \left[\left(N_y + R_y\right)e^{-0.50M} - C_y)\right]e^{-0.50M} \quad [5]$$

where juvenile and adult crabs are reduced by a half year of natural mortality before the catch is removed. Remaining survivors from the fishery are then reduced by another half year of natural mortality.

Survey indices of abundance are scaled to absolute abundance as:

$$n_y = q_n N_y e^{\eta_y} \text{ and } r_y = q_r R_y e^{\delta_y} \quad [6, 7]$$

where r_y and n_y are the observed abundance indices of juvenile and adult blue crabs, q_r and q_n are the respective catchabilities of the survey gear for juvenile and adult crabs, and e^{δ_y} and e^{η_y} are the log-normally distributed observation errors for the juvenile and adult abundance indices. Reconfiguring the model equation by substituting abundance indices for absolute abundance and incorporating lognormal process error e^{ε_y} yields:

$$n_{y+1} = \left[\left(n_y + \frac{r_y}{s_r}\right)e^{-0.50M} - q_n C_y)\right]e^{-0.50M}e^{\varepsilon_y} \quad [8]$$

where $s_r = \frac{q_r}{q_n}$ is the relative selectivity of juveniles to adult crabs in the sampling gear. Log-normal process error e^{ε_y} is taken as the difference between n_y calculated from equations [6] and [8]. Equation [8] is solved iteratively by minimizing the following objective function:

$$SSQ(\Theta_{CS}) = \lambda_\varepsilon \sum_{y=2}^{Y} \varepsilon_y^2 + \sum_{y=1}^{Y} \eta_y^2 + \lambda_\delta \sum_{y=1}^{Y-1} \delta_y^2$$

[9]

where Θ_{CS} is the parameter vector and λ_ε and λ_δ are user-defined weights of the process and juvenile observation error relative to the adult observation error. Thus, $2Y$ parameters are estimated: n_y for all years, r_y for all years except the terminal year, and q_n. Given these estimates, absolute abundances are estimated from the following:

$$R_y = \frac{\hat{r}_y}{s_r \hat{q}_n} \text{ and } N_y = \frac{\hat{n}_y}{\hat{q}_n} \quad [10, 11]$$

where $\hat{r}_y$ and $\hat{n}_y$ are the model estimated abundance indices of juvenile and adult crabs, respectively, and $\hat{q}_n$ is the model estimated catchability of adult crabs to the survey gear. Recruit abundance is estimated in the terminal year by using observed r_y.

4.2 Fishing Mortality Estimation

Annual estimates of instantaneous total mortality are derived from the following survival ratio:

$$Z_y = log_e\left[\frac{N_y + R_y}{N_{y+1}}\right] \quad [12]$$

Estimating annual instantaneous fishing mortality F_y from $Z_y - M$ would include R_y (or crabs not available to the fishery) into the fishing mortality calculation. Because harvest occurs concurrently with M in this fishery (i.e., type II fishery; Ricker, 1975) and to avoid additional bias from $F_y = Z_y - M$, we estimate F_y from the following rearrangement of Baranov's catch equation:

$$F_y = \frac{u_y Z_y}{1-e^{-Z_y}} \quad [13]$$

where annual exploitation is estimated as:

$$u_y = \left[\frac{C_y}{(R_y+N_y)}\right] \quad [14]$$

4.3 Biomass Conversions

Annual size distributions of Louisiana blue crab landings currently do not exist. Due to this lack of fishery dependent information, annual size distributions of blue crab captured from the LDWF FI marine inshore trawl survey are used as proxies to describe the annual size compositions of blue crab landings (see *Research and Data Needs*).

Annual landings in biomass are converted to individuals as:

$$C_y = H_y/\overline{W}_{y,\geq 125mm} \quad [15]$$

where C_y is annual harvest as individuals, H_y is annual harvest as biomass, and $\overline{W}_{y,\geq 125mm}$ are annual mean weights of adult blue crab catches derived from the LDWF FI marine inshore trawl survey (Table 8).

Model estimated abundance is converted to biomass as:

$$B_y = R_y\overline{W}_{y,<125mm} + N_y\overline{W}_{y,\geq 125mm} \quad [16]$$

where B_y is total annual biomass, R_y and N_y are model estimated annual abundances of juvenile and adult crabs, and $\overline{W}_{y,<125mm}$ and $\overline{W}_{y,\geq 125mm}$ are annual mean weights of juvenile and adult blue crab catches derived from the LDWF FI marine inshore trawl survey (Table 8).

4.4 Model Inputs / Assumptions

Catch-survey model assumptions are: 1) the stock is closed to migration, 2) natural mortality occurs at a constant rate, and 3) all surviving recruits will grow into the fully-recruited stage within the model year. Survey indices of abundance are assumed proportional to absolute abundance. Crabs greater than 25mm CW are assumed equally vulnerable to the survey gear implying s_r=1.0. Relative weights λ_ε and λ_δ are fixed as 1.0 in this assessment.

Louisiana blue crab harvest is derived from commercial hard crab landings, which include: NMFS statistical records, 1968-1998, and the LDWF Trip Ticket Program, 1999-2015 (Table 1). Commercial hard crab landings as individuals are expanded by 5% to approximate for recreational harvest. This rate is consistent with Guillory's (1999b) survey of the recreational blue crab fishery in Terrebonne Parish, LA.

Through simulation analysis, Mesnil (2003) demonstrates how staging error (i.e., analogous to aging error in a VPA) can bias estimates of absolute abundance and recommends "carefully allocating members to

either stage". Individuals that will not recruit to the fishery during the survey year are accounted for by reconfiguring r_y as the sum of the young-of-the-year index in year and the juvenile index in year+1 (Table 9). This creates an abundance index where all surviving recruits will recruit to legal-size within the survey year.

4.5 Model Results

The assessment model provides reasonable fits to the adult abundance index (Figures 2-3). However, the fit to the juvenile abundance index (Figure 4) is consistently overestimated in later years of the time-series. The juvenile index suggests a considerable decline over the latter half of the time-series examined. The assessment model tracks this decline, but underestimates its magnitude suggesting additional processes aren't captured by the assessment model (e.g. temporal, spatial, and/or environmental; see *Research and Data Needs* Section).

The catchability coefficient is estimated as $\hat{q}_n$ =0.0050 in this assessment. Annual exploitable (adult) biomass estimates range from 14 to 87 million pounds (Table 10, Figure 5). The 2015 exploitable biomass estimate is the lowest on record (14 million pounds). Exploitable biomass levels generally decline after 1990, where previous years estimates were rarely below 40 million pounds. Increases in exploitation during the 1990s coincide with this decline (Figure 6). A large population response is evident in the years following the passages of Hurricane Katrina and Rita which caused a substantial reduction in the directed effort and supporting infrastructure of the Louisiana commercial blue crab fleet. These storms also provided optimum environmental conditions for settlement of megalopae and young crabs into Louisiana estuaries via storm surge and likely enhanced recruitment.

Juvenile abundance estimates range from 173 to 547 million individuals (Table 10, Figure 5) and exhibit a considerable decline over the latter half of the time-series examined. The six most recent juvenile abundance estimates are the lowest on record with the exception of the 1976 estimate. Additionally, in the two most recent decades only two juvenile abundance estimates are above the time-series average and in the most recent decade no estimates are above the time-series average (Figure 7). It's important to point out here the consequence of this decline on management reference point estimation. Because equilibrium conditions (i.e., average recruitment) are assumed in reference point estimation, management benchmarks will generally be biased when below average conditions persist for extended time periods.

Annual instantaneous fishing mortality estimates range from 0.08-0.95, with peaks in exploitation occurring in 2002, 2012 and 2014 (Table 10, Figure 8). Trends in fishing mortality estimates, 1999-2014, are generally consistent with fishing effort (i.e., trap fisher trips) derived from the LDWF Trip Ticket Program (Figure 8). A large reduction in fishing mortality/effort was observed in the years following the passages of Hurricane Katrina and Rita. Fishing effort is not used in the assessment model but is presented here to validate trends in fishing mortality. However, the number of trap fisher trips may not be a suitable measure of fishing effort (specifically for catch per unit effort data) if the number of traps fished per trip increases (or decreases) through time and should be considered with caution.

No discernable relationship is observed between exploitable biomass and subsequent recruitment. However, the most recent half decade of data pairs are all below the juvenile abundance time-series average and are some of the lowest adult biomasses observed (Figure 9).

4.6 Management Benchmarks

Overfishing and overfished limits should be defined for exploitable stocks. The implication is that when biomass falls below a specified limit, there is an unacceptable risk that recruitment will be reduced to undesirable levels. Management actions are needed to avoid approaching this limit and to recover the stock if biomass falls below the limit.

Precautionary limits to fishing were established in an earlier assessment (West et al. 2011) by requiring that exploitable biomass not fall below the three lowest levels observed (1968-2009) where the stock demonstrated sustainability (i.e., no observed declines in recruitment over a wide-range of exploitable biomasses). This is equivalent to maintaining the stock above a limit spawning potential ratio (SPR; Goodyear, 1993). The method for calculating SPR_{limit} or equivalently SSB_{limit} is presented below.

Equilibrium recruitment $\bar{R}$ (under current biomass) is assumed as the average recruitment, 1968-2015. This is the horizontal line in Figure 10. Exploitable biomass (i.e., crabs ≥125mm) is used as a measure of spawning stock biomass (SSB). When the stock is in equilibrium, equations [5, 12, and 13] can be rearranged excluding the year index into SSB/R for any given exploitation rate as:

$$\frac{SSB}{R}|F = \sum_a p_{Na} W_a \times \frac{e^{-M-F/Z(1-e^{-Z})e^{-0.5M}}}{1-[e^{-M-F/Z(1-e^{-Z})e^{-0.5M}}]} \quad [17]$$

where a are ages in months ($a = 1\ to\ 36$), p_{Na} is the proportional equilibrium abundance of crabs $\geq 125mm$ (see below), W_a is the average weight-at-age, and M, F, Z are the instantaneous natural, fishing and total mortality rates (y^{-1}). Equilibrium abundance-at-age is estimated as:

$$N_a = \bar{R} S_a \quad [18]$$

where survivorship is calculated recursively from $S_a = S_{a-1} e^{-Z_a}$, $S_1 = 1$. Size-at-age, vulnerability-at-age v_a (i.e., knife-edged selection for ages ≥125mm) and resulting monthly mortality vectors (i.e., $Z_a = M/12 + F_a$ and $F_a = v_a F/12$) are derived from the non-seasonal Gompertz growth parameters (Table 5). To approximate changes in growth through the age interval, size-at-age is calculated using the midpoints of the months (i.e. $age = a - 0.5$). Equilibrium N_a of exploitable sized crabs is normalized to 1 as $p_{Na} = \frac{N_{a\geq 125mm}}{\sum_a N_{a\geq 125mm}}$.

If the biomass limit is chosen as the geometric mean of the three lowest exploitable biomasses observed (1968-2009), then the recruitment per SSB (R/SSB_{limit}) that is equivalent to the biomass limit is the slope of the diagonal line from the origin that intersects equilibrium recruitment at SSB_{limit}. This is the left-most diagonal line in Figure 10; unfished recruits per SSB ($R/SSB_{F=0}$) is a slope equivalent to the rightmost diagonal line.

The equilibrium SPR corresponding with the exploitable biomass limit is:

$$SPR_{limit} = \frac{R/SSB_{F=0}}{R/SSB_{limit}} \quad [19]$$

and is estimated to be 19.7%. This is equivalent to specifying SSB_{limit} equal to the average of the three years with the lowest biomasses (1968-2009) in which the stock demonstrated sustainability. Additionally, equations [17, 19] are solved for the fishing mortality rates that correspond with the SPR_{limit} and a SPR_{target} discussed below.

Overfishing, Overfished, and Target Definitions

The existing Louisiana blue crab data does not allow reliable estimates of MSY. Therefore, we have defined a limit based upon the history of the fishery as defined above (i.e., a 19.7% SPR_{limit}). The fishing mortality rate limit F_{limit} and SSB_{limit} that are equivalent to this SPR_{limit} are estimated as 0.96 $years^{-1}$ and 17.1 million pounds, respectively (Table 11).

The targets of fishing, (i.e., SSB, F, and SPR) should not be so close to the limits that the limits are exceeded by random variability of the environment. Therefore, the biomass target reference point SSB_{target} is defined as $SSB_{limit} \times 1.5$, or 25.4 million pounds. This biomass is achieved when there is an equilibrium SPR_{target} of 29.6% and F_{target} of 0.74 $years^{-1}$ (Table 11).

5. Stock Status

The history of the Louisiana blue crab stock relative to the reference points described above is illustrated in Figures 11 and 12. Fishing mortality rates exceeding F_{limit} (or ratios of $F/F_{limit}>1.0$) indicate overfishing; stock biomasses below SSB_{limit} (or ratios of $SSB/SSB_{limit}<1.0$) indicate an overfished condition.

Overfishing Status

The 2014 estimate of F/Flimit is 0.97, suggesting the stock is not currently experiencing overfishing. However, this value is very close to the overfishing threshold and should be considered from a precautionary viewpoint given the upward trend in fishing mortality coupled with the decrease in exploitable biomass observed in the most recent decade. Again, the overfishing reference point estimate in this assessment (i.e., the Flimit) is calculated assuming equilibrium conditions and maybe overestimated given the below average recruitment observed in the past 20 years. Further, the 2012 estimate of F/Flimit (0.98) was also very close to the overfishing threshold. Estimates of fishing mortality are not available for the terminal year of the assessment.

Overfished Status

The 2015 estimate of SSB/SSBlimit is 0.83, suggesting the stock is currently in an overfished condition. Results also indicate the stock was considered overfished in 1995, 1996, and 2013.

Control Rule

The Louisiana Wildlife and Fisheries Commission adopted a resolution on February 6, 2014 establishing the following policy based on the overfishing and overfished limits and targets of fishing described above: "Should the fishing mortality or exploitable biomass exceed the overfished or overfishing limits, or exceed the targets for three consecutive years, as defined in the most current Louisiana blue crab stock assessment, LDWF shall come before the Commission with an updated assessment and a series of management options for the Commission to review and act upon, intended to keep the fishery from becoming overfished, and that management options for review and action shall include provisions for emergency closures, time based closures, and spatial closures." This assessment update constitutes the updated assessment in the resolution above for the Louisiana Wildlife and Fisheries Commission to review and act upon.

7. Research and Data Needs

Research emphasis on the Louisiana blue crab fishery is lacking, particularly in consideration of the value and size of the fishery (Guillory et al. 1996). The authors suggest that blue crab research done on the Atlantic coast may not be applicable to Gulf of Mexico populations. Based on this assessment, the following research and data needs are identified as priorities for future assessment of the Louisiana blue crab stock.

Due to the rapid growth and short life span of blue crab an annual time-step in the assessment model may not adequately describe the population dynamics of blue crab. Future assessment modeling efforts should explore finer temporal scales.

Environmental factors influencing year-class strength and the survival of recruits to exploitable life stages are not well understood. Further analysis of these factors could elucidate the link between the environment and blue crab productivity. Contributing factors could also be used in development of predictive models allowing for short-term forecasts for resource managers and industry.

In addition to research specific to the Louisiana blue crab stock, continuous fishery dependent monitoring programs, as part of a comprehensive monitoring plan, are needed. Differences in exploitation rates of male and female blue crabs likely exist. Continuous information on size and sex distributions of the commercial and recreational harvest are not available. Continuous harvest data for the recreational sector is also lacking. These data would reduce the number of assumptions required in future assessments.

The magnitude of blue crab catch in shrimp trawls and the associated mortality is currently unknown. In this assessment, this mortality was assumed negligible. Future estimates of blue crab catches in shrimp trawls and the mortality induced would reduce the number of assumptions required in future assessments.

Commercial effort data is currently only available in terms of the number of trips taken. A more useful measure of effort that could improve future blue crab stock assessment and management is the number of traps fished by basin/season/region.

Estimates of natural mortality in this assessment are based on assumptions of longevity. Without the ability to directly age blue crabs with conventional methods (i.e., calcified hard parts), growth estimation and resulting longevity estimates remain difficult to quantify. Estimates of these life history parameters for the Louisiana blue crab stock, perhaps from tagging or pond studies, would aid in refining life history assumptions in future assessments.

Assessment of regional or basin-specific sub-populations could differentiate exploitation rates and stock status within the state. If available data is adequate for regional assessment, results could be used to determine if regional management is an effective alternative to optimize yield within the state.

The relationship between wetlands losses and the continuation of fishery production within Louisiana has been discussed by numerous authors. Understanding this relationship as it applies to the Louisiana blue crab stock should be an ongoing priority.

With the recent trend toward ecosystem-based assessment models, more data is needed linking blue crab population dynamics to environmental conditions. The addition of environmental data coupled with food web data may lead to a better understanding of the blue crab stock and its habitat.

Fishery dependent data alone is not sufficient to accurately assess stock status and trends in abundance. Consistent fishery independent monitoring, in addition to fishery dependent monitoring, are integral components of this ability. Present monitoring programs should be assessed for adequacy with respect to their ability to evaluate stock status and should be modified or enhanced to optimize their capabilities.

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10. Tables

Table 1: Louisiana blue crab *Callinectes sapidus* landings and dockside value. Landings and values, 1968-1998, are taken from NMFS statistical records. Landings and values, 1999-2015 (shaded values), are taken from the LDWF Trip Ticket Program. Landings are millions of pounds. Values are millions of dollars.

	Total		Hard crab		% Hard crabs		Soft/peeler		% Soft/peeler	
Year	Landings	Value	Landings	Value	Landings	Value	Landings	Value	Landings	Value
1968	9.83	1.01	9.55	0.81	97.11	79.64	0.28	0.21	2.89	20.36
1969	11.80	1.23	11.60	1.07	98.33	86.93	0.20	0.16	1.67	13.07
1970	10.34	1.01	10.25	0.93	99.13	92.11	0.09	0.08	0.87	7.89
1971	12.31	1.38	12.19	1.26	98.97	90.90	0.13	0.13	1.03	9.10
1972	15.18	1.89	15.08	1.78	99.33	94.21	0.10	0.11	0.67	5.79
1973	23.20	2.94	23.08	2.81	99.48	95.53	0.12	0.13	0.52	4.47
1974	20.74	2.83	20.64	2.70	99.54	95.51	0.10	0.13	0.46	4.49
1975	17.25	2.67	17.14	2.51	99.36	94.18	0.11	0.16	0.64	5.82
1976	15.30	3.21	15.21	3.06	99.42	95.48	0.09	0.14	0.58	4.52
1977	16.38	4.33	16.15	3.77	98.63	86.86	0.22	0.57	1.37	13.14
1978	15.21	3.47	15.07	3.19	99.13	92.04	0.13	0.28	0.87	7.96
1979	21.48	5.11	21.33	4.78	99.32	93.40	0.15	0.34	0.68	6.60
1980	18.30	4.60	18.18	4.33	99.35	94.06	0.12	0.27	0.65	5.94
1981	16.34	4.71	16.24	4.47	99.39	94.94	0.10	0.24	0.61	5.06
1982	17.45	5.28	17.28	4.84	99.06	91.82	0.16	0.43	0.94	8.18
1983	19.72	6.66	19.62	6.37	99.49	95.64	0.10	0.29	0.51	4.36
1984	29.69	8.40	29.62	8.19	99.75	97.58	0.08	0.20	0.25	2.42
1985	29.93	8.59	29.85	8.39	99.73	97.68	0.08	0.20	0.27	2.32
1986	31.69	9.48	31.61	9.30	99.75	98.09	0.08	0.18	0.25	1.91
1987	52.48	20.51	52.34	20.13	99.74	98.19	0.14	0.37	0.26	1.81
1988	53.72	21.89	53.55	21.45	99.70	97.99	0.16	0.44	0.30	2.01
1989	33.56	15.20	33.39	14.78	99.49	97.23	0.17	0.42	0.51	2.77
1990	39.14	14.83	38.89	14.21	99.36	95.81	0.25	0.62	0.64	4.19
1991	51.29	17.77	51.09	17.47	99.61	98.32	0.20	0.30	0.39	1.68
1992	51.98	27.20	51.74	26.67	99.54	98.04	0.24	0.53	0.46	1.96
1993	45.95	24.47	45.85	24.04	99.79	98.26	0.10	0.43	0.21	1.74
1994	36.76	22.53	36.66	22.09	99.73	98.07	0.10	0.44	0.27	1.93
1995	36.97	29.54	36.91	29.05	99.86	98.36	0.05	0.48	0.14	1.64
1996	40.00	24.48	39.90	23.96	99.75	97.89	0.10	0.52	0.25	2.11
1997	43.53	27.74	43.44	27.14	99.80	97.86	0.09	0.59	0.20	2.14
1998	43.66	30.74	43.48	29.34	99.59	95.45	0.18	1.40	0.41	4.55
1999	46.66	26.18	46.35	25.46	99.33	97.25	0.31	0.72	0.67	2.75
2000	52.04	34.46	51.44	33.29	98.84	96.59	0.60	1.17	1.16	3.41
2001	41.87	32.05	41.46	30.98	99.04	96.66	0.40	1.07	0.96	3.34
2002	50.12	30.69	49.75	29.76	99.26	96.99	0.37	0.92	0.74	3.01
2003	48.09	33.63	47.70	32.60	99.20	96.94	0.38	1.03	0.80	3.06
2004	44.41	29.70	44.08	28.83	99.26	97.08	0.33	0.87	0.74	2.92
2005	38.12	27.41	37.90	26.83	99.42	97.89	0.22	0.58	0.58	2.11
2006	53.29	32.31	53.15	31.91	99.74	98.77	0.14	0.40	0.26	1.23
2007	46.20	35.77	46.00	35.22	99.56	98.45	0.20	0.55	0.44	1.55
2008	44.66	34.61	44.56	34.32	99.77	99.15	0.10	0.29	0.23	0.85
2009	54.98	38.43	54.77	37.88	99.62	98.59	0.21	0.54	0.38	1.41
2010	30.90	30.50	30.76	30.10	99.56	98.69	0.13	0.40	0.44	1.31
2011	43.97	36.90	43.78	36.32	99.57	98.41	0.19	0.58	0.43	1.59
2012	46.37	44.16	46.21	43.64	99.65	98.84	0.16	0.51	0.35	1.16
2013	39.22	51.65	39.08	51.24	99.64	99.20	0.14	0.41	0.36	0.80
2014	43.30	67.15	43.13	66.65	99.61	99.26	0.17	0.50	0.39	0.74
2015	41.28	58.13	41.09	57.59	99.55	99.08	0.18	0.53	0.45	0.92

Table 2: Catch-per-unit-effort of adult blue crab *Callinectes sapidus*. Abundance indices are the delta-lognormal mean of fully-recruited crabs per tow from the LDWF fishery-independent trawl survey, 1967-2015. Adult crabs are≥125mm carapace width. Shaded areas represent the maximum of the monthly-cpue distributions.

	Catch-per-unit- effort (adults)													
Year	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	**est**	**CV**
1967	1.4	0.3	1.4	0.8	1.1	1.6	1.6	1.1	0.9	0.6	0.4	0.8	0.9	0.5
1968	0.5	0.3	0.9	1.1	0.8	1.3	1.0	0.6	0.8	0.8	0.5	0.5	0.7	0.5
1969	0.3	0.2	0.4	0.9	0.7	1.2	0.9	0.9	0.7	0.8	0.6	1.4	0.7	0.6
1970	0.7	1.3	1.4	1.8	1.1	1.2	1.0	0.9	1.3	0.6	1.2	1.2	1.1	0.5
1971	0.6	0.7	1.3	1.1	1.8	1.7	1.5	1.3	0.8	0.6	0.6	0.9	1.1	0.5
1972	0.7	0.9	1.7	1.0	0.8	1.3	0.5	1.0	0.9	0.8	0.8	0.5	0.9	0.5
1973	0.2	0.4	0.6	0.7	1.3	1.2	1.8	1.2	0.8	0.9	0.8	0.6	0.9	0.5
1974	0.7	0.5	0.8	1.2	1.4	1.9	1.4	1.3	0.7	1.0	0.8	0.4	1.0	0.5
1975	0.8	0.5	0.5	0.6	0.7	1.1	1.9	0.9	0.6	0.5	0.5	0.3	0.8	0.5
1976	0.2	0.6	0.7	0.9	0.5	0.9	0.5	0.5	0.2	0.1	0.2	0.2	0.5	0.6
1977	0.0	0.1	0.3	0.1	0.2	0.6	0.5	0.7	0.2	0.6	0.6	0.7	0.4	0.7
1978	0.1	0.1	0.2	0.2	0.7	0.7	1.3	0.8	0.5	0.4	0.7	0.2	0.5	0.6
1979	0.1	0.2	0.6	0.5	0.4	1.4	1.4	0.9	0.9	0.9	0.7	0.4	0.8	0.5
1980	0.7	0.1	0.6	0.9	2.0	1.6	1.5	0.9	0.8	0.9	0.4	0.9	1.0	0.5
1981	0.1	0.2	0.5	0.4	1.0	1.8	1.2	1.2	1.0	0.9	0.6	0.3	0.9	0.5
1982	0.4	0.1	0.2	0.6	0.7	1.0	1.2	1.0	0.7	0.4	0.2	0.3	0.6	0.5
1983	0.3	0.3	0.2	0.3	0.4	0.9	1.4	1.1	0.8	0.4	0.2	0.5	0.6	0.5
1984	0.2	0.4	0.7	0.6	0.8	1.2	2.1	1.1	0.7	0.5	0.4	0.3	0.9	0.5
1985	0.2	0.3	0.6	0.9	1.4	1.4	1.3	0.6	0.5	0.5	0.5	0.4	0.8	0.5
1986	0.2	0.5	0.4	0.8	0.8	1.6	1.4	0.6	0.5	0.4	0.3	0.4	0.7	0.6
1987	0.4	0.3	0.2	0.5	0.9	1.1	1.0	0.6	0.5	0.3	0.3	0.3	0.6	0.6
1988	0.3	0.3	0.5	0.7	0.6	0.6	0.7	0.7	0.4	0.4	0.2	0.0	0.5	0.6
1989	0.1	0.1	0.2	0.1	0.5	1.2	0.8	0.7	0.4	0.3	0.1	0.1	0.4	0.6
1990	0.2	0.5	0.3	0.5	1.1	1.6	1.6	0.9	0.8	0.7	0.5	0.3	0.8	0.5
1991	0.6	0.5	0.5	0.7	1.0	1.4	1.0	0.9	0.4	0.3	0.2	0.2	0.7	0.5
1992	0.1	0.2	0.2	0.3	0.5	0.5	0.6	0.2	0.5	0.1	0.2	0.4	0.3	0.7
1993	0.1	0.1	0.1	0.1	0.3	0.8	0.9	0.5	0.5	0.4	0.3	0.1	0.4	0.6
1994	0.2	0.2	0.3	0.2	0.4	0.6	0.5	0.2	0.1	0.3	0.1	0.2	0.3	0.7
1995	0.2	0.1	0.1	0.1	0.2	0.3	0.2	0.1	0.1	0.1	0.1	0.0	0.1	0.9
1996	0.1	0.1	0.2	0.1	0.2	0.3	0.2	0.3	0.2	0.2	0.3	0.1	0.2	0.7
1997	0.1	0.1	0.0	0.1	0.2	0.6	0.5	0.3	0.3	0.4	0.3	0.2	0.3	0.7
1998	0.2	0.1	0.1	0.1	0.1	0.6	0.7	0.5	0.4	0.3	0.3	0.2	0.3	0.7
1999	0.1	0.2	0.2	0.2	0.4	0.7	0.8	0.6	0.1	0.2	0.1	0.1	0.3	0.6
2000	0.2	0.2	0.1	0.3	0.7	0.6	0.5	0.3	0.2	0.1	0.1	0.1	0.3	0.7
2001	0.0	0.1	0.1	0.0	0.1	0.5	0.5	0.3	0.3	0.2	0.3	0.1	0.2	0.8
2002	0.2	0.1	0.1	0.1	0.2	0.5	0.9	0.7	0.4	0.1	0.5	0.2	0.3	0.6
2003	0.1	0.1	0.1	0.1	0.2	0.5	0.3	0.3	0.2	0.2	0.1	0.1	0.2	0.7
2004	0.0	0.2	0.1	0.1	0.2	0.6	0.5	0.4	0.2	0.2	0.3	0.1	0.2	0.7
2005	0.2	0.1	0.1	0.0	0.1	0.7	1.1	1.3	1.4	0.6	0.7	0.6	0.5	0.5
2006	0.9	0.8	0.5	0.6	1.5	2.5	2.4	1.3	0.7	0.5	0.6	0.4	1.1	0.5
2007	0.4	0.3	0.3	0.3	0.3	1.0	1.1	0.9	0.5	0.4	0.2	0.2	0.5	0.6
2008	0.2	0.4	0.1	0.1	0.2	0.6	0.8	0.6	0.4	0.4	0.4	0.6	0.4	0.6
2009	0.6	0.4	0.2	0.2	0.7	1.3	1.4	0.6	0.3	0.3	0.3	0.2	0.5	0.6
2010	0.1	0.0	0.1	0.1	0.2	0.7	0.9	0.6	0.5	0.2	0.5	0.2	0.3	0.6
2011	0.2	0.1	0.1	0.3	0.5	0.9	1.1	0.5	0.3	0.5	0.4	0.2	0.5	0.5
2012	0.1	0.4	0.1	0.1	0.3	0.4	0.5	0.2	0.2	0.2	0.2	0.1	0.3	0.6
2013	0.2	0.1	0.0	0.1	0.1	0.4	0.4	0.1	0.2	0.3	0.2	0.1	0.2	0.7
2014	0.0	0.2	0.0	0.1	0.2	0.6	0.8	0.5	0.4	0.3	0.2	0.1	0.3	0.6
2015	0.1	0.0	0.1	0.1	0.2	0.2	0.2	0.2	0.3	0.1	0.2	0.2	0.2	0.8
est	0.3	0.3	0.3	0.4	0.6	0.9	0.9	0.7	0.5	0.4	0.4	0.3		
CV	0.6	0.6	0.6	0.6	0.5	0.5	0.5	0.5	0.6	0.6	0.6	0.6		

Table 3: Catch-per-unit-effort of juvenile blue crab *Callinectes sapidus*. Abundance indices are the delta-lognormal mean of juvenile crabs per tow from the LDWF fishery-independent trawl survey, 1967-2015. Juveniles are crabs ≥25mm and <125mm carapace width that will grow to legal size during the survey year. Shaded areas represent the maximum of the monthly-cpue distributions.

	Catch-per-unit- effort (juveniles)													
Year	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	**est**	**CV**
1967	1.8	1.0	2.6	3.0	3.9	2.5	1.6	0.8	0.5	0.2	0.1	0.1	1.0	0.4
1968	1.2	1.4	2.0	2.1	3.0	3.5	1.4	0.6	0.4	0.2	0.1	0.1	1.3	0.4
1969	1.1	1.6	1.7	3.1	2.3	2.5	0.6	0.5	0.5	0.2	0.1	0.2	1.6	0.4
1970	2.2	2.2	2.5	2.5	1.6	1.9	1.2	0.5	0.6	0.3	0.1	0.0	1.2	0.4
1971	2.1	2.1	4.1	2.6	4.8	3.1	1.9	0.6	0.2	0.1	0.0	0.1	1.5	0.3
1972	4.6	5.3	2.6	2.9	1.8	2.9	1.0	0.7	0.6	0.4	0.1	0.1	1.6	0.3
1973	1.8	2.2	1.8	2.1	5.0	2.9	2.0	0.9	0.7	0.3	0.1	0.1	1.6	0.3
1974	1.6	2.2	2.3	2.7	3.3	3.7	1.2	0.7	0.4	0.3	0.1	0.0	1.7	0.3
1975	2.1	1.8	1.8	1.4	2.3	2.1	1.6	0.6	0.3	0.2	0.0	0.0	1.3	0.4
1976	0.4	0.7	1.8	1.4	1.2	1.9	0.7	0.2	0.2	0.1	0.0	0.0	0.7	0.5
1977	0.6	1.8	1.5	1.1	1.6	1.6	0.5	0.3	0.1	0.3	0.1	0.0	0.8	0.5
1978	1.4	1.8	1.3	1.9	2.7	2.3	1.4	0.5	0.5	0.1	0.1	0.0	1.0	0.4
1979	1.9	2.4	5.5	2.1	2.3	6.4	2.9	1.3	1.3	0.4	0.2	0.1	2.1	0.3
1980	3.6	2.6	2.8	5.0	6.2	5.8	1.8	0.6	0.3	0.4	0.0	0.2	2.4	0.2
1981	1.0	1.3	1.7	2.4	5.3	5.0	1.4	0.8	0.8	0.4	0.0	0.0	1.7	0.3
1982	1.4	1.7	4.5	3.5	3.2	5.0	2.8	1.4	0.9	0.3	0.0	0.1	2.2	0.3
1983	2.7	4.0	2.8	2.7	2.6	5.1	3.4	1.4	0.6	0.2	0.1	0.0	2.3	0.3
1984	2.0	1.7	2.7	3.2	3.2	3.2	2.4	0.9	0.6	0.2	0.1	0.0	1.8	0.3
1985	0.8	2.0	2.8	3.2	4.1	3.5	1.8	0.7	0.6	0.2	0.1	0.0	1.8	0.3
1986	1.1	3.0	2.6	2.6	2.3	3.1	2.0	0.5	0.4	0.3	0.1	0.1	1.7	0.3
1987	1.4	1.6	2.7	2.9	4.5	3.3	1.9	1.3	0.7	0.2	0.1	0.0	2.0	0.3
1988	3.3	4.2	4.4	5.3	4.9	3.1	2.0	1.2	0.6	0.2	0.0	0.0	2.2	0.2
1989	1.9	2.1	3.4	2.3	3.3	4.2	1.6	0.9	0.5	0.2	0.1	0.0	1.7	0.3
1990	1.4	3.3	3.7	5.0	5.2	5.3	2.8	1.1	1.0	0.5	0.3	0.0	2.5	0.2
1991	3.3	6.0	4.0	4.7	6.5	6.3	2.1	0.9	0.5	0.2	0.1	0.0	2.9	0.2
1992	5.1	2.1	1.9	1.9	2.2	2.5	1.2	0.3	0.3	0.1	0.0	0.1	1.4	0.3
1993	3.0	2.8	2.5	3.8	3.5	4.0	1.5	0.7	0.4	0.1	0.2	0.0	1.8	0.3
1994	5.6	3.3	4.0	4.5	4.5	3.6	0.9	0.3	0.1	0.1	0.0	0.0	2.1	0.2
1995	1.8	2.0	2.8	2.4	2.4	1.6	0.7	0.2	0.2	0.1	0.1	0.0	1.2	0.4
1996	3.4	1.2	2.1	2.1	2.2	1.6	0.7	0.6	0.2	0.0	0.0	0.0	1.2	0.4
1997	1.4	1.7	1.6	1.7	2.2	2.9	0.9	0.6	0.3	0.2	0.0	0.1	1.1	0.4
1998	3.3	2.8	2.2	1.3	1.8	4.5	1.2	0.6	0.3	0.1	0.0	0.0	1.4	0.3
1999	0.7	1.3	1.2	2.0	1.7	2.1	1.0	0.6	0.2	0.1	0.0	0.0	0.9	0.4
2000	1.9	3.2	2.4	1.9	2.1	1.3	0.6	0.3	0.2	0.1	0.0	0.0	1.0	0.4
2001	0.5	1.1	1.4	1.2	1.4	2.3	0.7	0.2	0.3	0.0	0.1	0.0	0.7	0.4
2002	0.6	1.7	1.3	1.3	1.9	1.8	0.8	0.2	0.2	0.0	0.0	0.0	0.8	0.4
2003	1.1	0.7	0.8	1.0	1.9	1.4	0.5	0.2	0.2	0.0	0.0	0.0	0.6	0.4
2004	0.8	2.6	1.7	1.2	1.3	2.3	0.7	0.3	0.2	0.1	0.0	0.0	0.9	0.4
2005	2.3	2.2	2.3	1.4	1.4	1.7	0.8	0.3	0.7	0.0	0.0	0.0	1.1	0.4
2006	1.5	2.4	2.3	2.8	3.3	2.2	0.8	0.2	0.3	0.1	0.1	0.0	1.3	0.3
2007	1.5	1.6	1.3	1.1	2.2	2.8	1.0	0.4	0.4	0.1	0.0	0.0	1.0	0.4
2008	0.9	1.9	1.5	1.0	1.5	1.5	0.7	0.4	0.1	0.0	0.0	0.0	0.8	0.5
2009	1.1	1.5	1.4	1.4	1.8	2.1	0.8	0.2	0.1	0.0	0.0	0.0	0.9	0.4
2010	0.7	0.5	1.0	1.3	1.1	1.6	0.4	0.3	0.3	0.0	0.1	0.0	0.6	0.5
2011	1.2	1.1	1.6	1.7	1.4	1.8	0.7	0.5	0.4	0.1	0.0	0.0	0.9	0.4
2012	1.6	2.1	1.5	1.1	0.7	1.0	0.3	0.1	0.2	0.1	0.0	0.0	0.7	0.4
2013	1.0	1.2	0.9	0.5	0.8	1.4	0.7	0.1	0.2	0.0	0.0	0.0	0.7	0.5
2014	1.4	0.6	2.2	1.2	0.7	0.9	0.6	0.5	0.3	0.1	0.0	0.0	0.7	0.5
2015	0.8	2.1	1.4	1.6	1.6	1.2	0.5	0.1	0.1	0.0	0.0	0.0	0.8	0.4
est	1.7	2.0	2.2	2.1	2.5	2.7	1.2	0.6	0.4	0.1	0.1	0.0		
CV	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.6	0.6	0.8	0.8	0.9		

Table 4: Catch-per-unit-effort of young-of-the-year blue crab *Callinectes sapidus*. Abundance indices are the delta-lognormal mean of pre-recruit crabs per tow from the LDWF fishery-independent trawl survey, 1967-2015. Young-of-the-year crabs are ≥25mm and <125mm carapace width and will not grow to legal size during the survey year. Shaded areas represent the maximum of the monthly-cpue distributions.

	Catch-per-unit- effort (young-of-the-year)													
Year	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	**est**	**CV**
1967	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.5	0.6	0.9	0.3	0.7	0.4	0.6
1968	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.4	0.8	1.5	1.0	1.2	0.4	0.5
1969	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.3	0.5	2.2	1.5	2.0	0.2	0.5
1970	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.1	0.9	1.0	2.3	1.6	0.5	0.4
1971	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.5	0.5	1.0	2.1	3.2	0.6	0.4
1972	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.4	0.4	0.7	1.4	1.8	0.4	0.4
1973	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.5	0.7	1.1	1.0	1.6	0.4	0.4
1974	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.4	0.4	0.7	0.7	1.5	0.2	0.6
1975	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.5	0.4	0.9	0.8	0.4	0.2	0.5
1976	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.1	0.3	0.4	0.7	1.6	0.3	0.4
1977	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.2	0.9	1.9	1.2	0.3	0.5
1978	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.3	0.8	0.7	0.9	1.8	0.4	0.6
1979	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.8	2.5	1.9	1.6	2.0	0.8	0.4
1980	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.6	0.9	1.5	1.2	2.1	0.5	0.4
1981	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.9	1.5	0.5	1.3	0.4	0.4
1982	0.0	0.0	0.0	0.0	0.0	0.0	1.5	1.1	1.5	1.9	2.5	2.3	0.9	0.3
1983	0.0	0.0	0.0	0.0	0.0	0.0	1.4	0.9	0.9	1.9	0.9	1.9	0.5	0.4
1984	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.8	1.3	1.5	1.8	1.9	0.5	0.4
1985	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.6	1.7	1.5	2.0	1.3	0.6	0.4
1986	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.4	0.8	1.7	1.0	4.0	0.5	0.4
1987	0.0	0.0	0.0	0.0	0.0	0.0	0.7	1.4	1.5	1.4	0.8	2.8	0.6	0.3
1988	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.7	1.0	0.8	1.1	0.3	0.4	0.5
1989	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.5	1.4	1.8	0.9	1.9	0.5	0.4
1990	0.0	0.0	0.0	0.0	0.0	0.0	1.4	0.7	1.7	2.3	1.9	2.9	0.8	0.3
1991	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.4	1.5	1.2	0.7	1.5	0.4	0.4
1992	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.6	1.0	0.7	0.6	1.2	0.4	0.4
1993	0.0	0.0	0.0	0.0	0.0	0.0	1.7	0.8	1.7	1.5	3.4	2.4	0.8	0.3
1994	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.7	0.7	1.4	3.3	1.7	0.5	0.4
1995	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.3	0.9	1.2	2.0	1.8	0.4	0.4
1996	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.6	0.7	0.6	1.8	1.7	0.4	0.4
1997	0.0	0.0	0.0	0.0	0.0	0.0	0.7	1.2	1.7	2.6	2.4	2.1	0.9	0.3
1998	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.7	0.6	0.8	0.6	0.8	0.3	0.5
1999	0.0	0.0	0.0	0.0	0.0	0.0	0.4	1.0	1.3	1.1	0.6	1.4	0.5	0.3
2000	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.5	0.9	0.6	0.8	1.2	0.3	0.4
2001	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.4	0.9	0.6	0.7	1.0	0.3	0.5
2002	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.4	0.4	0.7	1.1	0.6	0.3	0.5
2003	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.4	0.7	0.4	0.9	1.4	0.3	0.4
2004	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.6	0.8	0.9	1.5	2.0	0.5	0.4
2005	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.2	1.1	0.5	1.1	1.2	0.3	0.5
2006	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.2	0.3	0.4	0.5	0.5	0.2	0.6
2007	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.3	0.3	0.5	0.7	0.7	0.2	0.6
2008	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.6	0.4	0.4	0.5	0.6	0.2	0.6
2009	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.3	0.4	0.6	0.5	0.8	0.2	0.6
2010	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.2	0.3	0.2	0.6	0.3	0.2	0.6
2011	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.3	0.5	0.3	0.7	1.6	0.3	0.4
2012	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.2	0.7	0.2	0.2	0.4	0.1	0.6
2013	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.3	0.7	0.3	0.9	0.7	0.2	0.5
2014	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.7	0.9	0.6	0.4	0.4	0.3	0.5
2015	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.4	0.5	0.3	0.4	0.4	0.2	0.6
est	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.5	0.9	1.0	1.0	1.2		
CV	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.5	0.4	0.4	0.4	0.3		

Table 5: Gompertz growth parameters of blue crab *Callinectes sapidus* from West et al. (2011). Sizes are carapace-widths in mm.

	Gompertz parameters			
	Jan-Apr	*May-Aug*	*Sept-Dec*	*non-seasonal*
CW_∞	*164.8*	*175.9*	*174.8*	*174.5*
α	*-4.9*	*-4.6*	*-19.8*	*-5.5*
β	*-3.5*	*-2.6*	*-4.4*	*-3*

Table 6: Size-at-capture matrix of Louisiana blue crab *Callinectes sapidus* used to identify crabs that will not recruit to the fishery during the survey year. Cells represent carapace-widths at capture in mm from the LDWF fishery independent trawl survey. Crabs not fully-selected by the survey gear (<25mm) are not shown (i.e., blank cells). Month of capture represents samples from the trawl survey. Month of hatch represents monthly cohorts. Cells above the diagonal represent size-at-capture of the current year-class. Cells below the diagonal are size-at-capture of the previous year-class. The shaded area represents cohorts that will not recruit to the fishery during the survey year. Carapace widths in bold represent the maximum size-at-capture of crabs that will not recruit to the fishery during the survey year. Seasonal size-at-age (Jan-Apr, May-Aug, and Sept-Dec) is estimated from Gompertz growth models.

		Month of Capture											
		Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
Month of Hatch	**Jan**				*29*	*45*	*63*	*80*	*96*	*110*	*122*	*132*	*140*
	Feb	*140*				*29*	*45*	*63*	*80*	*96*	*110*	*122*	*132*
	Mar	*132*	*140*				*29*	***45***	***63***	***80***	***96***	***110***	***122***
	Apr	*122*	*132*	*140*				*29*	*45*	*63*	*80*	*96*	*110*
	May	*85*	*98*	*110*	*120*					*31*	*44*	*57*	*71*
	Jun	*71*	*85*	*98*	*110*	*120*					*31*	*44*	*57*
	Jul	*57*	*71*	*85*	*98*	*110*	*120*					*31*	*44*
	Aug	*44*	*57*	*71*	*85*	*98*	*110*	*120*					*31*
	Sept			*28*	*50*	*73*	*95*	*115*	*131*				
	Oct				*28*	*50*	*73*	*95*	*115*	*131*			
	Nov					*28*	*50*	*73*	*95*	*115*	*131*		
	Dec						*28*	*50*	*73*	*95*	*115*	*131*	

Table 7: FAO proposed guideline for indices of productivity for exploited aquatic species. Parameter values are taken from West et al. (2011) and GDAR1.

Parameter	**Productivity**			**Species**	
	Low	**Medium**	**High**	*Blue Crab*	**Score**
M	*<0.2*	*0.2 - 0.5*	*>0.5*	***1.0***	*3*
K	*<0.15*	*0.15 - 0.33*	*>0.33*	***1.9***	*3*
t_{mat}	*>8*	*3.3 - 8*	*<3.3*	***1***	*3*
t_{max}	*>25*	*14 - 25*	*<14*	***3***	*3*
Examples	*orange roughy, many sharks*	*cod, hake*	*sardine, anchovy*	***Blue Crab Productivity Score = 3.0 (high)***	

Table 8: Annual mean weights (lbs) of juvenile and adult blue crabs captured from the LDWF fishery-independent trawl survey, 1968-2015. Adult crabs are≥125mm carapace width. Juveniles are crabs ≥25mm and <125mm carapace width.

	Mean Weight (lbs)	
Year	*Adults*	*Juveniles*
1968	*0.40*	*0.05*
1969	*0.42*	*0.05*
1970	*0.41*	*0.06*
1971	*0.41*	*0.05*
1972	*0.41*	*0.05*
1973	*0.42*	*0.06*
1974	*0.42*	*0.06*
1975	*0.40*	*0.05*
1976	*0.44*	*0.05*
1977	*0.42*	*0.04*
1978	*0.42*	*0.05*
1979	*0.42*	*0.05*
1980	*0.42*	*0.04*
1981	*0.39*	*0.06*
1982	*0.39*	*0.05*
1983	*0.38*	*0.05*
1984	*0.40*	*0.06*
1985	*0.40*	*0.06*
1986	*0.38*	*0.05*
1987	*0.37*	*0.06*
1988	*0.40*	*0.05*
1989	*0.38*	*0.05*
1990	*0.38*	*0.05*
1991	*0.39*	*0.05*
1992	*0.39*	*0.04*
1993	*0.39*	*0.03*
1994	*0.40*	*0.03*
1995	*0.39*	*0.03*
1996	*0.40*	*0.03*
1997	*0.39*	*0.03*
1998	*0.40*	*0.03*
1999	*0.39*	*0.03*
2000	*0.42*	*0.03*
2001	*0.43*	*0.03*
2002	*0.42*	*0.04*
2003	*0.46*	*0.03*
2004	*0.45*	*0.03*
2005	*0.45*	*0.03*
2006	*0.44*	*0.04*
2007	*0.42*	*0.04*
2008	*0.44*	*0.03*
2009	*0.44*	*0.05*
2010	*0.43*	*0.04*
2011	*0.46*	*0.04*
2012	*0.46*	*0.03*
2013	*0.48*	*0.03*
2014	*0.47*	*0.03*
2015	*0.46*	*0.02*

Table 9: Catch-per-unit-effort of blue crab *Callinectes sapidus*. Adult, juvenile, and young-of-the-year abundance indices are derived as the delta-lognormal mean catch-per-tow from the LDWF fishery-independent trawl survey, 1967-2015. The juvenile abundance index r_y used in the catch-survey model is derived as the sum of young-of-the-year cpue in year and juvenile cpue in year+1. The shaded cells represent values not used as model inputs.

	Catch-per-unit-effort (crabs per tow)			*Model inputs*	
Year	*Adults*	*Juveniles*	*Young-of-the-year*	n_y	r_y
1967	*0.88*	*0.97*	*0.38*		
1968	*0.74*	*1.28*	*0.40*	*0.73*	*1.66*
1969	*0.66*	*1.64*	*0.22*	*0.65*	*2.03*
1970	*1.12*	*1.24*	*0.49*	*1.11*	*1.46*
1971	*1.08*	*1.52*	*0.64*	*1.07*	*2.01*
1972	*0.88*	*1.63*	*0.43*	*0.89*	*2.27*
1973	*0.93*	*1.65*	*0.45*	*0.93*	*2.08*
1974	*1.04*	*1.71*	*0.19*	*1.03*	*2.16*
1975	*0.78*	*1.28*	*0.23*	*0.80*	*1.46*
1976	*0.45*	*0.67*	*0.31*	*0.45*	*0.90*
1977	*0.37*	*0.78*	*0.30*	*0.36*	*1.09*
1978	*0.53*	*0.98*	*0.39*	*0.49*	*1.28*
1979	*0.75*	*2.14*	*0.79*	*0.76*	*2.52*
1980	*1.01*	*2.35*	*0.51*	*1.01*	*3.14*
1981	*0.88*	*1.74*	*0.39*	*0.88*	*2.25*
1982	*0.63*	*2.18*	*0.87*	*0.63*	*2.56*
1983	*0.64*	*2.29*	*0.55*	*0.63*	*3.15*
1984	*0.87*	*1.84*	*0.52*	*0.87*	*2.39*
1985	*0.79*	*1.81*	*0.55*	*0.79*	*2.33*
1986	*0.75*	*1.65*	*0.46*	*0.75*	*2.20*
1987	*0.57*	*1.97*	*0.56*	*0.57*	*2.44*
1988	*0.50*	*2.24*	*0.38*	*0.50*	*2.79*
1989	*0.41*	*1.75*	*0.48*	*0.41*	*2.12*
1990	*0.84*	*2.53*	*0.78*	*0.84*	*3.01*
1991	*0.70*	*2.86*	*0.41*	*0.70*	*3.64*
1992	*0.32*	*1.38*	*0.40*	*0.32*	*1.79*
1993	*0.38*	*1.83*	*0.80*	*0.38*	*2.23*
1994	*0.28*	*2.12*	*0.55*	*0.29*	*2.92*
1995	*0.14*	*1.18*	*0.44*	*0.14*	*1.72*
1996	*0.19*	*1.16*	*0.42*	*0.19*	*1.61*
1997	*0.27*	*1.13*	*0.87*	*0.26*	*1.54*
1998	*0.30*	*1.38*	*0.34*	*0.30*	*2.25*
1999	*0.32*	*0.93*	*0.46*	*0.32*	*1.27*
2000	*0.30*	*1.04*	*0.32*	*0.30*	*1.51*
2001	*0.21*	*0.74*	*0.34*	*0.21*	*1.07*
2002	*0.33*	*0.83*	*0.27*	*0.34*	*1.17*
2003	*0.20*	*0.65*	*0.33*	*0.20*	*0.92*
2004	*0.24*	*0.90*	*0.50*	*0.24*	*1.23*
2005	*0.54*	*1.10*	*0.32*	*0.54*	*1.60*
2006	*1.06*	*1.28*	*0.19*	*1.07*	*1.61*
2007	*0.51*	*1.00*	*0.24*	*0.51*	*1.19*
2008	*0.40*	*0.79*	*0.25*	*0.40*	*1.03*
2009	*0.53*	*0.93*	*0.21*	*0.54*	*1.18*
2010	*0.31*	*0.60*	*0.16*	*0.54*	*0.81*
2011	*0.50*	*0.94*	*0.25*	*0.54*	*1.10*
2012	*0.25*	*0.66*	*0.14*	*0.54*	*0.91*
2013	*0.17*	*0.71*	*0.18*	*0.54*	*0.85*
2014	*0.30*	*0.69*	*0.26*	*1.54*	*0.87*
2015	*0.16*	*0.76*	*0.20*	*2.54*	*1.02*

Table 10: Assessment model inputs and resulting estimates for the Louisiana blue crab *Callinectes sapidus* stock, 1968-2015. Descriptions of model inputs are: M = constant instantaneous natural mortality rate, C_y = harvest (as individuals), r_y = juvenile cpue, n_y = adult cpue, s_r = relative selectivity of juveniles to adult crabs in the survey gear. Descriptions of model estimates are: $\hat{q}_n$ = predicted catchability of adult crabs to the survey gear, $\hat{r}_y$ = predicted juvenile cpue, $\hat{n}_y$ = predicted adult cpue, n_y = calculated adult cpue (i.e., from process error), R_y = juvenile abundance, N_y = adult abundance, Z_y = instantaneous total mortality rate, u_y = exploitation rate, F_y = instantaneous fishing mortality rate. CPUE is derived as the delta-lognormal mean catch per tow from the LDWF fishery-independent trawl survey. Juveniles are crabs ≥25mm and <125mm carapace width. Adult crabs are ≥125mm carapace width. Abundance units are millions of individuals. Biomass units are millions of pounds.

Model inputs $M = 1.0$					***Model estimates*** $\hat{q}_n = 0.0050$									
Year	C_y	r_y	n_y	s_r	$\hat{r}_y$	$\hat{n}_y$	n_y	R_y	N_y	Z_y	u_y	F_y	R_y Biomass	N_y Biomass
1968	24.8	1.7	0.7	1.0	1.6	0.7	0.0	313.3	143.8	1.2	0.1	0.1	17.0	58.0
1969	28.8	2.0	0.7	1.0	2.2	0.7	0.8	434.0	142.8	1.0	0.0	0.1	22.9	60.4
1970	26.3	1.5	1.1	1.0	1.5	1.1	1.0	307.5	212.6	1.0	0.1	0.1	18.3	87.0
1971	31.2	2.0	1.1	1.0	1.9	1.0	0.9	384.0	192.1	1.1	0.1	0.1	17.6	78.7
1972	38.8	2.3	0.9	1.0	2.2	0.9	1.0	434.0	182.6	1.2	0.1	0.1	20.4	74.6
1973	58.2	2.1	0.9	1.0	2.1	1.0	1.0	417.4	194.0	1.2	0.1	0.2	23.7	80.7
1974	51.2	2.2	1.0	1.0	2.0	1.0	1.0	388.8	192.6	1.3	0.1	0.2	24.2	81.6
1975	45.3	1.5	0.8	1.0	1.3	0.8	0.9	254.5	161.2	1.4	0.1	0.2	13.5	64.0
1976	36.2	0.9	0.5	1.0	0.9	0.5	0.6	173.0	105.1	1.3	0.1	0.2	8.6	46.4
1977	40.5	1.1	0.4	1.0	1.2	0.4	0.4	236.8	77.6	1.1	0.1	0.2	10.3	32.5
1978	37.9	1.3	0.5	1.0	1.4	0.5	0.5	282.0	100.1	1.1	0.1	0.2	14.6	41.8
1979	53.8	2.5	0.8	1.0	2.5	0.7	0.6	491.4	132.4	1.2	0.1	0.1	27.0	55.2
1980	45.8	3.1	1.0	1.0	2.7	1.0	1.0	530.0	192.8	1.3	0.1	0.1	21.8	80.4
1981	43.9	2.2	0.9	1.0	1.9	1.0	1.2	376.7	195.1	1.4	0.1	0.1	21.5	75.8
1982	46.2	2.6	0.6	1.0	2.2	0.7	0.9	426.8	146.7	1.3	0.1	0.1	20.5	57.7
1983	54.0	3.2	0.6	1.0	2.8	0.8	0.9	547.3	149.1	1.3	0.1	0.1	27.8	56.9
1984	77.5	2.4	0.9	1.0	2.2	1.0	1.1	435.6	192.6	1.3	0.1	0.2	25.6	77.3
1985	78.8	2.3	0.8	1.0	2.1	0.8	0.9	424.4	167.1	1.3	0.1	0.2	23.7	66.5
1986	86.6	2.2	0.7	1.0	1.9	0.8	0.9	380.5	154.4	1.5	0.2	0.3	20.0	59.2
1987	148.3	2.4	0.6	1.0	2.2	0.6	0.7	427.1	124.9	1.7	0.3	0.6	23.9	46.3
1988	140.7	2.8	0.5	1.0	2.2	0.5	0.6	439.9	103.4	1.7	0.3	0.5	19.9	41.3
1989	93.3	2.1	0.4	1.0	2.2	0.5	0.6	445.1	97.2	1.3	0.2	0.3	20.7	36.5
1990	107.3	3.0	0.8	1.0	2.5	0.8	0.7	493.5	149.9	1.5	0.2	0.3	24.8	57.1
1991	137.9	3.6	0.7	1.0	2.3	0.7	0.9	452.1	143.4	1.9	0.2	0.5	23.3	55.8
1992	138.4	1.8	0.3	1.0	1.7	0.5	0.7	339.8	92.5	1.8	0.3	0.7	13.5	36.3
1993	122.4	2.2	0.4	1.0	1.6	0.4	0.4	320.8	73.0	1.9	0.3	0.7	10.4	28.7
1994	96.0	2.9	0.3	1.0	1.4	0.3	0.4	280.5	58.2	2.1	0.3	0.7	8.4	23.3
1995	99.1	1.7	0.1	1.0	1.3	0.2	0.3	257.7	41.7	1.9	0.3	0.8	9.0	16.3
1996	105.5	1.6	0.2	1.0	1.5	0.2	0.3	289.1	43.0	1.8	0.3	0.7	9.1	17.1
1997	115.5	1.5	0.3	1.0	1.5	0.3	0.3	296.0	55.1	1.8	0.3	0.7	9.9	21.8
1998	114.6	2.3	0.3	1.0	1.8	0.3	0.3	361.0	58.0	1.7	0.3	0.6	12.6	23.1
1999	123.3	1.3	0.3	1.0	1.4	0.4	0.4	275.6	73.9	1.8	0.4	0.8	8.9	29.2
2000	127.3	1.5	0.3	1.0	1.4	0.3	0.3	279.5	56.4	2.0	0.4	0.9	9.0	23.9
2001	100.1	1.1	0.2	1.0	1.3	0.2	0.2	264.0	45.0	1.6	0.3	0.7	7.8	19.6
2002	124.2	1.2	0.3	1.0	1.3	0.3	0.3	249.5	59.8	2.1	0.4	0.9	9.0	25.1
2003	110.0	0.9	0.2	1.0	1.2	0.2	0.2	247.2	39.7	1.9	0.4	0.8	7.3	18.1
2004	103.2	1.2	0.2	1.0	1.7	0.2	0.2	333.8	44.2	1.4	0.3	0.5	8.8	19.8
2005	87.6	1.6	0.5	1.0	2.1	0.5	0.4	413.9	93.0	1.1	0.2	0.3	11.1	42.2
2006	126.9	1.6	1.1	1.0	1.6	0.8	0.7	324.3	168.4	1.5	0.3	0.5	13.0	74.1
2007	115.7	1.2	0.5	1.0	1.4	0.5	0.5	276.1	105.9	1.6	0.3	0.6	10.6	44.2
2008	105.9	1.0	0.4	1.0	1.5	0.4	0.4	288.5	78.5	1.4	0.3	0.5	9.9	34.7
2009	130.4	1.2	0.5	1.0	1.4	0.4	0.4	278.2	89.1	1.8	0.4	0.8	12.7	39.3
2010	75.4	0.8	0.3	2.0	1.1	0.3	0.3	227.1	61.6	1.3	0.3	0.5	9.2	26.4
2011	100.6	1.1	0.5	3.0	1.1	0.4	0.3	224.1	77.5	1.8	0.3	0.7	10.0	35.4
2012	104.7	0.9	0.3	4.0	1.1	0.3	0.3	208.7	50.7	2.0	0.4	0.9	5.9	23.5
2013	85.4	0.8	0.2	5.0	1.1	0.2	0.2	226.9	33.9	1.6	0.3	0.7	7.5	16.3
2014	95.7	0.9	0.3	6.0	0.9	0.3	0.2	187.9	51.6	2.0	0.4	0.9	6.3	24.4
2015	94.2	1.0	0.2	7.0	--	0.2	0.2	201.5	31.2	--	0.4	--	4.9	14.3

Table 11: Derivation and management reference point estimates for the Louisiana blue crab *Callinectes sapidus* stock. Fishing mortality units are years^{-1}. Biomass units are millions of pounds.

Management Benchmarks		
Parameters	*Derivation*	*Estimates*
SPR_{limit}	*Equations [17,19] and* SSB_{limit}	*19.7%*
SSB_{limit}	*Geometric mean of 3 lowest biomasses (1968-2009)*	*17.1*
F_{limit}	*Equations [17,19] and* SPR_{limit}	*0.96*
SPR_{target}	*Equations [17,19] and* SSB_{target}	*29.6%*
SSB_{target}	$SSB_{limit} \times 1.5$	*25.7*
F_{target}	*Equations [17,19] and* SPR_{target}	*0.74*

11. Figures

Figure 1: Commercial hard crab landings and fishing effort for Louisiana blue crab *Callinectes sapidus*. Landings, 1967-1998, are taken from NMFS statistical records. Landings and fishing effort, 1999-2015, are taken from the LDWF Trip Ticket Program. Landings are millions of pounds. Fishing effort is thousands of trap fisher trips.

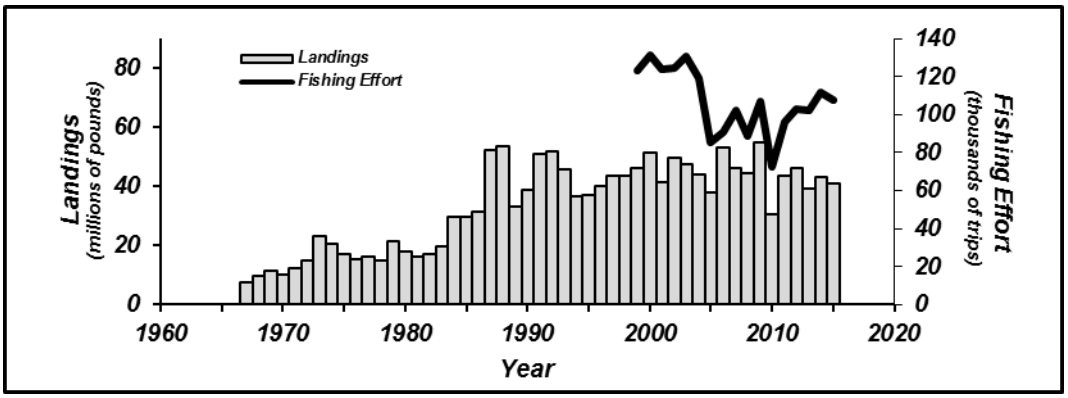

Figure 2: Catch-per-unit-effort of adult Louisiana blue crab *Callinectes sapidus*. The predicted index is derived from lognormal **observation error** of the catch-survey model. The observed index is the delta-lognormal mean catch-per-tow from the LDWF fishery-independent trawl survey, 1968-2015. Bottom graphic depicts lognormal residuals. Adult crabs are ≥125mm carapace-width.

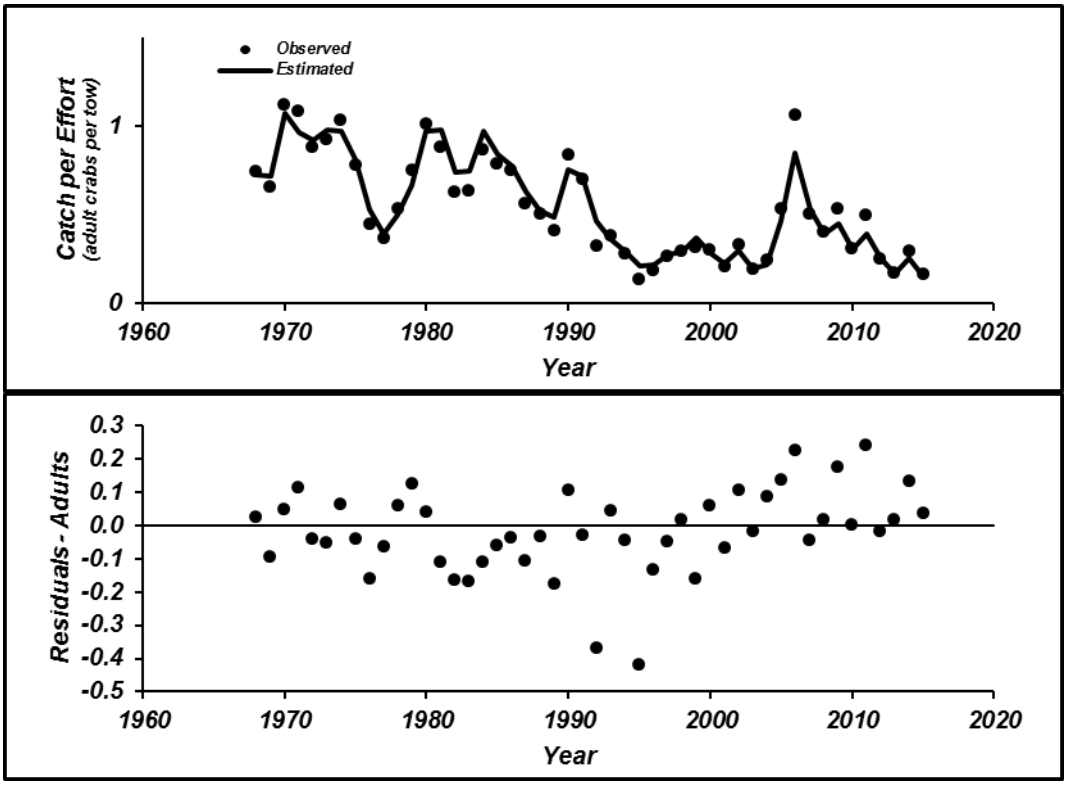

Figure 3: Catch-per-unit-effort of adult Louisiana blue crab *Callinectes sapidus.* The calculated index is derived from lognormal **process error** of the catch-survey model. The observed index is the delta-lognormal mean catch-per-tow from the LDWF fishery-independent trawl survey, 1968-2015. Bottom graphic depicts lognormal residuals. Adult crabs are ≥125mm carapace-width.

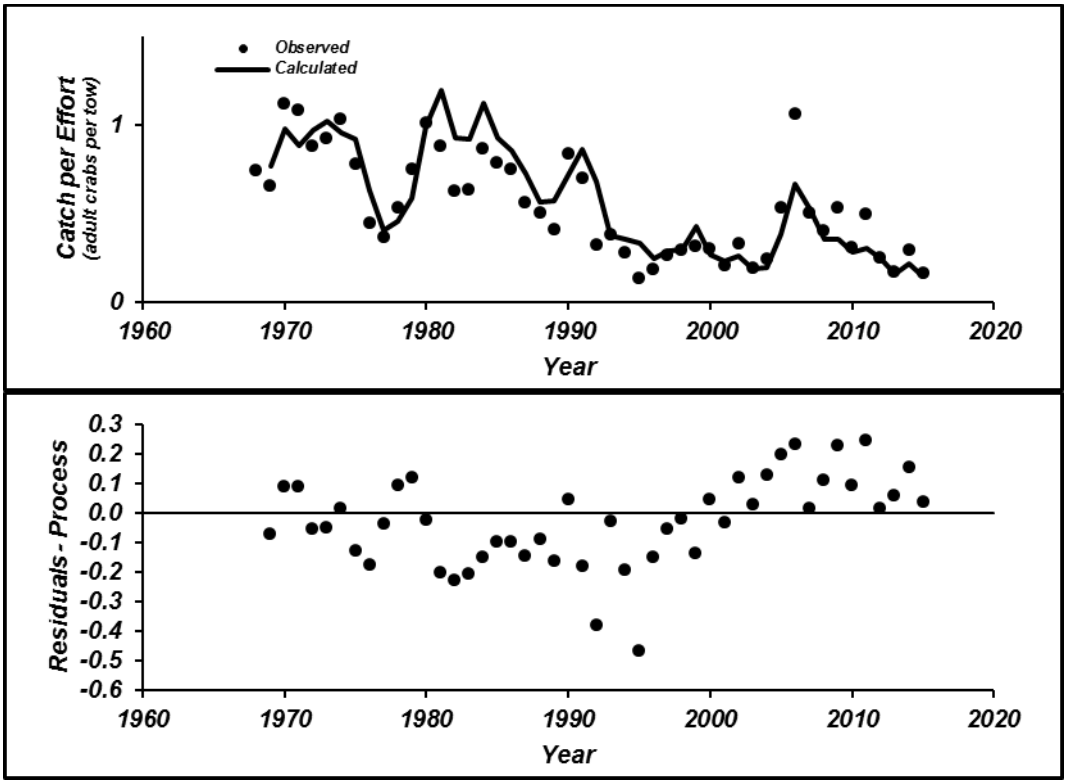

Figure 4: Catch-per-unit-effort of juvenile Louisiana blue crab *Callinectes sapidus*. The predicted index is derived from lognormal observation error of the catch-survey model. The observed index is the delta-lognormal mean catch-per-tow from the LDWF fishery-independent trawl survey, 1968-2015. Bottom graphic depicts lognormal residuals. Juveniles are crabs ≥25mm and <125mm carapace-width.

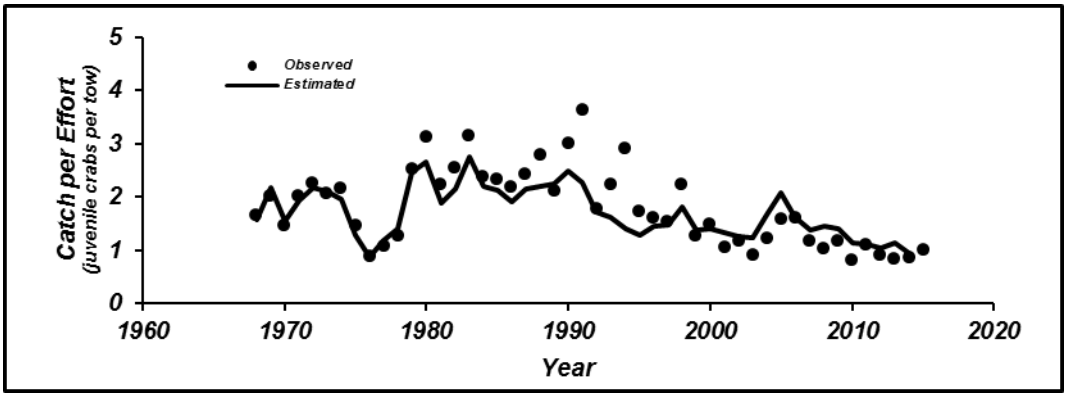

Figure 4 (cont.):

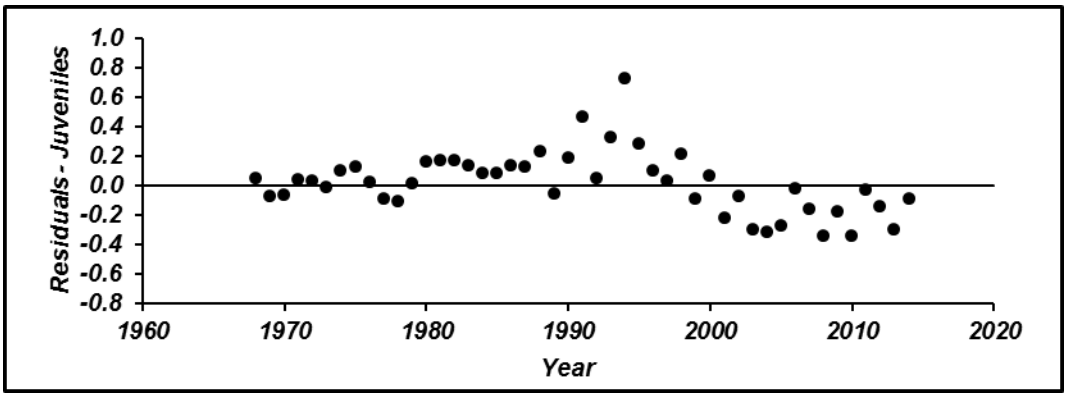

Figure 5: Abundance (top graphic) and biomass estimates (bottom graphic) of Louisiana blue crab *Callinectes sapidus* derived from the catch-survey model. Abundance units are millions of individuals. Biomass units are millions of pounds. Juveniles are crabs ≥25mm and <125mm carapace width. Adult crabs are ≥125mm carapace width.

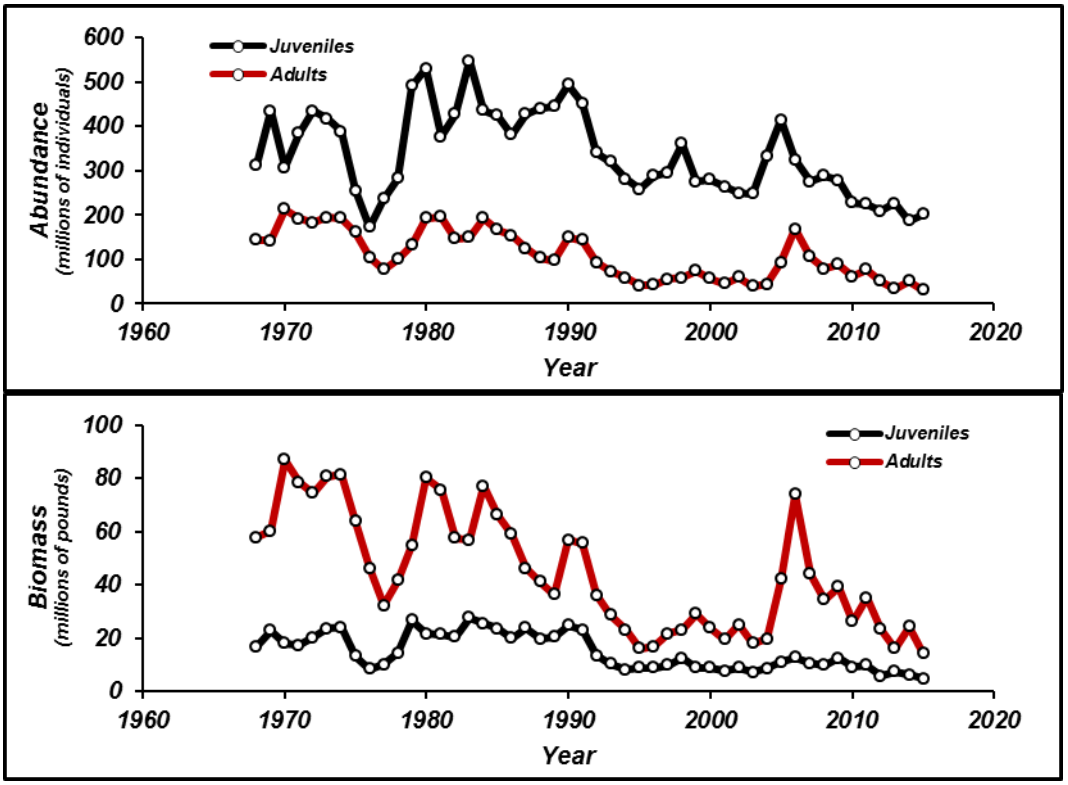

Figure 6: Estimated adult abundance and observed harvest of Louisiana blue crab *Callinectes sapidus*. Abundance is estimated from the catch-survey model. Commercial hard crab landings are expanded by 5% to approximate for recreational harvest. Units are millions of individuals.

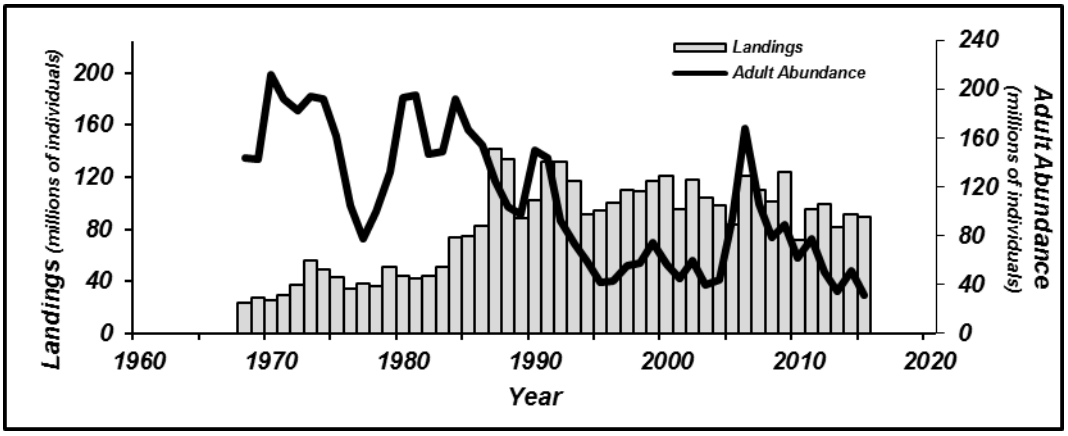

Figure 7: Juvenile abundance estimates of Louisiana blue crab *Callinectes sapidus* derived from the catch-survey model. Units are millions of individuals. Juveniles are crabs ≥25mm and <125mm carapace width. The yellow horizontal is the average abundance across the time-series. The blue and red horizontal are the respective most recent 20 and 10 year averages.

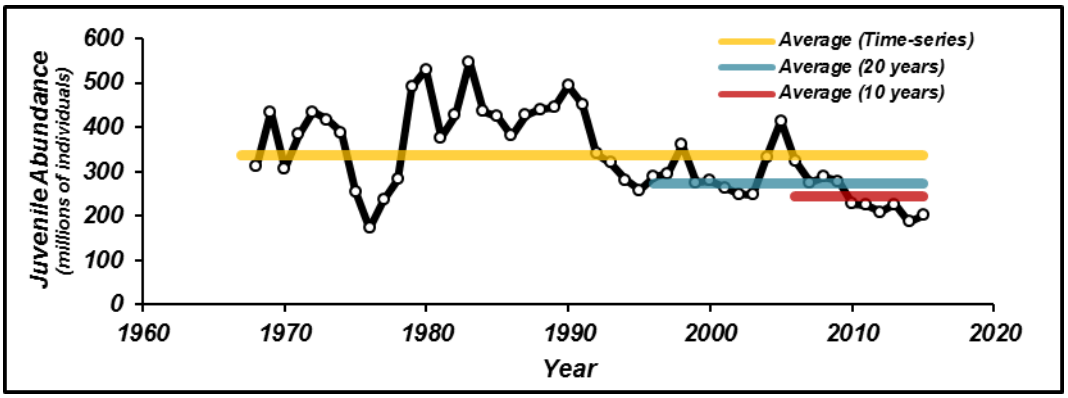

Figure 8: Estimated fishing mortality and nominal fishing effort for Louisiana blue crab *Callinectes sapidus*. Fishing mortality, 1968-2014, is estimated from the catch-survey model. Fishing effort, 1999-2015, is thousands of trap fisher trips per year taken from the LDWF Trip Ticket Program. Fishing effort is not used in the assessment model, but is presented here to validate trends in fishing mortality estimates.

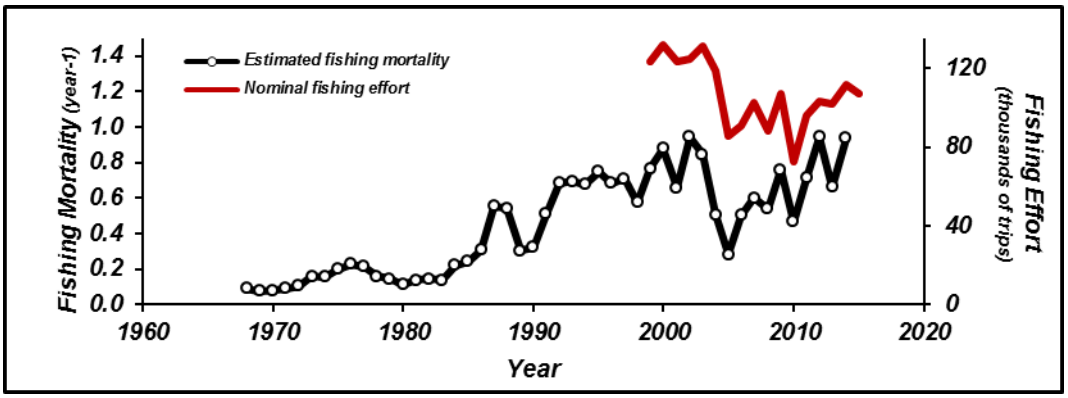

Figure 9: Exploitable biomass and subsequent recruitment of Louisiana blue crab *Callinectes sapidus*. Estimates are derived from the catch-survey model. Recruits (juveniles) are crabs ≥25mm and <125mm carapace width. Adult crabs are ≥125mm carapace width. Abundance units are millions of individuals. Biomass units are millions of pounds. The 5 most recent data pairs and the 2015 exploitable biomass estimate are identified.

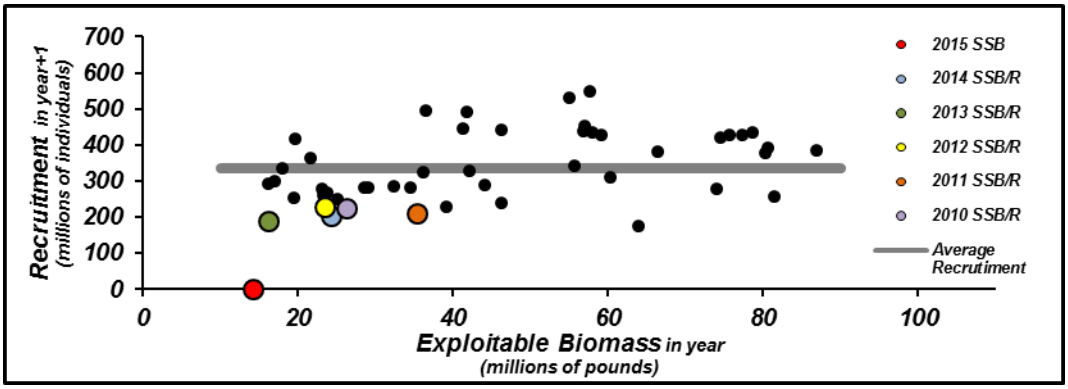

Figure 10: Equilibrium recruitment and the fished and unfished estimates of recruitment per spawner (represented by the slopes of the diagonal lines) corresponding with 19.7, 29.6, and 100% SPR's. Exploitable biomass and subsequent recruitment of Louisiana blue crab *Callinectes sapidus* are derived from the catch-survey model. Recruits (juveniles) are crabs ≥25mm and <125mm carapace width. Adult (exploitable) crabs are ≥125mm carapace width. Abundance units are millions of individuals. Biomass units are millions of pounds.

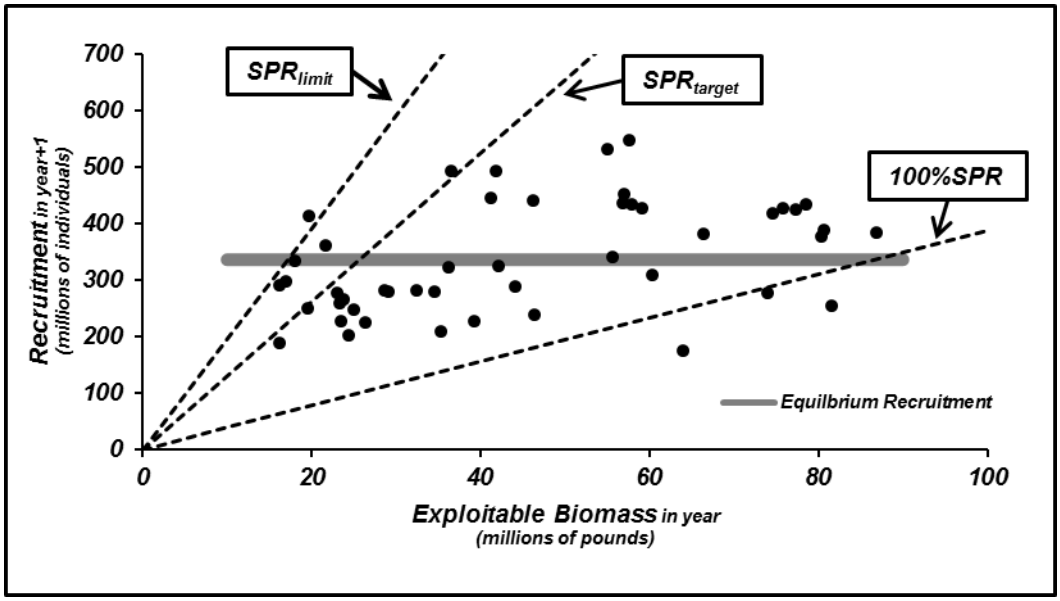

Figure 11: Time-series of catch-survey model fishing mortality rates and exploitable biomass estimates relative to management benchmarks.

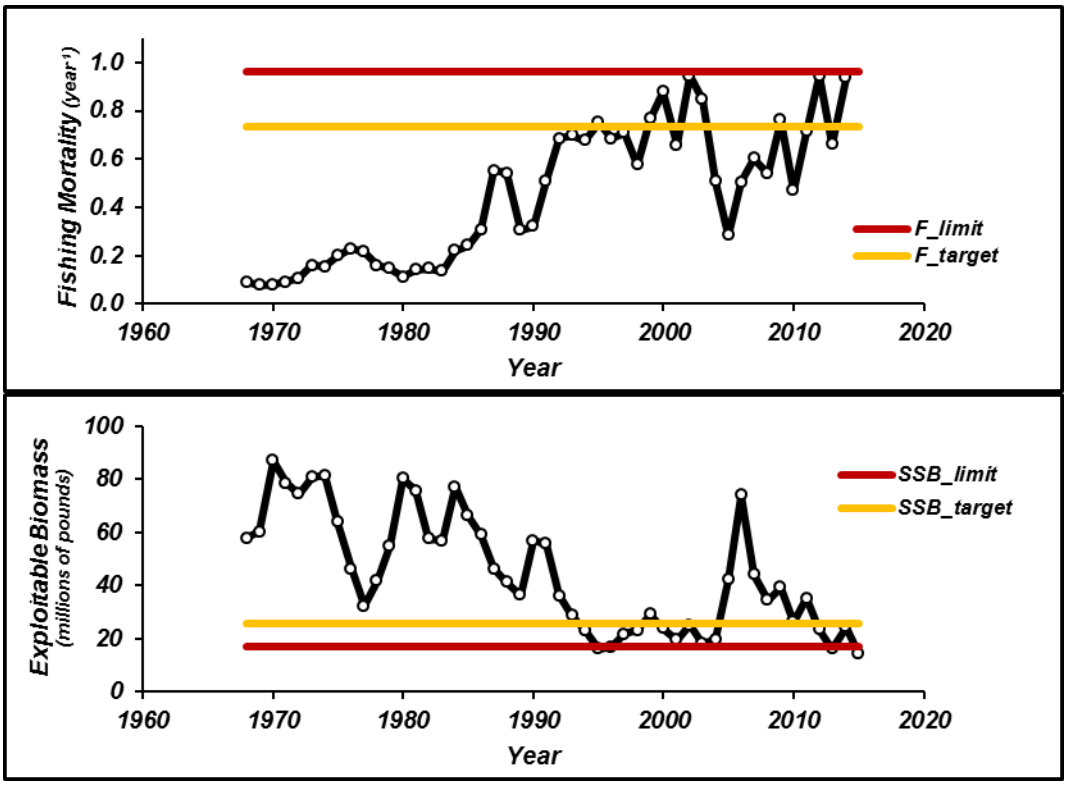
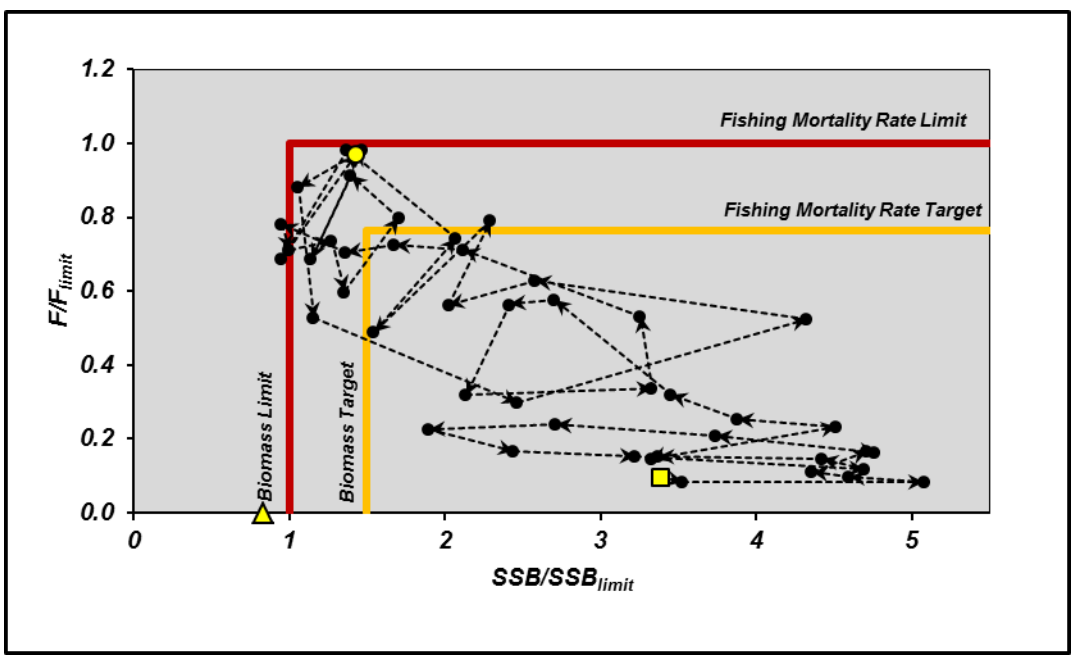
Figure 12: Ratios of annual fishing mortality rates and exploitable biomass estimates to F_{limit} and SSB_{limit}. Exploitable biomass and instantaneous fishing mortality are estimated from the catch-survey model. The biomass limit and target are represented by the solid vertical lines. The fishing mortality rate limit and target are represented by the solid horizontal lines. The square represents the first year of data pairs and the circle represents the last. The triangle represents the 2015 biomass estimate.