*Population Dynamics*

*Length and age structure*

* In total, 979 White Sturgeon were sampled by California Department of Fish and Wildlife (CDFW) during late summer and early autumn (2014-2016) in Suisun Bay, California.
  + White Sturgeon varied in length from 53 to 217 cm fork length (FL) and had an overall mean length of 98 cm.

*Table 1. Summary statistics for fork length (cm) of White Sturgeon sampled in San Pablo and Suisun bays, California during the summer and autumn of 2014-2016. Sample size (*n*) is also provided.*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Sample year** | | | | |
|  | **2014** | **2015** | **2016** | **2014-2016** |
| *n* | 508 | 350 | 121 | 979 |
| Min | 55 | 53 | 65 | 53 |
| Max | 204 | 200 | 217 | 217 |
| Mean | 96 | 100 | 99 | 98 |
| Median | 88 | 93 | 92 | 90 |
| Mode | 88 | 101 | 75 | 81 |



*Figure 1. Length-frequency distribution of White Sturgeon sampled in Suisun Bay, California during the summer and autumn months of 2014-2016.*

* A subsample of 374 White Sturgeon was used to create an age-length key.
  + Fish varied in (estimated) age from 3 to 29 years old.

*Table 2. Summary of estimated ages (years) from subsample of White Sturgeon sampled in Suisun Bay, California during the summer and autumn months of 2014-2016. Sample size (*n*) is also provided for each sample year.*

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Sample year** | | |
|  | **2014** | **2015** | **2016** |
| *n* | 137 | 149 | 88 |
| Min | 3 | 3 | 4 |
| Max | 19 | 29 | 29 |
| Median | 6 | 9 | 9 |
| Mean | 6 | 9 | 10 |



*Figure 2. Estimated age structure of White Sturgeon in Suisun Bay, California (2014-2016).*

*Growth model*

* A von Bertalanffy growth model was then fit to observed length-at-age data:
  + *Lage* = 657 { 1 – *e* [-0.014(*age* + 4.266)]}

*Mortality*

* Instantaneous total annual mortality (*Z*) was estimated for age-3 to age-29 White Sturgeon. The Chapman-Robson estimator was used with peak-plus criterion and corrected for overdispersion (Chapman and Robson 1960; Smith et al. 2012).
* Exploitation (*µ*) for White Sturgeon 102-152 cm FL was estimated using tags reported during the 1-year period after tagging. The number of tags returned was adjusted for non-reporting with the assumption that tags with the highest monetary value (i.e., US$100, US$150) were reported by anglers at a rate of 100%.
  + Values for tag loss (i.e., 10%) after one year and tagging mortality (i.e., 1%) were obtained from literature (Rien 1994).
* Exploitation was converted to instantaneous fishing mortality (*F*) using the relationship for a Type 2 fishery: *F* = *µZ/A* and instantaneous natural mortality (*M*) was obtained by *M* = *Z* – *F* (Ricker 1975).
* Conditional natural mortality (*cm*; mortality in the absence of exploitation) was estimated by the equation: *cm* = 1– e ^-*M*.

*Table 3. Definitions and parameter estimates for White Sturgeon in Suisun Bay, California 2014-2016.*

|  |  |  |
| --- | --- | --- |
| **Symbol** | **Definition** | **Estimate** |
| *Z* | Instantaneous total mortality | 0.299 |
| *M* | Instantaneous natural mortality | 0.108 |
| *F* | Instantaneous fishing mortality | 0.191 |
| *S* | Annual total survival | 0.741 |
| *A* | Annual total mortality | 0.258 |
| *cm* | Conditional natural mortality | 0.102 |
| *µ* | Exploitation | 0.165 |

* Because age-1 and age-2 White Sturgeon were absent from the sample and because no data on survival of age-0 or age-1 were available for California (or for wild White Sturgeon in general), survival estimates for age-0 White Sturgeon were obtained from a study on Lake Sturgeon (Caroffino et al. 2010) and age-1 from Pine et al. (2001).

*Maturity and fecundity*

* Maturity (i.e., age-specific probability of maturity or spawning) were modeled using logistic regression based on data from Chapman (1989) and Chapman et al. (1996).
  + The observed age of first maturity was 104 cm FL (Chapman et al. 1996) and approximately 50% of female White Sturgeon were sexually mature at 145 cm FL (Chapman 1989).
  + Estimated 15% of mature females spawning in a given year
* Mean fecundity at age was estimated using results from DeVore et al. (1995) on White Sturgeon in the lower, unimpounded Colombia River.
  + Did not use Chapman et al. (1996) estimate of 5,648 eggs/kg per recommendation of Dr. Chapman and Joel Van Eenennaam.
  + Instead, used equation from Devore et al. (1995): fecundity = 0.072 × FL2.94
  + However, the predicted number of eggs ended up being similar to Chapman et al. (1996).

*Table 4. Comparison of the predicted number of eggs for White Sturgeon at various fork lengths.*

|  |  |  |
| --- | --- | --- |
| **Fork length (cm)** | **DeVore et al. (1995)** | **Chapman et al. (1996)** |
| 125 | 105,256 | 92,484 |
| 145 | 162,837 | 149,415 |
| 165 | 238,087 | 226,861 |
| 185 | 333,286 | 328,361 |
| 195 | 389,076 | 389,264 |

*Population Modeling*

* An age-structured, female-based matrix Leslie matric model was used to evaluate White Sturgeon in the SSJ population growth trajectory and dynamics.
* Although the oldest estimated age was 29, the base matrix model included just 18 age classes.
  + Older fish (i.e., age 19 or older) were excluded because of low sample numbers (*n* = 5)
* For literature values of survival where no standard errors were available, the variance was specified as equal to 20% of the value.

*Table 5. Vital rates used to construct preliminary population matrix for the unexploited White Sturgeon population in the Sacramento-San Joaquin River basins.*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Symbol** | **Definition** | **Age(*t*)** | **Value** | **Error** | **Source** |
| Fertility elements | | | | | |
| *ft* | Fecundity at age *t* | 0-9 | 0.00 | N/A | DeVore et al. (1995) |
|  |  | 10 | 40,205.84 | 11,687.50 |  |
|  |  | 11 | 94,369.80 | 9,262.66 |  |
|  |  | 12 | 112,424.50 | 8,566.15 |  |
|  |  | 13 | 144,922.80 | 7,531.02 |  |
|  |  | 14 | 170,199.30 | 6,986.70 |  |
|  |  | 15 | 206,308.70 | 6,723.20 |  |
|  |  | 16 | 220,752.40 | 6,803.32 |  |
|  |  | 17 | 253,250.80 | 7,348.94 |  |
|  |  | 18 | 260,472.60 | 7,531.02 |  |
| *pm* | Probability of maturity at age *t* |  |  |  |  |
|  |  | 0-9 | 0.000 | N/A | Chapman et al. (1996) |
|  |  | 10 | 0.065 | 0.022 |  |
|  |  | 11 | 0.083 | 0.024 |  |
|  |  | 12 | 0.100 | 0.026 |  |
|  |  | 13 | 0.145 | 0.028 |  |
|  |  | 14 | 0.174 | 0.029 |  |
|  |  | 15 | 0.275 | 0.029 |  |
|  |  | 16 | 0.328 | 0.030 |  |
|  |  | 17 | 0.376 | 0.033 |  |
|  |  | 18 | 0.448 | 0.039 |  |
|  |  |  |  |  |  |
| *pf* | Proportion of offspring that are females | 10-18 | 0.500 | N/A | Chapman (1989) |
|  |  |  |  |  |  |
| Transition elements | | | | | |
| *SO* | Egg to age 1 survival | 0 | 0.002 | 0.003 | Caroffino et al. (2010) |
| *S1* | Age 1 survival | 1 | 0.250 | 0.008 | Pine et al. (2001) |
| *S2-S18* | Asymptotic survival | 2-18 | 0.898 | 0.039 | This study |

* Evaluated asymptotic population growth:
  + Incorporated fishing mortality into the population models to evaluate current and potential management scenarios.
* Matrix models were not sensitive to starting population size because they did not incorporate density dependence (Morris and Doak 2002).
  + Total abundance was selected at 48,000 adults based on DuBois and Gingras (2011) and Hildebrand et al. (2016).
  + Total abundance was multiplied by the proportion of individuals in each age-class to acquire starting values for population simulation.
  + Age-1 and age-2 White Sturgeon were not recruited to CDFW sampling gear so a linear model was used to predict the abundance of these two age classes.
* Each management scenario was ran 100 times using functions in the ‘popbio’ package in R (Stubben and Milligan 2007).
  + Will run simulation 1,000 times or more in future iterations (Morris and Doak 2002).



*Figure 3. Preliminary population growth rates (Λ) over a 100-year time frame for White Sturgeon in Suisun Bay, California at various levels of exploitation with the current slot-length limit (102-152 cm FL). The dotted line represents a Λ of one where a population is considered stable. The triangle symbolizes Λ at the current level of exploitation (16.5%) and solid circles represents Λ modeled at reduced levels of exploitation (i.e., 9.8%, 4.6%, 3.7%, 1.9%, 0.9%). Reduced levels of exploitation might reflect changes to the season or reduced bag limits.*



*Figure 4. Preliminary population growth rates (Λ) over a 100-year time frame for White Sturgeon in Suisun Bay, California at various levels of exploitation at a proposed smaller slot length limit (76-112 cm FL). The dotted line represents a Λ of one where a population is considered stable. Empty circles represents Λ modeled at various levels of exploitation (i.e., 16.5%, 9.8%, 4.6%, 3.7%, 1.9%, 0.9%).* *Reduced levels of exploitation might reflect changes to the season or reduced bag limits.*

* Again, the purpose of this document is to just familiarize everyone with the structure of the model and the model inputs. This is by no means a final version but rather serves as a platform for discussion. We can (and will) tweak the management scenarios as necessary.

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