Title: 2006 Field Season Summary for Adult Sturgeon Population Study

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The California Department of Fish and Game's adult sturgeon population study has been ongoing since 1967, and here we present a summary of the 2006 field season. This mark-recapture project is designed to understand and monitor the population dynamics of white sturgeon (*Acipenser transmontanus*) and (to a lesser degree) green sturgeon (*Acipenser medirostris)*, with the ultimate goal being to guide science-based resource management decisions. Primary metrics of population dynamics investigated by this study include relative and absolute abundance, harvest rate, overall mortality rate, growth rates, and large-scale movement/migration. As such, our objective during the field study was to capture, tag, measure, and release in good condition as many sturgeon as possible, and to document previously-tagged individuals. Secondary objectives included: 1) collaboration with other researchers investigating various aspects of sturgeon biology, 2) collection of baseline biological data for leopard sharks, 3) evaluation of a method to non-invasively determine the gender of sturgeon by observing external morphology, and 4) collection of morphometric data for sturgeon to determine formulae that can be used by anglers to estimate length of their catch without removing the fish from the water.

METHODS:

Sturgeon were captured in trammel nets deployed from research vessels operating in San Pablo Bay and Suisun Bay from August 2 to October 30, 2006. In contrast to tagging operations in previous years, two research vessels *(New Alosa* and *Striper II*) were employed for the 2006 tagging season and sampling commenced one month earlier than usual. This was a strategic attempt to increase the number of sturgeon tagged (relative to the 2005 season), with the ultimate objective being to improve certainty in our estimates of population parameters.

The *New Alosa* is a 42-foot West Coast-style combination-type fishing vessel with a 610 HP Volvo engine capable of cruising at 17 knots, and the *Striper II* is a 32-foot Southeast Alaska-style gillnetting vessel with a 6-V 53 Detroit Diesel engine capable of 7.5 knots. The vessels were berthed at the Vallejo Marina for tagging in San Pablo Bay, and at the Benicia Marina for tagging in Suisun Bay. Standard crew size was three to four, depending on the vessel, crew availability, and the experience of the crew members. Crews generally included one boat operator, one-to-two scientific aides, and a deck hand or lead person. Both the *New Alosa* and *Striper II* were equipped with one trammel net, one net reel, and one tagging station. In general, the boat operator ran the boat, operated net hydraulics, and extracted fish from the net upon retrieval; the deckhand tended the net during deployment, and assisted the boat operator with removing fish and debris from the net upon retrieval; the scientific aide(s) and/or lead biologist measured and tagged sturgeon, collected biological data, tallied bycatch, and assisted with other duties as needed.

Trammel nets were comprised of eight contiguous 25-fathom (45.7 m) long x 2 fathom (3.7 m) wide sections of net, for a total length of 200 fathoms (365.8 m). Each of the net sections were made up of a gillnet "panel" inserted between two panels of trammel net. The gillnet was an Alaska salmon-style webbing made up of multi-strand monofilament twist, and the trammel net was made up of three multi-strand twisted nylon braid. The diagonal mesh size of the gillnets varied by net section, and the 25-fathom sections were assembled in the following order: 8", 8", 7", 7", 6", 6", 8", 8".

In order of priority, the decision of where to set the net was based upon the following criteria: 1) avoidance of known snags, 2) presence of jumping sturgeon, and 3) the knowledge and experience of the vessel captain. The net was deployed across the prevailing current or wind (whichever was stronger), and took approximately five minutes to set. Once deployed, it was carefully monitored during the drift to reduce snags, tangles, minimize undue stress to sturgeon and other bycatch species, as well as avoid conflicts with other vessels, channel markers and other hazards. Nets were set as many times as possible (typically 3-4, but up to 5) in a given workday, and soaked for approximately 30 minutes after the initial set before beginning the retrieval. The amount of net that was set, as well as the number of sets, depended on the weather (especially wind and wind-generated chop), tides, and the abundance of sturgeon, bycatch, and debris in the net. Our goal was to keep the total time for a given net set under 100 minutes to minimize mortality and stress to the fish.

Each sturgeon was immediately removed from the net after being brought over the stern-mounted net roller, then carefully placed on the tagging cradle, checked for old tags or evidence of a shed or clipped tag, measured (total length, in cm), tagged (if the fish was not a recapture), subjectively assessed for overall physical condition ("good" or "fair/poor"), and then released as quickly as possible. For a one-week period in 2006 we evaluated a published method (Vecsei et al., 2003) to non-invasively determine the gender of live sturgeon by observing the morphology of the urogenital vent before releasing the fish. Fish too large to place safely in the cradle were processed on the deck. Deck-processing was only used when necessary, because length measurements were less accurate without the benefit of the cradle.

We applied disc-dangler tags to all green sturgeon and white sturgeon that were in reasonable physical condition. Each tag offered a reward of $20, $50 or $100 to anyone who returns it to CDFG. When previously-tagged fish were recaptured, their tag numbers were recorded and later checked against a list to determine their release years. If old tags were too tight or coming loose, they were replaced with new tags. Captured sturgeon that had obviously been tagged at one time but in which the tag was no longer present (i.e. wires sticking out of the fish below the dorsal fin) were recorded as having a "shed tag", then re-tagged and released after removing extraneous wires. Sturgeon that did not have a tag or wires present but that exhibited open sores or scars at the precise location of tagging (below the dorsal fin) were counted as having "possibly shed tags".

Bycatch species were documented, measured (if a California halibut, leopard shark, or Chinook salmon), sexed (leopard shark only), and released as quickly as possible. We began collection of pilot biological data for leopard sharks because a popular fishery exists for this species in San Francisco Bay, yet essentially no baseline data exists for fishery managers.

RESULTS:

We tended 212 trammel net sets over the course of 65 boat-days, for a total of 252 net-hours. Net sets averaged 1.2 hours long, and we averaged 3.3 sets per day. We tagged a total of 730 white sturgeon and 28 green sturgeon that had not been tagged in previous years. The catch was distributed unevenly over time, with 10 of the 65 boat-days (15%) accounting for 40% of the white sturgeon catch, and 3 boat-days (5%) accounting for 19% of the catch. Most of the fishing effort and catch was in a 5 x 7 kilometer area in San Pablo Bay, but larger catches were also had near the Petaluma River channel in the western part of the bay (Figure 1). Productive net sets were also had in Suisun Bay near Garnet Point during October.

We recaptured 18 white sturgeon, including six that were tagged in previous years and had retained their tags. Seven of the 18 recaptured fish were missing their tag but had unequivocal evidence of having been previously tagged (i.e. wires sticking out of the precise anatomical location where tags are inserted). Two fish had equivocal evidence of having been previously tagged, such as lesions, scars, or open sores where tagging would have occurred, and these fish were considered potential but not definite recaptures. The remaining three fish had been tagged earlier in the 2006 season. Of the recaptured fish that retained their original tags, three were tagged in 1998, two in 2001, and one in 2002. Three fish that were tagged in San Pablo Bay in 2006 were recaptured in Suisun Bay 1-5 weeks later.

Approximately 87% of the white sturgeon captured were released in “good” condition, and 13% were released in “fair to poor” condition. On average, the condition of released green sturgeon was slightly poorer, with 81% released in good condition and 19% released in fair/poor condition. Several highly-exhausted fish were manually revived in the water off of the *Striper II*. The deck of the *New Alosa* was too high above waterline to effectively provide in-water resuscitation, and exhausted fish were simply released.

Because the number of sturgeon caught is dependent upon the amount of fishing effort to catch them (e.g., number of boats fishing in a day, length of fishing day), the Catch Per Unit Effort (CPUE) was calculated in order to standardize comparisons. Catch was calculated as the sum of all newly-tagged fish, recaptured fish, and untagged fish brought to the boat. Effort was calculated as the total amount of time that the trammel net fished in a day on a given boat (from the completion of the initial net layout to when the net was back on the boat). Overall, CPUE for white sturgeon was 2.9 fish per net-hour, but this varied by boat and date. The CPUE was greater than 6 fish per net-hour during only 5 of 65 boat-days, with four of these days involving the *New Alosa*. These relatively exceptional days appeared to occur randomly in time, as they did not seem to be correlated with the CPUE of the other boat fishing on the same day or with the CPUE on adjacent days. The CPUE time series (not shown) was relatively “noisy”, and there did not appear to be strong temporal autocorrelation, although a weak monthly periodicity may have been present. The CPUE on the *Striper II* increased markedly in mid/late October, coincident with the relocation of operations from San Pablo Bay to Suisun Bay. Overall, however, CPUE for both white sturgeon and green sturgeon was significantly greater in August than in September and October (Figure 2). Analyses of the relationship between CPUE and tidal state, depth, and other habitat variables is ongoing.

A total of 752 white sturgeon were measured and the resulting frequency distribution was bimodal, with most of the fish at or around the minimum legal size of 117 cm (46”; Figure 3). In sum, 41% of the white sturgeon measured were less than 117 cm (46 inches) total length, 56% were within the pre-2007 “slot limit” of 117-183 cm (46-72 inches) total length, and 3% were over 183 cm (72”) total length. A small number (~ 5-10) of very large fish (> 180 cm) were observed but not measured, either because they were too large to bring into the boat or they broke free of the net before being brought close enough to measure. Two primary cohorts are evident in Figure 3: an older cohort from the early 1980s with a mode at 161-170 cm, and a younger, more abundant cohort produced in the mid-1990s with a mode at 111-120 cm. Although sample size was small (n=28), green sturgeon exhibited a similar size structure to white sturgeon (Figure 3), with the main difference being that the mode of the distribution was slightly less (100-110 cm).

Gear selectivity for different size classes of white sturgeon was apparent when histograms were constructed for each net's mesh size (Figure 4). The 7-inch net mesh clearly outperformed the 6- and 8-inch net mesh in the 101-120 cm size class, and the 6-inch net mesh clearly underperformed in the 101-140 cm size class range. The 8-inch net mesh substantially underperformed in the 91-100 cm size class, and few sturgeon less than 90 cm were captured with any net. Analyses of gear selectivity are ongoing.

We evaluated a method to non-invasively determine the gender of live sturgeon by observing the morphology of the urogenital vent (Vecsei et al. 2003), but we were unsuccessful in repeating the results. The vent was usually closed tightly, preventing observation of the shape of the opening.

Analysis of morphometric data is ongoing, and will be reported at a later date.

The unintended bycatch during tagging was dominated numerically by California bat rays (510, or 48%), followed by Chinook salmon (228, or 22%) and leopard shark (185, or 18%; Figure 5). In order of decreasing abundance, starry flounder, striped bass, brown smoothhound, and California halibut, made up 10% of the bycatch collectively, and five other fish species (diamond turbot, white croaker, unidentified skates, steelhead, and thornback) made up 2% of the bycatch. With the notable exception of Chinook salmon, most of the fish bycatch was released unharmed. Salmon died quickly in the net due to asphyxiation, and an unknown number of netted salmon were killed by California sea lions and harbor seals. We measured 134 leopard sharks and the resulting length-frequency histogram was indicative of a population with a natural age structure (Figure 6). Of the 96 leopard sharks examined for gender, 47% were female and 53% were male.

DISCUSSION:

The population metrics derived from the data collected this season will be calculated and presented in detail in a future publication. Therefore, in the following discussion we briefly summarize and put into context the important findings from this season.

Sampling effort was increased substantially in 2006, and the increase in total catch was roughly proportional to the increase in effort. The total catch of white sturgeon was 2.6 times greater than in 2005 with 2.2 times the fishing effort (measured in total net soak time). This was a modest increase in CPUE from 2.4 fish per net-hour in 2005 to 2.9 in 2006, but the gain was largely offset by a decrease in average daily net soak time of 42 minutes. As a result, the mean number of white sturgeon caught per boat-day remained the same as in 2005 at 11.6 fish. In large part, the decrease in average net soak time was due to the re-incorporation of the *Striper II* into the tagging operation. The *Striper II* is relatively slow, and daily fishing time was reduced due to the increase in commute time to the fishing grounds. Nevertheless, the CPUE remained at a low level relative to the late 1990s and earlier, especially considering that CPUE was reported for only legal-sized fish prior to 2005 (CDFG, unpublished data).

One important difference in our 2006 results was an increase in the number of recaptured fish. One fish was recaptured during 2005, but 13-15 were recaptured in 2006. The reason for the uncertainty in the number of recaptured fish in 2006 was that two fish apparently shed their tags, but the evidence was circumstantial and not conclusive. Adjusting for the increase in sampling effort, 2-3 recaptures would have been expected in 2006, but the rate instead increased by 4-7 fold. Another difference between the results in 2006 and all previous years also involved recaptured fish, specifically the ratio of 'fish with clearly shed tags' to 'fish with old tags that remained firmly in place'. The ratio of shed tags to old tags on recaptured fish was >1 during 2006, which was atypical (Dave Kohlhorst, personal communication). The reason for the increase in this ratio is unknown, but potential mechanisms include tag removal by catch-and-release anglers, faulty tag wire, or inadequate tagging technique by one or more individuals.

The number of white sturgeon measured in 2006 was more than adequate to construct a robust length-frequency distribution, and this distribution shifted to the right from 2005 (figure not shown), consistent with the growth of individuals. The cohorts from the mid-1990s are now beginning to enter the current legal-sized slot limit (46"- 66") and will become increasingly prominent in the recreational fishery in the near future. Complicating the interpretation of the length-frequency data, however, is the issue of gear selectivity for different size classes. This issue will be analyzed in depth using data from previous years and reported in a future publication. Nevertheless, one of the most striking aspects of the length-frequency histogram was that a very small percentage of the fish caught (< 5%) survived the pre-2007 slot limit of 46-72".

Although these data for white sturgeon will be analyzed in greater detail soon, several indices warrant concern, including the low CPUE in 2005 and 2006, the large number of recaptured fish in 2006 (relative to the number of untagged fish captured), and the paucity of large fish (>183 cm).

Green sturgeon were officially listed by the federal government as a Threatened Species in 2006, and in large part our decision to initiate sampling in August was driven by our desire to collect baseline biological data for this species. Green sturgeon are known to be more common in the San Francisco Bay-Delta at this time of year, relative to later in the Fall during our typical sampling months. Most of the green sturgeon that we caught in 2006 were captured during August, but our efforts met with limited success, as only 28 fish were measured and tagged during the 2006 season. A total of 14 green sturgeon were captured in 2005, therefore the number of fish caught in 2006 was consistent with the value expected due to the increase in fishing effort (assuming constant CPUE). Based on the relatively few tagged green sturgeon at large, we did not expect to recapture any individuals, and indeed we did not. We did, however, compile enough length measurements to construct a rudimentary length-frequency histogram. Visual inspection of the histogram indicated that the statistical population of green sturgeon in San Pablo Bay during August, and to a lesser extent in September and October, was largely comprised of juveniles.

The large component of leopard shark in the bycatch provided a good opportunity to collect biological data for the local population in San Pablo Bay. The length-frequency distribution appears to show a population with a natural age structure (e.g., there is no truncation of larger size classes at the minimum size limit of 36" (91 cm), as one would expect if the population was heavily exploited). However, Eschmeyer et al. (1983) reported that the maximum length for male leopard sharks is approximately 150 cm and 210 cm for females, yet no fish larger than 138 cm were captured during our survey. The other line of evidence that supports the notion that the population is healthy is the ~ 50:50 sex ratio. A skewed sex ratio for populations of this species would be cause for concern. The cost of opportunistically collecting this data is negligible, but the information we have gathered and can continue to gather is useful to fishery managers, therefore we plan to continue this endeavor.

We made several (mostly minor) changes to the tagging protocol in 2006. The over-arching goal was (and is) to continually improve the quality and quantity of the useful information produced by this project, and to meet and exceed our project goals and objectives while maintaining the integrity of the long-term dataset. As such, several protocol changes have been proposed by project staff for implementation during tagging in 2007:

1. Implement a double-tagging experiment to determine rate of disk-dangler tag loss to shedding (using PIT tags).
2. Increase average condition factor of released sturgeon via procedural and equipment modifications.
3. Consider implementing a random sampling component to the mark-recapture study to minimize the risk of violating the assumption of random mixing into the general population prior to re-sampling.
4. Inspect netted sturgeon as they near the boat to determine whether they are tagged (i.e. increase the number of fish captured for population estimate calculation), in case they break free of the net while being hauled aboard.
5. Create an additional option for the fish condition assessment (separate "fair/poor" into two categories).

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Eschmeyer, W. N., E. S. Herald, and H. Hammann. 1983. Pacific coast fishes. Houghton Mifflin, Massachusetts. 336 pp.

NOTES:

Kohlhorst, David. Personal Communication, in-person conversation.

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Figure 1. Locations of net set-specific catch of white sturgeon and green sturgeon, with inset of San Francisco Bay region. Note that the size of the symbol is proportional to catch, and black dots identify sets in which no sturgeon were caught.

Figure 2. Mean monthly CPUE by species +/- 1 Standard Error. CPUE was summarized for all unique boat-days; for example, if 2 boats when out on a given day and fished all day, it would equal 2 boat-days.

Figure 3. Length-frequency histogram of white sturgeon and green sturgeon (includes newly tagged fish, recaptures, and untagged fish).

Figure 4. Length-frequency histogram of white sturgeon (includes newly tagged fish, recaptures, and untagged fish) by net mesh size. Because twice as much 8-inch net was fished compared to each of the other mesh sizes, the number of fish caught by the 8-inch mesh was divided by two to facilitate comparisons. Also, only data from complete net sets (when the net was fully deployed) were used to construct these histograms so that the relative proportion of nets with different mesh sizes was even.

Figure 5. Total bycatch from tagging operations during 2006 field season, with the number of individuals caught after the species name.

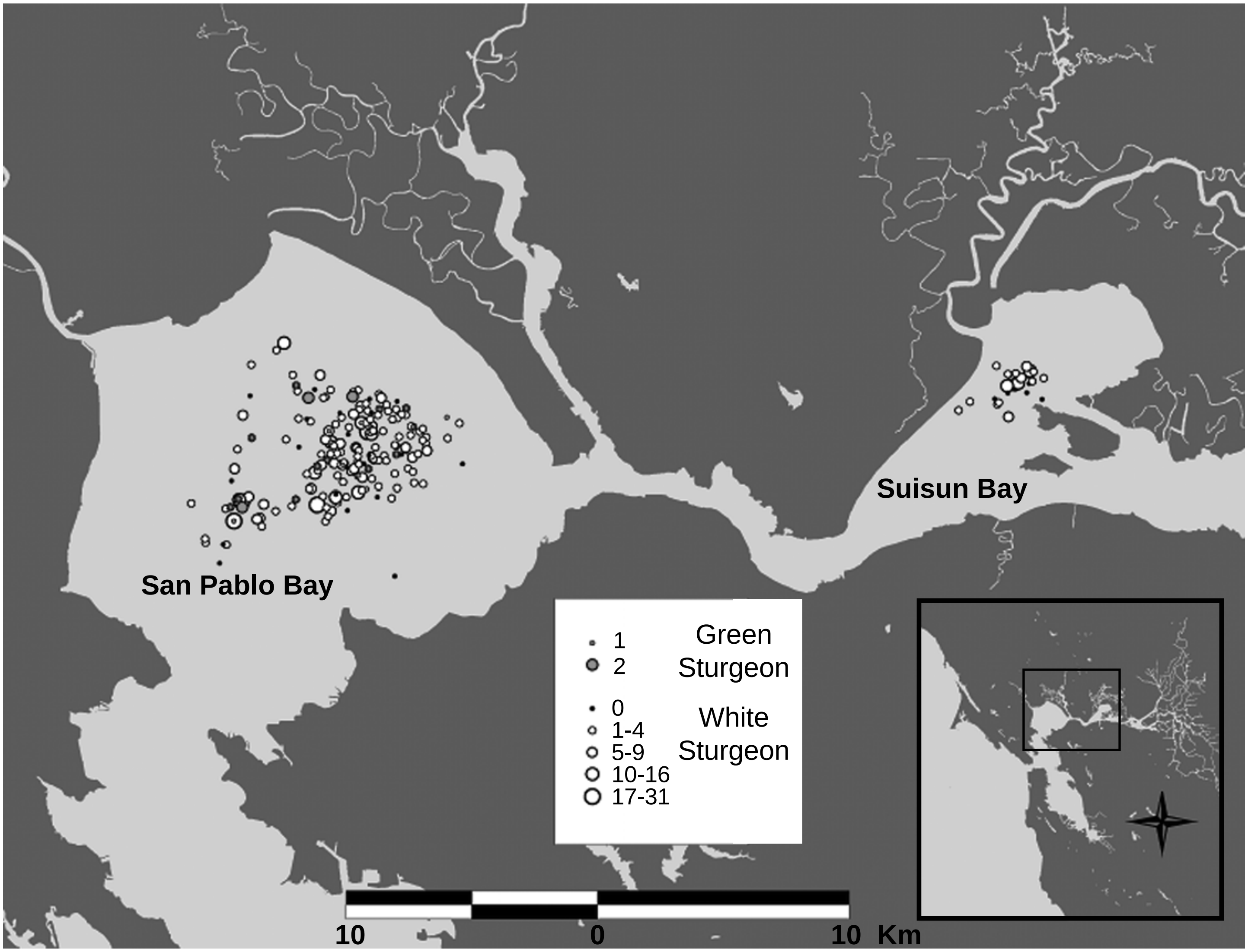

San Pablo Bay
Suisun Bay
1
2
Green Sturgeon
0
1-4
5-9
10-16
17-31
White Sturgeon
10
0
10 Km

Figure 1.

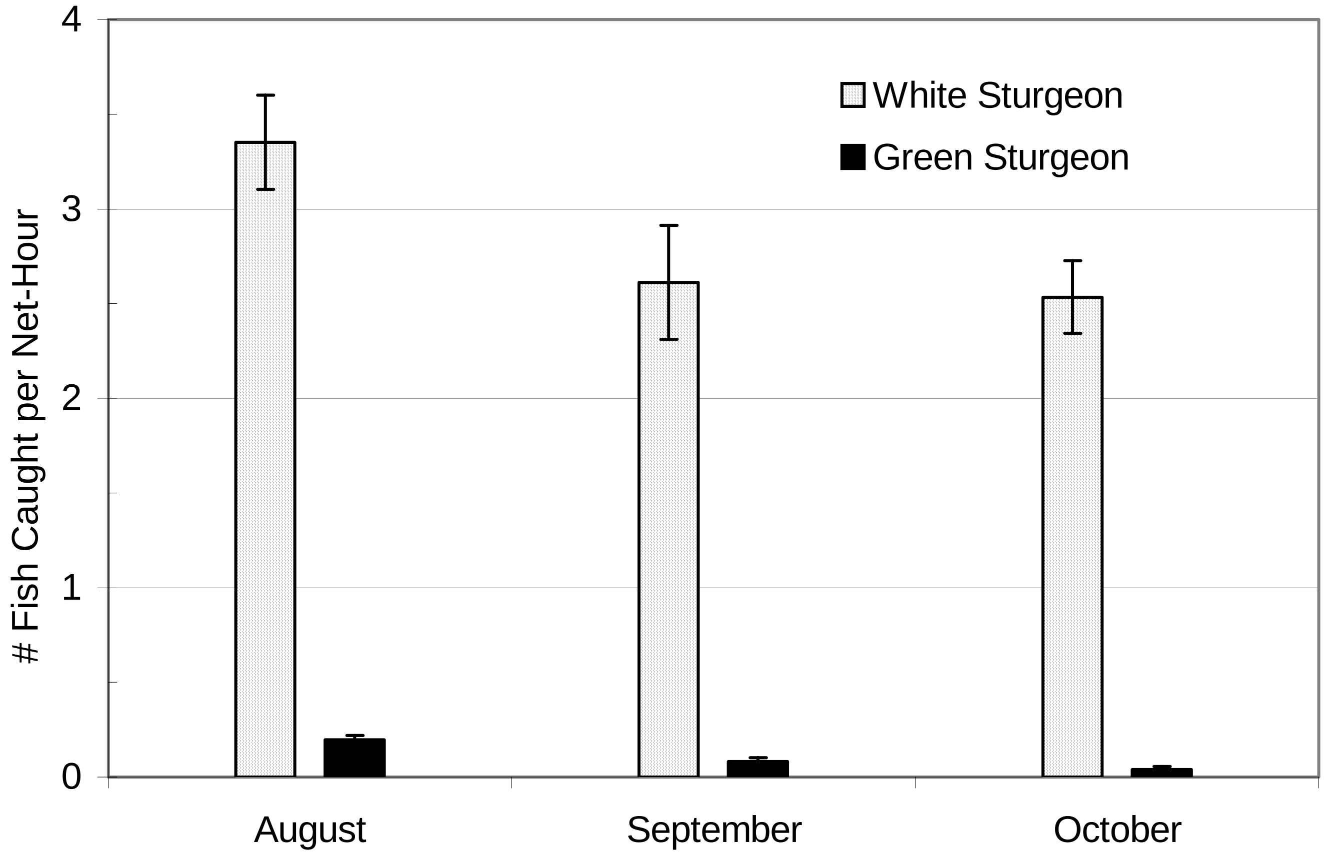
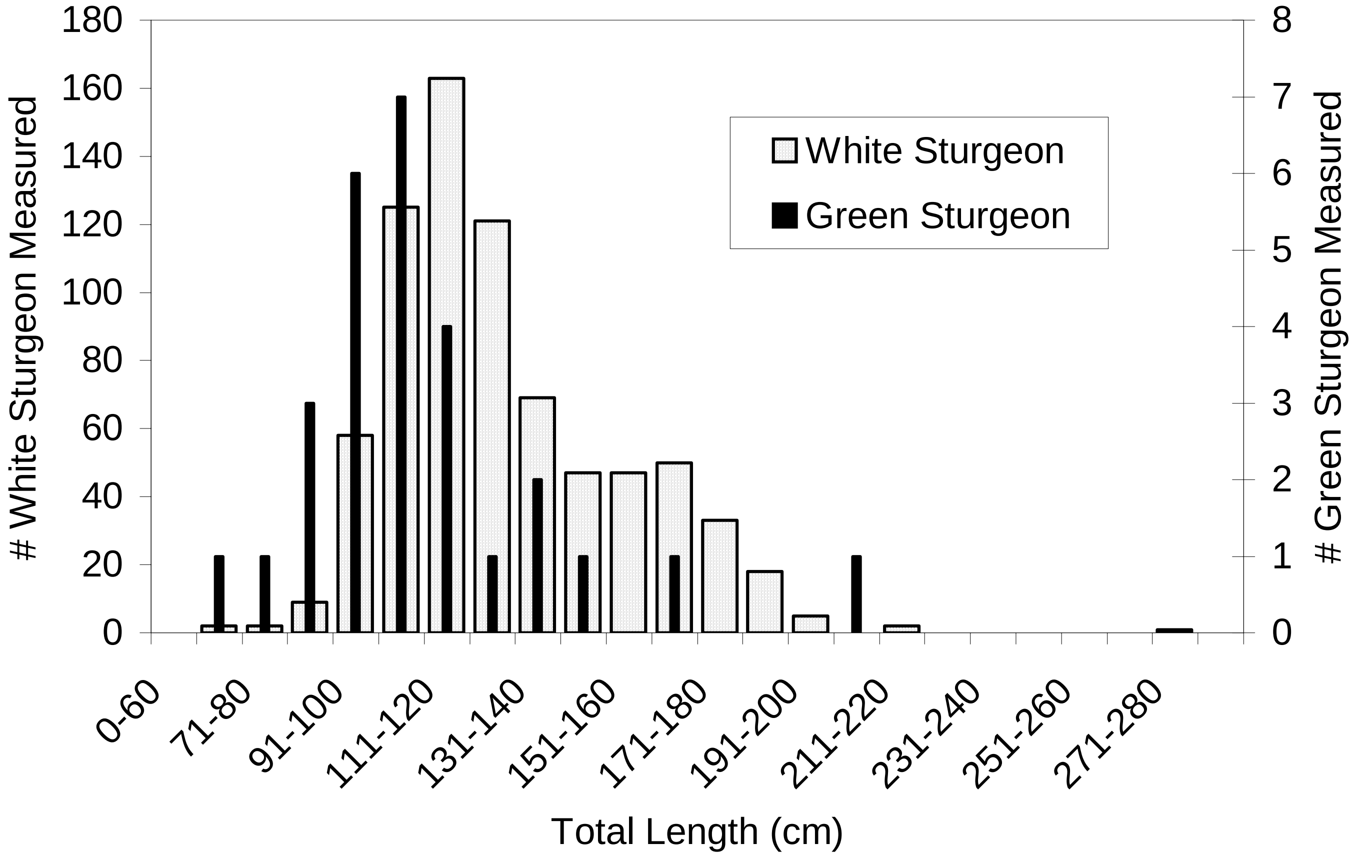
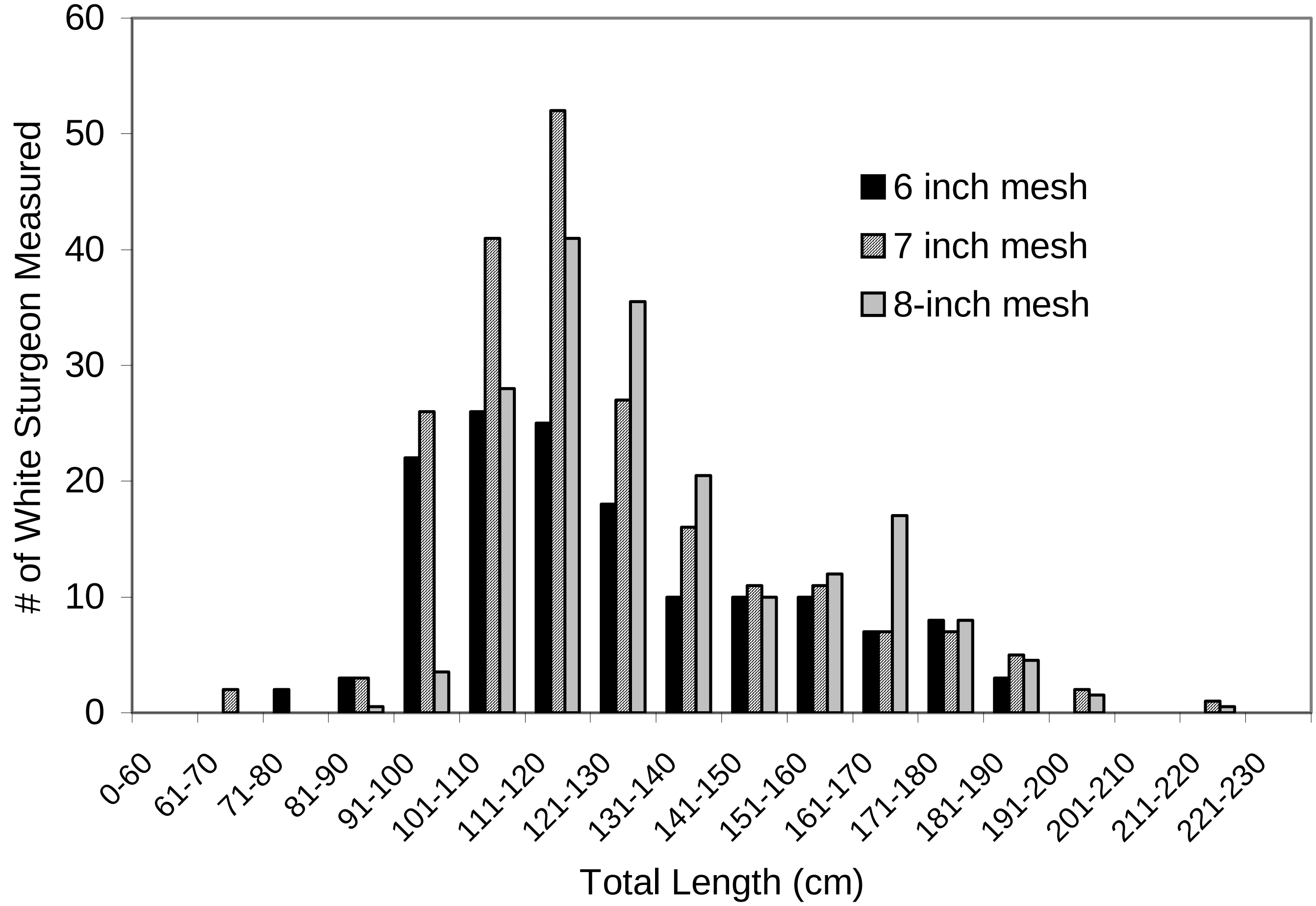

4
3
2
1
0
Fish Caught per Net-Hour
White Sturgeon
Green Sturgeon
August
September
October

Figure 2.



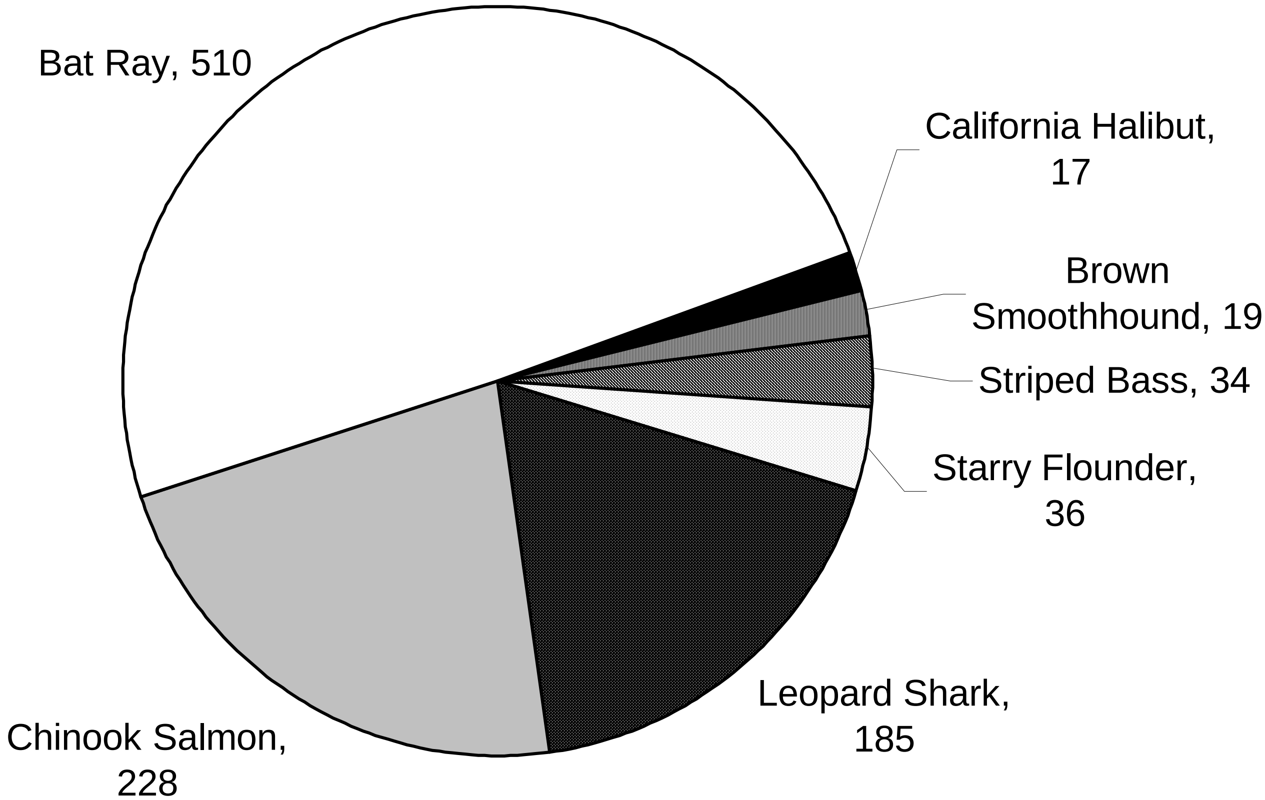
180
160
140
120
100
80
60
40
20
0
8
7
6
5
4
3
2
1
0
White Sturgeon Measured
Green Sturgeon Measured
White Sturgeon
Green Sturgeon
0-60
71-80
91-100
111-120
131-140
151-160
171-180
191-200
211-220
231-240
251-260
271-280
Total Length (cm)

Figure 3.



60
50
40
30
20
10
0
# of White Sturgeon Measured
6 inch mesh
7 inch mesh
8-inch mesh
0-60
61-70
71-80
81-90
91-100
101-110
111-120
121-130
131-140
141-150
151-160
161-170
171-180
181-190
191-200
201-210
211-220
221-230
Total Length (cm)

Figure 4.



Bat Ray, 510
California Halibut, 17
Brown Smoothhound, 19
Striped Bass, 34
Starry Flounder, 36
Leopard Shark, 185
Chinook Salmon, 228

Figure 5.

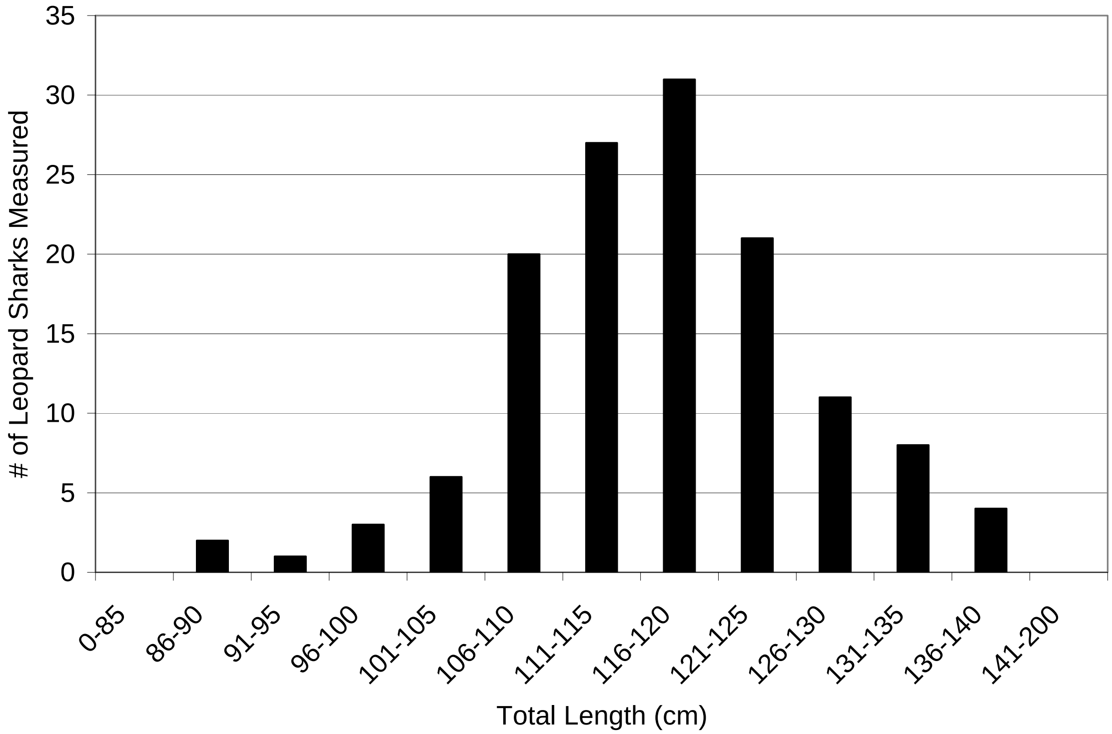

35
30
25
20
15
10
5
0
# of Leopard Sharks Measured
0-85
86-90
91-95
96-100
101-105
106-110
111-115
116-120
121-125
126-130
131-135
136-140
141-200
Total Length (cm)

Figure 6.