White Sturgeon Oversize Sports Fishery Below Bonneville Dam

Issue Statement and Introduction:

The legal harvest of White Sturgeon (*Acipenser transmontanus*) in the lower Columbia River below Bonneville Dam targets a slot that protects both smaller individuals and larger individuals. The legal slot for the sports harvest is currently 107 to 152 cm total length (TL)(or 42 to 60 inches) and for the commercial harvest is currently 122 to 152 cm TL (48 to 60 inches). Individuals that are larger than the slot are old enough to reproduce. The slot size limits are intended to allow adequate numbers of white sturgeon to reach reproductive size and protect the adult population from harvest and ensure sustained production. If sturgeon are caught that are outside of the legal slot size, they are to be released.

Since the early 1990s, an apparent directed catch and release fishery began to target sturgeon that are larger than the legal slot. There has been an apparent increase in the handle of "oversize" sturgeon starting in 1992 (Figure 1). Part of this apparent increase may be related to changes in the upper limit of the slot which changed the definition of "oversized" to be inclusive of sturgeon that had previously been legal. In 1994, Washington Department of Fish and Wildlife (WDFW) and Oregon Department of Fish and Wildlife (ODFW) changed their upper maximum size limit from 182 cm TL (72 inches) to 167 cm TL (66 inches). Then in 1997, both WDFW and ODFW adopted the current 152 cm TL (60 inches) limit. However, other information provides evidence that a targeted catch and release boat fishery on oversized sturgeon exists and increased in the early 1990s (also see Appendix 1 at the end of this report). In particular, the total handle (Figure 2) and the handle in the boat fishery (Figure 3) increased for the period of May through July in the Columbia Gorge (between River kilometer (Rkm) 215 and 234), developing in about 1992 through 1995. The Columbia Gorge in May - July are a location and time of apparent concentration of larger sturgeon associated with the major spawning location and season in the lower Columbia (McCabe and Tracy 1994), while smaller sturgeon appear to be moving down river in the spring and summer (Bakjov 1955). There is also evidence that gear is being used that specifically targets larger sturgeon and that guide services are specifically promoting this fishery. The fishery seems to have stabilized in terms of the number of oversized fish handled since about 1995 (Figures 1 and 2).

Observations of oversized sturgeon that had been handled in this fishery have been made incidental to other studies and monitoring in the lower Columbia starting in 1994. These observations raised a concern about the potential impact of the oversize sport fishery on the lower Columbia River adult population. These observations include carcass surveys made by WDFW staff starting in 1994 which showed that some dead sturgeon had injuries associated with handling in sports fisheries. The injuries included hooks and leaders retained in the mouth or gut, including hooks that had penetrated the gut. Staff also found evidence of extensive bleeding caused by hooks in the tongue or gills and injuries caused by boat propellers among the carcasses. Between 40% and 47% of the dead sturgeon found since 2000, when staff began to conduct thorough internal exams, showed evidence of sports fishing related injuries.

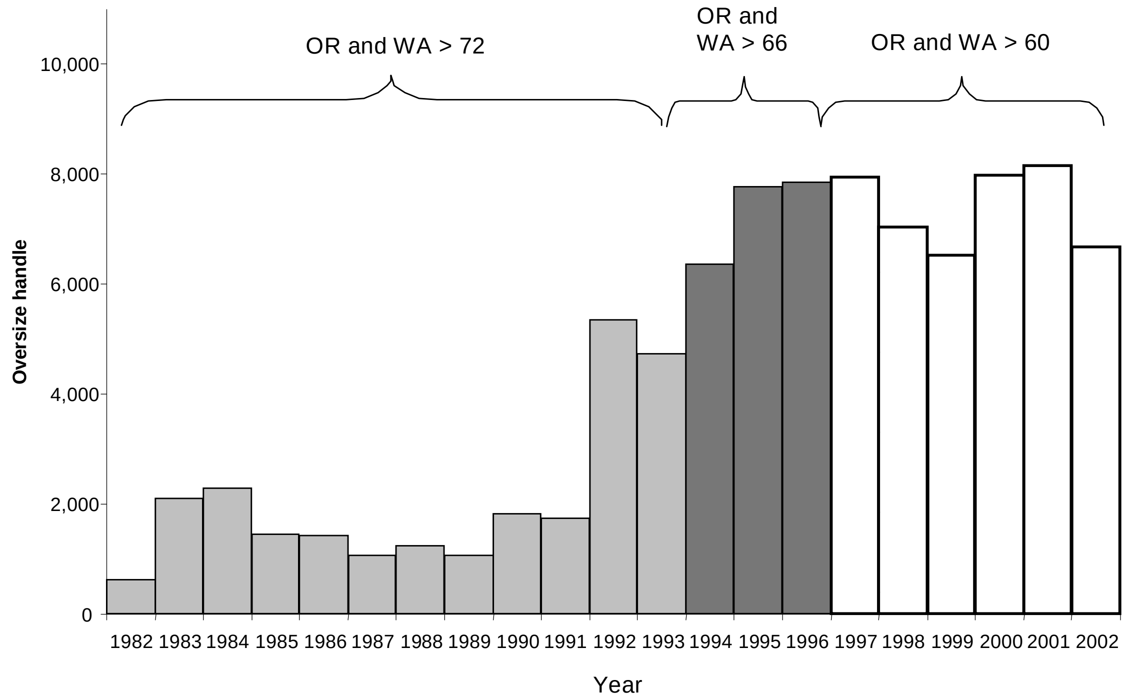

Figure 1a. The trend in handle of oversized sturgeon in the reach between Rkm 215 and 234, from 1982 - 2002. Maximum size limits (TL, inches) for the three periods are shown at the top. Data from WDFW.

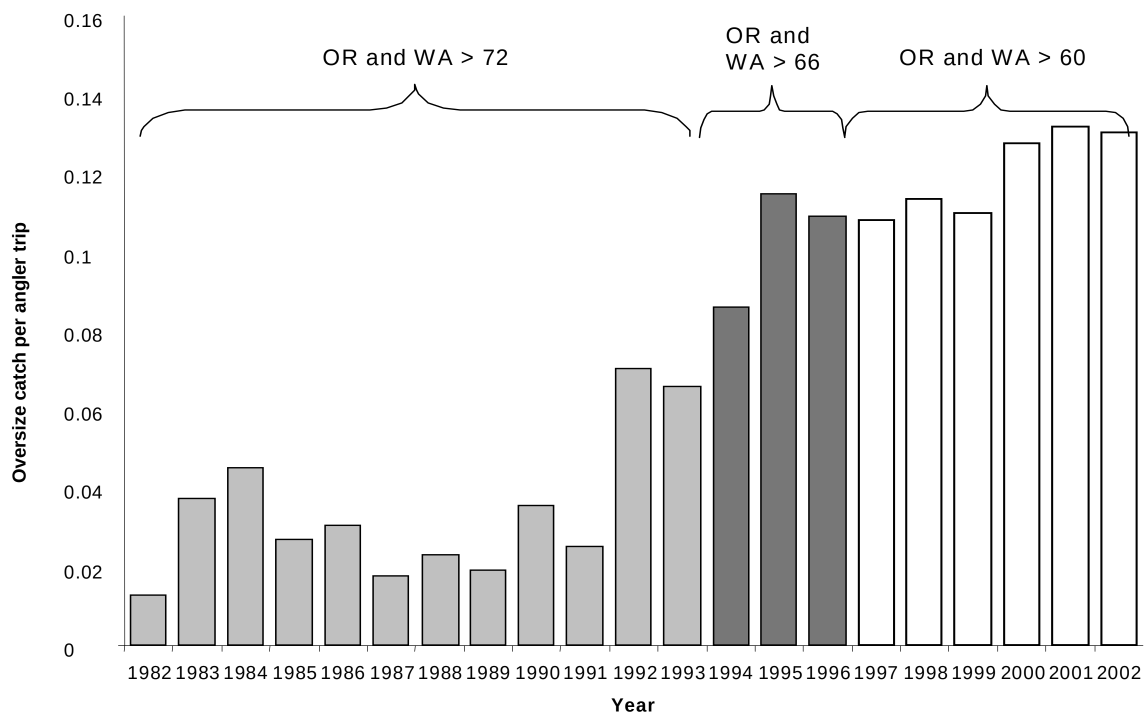

Figure 1b. The trend in catch of oversized sturgeon per angler trip, 1982 - 2002. Maximum size limits (TL, inches) for the three periods are shown at the top. Data from WDFW.

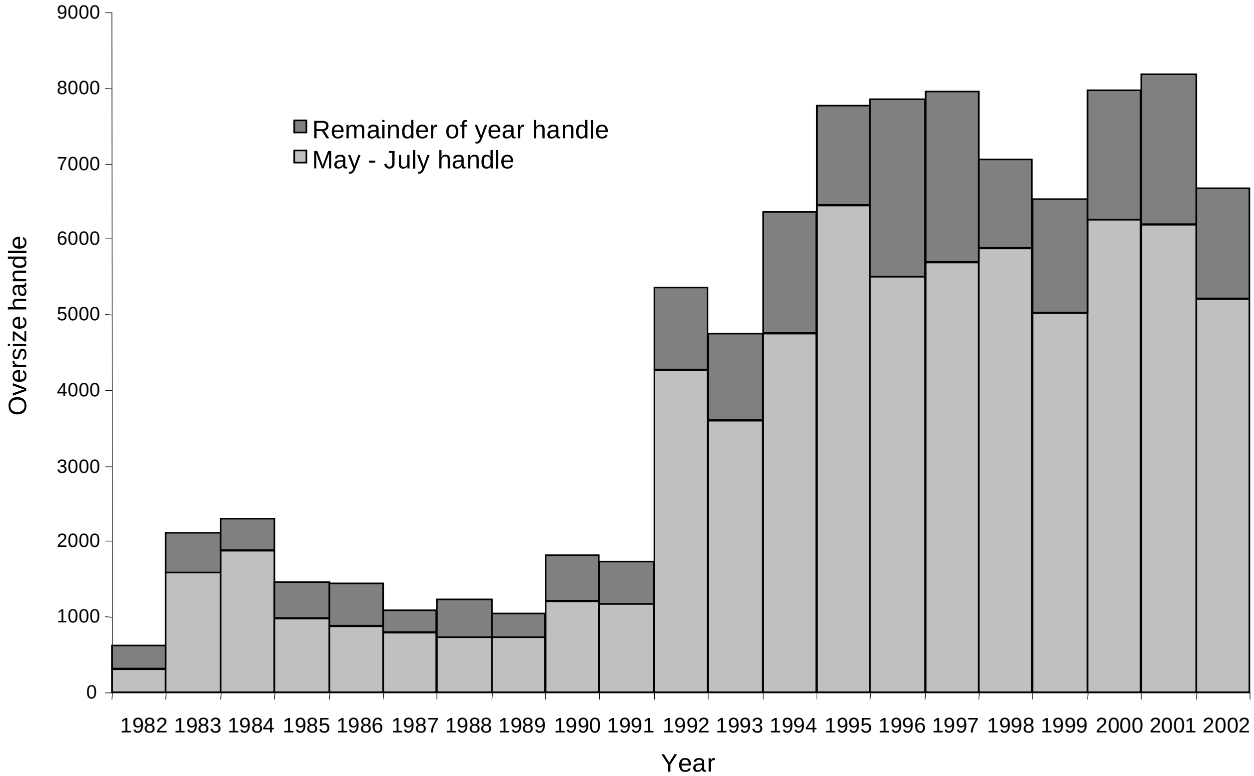

Figure 2. Trend in the handle of oversize sturgeon by season. Data from WDFW.

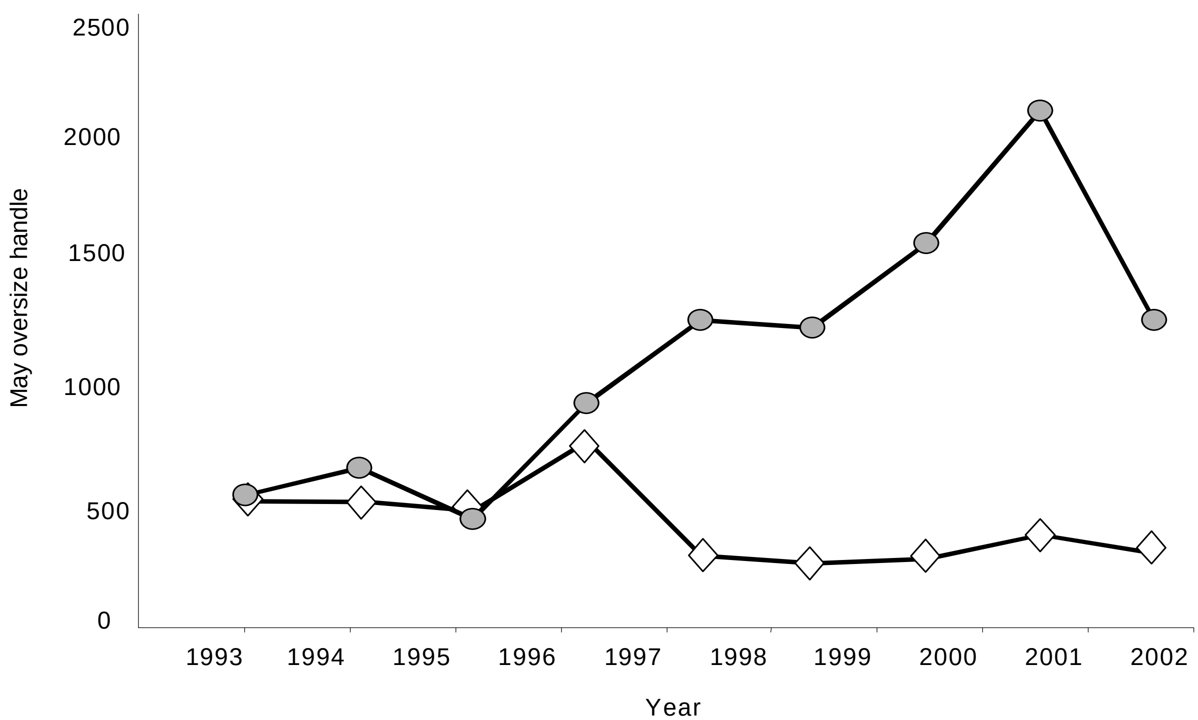

Figure 3. Trend in the oversize handle in the month of May, 1993 - 2002, comparing handle in the boat fishery ( ) and in the bank fishery ( ). Data from WDFW.

Also in 2000 - 2003, Oregon State University (OSU) and WDFW staff observed the sports fishery below Bonneville Dam in June and July, with the assistance of cooperating guides and private boat anglers, for the purpose of tagging large fish and collecting tissue samples for physiological studies. From 2000 to 2002, 42% of the sturgeon observed had hooks or hook scars in their mouth region, while 22% had one or more leaders extending from their vent, indicating swallowed hooks and leaders. In 2003, the rate of injuries increased to 71% with hooks or hook scars in their mouth region. Injuries due to contact with boat propellers and serous bleeding from gills due to hook injuries have also been observed during the fishery. Some observers see these patterns as an indication that some of the sturgeon handled in the fishery may be stressed or injured, possibly to the extent of reduced reproduction or even death.

The purpose of this paper is to begin a discussion of this issue in an effort to determine whether the perceived impact is real, what it's consequences might be, and whether changes in regulations will be needed to mitigate the impacts. This paper does not attempt to conduct the analyses and assessments that might be required to evaluate the impacts, but rather identifies what kind of analyses and assessments would be useful and whether the necessary information is available, or could become available in the near future given current resources. Some information may not be available within the foreseeable future; therefore some assumptions may be necessary in order for management to proceed while a longer-term investigation is planned, financed and conducted.

An impact assessment requires two areas of investigation. The first area is a review of the status of the white sturgeon adult population in the lower Columbia. The status review is important because the consequences of a given risk are more serious if the status of the breeding population is weak, while a strong population may be capable of withstanding a higher level of risk with acceptable consequences. The second area is an investigation of the impacts, determining whether they are real, and how they may affect survival and reproduction of the breeding population. The following sections of this paper address each of these areas.

Approaches and Requirements for a Status Review of the Adult Population

A considerable amount of information is available about white sturgeon in the Columbia River, although much of it is from the populations in reservoirs above the mainstem dams. With regard to the population below Bonneville Dam, we lack answers to several key questions about the status of the population. For example, we are uncertain about how large the adult population is, or what the annual recruitment into the adult population is, or what the natural annual survival rate is, or how many individuals actually reproduce each year. Some of these statistics have been estimated by modeling (DeVore et al. 1995) however we have reason to believe these past estimates contained errors. If we had an accurate measure of these statistics, we might be able to directly determine whether the oversize sports fishery lowers annual survival by an appreciable amount, or affects annual reproduction. It will not be possible to do this direct analysis given the available data or any new data that could be collected in the near term given currently available resources.

However, it would be possible to do an informative status assessment given currently available data and updating past modeling approaches to address suspected sources of error. While this assessment may not directly answer all our questions, it would significantly improve our understanding of this population. The following kinds of information are available which would contribute to a useful status assessment:

1) ***Population boundaries and current and historic distribution:*** A good status assessment begins by defining the boundaries of the population that is being assessed and by determining whether it still occupies all of its historic range. This information is readily available for the white sturgeon population below Bonneville Dam.

    a) ***Total distribution:*** The lower Columbia River white sturgeon appear to form a separate breeding population from those in the Fraser or Sacramento rivers based on genetics analysis (Brown et al. 1992). The historic range of the white sturgeon population in the lower Columbia was likely the lower mainstem and adjacent coastal rivers upstream to Celilo Falls (Figure 4).

    Celilo Falls was likely at least a partial migration barrier and likely formed a natural breeding population boundary since sturgeon do not naturally pass similar features like Willamette Falls or Sherars Falls. Bakjov (1955) noted that adult sturgeon do not easily pass upstream over substantial barriers. This does not imply that there was no gene flow across Celilo Falls or that the differences between the upper and lower Columbia populations constituted unique Evolutionarily Significant Units (ESUs) or Distinct Population Segments (DPSs). But gene flow was likely restricted at the falls and was possibly largely unidirectional (downstream). The current upstream boundary of the population is Bonneville Dam. The opportunity for small amounts of downstream gene flow still occurs across the dam (Ward 2002).

The range of the lower Columbia population clearly extends into coastal basins adjacent to the Columbia (Bakjov 1955 and unpublished ODFW and WDFW tagging data), however spawning apparently does not occur in these areas. Biologists believe that only a small part of the population resides in marine areas for any significant period of time but that access to the marine habitat provides valuable food resources that increase growth and productivity relative to non-anadromous populations (DeVore et al. 1995).

b) ***Spawning distribution:*** The current spawning area for the lower Columbia River population appears to be limited to only a small portion of the population's home range. According to McCabe and Tracy (1994), the primary spawning area in 1988-1991 was in a fairly restricted part of the lower Columbia, between Rkm 223 - 234 (from 600 m down stream of Bonneville Dam spillway)(Figure 4). A low level of spawning apparently also occurred around Rkm 193 during their study. No evidence of spawning activity was found in the rest of the lower Columbia.

The current spawning area appears to be substantially decreased from what was historically available due to the blockage caused by Bonneville Dam starting in 1938. Bonneville Dam, and later, The Dalles Dam, also inundated much of the historic spawning grounds. White sturgeon prefer spawning areas with steeper gradients and

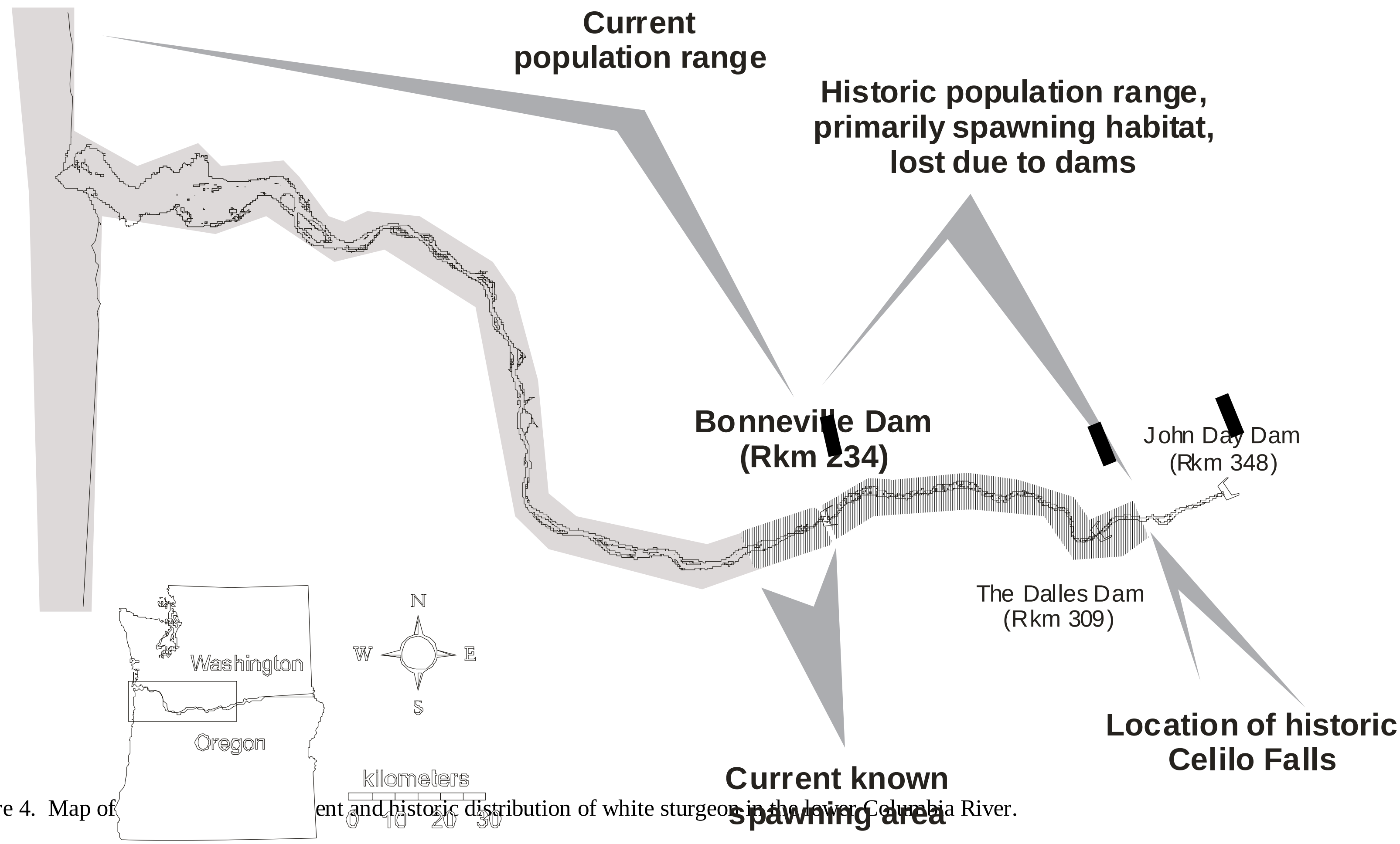

Figure 4. Map of ent and historic distribution of white sturgeon in the lower Columbia River.

swifter flows (Parsley and Beckman 1994). Such conditions historically occurred from Cascade Rapids, through The Dalles rapids and up to the base of Celilo Falls at Rkm 323 but was and is less common lower in the Columbia River. Much of the fisheries on large adult sturgeon that occurred during the late 1800s was concentrated in the area from Oneonta Creek to The Dalles rapids (Craig and Hacker 1940), indicating a high concentration in these reaches of reproductive-sized adults. It is possible to infer from this information that the available spawning area, in terms of river kilometers, may be only about 10% to 12% of what was historically available to the population. This is a substantial decline and would affect the productivity of the population.

2) ***Population bottlenecks:*** There is evidence that the lower Columbia River white sturgeon recently suffered a severe enough population bottleneck to measurably decrease genetic variation in the population (Brown et al. 1992). To put this event into perspective, most of the Endangered Species Act (ESA) listed chinook, steelhead and coho in the Pacific Northwest do not show similar evidence of measurable decreases in genetic variation, even though it is generally recognized they have declined to small numbers (e.g. genetics data in Busby et al. 1996, Myers et al. 1998). This bottleneck probably occurred during the early part of the 20th Century, following the collapse of the population due to overfishing in the 1880s (Craig and Hacker 1940). The population entered a recovery phase starting in the 1950s in response to harvest restrictions. However, as demonstrated by Nei et al. (1975) the impacts caused by a genetic bottleneck linger for several generations, and would particularly be retained over time by a species like white sturgeon that has a very long generation time. For example, the current breeding population (circa 2000, fish ranging from 25 to perhaps 80 years old) was produced between 1975 and 1920, so many individuals were directly affected by the period of low abundance. This genetic bottleneck event increases the vulnerability of the population.

3) ***Survival rates:*** The life history of white sturgeon make them naturally vulnerable to increased mortality levels during their large juvenile and adult life stages. White sturgeon are a late-maturing, long-lived species. Males mature at about 10 to 12 years, and females mature at about 15 to 32 years (Galbreath 1985, PSFMC 1992, DeVore et al. 1995). Although fish older than 50 are rare, individuals may live up to 100 years. They are characterized by low natural mortality as adults. DeVore et al. (1995) estimated the natural annual survival rate for white sturgeon was 91% after the first year of life.

   According to elasticity analyses on other long-lived species with similar life histories, even small decreases in survival during late juvenile and adult stages may have large consequences for population growth and stability (Heppell et al. 1999). Gross et al. (2002) used a natural survival rate of 90% for fish older than age 2 years in elasticity modeling of white sturgeon. The authors argued that increasing the survival rate of large juvenile and adult sturgeon to over 90% would provide little improvement to the growth rate of the population, primarily because the base survival rate is already very high. However, as explained by de Kroon et al. (2000), elasticities can be highly asymmetrical in long lived species. While there may be little opportunity to increase a high natural survival rate, there are plenty of opportunities to decrease it and this makes the species vulnerable. The issue in the lower Columbia white sturgeon population is a decrease from natural survival due to harvest of large juveniles and small adults or due to incidental mortality of large adults in catch-and-release fisheries. DeVore et al. (1995) estimated that harvest rates on large juveniles ranged from 19% to 38% during the late 1980s while total survivals (taking both natural mortality and harvest mortality into account) were about 54%. Harvest rates calculated from annual catches and annual estimated abundances of fish in the legal slot have ranged from 20% to 40%, averaging 30% between 1989 and 2001 (based on data from WDFW and ODFW 2002). Observed survival rates from smaller to larger size classes of lower Columbia River sturgeon in the legal slot, where the fish may be about 10 to over 20 years old depending on individual variation (Kern et al. 2002), have been closer to 30% based on the same abundance data (WDFW and ODFW 2002), although these survival rates are possibly over a period of more than one year depending on growth rate from one size class to another.

   The current annual survival rate of adult sturgeon that have escaped the legal slot is not known. DeVore et al. (1995) estimated that it was about 90% in the late 1980s, or essentially the natural survival level. However their estimates were based on a recapture study that included very few large sturgeon. One potential impact of the oversized catch-and-release

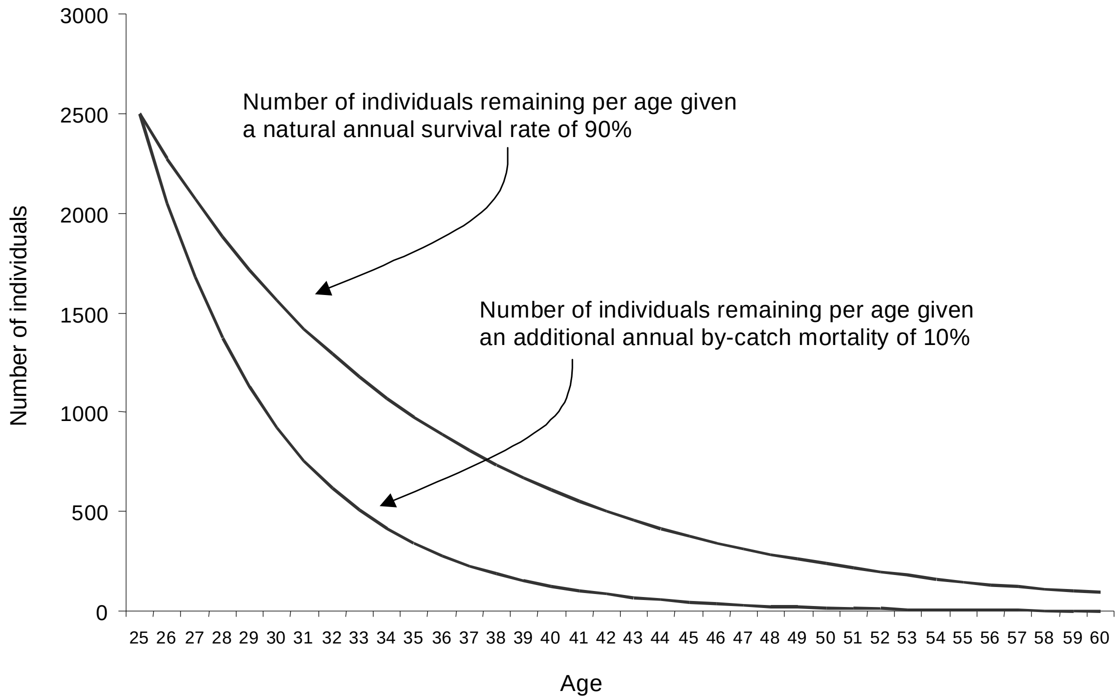

Figure 5. A modeled example of the change in abundance of a year class of 2,500 sturgeon over time with a natural mortality of 10% and with an additional 10% mortality caused by the fishery. The model assumes the average age of these sturgeon at recruitment is 25 and estimates the number of remaining individuals up to age 60.

fishery is a decrease in the annual survival rate of the adults. Figure 5 demonstrates with a simple model the difference in the abundance over time of one year class of oversize adults if they experience an additional annual incidental mortality of about 10%. Essentially no fish, from an initial recruitment of 2,500 fish, would reach age 50 with the added harvest mortality.

4) ***Periodic Reproduction:*** In addition to delayed maturation, white sturgeon also do not reproduce annually or regularly. Female white sturgeon appear to physiologically require two years between spawning episodes. The spawning periodicity for individuals has been reported to be 2 to 11 years (Doroshov et al. 1997; Billard and Lecointre 2001). Males appear to be able to spawn each year, but non-breeding males are observed in the lower Columbia population indicating that they also do not spawn annually (Webb et al. 2001).

   Winemiller and Rose (1992) categorize sturgeon as "periodic" species that are characterized by highly irregular reproductive success. These species typically have long adult life spans but also large clutches. When they do reproduce they produce a huge number of eggs, but they have very low egg and larval survival such that very few offspring ever recruit to adults. In a stable population, each female on average will produce only two reproductive offspring over her life time, in spite of high fecundities and numerous spawning efforts. The authors identify two management consequences of this life history. First, maintenance of a critical density of adults and protection of spawners and spawning habitats are important for the maintenance of the species, and second, different year classes may naturally vary in size by a large amount corresponding to periodic, optimal reproductive events.

5) ***Recruitment to adults:*** Recruitment to the protected oversize category is difficult to measure. WDFW and ODFW have set a recruitment goal of 2,500 fish to age 26 annually (WDFW and ODFW 2002). Population modeling could be used to evaluate this goal to determine if it is adequate. A key part of such an assessment

would be the expected annual survival of the adults. If survival is lower, a larger recruitment goal would be needed.

The next question, however, is whether the recruitment goal is being reached. DeVore (1995) estimated the annual number of 25-year old fish in the lower Columbia River for five years between 1986 and 1990 (Figure 6). They estimated that between 600 and 1,000 fish were age 25 each year.

Another way to estimate recruitment from one size group to another is to use abundance data from fish in the legal slot, which is available since the late 1970s and has been tabulated into various size categories, and look at apparent changes in abundance from one size category to the next over time. An example is a data set from WDFW and ODFW (2002) showing the number of fish harvested in the 4 to 5 foot and 5 to 6 foot size categories per angler trip (Figure 7). This example demonstrates the period in the late 1980s when biologists believe over harvest decreased recruitment, although the trends were also influenced by changes in the way the legal slot was defined.

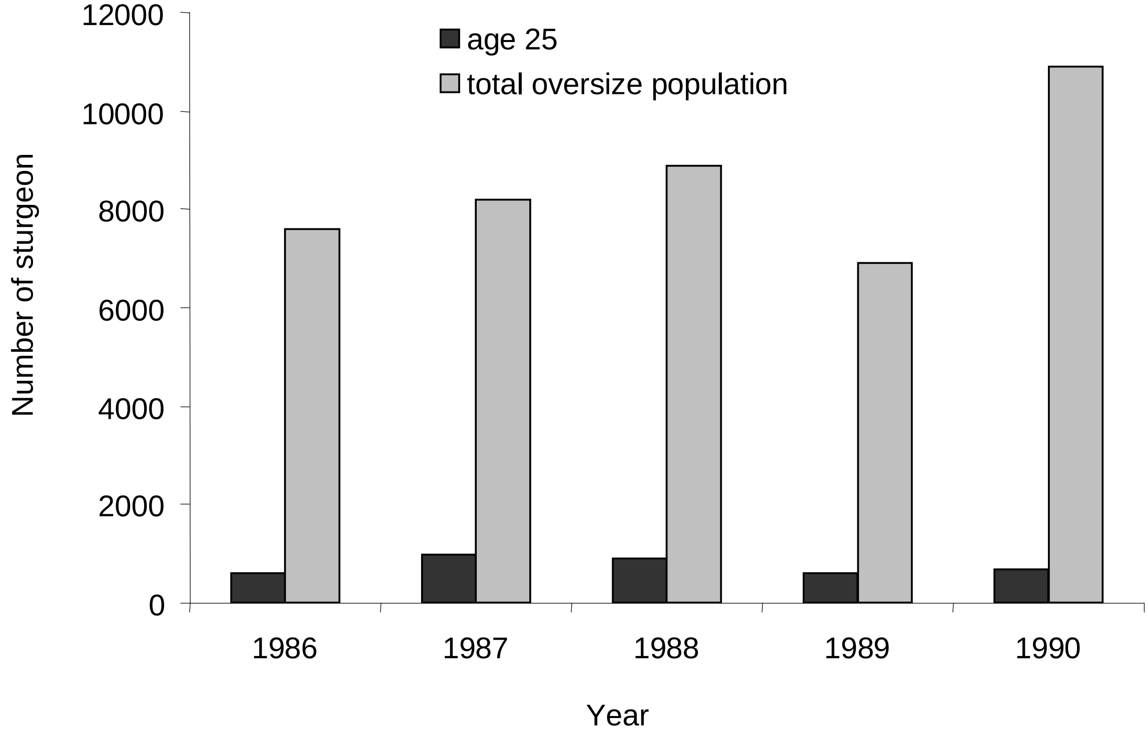

Figure 6. Abundance estimates of age 25 sturgeon, which are annual recruits into the protected adult population, and of the entire adult population, 1986 - 1990. Based on data from DeVore et al. (1995) Table 3.

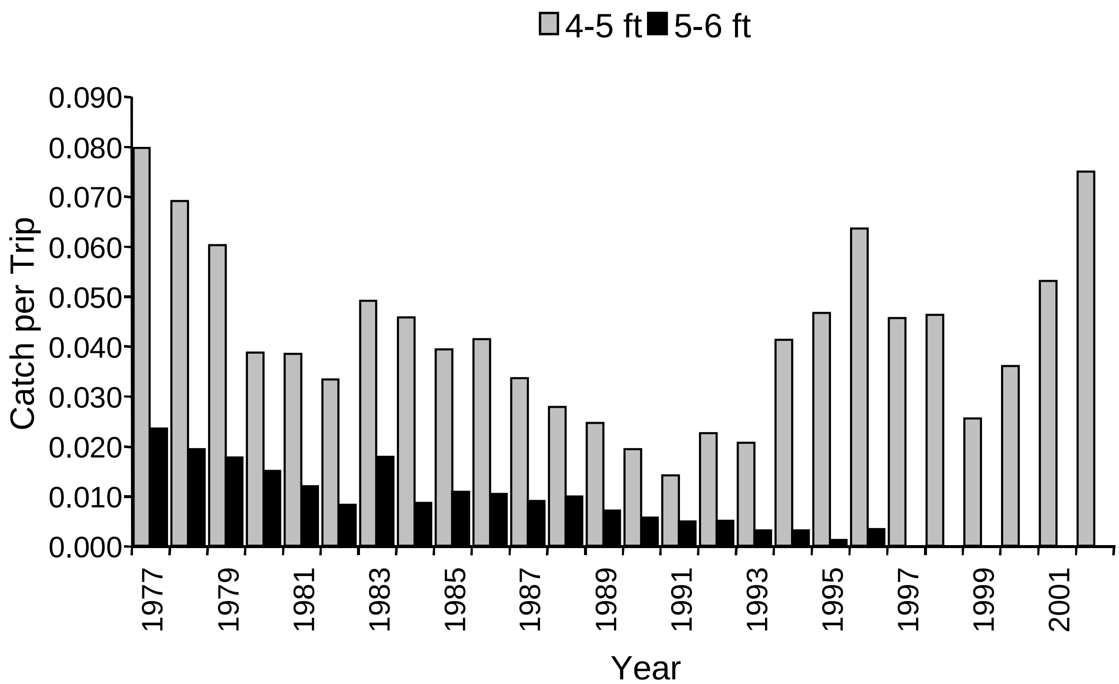

Figure 7. Number of fish caught per angler trip in the 4-5 foot and 5-6 foot slots. Some of the data patterns are caused by regulation changes. The 5 foot legal slot was eliminated in the 1990s and changes in the commercial share also affected the data distribution.

A similar approach could be used to estimate the recruitment from the largest legal fish (for example those that are 58 to 60 inches TL) into the oversized adult category. However there are several problems with making this estimate. These include:

a) The abundance estimates are based on mark-recapture methods. Very few fish at the largest end of the slot are ever marked or recaptured. This occurs for several reasons including gear selectivity and the location of tagging operations, which appear to exclude larger fish. Also fewer larger fish are present and therefore fewer are encountered during trapping or recapture in the fishery.

b) The annual growth rate of larger and older sturgeon is highly variable (Kern et al. 2002). Older fish may stay the same size for many years, or may even decrease in size. There also are more errors in estimating age of older fish (Rien and Beamesderfer 1994). It is therefore difficult to determine how quickly a fish will grow out of the legal slot.

c) The approach depends on having a good estimate of survival from the largest size category in the legal slot to the protected size. As discussed under 3, above, it is difficult to get a good measurement of survival.

6) ***Abundance:*** The abundance of the adult population is a critical piece of information, but unfortunately it is very difficult to obtain. One of the oldest approaches to making an abundance estimate is to look at catch data (Figure 8). The oldest catch data from the late 1800s and early 1900s is reported in pounds (Craig and Hacker 1940). The fish that were caught and reported were all large adults ranging from 50 to 200 pounds. White sturgeon were clearly very abundant in the Columbia Basin in the late 1800s.

Recent abundance estimates since the late 1980s for the fish in the legal slot, which are large juveniles and small adults, have been made using mark-recapture methods (Figure 8). The recapture rate is high for this group because the harvest provides a good method for recapturing tagged fish. Catch data of fish in the legal slot is also included in the figure.

Abundance estimates of oversized sturgeon are difficult to make. All measurements of adult sturgeon abundance include many sampling errors. Large fish are rare so they are not often encountered incidental to other sampling activities and to date relatively few resources have been focused on them. Therefore the marking and recapture of adult sturgeon has been very limited due to the difficulty and the costs. Neither marking nor recaptures are well distributed or random over the population's entire range. This condition violates key assumptions in the models used to calculate an abundance from mark/recapture data (DeVore et al. 1995). Nor are marking or recaptures random by time of year or by the size of the fish. Adults are marked only at a few locations and only during a brief period of time. Recaptures are also limited to a portion of the home range and are rare since the fish are not taken in consumptive fisheries which is the primary source of recaptures of the legal slot fish. Finally, the largest fish in the population are difficult to handle and cannot be landed easily and safely for marking or for the recording of marks. Some of these problems could be mitigated by an increased investment in the monitoring of this population.

Several abundance estimates have been made using the available data. DeVore et al. (1995) estimated annual abundance of fish larger than 183 cm TL for the same five years that they

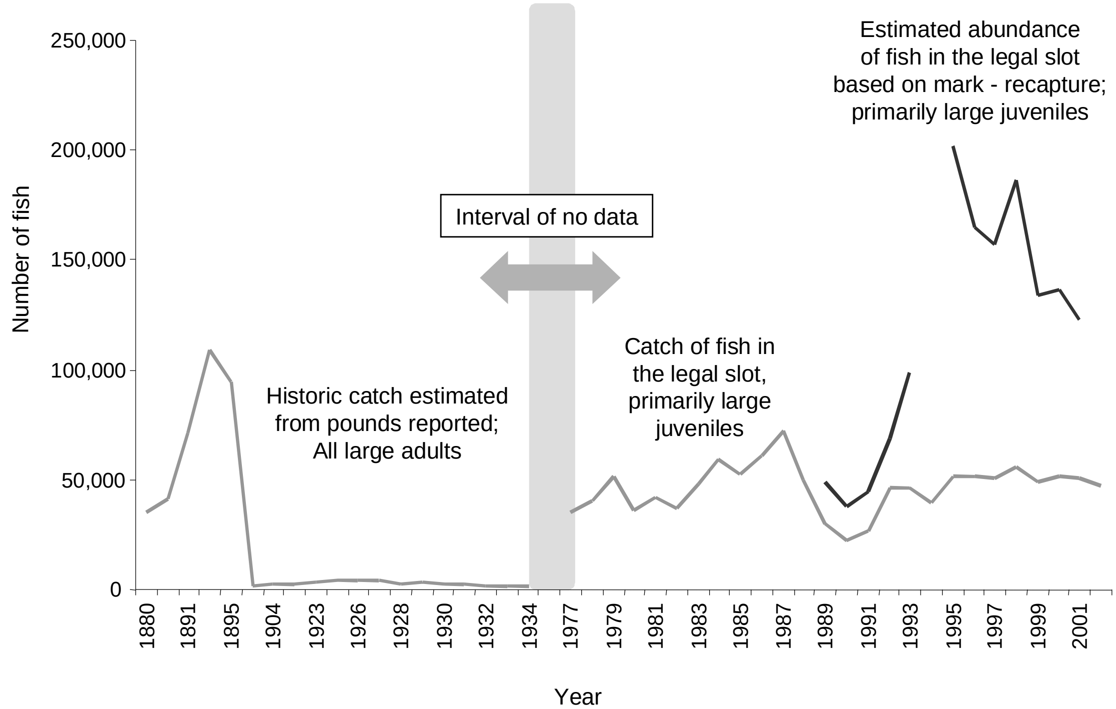

Figure 8. Number of fish caught and estimated abundance of large juveniles and small adults in the legal slot. Data from WDFW and ODFW (2002) and from Craig and Hacker (1940).

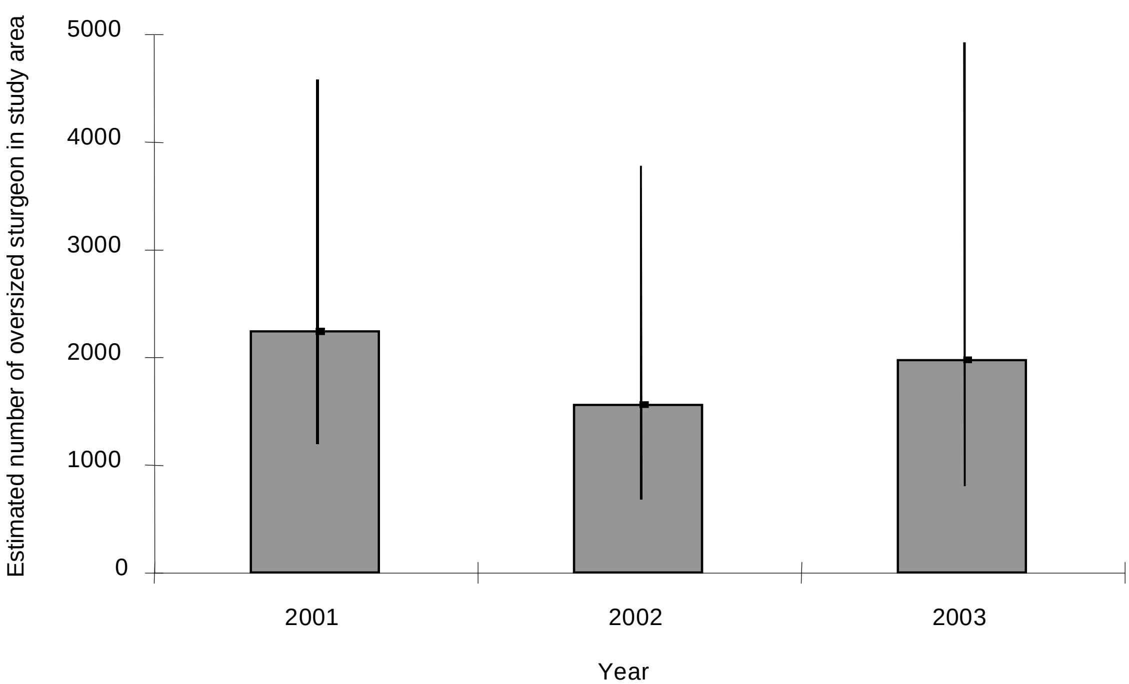

Figure 9. Three oversize sturgeon abundance estimates for the Columbia River between Portland and Bonneville Dam from mark-recapture surveys. 95% confidence intervals shown. Data from WDFW.

estimated recruitment (Figure 6). Their estimates ranged from about 7,500 to about 11,000 fish. The year-to-year variation in their estimates was likely due to sampling error rather than to actual variation in population size.

WDFW and OSU staff have been targeting oversize sturgeon for tagging below Bonneville Dam since 2000. Their recapture rates have been low, however WDFW staff have developed abundance estimates from the information (see Appendix 2 at the end of this report). The abundance estimates based on all marking and recapture locations and methods from 2001 through 2003 are shown in Figure 9. The estimates are in the neighborhood of two thousand fish, although the 95% confidence intervals around the point estimates are very large.

A status review using these and other existing information and incorporating conservation biology principles could be completed without additional data collection. Although somewhat limited in scope, such an assessment would update our knowledge about the status of the white sturgeon breeding population in the lower Columbia.

Ideally, a status review would revisit earlier modeling efforts that have been used to evaluate the productivity of the population, recruitment to the legal slot and to the adult population, and survival of fish in the legal slot and of adults. The modeling to date has not provided reliable predictions of how the population is behaving in that it has predicted certain population responses, specifically abundance increases of certain age classes, that have not occurred. This is thought to be because the models are very sensitive to several variables that are suspected to contain high levels of error, including estimates of abundance made from the mark/recapture studies, estimates of growth rates from one size class to the next, estimates of total survival by age or size class, and estimates of ages of older sturgeon. Point estimates and constants have been used for some of these variables. An alternate approach is to use an array of values that encompass the suspected variation. The approach of using arrays of values for variables produces a family of predicted population responses which can be compared to observed responses. The approach also demonstrates how sensitive the predicted response is to the variables. In some cases, the past models also used productivity functions, either Ricker or Beaverton-Holt functions, that are likely not valid for sturgeon. An evaluation of appropriate approaches for measuring the population productivity of a species with a sturgeon life history needs to occur.

The states of Oregon and Washington need to continue collecting information about the adult white sturgeon population in the lower Columbia, and increase the effort if resources are available to do so. Existing activities that should be continued include the mark-recapture effort on oversized sturgeon by WDFW and the study by OSU of the periodic maturation cycle of adult males and females. Observer programs in the oversized sports fishery and in cooperation with Pelfrey's Sturgeon Hatchery during broodstock collection should continue as these activities provide opportunities to observed the condition of adults, collect population data about them and tag and recapture adults. The WDFW carcass surveys should also continue. The states also must maintain their current monitoring program for the lower Columbia sports and commercial fisheries, which provide annual catch estimates and other biological information.

New or expanded research and monitoring activities that would be highly valuable for improving our information about this population, but would require new resource investments include:

1) Significantly expand the oversize sturgeon mark-recapture study underway by WDFW and OSU to improve the distribution of marking and sampling locations and time intervals to address the design limitations discussed above and to increase the sample sizes.

2) Update the description of the lower Columbia spawning area(s) and date(s), last assessed for the years 1988-1991 (McCabe and Tracy 1994), and improve the information about adult migration and movement within the Lower Columbia population range;

3) Monitor the recruitment of age 0+ white sturgeon through annual fall gill-net or trawling surveys. Age 0+ abundance is related to spawner abundance, although it is also influenced by other variables.

4) Revisit and improve the existing sturgeon population models as discussed above.

This additional research and monitoring would improve our information base and allow a better status assessment in the future.

Approaches and Requirements for Assessing the Impacts of the Oversize Fishery

The second area that needs to be investigated is the extent and consequences of the oversize catch-and-release sports fishery on the lower Columbia River white sturgeon adult population. From the available information we are able to conclude the following about the existence of the fishery and the occurrence of impacts:

1) Oversize and sub-legal sturgeon are frequently caught and released in the lower Columbia fisheries. This activity occurs in the sturgeon sport and commercial fisheries and in fisheries for other species, using both gill nets and hook-and-line. However, the catch-and-release sport fishery that occurs between Rkm 215 and 234 in the Columbia Gorge below Bonneville Dam, primarily a hook-and-line boat fishery, began to target oversized adults in the early 1990s, as demonstrated in Figures 1-3 and Appendix 1. This fishery increased rapidly in the early 1990s, but seems to have stabilized since about 1995. Although the fishery in the Gorge specifically targets adult sturgeon, the affect of all fisheries that catch-and-release adult sturgeon should be assessed to determine which fishery and which gears impact the population.

2) Some individual oversized sturgeon are being caught and released multiple times in a season. Sturgeon observed in the sports fishery and in other sampling conducted in 2000 through 2002 indicate that 42% of the sturgeon captured had previous hook marks around their mouth area. This number increased to 71% in 2003. The incidence of hook marks increases from early June through July. Some sturgeon have multiple hook marks indicating that they had already been caught repeatedly before the capture that was observed. Staff at Pelfrey's Sturgeon Hatchery also noted that up to 38% of the adult sturgeon they catch annually during their broodstock collection had hook marks indicating previous handling in the sports fishery. These data document recaptures in a single season in the limited area where the oversize sports fishery is occurring.

Table 1. Sport fishing-related injuries to adult sturgeon observed during the oversize fishery in 2003. Some fish had multiple kinds of injuries and are included under more than one category. Classification of injuries differed in the gill net and sport fishery as compared to the carcass survey (NA = this information was not collected). Data from WDFW and M. Webb, OSU.

Type of injury	Sampling Method:		
	Research Gill Net N = 34	Sports Fishery N = 80	Carcasses Observed N = 43
No injury observed	56%	10%	34%
One hook scar	9%	6%	9% (not broken out)
Multiple hook scars	21%	65%	
Excessive bleeding observed or bled out due to hook injury in gills or mouth	3%	1%	7%
One leader extruding from vent or one hook found in gut	0%	9%	12%
Multiple leaders extruding from vent or multiple hooks found in gut	6%	5%	5%
Hook extruding from vent	3%	4%	NA
Intestine extruding from vent	0%	5%	NA
Propeller injury	6%	0%	2%
Poaching indicated (eggs or other parts removed)	NA	NA	5%
Unable to determine potential injuries due to deteriorated condition of carcass	NA	NA	33%

This pattern of repeatedly capturing some individuals may be repeated annually, particularly if individuals return to the same holding areas each year. Some sturgeon carcasses observed in the lower Columbia contained multiple hooks internally, demonstrating that they had been caught and released multiple times, possibly over multiple seasons.

3) Some sturgeon are being injured by hooks, including torn mouth parts, torn gills that cause extensive and in some cases lethal bleeding, and perforated guts caused by swallowed hooks (Table 1 summarizes the 2003 observations).

4) Some sturgeon also have been injured, in some cases lethally, by contact with boat propellers as the fish were being landed (Table 1 summarizes the 2003 observations).

5) Sport fishing-related injuries were observed in about 40% to 45% of the sturgeon carcasses found during surveys in the lower Columbia (Rkm 195-230) in 2000 through 2003, since thorough internal exams were conducted. Table 1 summarizes the 2003 observations. Fewer injuries were observed prior to 2000, but the likely reason was that the internal exam was less extensive and injuries were likely missed. Also, about one third of the carcasses are found in a state of advanced deterioration such that evidence of injuries are no longer obvious. About 20 sturgeon carcasses were observed each year from 1994 - 2002. The number increased to 38 carcasses in 2003 (plus five additional carcasses observed outside of the regular surveys, included in the table). With the exception of a few severe cases where hook-torn gills or propeller injuries appear to have caused immediate mortality, it is not known whether the injuries were a cause of or contributor to mortality.

6) It is generally believed that actively breeding adults are not feeding and are not very susceptible to line fisheries that use bait. However, baited hook and line gear has been used to collect ripe males and females from spawning grounds in other Columbia River populations. Furthermore, ripe males and females that are preparing to spawn or have already spawned in the current year are being caught in the sport fishery below Bonneville Dam based on monitoring of the oversize fishery conducted by WDFW. Mature males have been seen most often. Between 2000 and 2002, 14% of the males observed were actively spermiating. Prior to 2003, no ripe females had been observed. However, this was probably the result of when the observations occurred, which was in late June and July when most ripe fish should be on spawning grounds. In 2003, observations began earlier in June and three black-egg females were observed. Also in 2003, a ripe female captured in early June for Pelfry's Sturgeon Hatchery broodstock showed evidence of having been previously caught in the sports fishery. The brood female had a leader extending from her vent indicating that she was carrying a swallowed hook. It is possible that more ripe fish are being caught in May as they approach their spawning area. The actual area where spawning occurs was closed to boat angling May 1 through June 30 since 1996, extending to July 15 since 2000. Several post-spawning females, females who are absorbing their eggs, and "maturing" males and females who would likely spawn the following year also have been caught (Webb et al. 2001).

7) Physiological studies have demonstrated that some aspects of the sport fisheries are increasing stress, as measured by cortisol concentrations (Webb et al. 2001). It appears that repeat captures and longer or rougher "play times" are correlated with elevated cortisol, indicating elevated stress. Elevated stress has been found to reduce gamete and/or progeny quality, increase the incidence of atresia, compromise immune function and lead to direct mortality in vertebrates. Elevated stress associated with the catch-and-release sturgeon fishery could affect maturation and reproduction. The affect of sport fishing-related injuries on maturation and reproduction are not known, although staff at Pelfry Sturgeon Hatchery observed that the brood female taken in 2003 that had evidence of sport fishing-related injuries produced eggs that were not viable.

8) Even small increases in annual mortality or decreases in reproductive success may have a substantial impact on the population abundance, growth, stability and productivity of white sturgeon, due to their life history characteristics (see Figure 5).

The available information indicates that oversized sturgeon are being injured and it is possible that there are consequences to population status. The issue warrants further investigation. This is, however, an extremely difficult issue to investigate because adult sturgeon are not easy to observe, track or study. The most valuable information that we would like to have is the incremental decrease in survival or reproductive success that results from handling. Unfortunately such information is not available nor likely to become available in the near future.

Monitoring and study of this issue needs to continue and to be expanded in the lower Columbia. The existing tagging program for oversized sturgeon by WDFW and OSU needs to continue with an improved sampling design. Observations of injury rates in the oversized catch and release fishery need to continue and become more systematic, and the monitoring period needs to expand to include the month of May. Measurement of recapture frequency in the fishery needs to become more systematic. The carcass surveys in the lower Columbia need to continue, using the thorough internal exams that started in 2000. While these activities will increase our existing information base, they will still not directly answer our key questions about the consequences of the observed injuries.

There seems to be no consensus about how to obtain new information that would more directly address the consequences of the observed injuries in the oversized fishery. Several options for proceeding with this issue are included in the following recommendations.

Recommendations

1. Develop an elasticity model similar to that developed by Gross et al. (2002) or discussed by Heppell et al. (1999) and reviewed by de Kroon et al. (2000), specifically designed to investigate the population consequences of incremental decreases in survival and decreases in reproduction by adult white sturgeon. This analysis would provide information about how much of an impact a species like white sturgeon could be expected to tolerate with little or no consequences.

2. Review the types of gear that have been found associated with injuries. The hooks and leaders that are found in mouths or guts during sport fishery observations and carcass surveys have been retained. An analysis of them may provide some information about which fishery and which hook-and-line gears appear to be causing the most injuries.

3. Conduct a workshop with biologists that would focus on how to better study this issue. The product of this workshop could be a research or monitoring proposal that could be implemented if new funding and resources become available.

4. Take a conservative approach to this issue and assume the injury rate should be decreased while new information is being obtained. Several actions that would facilitate this approach include:

    a) Conduct a workshop with cooperating guides to review and discuss fishing practices that would decrease the rate and extent of injuries;

    b) Conduct a review of fishing practices such as gear design, ranging from hook designs to propeller guards, and handling protocols that would decrease the rate and extent of injuries;

    c) Review the fishery season and current sanctuary area to determine if changes are needed;

    d) Host a public meeting about oversize sturgeon fishery management prior to any Commission action.

    e) Develop as appropriate a package of fishing regulations and education programs that could be adopted or endorsed by the Washington and Oregon Fish and Wildlife Commissions in early 2004 and implemented by the Columbia River Compact prior to the onset of the target oversize sports fishery that begins in May.

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October 13, 2003

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APPENDIX 1

REASONS FOR OBSERVED INCREASES IN RECREATIONAL FISHERY HANDLE OF OVERSIZE WHITE STURGEON IN THE LOWER COLUMBIA RIVER SINCE 1992.

In 1992 the handle of oversize white sturgeon in Lower Columbia River (LCR) recreational fisheries increased dramatically. The increase coincided with 1) regulation changes that progressively reduced the maximum legal retention size limit (see Appendix Table 16 in Watts 2003) and 2) the development of a recreational fishery targeting late spring/early summer concentrations of adult fish staging in the upper reaches of LCR recreational sampling section 1 (see Table 1 and Figure 1 in Watts 2003).

1) Regulation changes
The increase in oversize handle is partly attributable to the contribution of fish newly classified as oversize following reductions in maximum legal size. However it is unlikely that the contribution of these fish to the oversize population was sufficient to account for the observed magnitude of the increase in handle during the 1990's. During the period 1989–1993, when the maximum legal size limit was 72", recreational catch of fish in the 60"-72" size group numbered on average around 800 fish annually (Appendix Table 37 in Watts 2003). This number of recruits to the oversize pool is not sufficient to result in the observed handle increase of several thousands of oversize fish.

2) Changes in the Fishery
Increases in oversize handle have been observed in all areas of the LCR since 1992 but by far the greatest contribution has come from recreational sampling section 1 (Appendix1, Figure 1) during the months of May, June and July (Appendix 1, Figure 2). The boat component of the recreational fishery in section 1 is responsible for the increase (Appendix 1, Figure 3a). During the 1980's oversize handle per boat angler trip was negligible but increased rapidly from 1992 to 1997 after which it stabilized. This is consistent with the development of a fishery targeting spring/summer oversize sturgeon concentrations in this area of the river. Angling techniques targeting oversize evolved rapidly during this period resulting in a steady increase in efficiency at locating, attracting, and hooking these fish. Oversize handle-per-bank-angler-trip in section 1 has remained relatively stable since 1982 suggesting that this component of the fishery has remained focused upon targeting legal fish (Appendix 1, Figure 3a-c). In 2003 a retention closure for all sturgeon angling upstream of Wauna Powerlines (River Mile 40) lasted through June. Bank angling effort in section 1 declined over 90% during the closure, further emphasizing that bank anglers primarily target legal size fish and inadvertently hook into oversize in the process.

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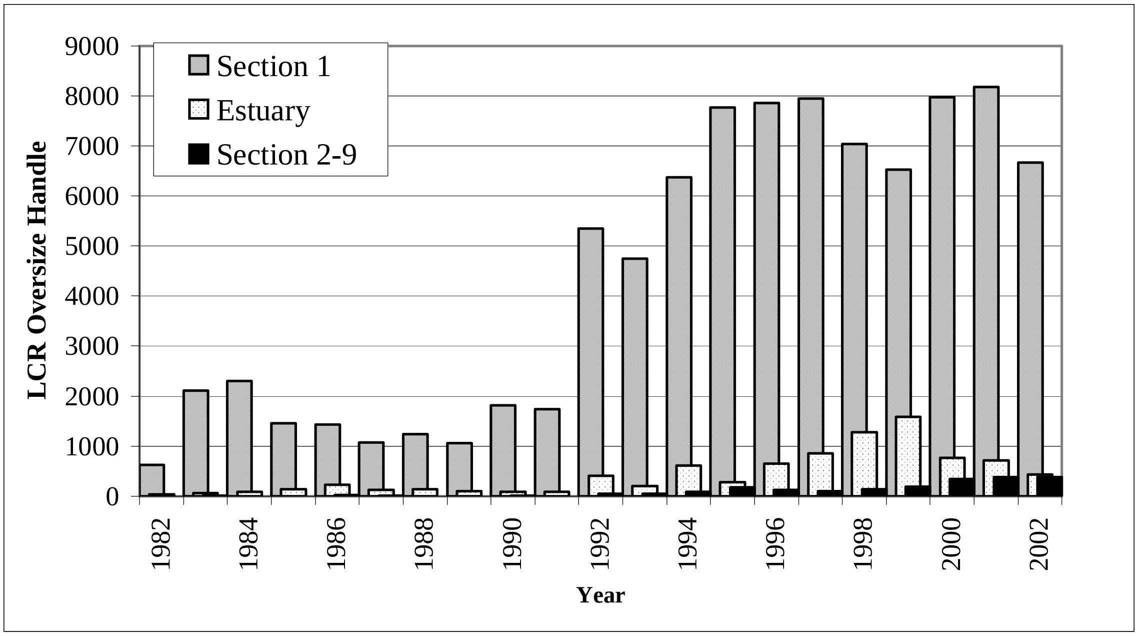

Figure 1. Annual recreational handle of oversize white sturgeon in the Lower Columbia River 1982-2002.

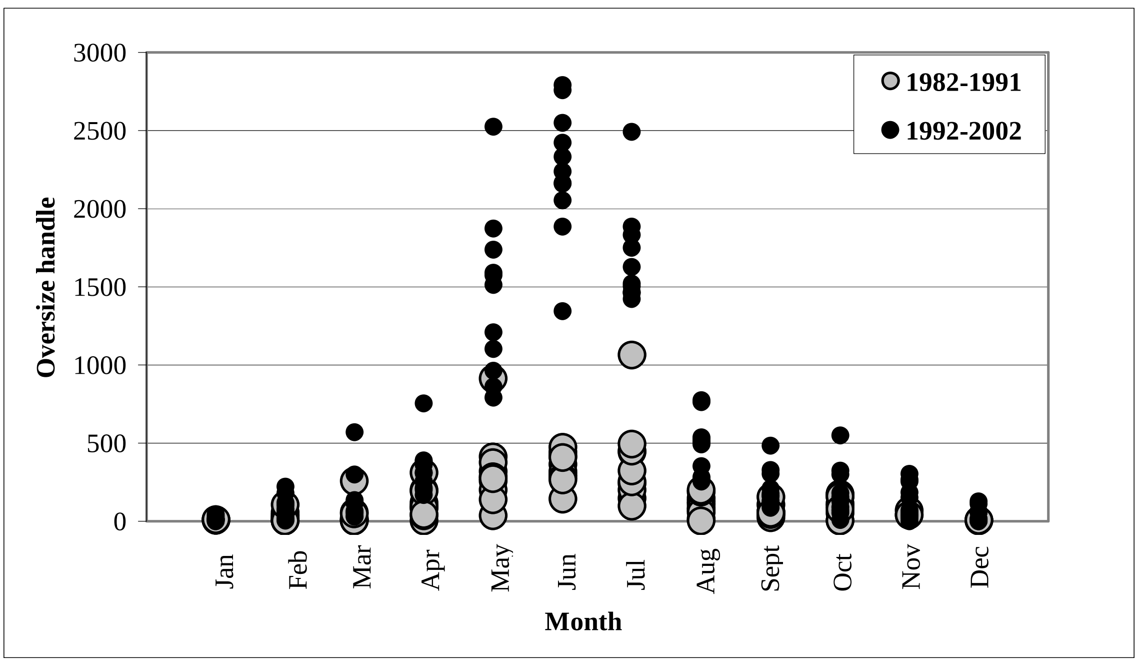

Figure 2. Comparison of monthly recreational handle of oversize white sturgeon in recreational sampling section 1, Lower Columbia River, between periods 1982-1991 and 1992-2002.

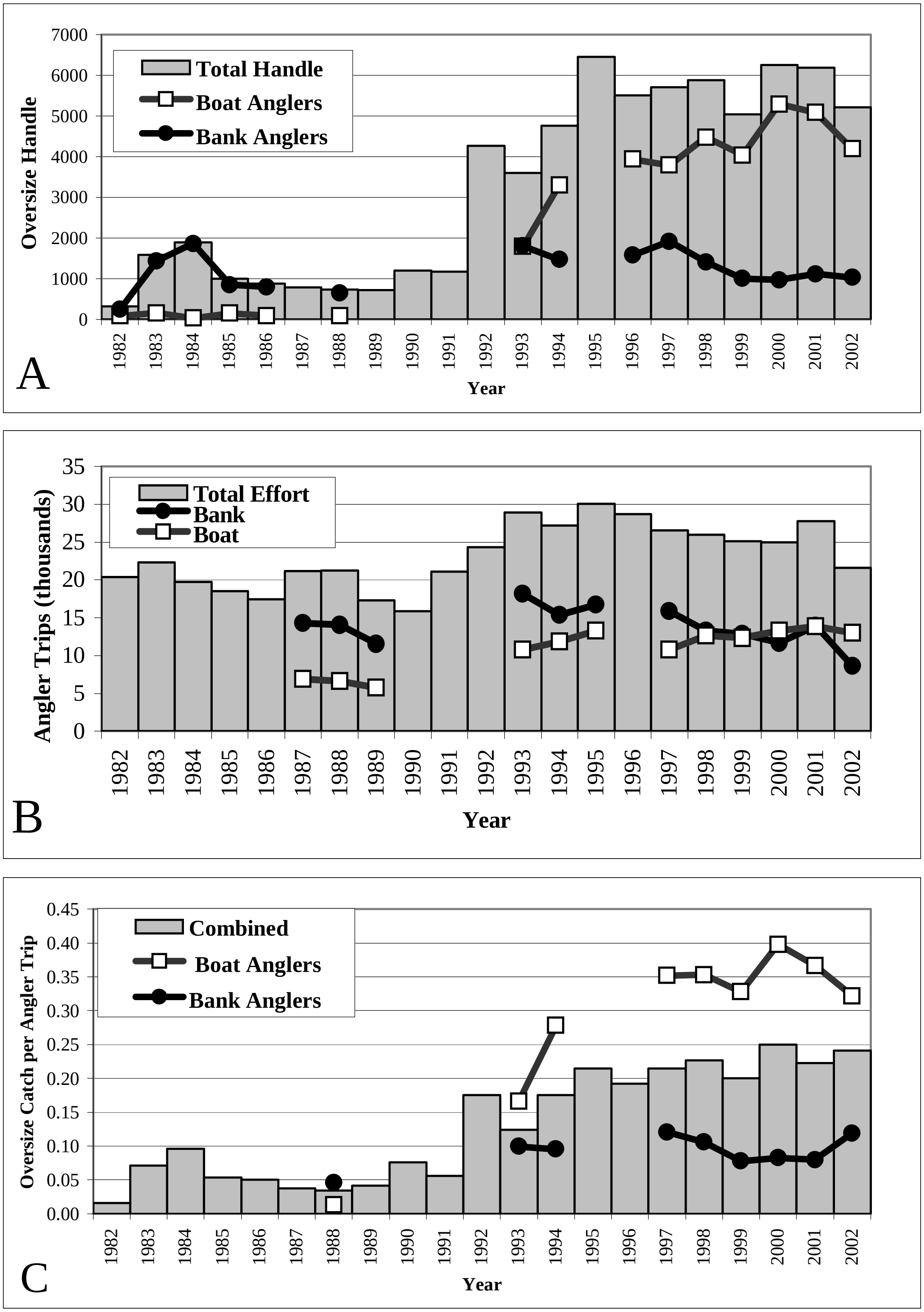

Figure 3. Trends in oversize handle (A), angler effort (B), and handle per angler trip (C) in recreational sampling section 1, Lower Columbia River, during May-July, 1982-2002. Trendline breaks are due to incomplete records of catch statistics at WDFW.

APPENDIX 2

ESTIMATING OVERSIZE WHITE STURGEON ABUNDANCE BELOW BONNEVILLE DAM, LOWER COLUMBIA RIVER, FROM RECENT MARK- RECAPTURE ACTIVITIES.

Through a collaborative effort with OSU researchers, WDFW staff have marked (PIT & Spaghetti tags) 426 over-legal size (oversize) white sturgeon (T.L. $\geq$ 153 cm) in the Lower Columbia River (LCR) between river miles (RM) 124-144 during late spring/early summers of 2000-2003. The intent of the BPA funded research effort has been to develop non-invasive methods to identify sex and stage of maturity using steroids in biological media (urine, mucus, blood) and to expand upon current knowledge of white sturgeon maturation cycles by sampling fish recaptured over multiple years. Tagging efforts also provide an opportunity to derive estimates of oversize abundance based on recapture data. However, sampling has been geared toward achieving OSU research goals and it is unclear if formal mark-recapture study protocols have been followed sufficiently well to allow robust estimates of abundance.

Tagging has employed two methods to capture fish for sampling and has concentrated in two distinct areas in the LCR below Bonneville Dam (Table 1): 1) Gillnetting at night with large mesh nets (150 fathoms, 9 and 12 inch stretch measure) deployed from a commercial vessel. Sampling is conducted during May and early June and concentrated in RM 140 in 2000 and RM 144 in 2001-2003; and 2) sampling fish caught by sport fishers (guides and private fishers) participating in the catch and release oversize fishery below Bonneville Dam. Sampling was performed from late June through late July in 2000–2002 and early June through late July in 2003. Sampling is concentrated in RM's 138 – 140 before July 15 while the Beacon Rock to Bonneville Dam spawning sanctuary is in effect. After this date the sanctuary restriction is lifted and sport fishers move upstream toward the dam. Some sampling of the fishery has occurred in this area in late July.

Table 1. Distribution of tags applied to oversize white sturgeon in the Lower Columbia River during WDFW/OSU gillnetting and sport sampling activities 2000-2003. Numbers in parentheses indicate additional fish captured by gillnet but too large to boat and tag.

Location (RM)	Sport				Gillnet				Total
	2000	2001	2002	2003	2000	2001	2002	2003	
126-128	1								1
129-131	5								5
132-134	2								2
135-137	5		2	1					8
138-140	68	33	41	55	73				270
141-143									
144-145	18	12	4	14		45(16)	16(7)	31(7)	140
Total	99	45	47	70	73	45	16	31	426

Closed population estimation techniques such as the Petersen method (Table 2) operate under the assumption that the population under study remains constant over the period of investigation and is not subject to the effects of immigration, emigration, births (recruitment of individuals through growth in this particular case) or mortality between marking and recapture events. Historical tagging studies performed for the purposes of LCR fishery management show that juvenile and sub-adult sturgeon exhibit marked seasonal mobility, migrating to the estuary (from upstream as well as the ocean) in the summer and then upriver and out to the ocean during the fall – presumably in response to seasonal changes in abundance of food sources. Oversize (adult) behavior in the LCR is less well documented though it is known that significant numbers are present in the reach directly below Bonneville Dam during the spring and summer months. The reasons for this are not clear – presumably there is a spawning component to the population, however the majority of fish sampled by WDFW/OSU have not been observed to be in spawning condition. During WDFW/OSU sampling only three of a total 34 recaptures of fish at large more than a year have been found more than one river-mile from where initially tagged. Voluntary reporting from guides and private sport fishers also show that most fish are taken close to initial tagging sites over multiple years. This suggests that a portion of the oversize population found in the study area is either resident in, or returns to, the area on an annual basis. If this is true, then estimation bias due to violation of the closed system assumption in the Peterson model maybe somewhat ameliorated. However, other observations suggest that the population is not demographically closed based on 1) annual carcass surveys in the study area that indicate loss due to mortality is a significant operating factor and that 2) recruitment to the oversize population through grow-in of individuals from smaller size classes is likely given the length of time between marking and recapture events. To what extent these factors violate closed system assumptions is unclear.

Table 2. Petersen estimates of oversize white sturgeon abundance in the gorge area of the LCR below Bonneville Dam from WDFW/OSU research activities, 2000-2003. Two estimates are provided: one pertaining to the whole area of study (RM 138 –145); and one to the area where oversize sport fishing is concentrated (RM 138-140). A few tags have been applied to oversize captured downstream from RM 138 but these have been omitted from the calculations. Estimates are based on recaptures of fish tagged during the previous season. An adjusted (Chapman) Peterson estimator was employed to derive estimates due to low sample sizes and recapture rates. Sampling error (95% confidence intervals) was calculated from the Poisson distribution using recaptures as the entering variable.

Year	RM 138-145	RM 138-140
2001	2,243 (1,201-4,587)	1,079 (491-2,698)
2002	1,511 (674-3,777)	499 (182-1,247)
2003	1,968 (803-4,920)	620 (253-1,549)

With four years of mark-recapture data it is possible to derive estimates of abundance and other population parameters using multiple mark recapture methods such as the Jolly-Seber model - typically used in open system situations (Table 3).

Table 3. Jolly-Seber population parameter estimates for oversize white sturgeon in the Lower Columbia River between (1) river miles 138-145 and (2) river miles 138-140 (area immediately downstream from the spawning sanctuary where oversize sport fishing is most heavily concentrated). NA indicates values that cannot be calculated in the analysis. Note: probability of survival includes losses to the population from emigration in addition to mortality.

1) Year	Proportion of recaptures marked (α_t)	Previously marked fish at large (M_t)	Population estimate (N_t)	Probability of survival (ϕ_t)	Number joining (B_t)
2000	0.000	0	NA	0.847	NA
2001	0.078	147	1,890	0.934	-388
2002	0.157	221	1,411	NA	NA
2003	0.122	NA	NA	NA	NA

2) Year	Proportion of recaptures marked (α_t)	Previously marked fish at large (M_t)	Population estimate (N_t)	Probability of survival (ϕ_t)	Number joining (B_t)
2000	0.000	0	NA	0.904	NA
2001	0.132	128	969	0.548	-115
2002	0.212	88	416	NA	NA
2003	0.154	NA	NA	NA	NA

The results from both Petersen and Jolly-Seber estimators are in fairly good agreement, suggesting that a population of around 2,000 individuals exists in the study area, with slightly less than half congregating immediately below the spawning sanctuary where the majority of oversize target fishing takes place. It should be noted that these may be underestimates due to population heterogeneity with respect to the sport fishing method of capture i.e. some fish may be more susceptible to sport gear than others leading to inflated numbers of recaptures and subsequent reduced estimates of abundance.

Spawning fish may have been under-represented by sport gear since very few ripe females and spawned-out females were observed from the sport fishery. Ripe broodstock are readily caught with baited setlines in the upper (Canadian) Columbia River white sturgeon restoration program and by rod and reel for the Kootenai River white sturgeon conservation hatchery so it is likely that ripe fish are susceptible to baited gear. A more likely explanation for the lack of ripe females from the sampled LCR sport catch is probably a function of the timing of sampling activities. Sampling of the catch and release fishery has been performed mid-June through late-July when most spawners are presumably within the sanctuary above Beacon Rock and not available to the catch and release fishery (and hence sampling efforts). No sampling of the fishery has been performed during May when ripe fish may still be holding below, or migrating upstream toward, the sanctuary and thus vulnerable to sport fishers. Sampling is performed in the spawning area after the sanctuary restriction is lifted, but occurs after the assumed peak of spawning activity.

Another point of concern hinges upon pooling of data from the two areas of concentrated tagging in the study area (Table 1). Differences in sampling efficiency in the two areas will result in inaccurate estimates of abundance with pooled data unless tagged and untagged fish from each area become adequately mixed between sampling periods. Three out of a total 34 recaptures at large for a year or more during the course of this study were fish that had moved from one area to the other. This suggests that at least some degree of mixing between the localized populations does occur.

Given the uncertainties regarding population closure and adequate mixing it seems likely that the best abundance estimate is that involving data from RM's 138-140 applied to the Jolly Seber method.