Green Sturgeon (*Acipenser medirostris*) Status Review Update

Biological Review Team
Santa Cruz Laboratory
Southwest Fisheries Science Center
NOAA Fisheries
December 2004

TABLE OF CONTENTS

EXECTIVE SUMMARY

The National Marine Fisheries Service's (NMFS's) Southwest and Northwest Fisheries Science Centers were requested to conduct an update of the Status Review for North American Green Sturgeon (*Acipenser medirostris*) (Adams et al. 2002). The request came as the result of a 2004 court ruling remanding to NMFS for further consideration the issue of whether green sturgeon are endangered or threatened in a "significant portion of the species' range". The Biological Review Team (BRT) was requested to include in its updated review any new scientific or commercial information available since the last status review and to identify and conduct a relative ranking of the sources, severity, and geographic scope of threats to green sturgeon. Informed by information and finds of the original status review, the BRT reconsidered green sturgeon's Distinct Population Segment (DPS) structure and the risk status for each DPS in the light of any new information in this current update. The BRT also considered whether there were subsets of the green sturgeon DPSs that were "a significant portion of the range". In addition, the BRT considered the geographic extent and relative importance of confirmed, current or lost spawning habitat within each DPS. Finally, the BRT identified the sources, severity, and geographic scope of threats to each DPS and considered the possibility of ranking those threats.

The BRT received new and updated green sturgeon information on genetic analyses, oceanic distribution and behavior, freshwater distribution, and catch data. New genetic analyses were available that included new adult samples from the Umpqua River, new juvenile samples from the upper Sacramento River, and additional adult samples from the Rogue and Klamath rivers. The new analyses used nine loci rather than the six used in previous studies. The new genetic analyses showed a strong division between northern and southern spawning areas. The northern spawning area included the single stock areas of the Rogue and Klamath rivers along with the mixed stock area of the Umpqua River. The southern spawning area included the single stock area of the Sacramento River and the mixed stock areas of San Pablo Bay and the Columbia River. New oceanic distribution and behavior information came from archival tags, Oregon trawl logbook analysis, and acoustic tags. These data indicated that green sturgeon make generally northern migrations, apparently occurring in numbers off Vancouver Island, and are taken by trawl at shallow depths almost exclusively inside the 110 m contour. New freshwater distribution records in the Northern DPS documented two juvenile green sturgeon captured in the Umpqua River, although the status of current spawning there is uncertain. In the Southern DPS, the BRT concluded that green sturgeon originally spawned above Keswick and Shasta dams on the Sacramento River, that green sturgeon were using the Feather River system for spawning before the construction of Oroville Dam, and that there is no evidence of green sturgeon ever occurring in the San Joaquin system. Updated catch information showed the continued decline in green sturgeon coastwide catch from a high of 9065 in 1986 to 512 in 2003.

The BRT considered both the green sturgeon DPS structure from the previous status review and the updated genetic analyses, and concluded that the new information further supported their previous conclusion that there are at least a Northern DPS and a Southern DPS. In the updated green sturgeon dendrogram, the split between the group of the Rogue, Klamath, and Umpqua populations and the group of the Sacramento River (juveniles), San Pablo Bay, and Columbia River populations occurred in 100% of the bootstrap runs. The Northern DPS is made up of single stock green sturgeon spawning populations in the Rogue, Klamath and Eel rivers. The Southern DPS at present contains only a single spawning population in the Sacramento River. Recent habitat evaluations conducted in the upper Sacramento River for salmonid recovery planning have indicated that significant green sturgeon habitat was probably altered or made inaccessible by dam construction. The historical presence of green sturgeon spawning populations in the Feather and San Joaquin rivers are less clear. CDFG (2002) considers the Feather River to be "the most likely loss of spawning habitat [of green sturgeon in the Central Valley]". While there is some recent evidence that white sturgeon spawn in the San Joaquin River, there are no current or historic records confirming green sturgeon use of this drainage.

The BRT concluded that the Northern Green Sturgeon DPS was not in danger of extinction now or likely to become endangered in the foreseeable future throughout all of its range. A majority of the likelihood votes were placed in the not being in danger of extinction now or likely to become so in the foreseeable future category while a minority of the votes were placed for becoming in danger of extinction in the foreseeable future category, and a single vote was placed in the in danger of extinction category. It should be noted that every BRT member placed at least three votes in the likely to become endangered in the foreseeable future category. This indicates the uncertainty associated with making informed risk assessments with the lack of available data and the potential for change in assessing levels of risk as more data becomes available. The majority of the BRT felt that the inclusion of two significant spawning rivers in the DPS, the continued reduction in green sturgeon catch, and improvement in data from the Rogue River were encouraging information. A minority felt that there was too much uncertainty in the green sturgeon data and that their status could be much worse than we currently think. The BRT was not convinced that green sturgeon populations were extirpated from either the South Fork of the Trinity or the Eel rivers. "Significant portion of the species' range" discussions for this DPS ended without resolution due to the uncertainty resulting from the lack of historical data about green sturgeon spawning areas, but there was consensus that the Eel River by itself was not a significant portion of the range of Northern DPS. The entire BRT felt that the green sturgeon populations in the Northern DPS faced potentially serious threats that are particularly worrisome with the lack of data to adequately monitor population status. The BRT reiterated their previous comment that the Northern Green Sturgeon DPS should be placed on the Species of Concern list (previously the list of Candidate species), that their status be reviewed at least every five years, and that population status monitoring be implemented. The BRT compiled known threats to green sturgeon in this DPS (Table 3), but were unable to rank them in importance due to lack of understanding of their impact on green sturgeon.

All but one member of the BRT concluded that green sturgeon in the Southern DPS were likely to become endangered in the foreseeable future throughout all of its range, with the remaining member concluding that the DPS was not in danger of extinction or likely to become endangered within the foreseeable future throughout all of its range. The likelihood votes placed ranged from in danger of extinction to not in danger of extinction now or in the foreseeable future, again reflecting the uncertainty associated with the extremely limited green sturgeon data. The majority of the BRT felt that the blockage of green sturgeon spawning from what were certainly their historic spawning areas above Shasta Dam and the accompanying decrease in spawning habitat in the Feather River with the construction of Oroville Dam made the Southern Green Sturgeon DPS likely to become endangered in the foreseeable future throughout all of its range.

Since the BRT concluded that the Southern DPS was likely to become endangered in the foreseeable future throughout all of its range, the consideration of risk in a significant portion was rendered moot. Moreover the BRT felt that potential threats faced by green sturgeon in the Southern DPS were more serious than the threats faced in the northern one. The concentration of spawning adults into the Sacramento River places the Southern DPS at an even greater risk level. The BRT compiled known threats to green sturgeon in the Southern DPS (Table 4), but were unable to rank them in importance due to lack of understanding of their impact on green sturgeon.

INTRODUCTION

Scope and Intent of the Status Review Update

On August 23, 2004, the Southwest and Northwest Regions requested that the Southwest and Northwest Fisheries Science Centers conduct an update of the Status Review for North American Green Sturgeon (*Acipenser medirostris*) (Adams et al. 2002). The request asked the Biological Review Team (BRT) to include in its consideration any new scientific or commercial information that may have come to light since the last status review and to include green sturgeon extinction risk for any "significant portion of the species' range". The request came as the result of a 2004 court ruling that remanded the Service's 2003 green sturgeon Endangered Species Act (ESA) listing determination for reconsideration (the court's ruling is further described in the History of the Listing Status of Green Sturgeon section).

In addition, the BRT was asked to consider a number of questions in regard to the Distinct Population Segment (DPS) structure and risk status of green sturgeon. The first was to reconsider the green sturgeon's DPS structure proposed in the previous status review in light of any new information. If a new DPS structure were warranted, what would the new DPS structure be? For each DPS, what is the risk of that DPS being in danger of extinction or likely to become so within the foreseeable future throughout all of its range? If a DPS is not in danger of extinction or likely to become so in the foreseeable future, is there a subset of the DPS that represents a significant portion of the range of the DPS? If there is a subset of the DPS that is a significant portion of the range, is that subset in danger of extinction or likely to become so in the foreseeable future? In addition, the BRT was asked if possible to quantify the geographic extent and relative importance of both known and suspected spawning habitat within each DPS. The BRT was also asked to identify known and suspected lost spawning habitat. Finally, the BRT was asked to consider the sources, severity, and geographic scope of threats to each DPS and to conduct a relative ranking of threats to determine their contribution to survival risk of each DPS.

The National Marine Fisheries Service (NMFS) convened a second BRT to update the status of green sturgeon throughout its North American range. The green sturgeon BRT met on November 9 and 10, 2004 at Santa Cruz, California to review the best available information on green sturgeon DPS structure and the risk faced by each DPS under consideration, including any new information made available since the 2002 status review. The BRT included Dr. Peter Adams, Dr. Churchill Grimes, and Dr. Steven Lindley from NMFS, Southwest Fisheries Science Center, Dr. Mary Moser from NMFS, Northwest Fisheries Science Center, Dr. Joseph Hightower from U. S. Geological Survey, North Carolina Cooperative Fish and Wildlife Research Unit, and Michael Parsley from U. S. Geological Survey, Western Fisheries Research Center, Columbia River Research Laboratory.

History of the Listing Status of Green Sturgeon

On June 12, 2001, NMFS received a petition from the Environmental Protection Information Center, the Center for Biological Diversity, and Waterkeepers Northern California requesting that NMFS list the green sturgeon as threatened or endangered under the ESA and that critical habitat be designated for the species concurrently with any listing determination. On December 14, 2001, NMFS provided notice of its determination that the petition presented substantial information that a listing may be warranted and requested information to assist with a status review to determine if green sturgeon warranted listing under the ESA (NMFS 2001 66 FR 64793). To assist in the status review, NMFS formed a BRT comprised of scientists from the Northwest and Southwest Fisheries Science Centers and from the U. S. Geological Survey. NMFS also requested technical information and comments from State and Tribal co-managers in California, Oregon, and Washington, as well as from scientists and individuals having research or management expertise pertaining to green sturgeon from California and the Pacific Northwest. The BRT considered information presented in the petition and the best available scientific and commercial information provided in response to NMFS' information request to prepare a final review of the biological status of green sturgeon (Adams et al. 2002).

After conducting the status review, NMFS determined that green sturgeon population structure is comprised of (at least) two DPSs that qualify as species under the ESA: (1) a northern coastal DPS consisting of populations spawning in coastal watersheds northward of and including the Eel River; and (2) a southern DPS consisting of coastal or Central Valley populations spawning in watersheds south of the Eel River, with the only known extant population in the Sacramento River.

The BRT considered the following information to assess risk factors for each green sturgeon DPS: (1) abundance trends indicated by fisheries and survey data; (2) the effects of harvest and bycatch; (3) the possible loss of spawning habitat in, for example, the Eel, South Fork of the Trinity, and San Joaquin rivers; (4) concentration of spawning in the Klamath (Northern DPS) and Sacramento (Southern DPS) river systems; (5) lack of adequate population abundance data; (6) potentially lethal water temperatures and adverse effects by contaminants (Southern DPS); (7) entrainment by water projects (Southern DPS); and (8) adverse effects by exotic species (Southern DPS). Based on this risk assessment, NMFS determined that neither DPS warranted listing as threatened or endangered (NMFS 2003 68 FR 4433). Uncertainties in the structure and status of both DPSs due to lack of data led NMFS to add them to its Species of Concern list (formerly the Candidate species list; NMFS 2004a. 69 FR 19975). Along with the finding, NMFS announced that it would reevaluate the status of green sturgeon in 5 years provided that sufficient new information warrants an update of the status review.

On April 7, 2003, the Environmental Protection Information Center (EPIC) and other plaintiffs challenged NMFS' not warranted finding. The U.S. District Court for the Northern District of California issued an order on March 2, 2004, which set aside NMFS's not warranted finding and remanded the matter back to NMFS for redetermination of whether green sturgeon is in danger of extinction throughout all or a significant portion of its range, or is likely to become endangered within the foreseeable future throughout all or a significant portion of its range (EPIC et al. v. NMFS, No. C-02-5401, N.D. Cal. Filed Mar. 3, 2004). Specifically, the Court ruled that NMFS had failed to consider "whether the lost spawning habitats constituted a significant portion of the green sturgeon's range for the purposes of determining whether the green sturgeon is endangered or threatened." The Court advised that "Although the agency has wide discretion in determining what constitutes a significant portion of the range, the agency ...

must at least explain [its] conclusion that the area in which the species can no longer live is not a “significant portion of its range."

The Northern and Southern DPSs are now considered candidate species (DPSs that are the subject of a listing petition which NMFS has accepted and has initiated an ESA status review), as well as Species of Concern (see NMFS 2004a 69 FR 19975). NMFS reconvened the green sturgeon BRT to update the status review. NMFS published a *Federal Register* notice on June 18, 2004 soliciting information from the public to assist the agency in updating its status review and making a new listing determination (NMFS 2004b. 69 FR 34135). To ensure that the updated status review considered the best scientific and commercial information, NMFS specifically solicited new information beyond that considered in the 2002 green sturgeon status review and the January 2003 one-year finding. The public comment period closed on August 17, 2004. Access to the public comments was provided to Plaintiffs and Intervenors on August 17, 2004. NMFS will make its new one-year determination on or before March 2, 2005.

Key Questions in ESA Evaluations

In determining whether a listing under the ESA is warranted, two key questions must be addressed:

1) Is the entity in question a "species" as defined by the ESA?
2) If so, is the "species" in danger of extinction or likely to become an endangered species in the foreseeable future throughout all or a significant portion of its range?

These two questions are addressed in separate sections of this status review update. In addressing the second question, if it was determined that a green sturgeon DPS was not in danger of extinction or likely to become endangered within the foreseeable future throughout all of its range, the BRT held a discussion of what would constitute “a significant portion of a species’ range” for the green sturgeon DPS, and whether that significant portion was in danger of extinction or likely to become so within the foreseeable future.

The "Species" Question

For the purpose of the ESA, a species is defined as

> “any subspecies of wildlife or plants, or any distinct population segment of any species of vertebrate fish or wildlife which interbreeds when mature.”

As amended in 1978, the ESA allows listing of "distinct population segments" of vertebrates as well as named species and subspecies. The United States Fish and Wildlife Service (USFWS) and NMFS published a Policy Regarding the Recognition of Distinct Vertebrate Population Segments Under the Endangered Species Act (USFWS and NOAA 1996) to give guidance to distinguish DPSs. The policy identifies two elements in a decision regarding whether it is appropriate to identify separate DPSs: discreteness and significance of the population segment to the species. A DPS may be considered discrete if it is markedly separate from other populations of the same taxon as a consequence of physical, physiological, ecological, or behavioral factors or if it is delimited by international governmental boundaries. If a population segment is considered discrete, it's biological and ecological significance will be considered on the basis of considerations including, but not limited to its persistence, evidence that loss of the DPS would result in a significant gap in spatial structure, evidence of the DPS representing the only surviving natural occurrence of a taxon, or evidence that the DPS differs markedly in its genetic characteristics. If it is deemed appropriate to identify separate DPSs, the status of each DPS should be considered separately in relation to the standards for ESA.

The "Extinction Risk" Question

The ESA (section 3) defines the term "endangered species" as "any species which is in danger of extinction throughout all or a significant portion of its range." The term "threatened species" is defined as "any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range." NMFS considers a variety of information in evaluating the level of risk faced by a species or DPS. Important considerations include 1) absolute numbers and their spatial and temporal distribution; 2) current abundance in relation to historical abundance and carrying capacity of the habitat; 3) any spatial and temporal trends in abundance; 4) natural and human-influenced factors that cause variability in survival and abundance; 5) possible threats to genetic integrity (e.g., artificial rearing); and 6) recent events (e.g., a drought or a change in management) that have predictable short-term consequences for abundance of the species. Additional risk factors, such as disease prevalence or changes in life history traits, may also be considered in evaluating risk to populations. The determination of whether a species as "in danger of extinction" or "likely to become an endangered species within the foreseeable future" should be made on the basis of "the best scientific and commercial information" available regarding its current status.

"A significant portion of the species' range" Issue

The district court in EPIC et al. v. NMFS remanded NMFS' 2003 listing determinations for the Northern and Southern Green Sturgeon DPSs for failing to analyze whether the DPSs are threatened in a significant portion of their range. However, interpreting what is meant by the statutory phrase "significant portion of its range" is difficult; the phrase is ambiguous and not defined in the statute, the legislative history, or in NMFS' ESA implementing regulations. Neither the USFWS nor NMFS have provided policy guidance for the interpretation or implementation of the phrase in their ESA listing determinations.

A number of courts have considered the meaning of the phrase, and most have found that the statutory language is ambiguous and that the Services (NMFS and USFWS) have discretion to interpret it (e.g., Defenders of Wildlife v. Norton, 258 F.3d 1136, 9^{th} Cir. 2001; Southwest Center for Biological Diversity v. Norton, LEXIS 13661, D.D.C. 2002; and EPIC et al. v. NMFS). The U.S. Ninth Circuit Court of Appeals' (in Defenders of Wildlife v. Norton, concerning the USFWS' listing determination for the flat-tail horned lizard) has applied a standard that a species may be at risk of extinction throughout a significant portion of its range if there are "major geographical areas in which it is no longer viable, but once was." The district court in EPIC et al. v. NMFS applied the 9th Circuit's standard in its ruling that NMFS did not "assess whether the lost spawning habitats together constituted a major geographical area in which the green sturgeon once was viable, but is no longer." Other court rulings have similarly applied the 9th Circuit's standard in the flat-tail horned lizard case (e.g., National Association of Homebuilders v. Norton, 340 F.3d. 835, 9th Cir. 2003; Defenders of Wildlife v. Norton, 239 F. Supp.2d 9, D.D.C. 2002). Some court rulings addressing "significant portion of its range" also suggest that a geographic area may be a significant portion of the species' range if it is important to its continued viability, for example, by containing a large amount of suitable, high-value habitat (e.g., EPIC et al. v NMFS; Southwest Center for Biological Diversity v. Norton; Defenders of Wildlife v. Norton, Civ. 99-02072 HHK, D.D.C. 2001).

The request of the Southwest and Northwest Fisheries Science Centers to update the status review for green sturgeon specifically asked that the BRT address the "significant portion of its range" issue. In addressing "significant portion of its range", the BRT was encouraged to consider whether there are areas within an identified DPS that, if lost, would significantly impair the long-term viability of the DPS. Such areas might include habitats where green sturgeon spawned historically, but no longer do so.

In light of limited guidance provided and the considerable ambiguity concerning the phrase, the BRT had lengthy discussions to formalize what might constitute "a significant portion of the species' range" for green sturgeon. The BRT concluded that a key consideration for evaluating what might constitute a significant portion of a green sturgeon DPS' range is the impact that the loss of an area would have on the DPS' spatial structure. The importance of spatial structure for green sturgeon is a natural consequence of the interaction between the species' trait of returning to its natal stream for spawning and the patchy nature of these spawning habitats. The level of reproductive exchange among green sturgeon spawning locations is unknown, but it is assumed that there is some degree of straying and reproductive exchange from one population to another, which decreases with distance between the populations. Otherwise, each population would have a unique genetic structure (and such genetic uniqueness is not evident in the most recent genetic information, see below). With the loss of a significant portion of a green sturgeon DPS' range, the remaining populations would become more and more isolated. This would change the extinction risk of the overall DPS in ways that are not immediately apparent. Although some isolated populations may persist over the short term, poor spatial structure and connectivity among these populations present small population risks (e.g., genetic risks, demographic stochasticity, and catastrophic events) that may confer an increased level of risk to the viability of the DPS into the foreseeable future. Furthermore, the use of widespread spawning habitats reduces the risk of DPS extinction from catastrophic events, and reduction in this spatial diversity increases this risk. Finally, the BRT felt that uncertainty due to lack of knowledge of green sturgeon population dynamics necessitated a cautious approach to considering significant portion of its range.

RECENTLY UPDATED GREEN STURGEON INFORMATION

Genetic Information

Updated analyses of green sturgeon genetic structure were made available from UC Davis (J. Israel and B. May pers. comm.). These results incorporated a greater number of samples including new adult samples from the Umpqua River, new juvenile samples from the Sacramento River, and an increase in microsatellite DNA loci to nine over the six reported in the previous status review and discussed in the Israel et al. (2004) article.

Both F_{st} comparisons (Table 1) and unweighted pair group method with arithmetic mean (UPGMA) clustering (Figure 1) of green sturgeon samples demonstrate a strong division between a grouping of the Rogue, Klamath, and Umpqua rivers versus a grouping of the Sacramento and Columbia rivers and San Pablo Bay samples. The northern group included mixed stock green sturgeon samples from the Umpqua River as well as single stock samples from the Rogue and Klamath rivers and the southern group included mixed-stock samples from the Columbia River, samples from San Pablo Bay that may be either mixed or single stock, and single stock samples from the Sacramento River. Israel et al. (2004) suggested that the grouping of Sacramento and Columbia rivers could result from learned migratory behavior, but the BRT considered other explanations such as sampling artifacts or incomplete identification of diagnostic loci equally likely. Within those two major genetic cluster groups, there was as much interannual separation as separation across rivers. The reasons for this are unclear, but it probably highlights the difficult of collecting a representative sample of these fishes. The BRT reiterates its suggestion for a genetic analysis based on outmigrating juveniles from the single stock systems (Adams et al. 2002).

Oceanic Distribution and Behavior

Archival Tagging

Seven green sturgeon from the Rogue River were tagged with pop-off archival tags (PATs) during the fall of 2001 and 2002 (Erickson and Hightower 2004). These tagged green sturgeon made long migrations after they returned to the ocean, traveling from 221 to 968 km before the tags released. All tagged sturgeon traveled in a northward direction. Pop-off locations ranged from the central Oregon coast to northwest Vancouver Island, Canada. During these migrations, these green sturgeon were more active at night than during the day and occasionally made rapid ascents to the surface. They occupied depths of 40-70 m and all of the pop-off locations were inside the 110 m contour.

Logbook Analysis

Oregon bottom trawl logbook records showed that green sturgeon were captured almost exclusively inside of the 110 m contour and had areas of concentration near major ports (Figure 2, from Erickson and Hightower 2004). Logbook data needs to be interpreted cautiously since the observations are not adjusted for effort. This and other reasons for caution are fully discussed by the authors. However the concentration around major ports may have a biological cause since many ports are at the mouth of a major river. The capture of green sturgeon inside of the 110 m contour suggests a shallow distribution as most bottom trawling takes place in waters that are deeper. Bottom trawl catches were also concentrated near major ports, which may be the result of increased effort there, but two of the PAT tags were also released in these areas.

Acoustic Tagging

Studies have been initiated using acoustic tags to investigate green sturgeon migration (S. Lindley and M. Moser pers. comm.). One hundred and sixty-eight green sturgeon were tagged in both spawning areas (Rogue and Klamath rivers and San Pablo Bay) and mixed stock areas (Columbia River and Willapa Bay) in 2002, 2003, and 2004. Receivers were located on the Sacramento, Klamath, Rogue, and Umpqua rivers, Willapa Bay, Cape Elizabeth, Strait of Juan de Fuca, and northern Vancouver Island. To date, the tagging has documented movement of green sturgeon from all spawning areas to Willapa Bay. Surprisingly, the receiver array off the Brooks Peninsula of northern Vancouver Island detected 41 of the sturgeon tagged in 2003, with a number of fish taking up residence in the vicinity of one of the receivers for several weeks. Sustained migrations of 100 km day^{-1} have been documented. Several sturgeon tagged in 2002 have returned to the Rogue River in 2004, raising the possibility of two-year spawning periodicity.

Freshwater Distribution Information

New information about green sturgeon freshwater distribution has been made available from the Chehalis, Umpqua, Rogue, Eel, Sacramento, Feather, and San Joaquin rivers. Much of these data are from personal communications and as such are not comprehensive. These are useful for establishing presence, but the lack of such information should not be interpreted as evidence that green sturgeon do not use the area.

Washington Department of Fish and Wildlife investigated the Chehalis River as green sturgeon habitat and while it appears to possess suitable spawning habitat, there has not been evidence of actual spawning occurring in this basin (WDFW 2004). Data summarized from catch record cards suggest that a few green sturgeon were caught in sport fisheries as far upriver as 60 kilometers during July 2002, March 2003, and December 2003, but these may be misidentifications. Sport anglers have reported small green sturgeon in Greys Harbor; however, these fish were most likely of a post-migratory size and therefore were not 1 - 3 year old fish rearing in the estuary. Eggs and larvae from green sturgeon have not been observed in the Chehalis River or Greys Harbor.

A presumed juvenile green sturgeon was captured at Big Butte Creek (rkm 254) near Lost Creek Dam on the Rogue River (R. Reisenbichler pers. comm.). This is surprising because it is very high in the system and above two major dams with fish ladders (Savage Rapids and Gold Ray) and several smaller dams.

There are two confirmed records of green sturgeon captured above tidal influence in the Umpqua River (T. Rien pers. comm.). In July 2000, two juvenile green sturgeon (each approximately 10-cm long) were regurgitated from two smallmouth bass caught at river kilometer 134 on the Umpqua River. Oregon Department of Fish and Wildlife (ODFW) interviewed the local angling guide and the one available regurgitated fish was positively identified as a green sturgeon. The other regurgitated sturgeon was not available to examine. In April 1979, a 1.8 m green sturgeon was caught at rkm 164 on the Umpqua River. A picture of the fish was published in the Roseburg News Review (May 3, 1979) and it was visually identified as a green sturgeon by ODFW. ODFW has sampled the Umpqua River in 2002, 2003, and 2004 using gill nets, beach seines, snorkeling, and underwater video and their sampling efforts did not detect any green sturgeon above tidal influence in the Umpqua River.

Adult green sturgeon were sighted on the mainstem Eel River near Fort Seward (rkm 101) during snorkel surveys in 1995 and 1996 (S. Downie pers. comm.). Three sturgeon were sighted each year at a place locally known as “The Sturgeon Hole”. Two juvenile green sturgeon were captured in the Eel River Estuary in 1994 by trawl (S. Cannata pers. comm.). The first one was 282 mm FL and the second was 510 mm. This is in addition to the previously reported capture of 26 juvenile green sturgeon near Fort Seward in 1967 and 1968 (Pluckett 1976).

Recent habitat evaluations conducted in the upper Sacramento River for salmonid recovery planning suggests that significant potential green sturgeon spawning habitat was made inaccessible or altered by dams (historical habitat characteristics, temperature, and geology summarized in Lindley et al. 2004). This spawning habitat may have extended up into the three major branches of the Sacramento River; the Little Sacramento River, the Pitt River system, and the McCloud River.

Green and white sturgeon adults have been observed periodically in small numbers in the Feather River (Beamesderfer et al. 2004). There are at least two confirmed records of adult green sturgeon. There are no records of larval or juvenile sturgeon of either species, even prior to the 1960’s when Oroville Dam was built. There are reports that green sturgeon may reproduce in the Feather River during high flow years (CDFG 2002), but these are not specific and are unconfirmed. Salmonid recovery habitat evaluations are also available for the Feather River.

No green sturgeon has ever been documented in the San Joaquin River or its tributaries (CDFG 2002, Beamesderfer et al. 2004). Small numbers of adult sturgeon occur in the San Joaquin River, but all identified to date have been white sturgeon. Small fisheries for sturgeon occur in spring between Mossdale and the Merced River (Kohlhorst 1976). Two unidentified juvenile sturgeon caught at Woodbridge on the Mokelumne River (rkm 63) in 2003 are the first confirmation of sturgeon reproduction in the San Joaquin River system (Beamesderfer et al. 2004). The San Joaquin River and its tributaries have been heavily modified in ways that reduce suitability for sturgeon since the 1940’s, so the lack of contemporary information can not be considered evidence of historical green sturgeon absence.

Catch Information

As noted in the previous status review, the coastwide harvest of green sturgeon has continued to be reduced over time (Table 2). Based on updated and corrected catch numbers, green sturgeon catch has deceased from a high of 9,065 in 1986 to 862 in 2001, the last year in the previous status review, to 512 in 2003. The greatest decreases in harvest were for the commercial gears in the Columbia River, Willapa Bay, and Greys Harbor. This decrease has occurred due to regulatory changes summarized in Adams et al. (2002), Appendix 1 Table 2. Yurok and Hoopa tribal harvest has remained constant; it accounted for 59% of the total green sturgeon catch in 2003.

THE "SPECIES" QUESTION

Previous Species and DPS Determinations

The previous status review recognized North American green sturgeon as a species under the ESA. It also recognized the North American species, *A. medirostris*, as a separate species from the western Pacific Tumnin River population, *A. mikadoi*. The distinction is based on a lower chromosome number in *A. medirostris* (Birstein et al. 1993), even thought there appears to be no difference in meristic or morphometric characters (North et al. 2002).

The previous status review also concluded that green sturgeon have at least two DPSs; a Northern DPS extending north from and including the Eel River and a Southern DPS beginning south of the Eel River. The only known population in the southern DPS is in the upper Sacramento River. This decision was based on: 1) sturgeons generally show fidelity to their spawning sites so they would have a general pattern of multiple DPSs (Bemis and Kynard 1997), and 2) preliminary genetic evidence indicating that there are differences at least between the Klamath and San Pablo Bay populations. This meets the requirement for both discreteness and significance in the DPS policy (USFWS and NOAA 1996). The BRT commented that the available evidence did not exclude the possibility that there were additional DPS(s) that are as yet unidentified.

Discussions and Conclusions for DPS Determinations

The BRT discussed the updated genetic analyses and concluded that the new information further supported their previous conclusion that there are at least a Northern and a Southern DPS. This is particularly apparent in the green sturgeon dendrogram provided by Israel and May (Figure 1, pers. comm.). The split between the group of the Rogue, Klamath, and Umpqua samples and the group of the Sacramento (juveniles) River, San Pablo Bay, and Columbia River samples was made in 100% of the bootstrap runs (Figure 1). The F_{ST} values also show the strong division between the two groups (Table 1).

The Northern DPS is made up of known green sturgeon spawning (or single stock) populations in the Rogue, Klamath, and Eel rivers (Figure 3). The populations in the larger spawning populations of the Rogue and Klamath rivers were considered members of the Northern DPS due to their level of genetic similarity. The Eel River Population was included in the Northern DPS based on an isolation-by- distance argument. The argument is essentially that in a species with spawning fidelity, a population is more likely to be similar to a closer population than a further one. The Umpqua mixed-stock population showed close genetic similarity to the Rogue and Klamath populations.

The Southern DPS currently has only has single spawning population in the Sacramento River (Figure 3). Whether green sturgeon historically spawned in the Feather and San Joaquin rivers is less clear. CDFG (2002) considers the Feather River to be “the most likely loss of spawning habitat [of green sturgeon in the Central Valley]”. CDFG suggests that Oroville Dam blocks access to potential spawning habitat and that Thermalito Afterbay warm water releases may increase temperatures to levels that are undesirable for spawning and incubation. Green sturgeon continue to be occasionally sighted in the Feather River (Beamesderfer et al. 2004) and green sturgeon are thought to enter the Bear River (a lower Feather River tributary) during the spring of most wet years (USFWS 1995b). Salmonid habitat evaluations also suggest spawning habitat above Oroville Dam. No green sturgeon spawning, eggs, larvae, or juveniles have ever been documented in the Feather River (Beamesderfer et al. 2004). The issue of green sturgeon spawning in the San Joaquin River is even more obscure. No green sturgeon has ever been documented in the San Joaquin River, although two adult green sturgeon have been captured in the Delta (Adams et al. 2002). Moyle et al. (1992) suggested that green sturgeon spawn in the San Joaquin River apparently based on the presence of green sturgeon in the Delta. White sturgeon occur the San Joaquin River based on the Kohlhorst (1976) observation that anglers often catch white sturgeon in later winter and early spring and Beamesderfer et al. (2004) reported the catch of two unidentified sturgeon juveniles in the Mokelumne River, the first documentation of any sturgeon reproduction within the Central Valley outside of the Sacramento River.

THE EXTINCTION RISK QUESTION

Species Wide Threats

Ocean and estuarine green sturgeon harvest was considered a species wide threat since its impact could not be apportioned to one DPS or the other (except for the Yurok and Hoopa in-river catches in the Klamath River) (Table 2).   Even catches in San Pablo Bay could be fish that originated in the Northern DPS. Harvest impact would be very different if there were disproportionately high harvest of only one DPS. Current total harvest has been reduced to 6% of its 1986 high value of 9065 fish. The recent reduction is due to newly imposed fishing regulations in Oregon and Washington. Commercial fisheries targeting sturgeon have not been allowed in the Columbia River or Willapa Bay since 2001 (WDFW 2004). Yurok and Hoopa tribal catch has remained relatively constant during the entire time series. The decrease in catch due to changes in regulations represents a reduction in risk to green sturgeon.

The Northern Green Sturgeon DPS

Previous Risk Determination

In the previous status review, a majority of the BRT concluded that there is not sufficient information that shows green sturgeon in this DPS are in danger of extinction or would be likely to become so in the foreseeable future, while a minority of the BRT concluded that green sturgeon in this DPS are not currently in danger of extinction but are likely to become so in the foreseeable future. The BRT judged the Klamath River Yurok catch data to be the most representative available population measure since the data were based on spawning fish rather than on fish involved in their summer concentration behavior. Both catch and CPUE did not have a negative slope, but trends for both were also not statistically significant. The length data did not indicate that large fish were decreasing within the population, but sample sizes were very small. The BRT felt that green sturgeon in this DPS faced significant threats to their population and were concerned about the lack of data and its impact on their ability to make an informed decision.

Sources, Severity, and Geographic Scope of Threats

The BRT identified known threats to green sturgeon in the Northern DPS by river (Table 3). The BRT used three categories to identify spawning rivers in the threat table: known spawning, suspected spawning, and no evidence. Known spawning indicates that some evidence of spawning is available, usually the presence of juveniles. Suspected spawning indicates that the BRT has strong reason to believe that spawning is occurring, usually the presence of adults in freshwater areas above tidal influence. No evidence indicates that there are no records or information available. This category does not automatically imply that no spawning is taking place since there are very few sampling efforts that would detect green sturgeon. The BRT evaluated their ability to rank these threats, but concluded that this was not possible due to the lack of information about their impact on green sturgeon. The principal threats in this DPS are water diversions and the associated impacts of reduced flows, changed flow regime, increased temperatures, and reduced oxygen concentrations. Other major impacts result from land use practices that can lead to increased sedimentation. This DPS also has the only major in-river harvest of green sturgeon (Yurok and Hoopa tribal harvest in the Klamath-Trinity River system).

Discussions and Conclusions

The Northern DPS risk assessment was conducted two years ago and there is little new information. It has two known spawning populations, one in the Klamath-Trinity River system and one in the Rogue River, which spreads the risk over more than one spawning area. In addition, the two systems are not geographically close and thus do not share the same risks due to catastrophic events. Spawning appears to occur infrequently in the Umpqua River. This gives the Northern DPS some additional protection.

Several northern river systems that are not thought to support spawning currently, but may have in the past, were discussed at length by the BRT. BRT opinion ranged from the position that it was unlikely that these systems ever supported significant spawning to the position that we have no way of knowing whether they were major spawning areas. The Fraser River in Canada currently has a catch and release fishery for sturgeon, but the number of green sturgeon captured is extremely small. A tagging study in 1992-1993 tagged 2300 sturgeon and only one was a green sturgeon (D. Lane pers. comm.). Green sturgeon occur off the West Coast of Vancouver Island where there are taken in the trawl fishery. These fish are thought to be from spawning areas in the United States and this idea is supported by the recent acoustic and PAT tagging. WDFW has investigated the possibility of green sturgeon spawning in the Chehalis River as it appears to provide adequate potential spawning habitat. Currently, there are low levels of adult harvest in Greys Harbor (into which the Chehalis River drains), but no evidence of actual spawning activities has been found (WDFW 2004).

Spawning does appear to take place in the Umpqua River, but is probably rare. Juvenile green sturgeon were identified in the system in 2000. Spawning in the Umpqua River apparently is not common since substantial sampling efforts in 2002, 2003, and 2004 failed to find any evidence of green sturgeon spawning.

The extent of green sturgeon spawning in the Rogue River has only been recently understood. The river is less manipulated and habitat seems to be of better quality than in other green sturgeon spawning rivers. Blockages to migration do not seem to be limiting and habitat seems to be roughly what it was historically. Other anadromous salmonid fishes are generally doing well in the Rogue River (Weitkamp et al. 1995, Busby et al. 1996, Myers et al. 1998).

The Klamath River has the largest green sturgeon spawning population. Spawning still occurs upstream to the historical limit of its habitat range (Ishi Pishi Falls). Out-migrant juvenile green sturgeon are captured each year in screw traps at Big Bar (Schieff et al. 2001). The BRT expressed concerns about the temperature regime in the Klamath River, an issue that has been highlighted by recent fish kills. Yurok tribal harvest now accounts for the majority of total coastwide harvest. There is no new information regarding abundance trends since the last status review (Adams et al. 2002). As discussed in the previous status review, the trends in numbers and size are difficult to interpret, but do not raise obvious signs of population decline.

The Trinity River has less data than the Klamath. The Hoopa Tribe has a small in-river fishery which takes less than 30 adult green sturgeon each year (Table 2). Juvenile out-migrant green sturgeon are captured in most years in small numbers at Willow Creek (Schieff et al. 2001). The BRT was not convinced that green sturgeon were extirpated from the South Fork of the Trinity River by the 1964 flood as suggested by Moyle (2002).

The Eel River is the southern most known spawning area in the Northern DPS. Moyle et al. (1992) suggested that green sturgeon were lost from the Eel River following the 1964 flood. This event along with the 1955 flood and combined with land use practices brought large amounts of sediment into the Eel River, and this high sediment level is present today. Some portion of the deep holes that green sturgeon use during spawning were filled in by these events, but the extent is unknown. The BRT was not convinced that green sturgeon were extirpated from the Eel River because of sightings of adults in both 1995 and 1996 and juveniles in the estuary in 1994. The adult surveys were only conducted in those years and the estuary surveys were only conducted in one other year. Nevertheless, the BRT concluded that green sturgeon populations in the Eel River are severely reduced.

The BRT concluded that green sturgeon in the Northern DPS were not in danger of extinction now or likely to become endangered in the foreseeable future throughout all of its range. A majority of the likelihood votes were placed in not being in danger of extinction now or in the foreseeable future category while a minority of the votes were placed in likely to become endangered in the foreseeable future category, and a single vote was placed for in danger of extinction. It should be noted that every BRT member placed at least three votes for likely to become endangered in the foreseeable future category. This indicates the uncertainty associated with making informed decisions with the available data and the potential for change in the levels of risk assessment as more data becomes available. The majority of the BRT felt that the inclusion of two significant spawning rivers in the DPS, the continued reduction in green sturgeon catch, and improvement in data from the Rogue River were encouraging information. A minority felt that there was too much uncertainty in the green sturgeon data and their status may be much worse than we currently understand. The BRT was not convinced that green sturgeon populations were extirpated from the South Fork of the Trinity or the Eel rivers. but concluded that these systems by themselves did not represent a significant portion of the species' range. The entire BRT felt that the green sturgeon populations in this DPS faced serious potential threats that are particularly worrisome given the lack of data to adequately monitor population status. The BRT reiterated their previous comment that the Northern DPS should be placed on the Species of Concern list, that their status be reviewed at least every five years, and that population status monitoring should be implemented.

"Significant portion of its range" discussions are difficult for this DPS because of the lack of historical data about green sturgeon spawning areas. All BRT members felt that historical spawning areas had been larger than they are now, but with no historical data describing spawning areas, there was a range of thought about how much larger. Whether the Eel or Umpqua rivers had supported significant spawning populations was unresolved. The BRT was unable to come to consensus on what should be considered "a significant portion" for this DPS, except that the Eel River was discussed specifically and it was concluded that it would not be considered a significant portion based on what little is known about historical occurrence of green sturgeon in this drainage.

The Southern Green Sturgeon DPS

Previous Risk Determination

In the previous status review, the BRT had mixed conclusions on whether there was sufficient information that shows green sturgeon in this DPS were not in danger of extinction or would be likely to become endangered in the foreseeable future. Every BRT member placed at least four likelihood votes for likely to become endangered in the foreseeable future category. The BRT felt that the single green sturgeon population in this DPS faced an even larger number of potential threats than the Northern DPS including vulnerability due to concentration of spawning, smaller population size, lack of population data, potentially growth-limiting and lethal temperatures, harvest concerns, loss of spawning habitat, entrainment by water projects, and influence of toxic material and exotic species. In the Southern DPS, spawning appears to be concentrated in the upper portion of the Sacramento River that is still accessible to anadromous fish. Catastrophic events have occurred in this DPS, such as the large-scale Cantara herbicide spill which killed all fish in a ten-mile stretch of river upstream from Shasta Dam and the 1977-78 drought that caused year-class failure of winter-run chinook salmon. Population sizes are unknown in this DPS, but are clearly much smaller than in the northern one and therefore the DPS is much more susceptible to catastrophic events. Recent numbers of green sturgeon juveniles documented during salvage operations at state and federal facilities in the Sacramento River Delta remain low compared to levels in the mid-1970's (state facility) and mid-1980's (federal facility). The San Pablo Bay green sturgeon population estimates have limited usefulness due to be based on summer concentrations and because tag recovery effort used in the estimate is unknown. However, the time series of estimates has a non-negative trend and the last estimate (2001) was over four times higher than the next highest estimate.

Sources, Severity, and Geographic Scope of Threats

The BRT identified known threats to green sturgeon in the Southern DPS (Table 4). The BRT evaluated their ability to rank these threats, but concluded that this was not possible due the lack of information about their impact on green sturgeon. The principal threat to this DPS comes from the reduction of green sturgeon spawning area to a single population in the Sacramento River. The Sacramento River has impassible barriers blocking green sturgeon access to what were almost certainly historical spawning grounds upstream from Shasta and Keswick dams constructed in the 1940's and 50's (USFWS 1995b). The same is also true for Feather River and Oroville Dam (USFWS 1995b), completed in 1968. In addition, there are also other migration barriers such as Red Bluff Diversion Dam (RBDD) and Anderson-Cottonwood Irrigation District Dam that don't complete block migrations or only block them seasonally. The Sacramento River now has both reduced and controlled flow (USFWS 1995b). CDFG (1992) and USFWS (1995b) found a strong correlation between mean daily temperature and white sturgeon year-class strength. Similar relationships may exist for green sturgeon. High temperatures no longer seem to be the problem that they once were with the installation of the Shasta Dam temperature control device in 1997, although Shasta Dam has a limited storage capacity and cold water reserves could be depleted in long droughts. Temperatures at RBDD have not been higher than 16^0 C since 1995 (California Data Exchange Center) that is near green sturgeon egg and larvae optimum of 15^0 to 19^0 C (Mayfield and Cech 2004). However, green sturgeon reproduction before 1995 may well have been adversely affected by temperature and these earlier high temperatures may have caused population reductions that would still affect the overall population size and age-structure. The previous status review (Adams et al. 2002) summarized juvenile entrainment and change in annual mean number over time. For the state facility (1968-2001), the average number of green sturgeon taken per year prior to 1986 was 732; while from 1986 on, the average number was 47. For the federal facility (1980-2001), the average number prior to 1986 was 889; while from 1986 on, the average was 32. There is no apparent reason for the large reduction in numbers. These entrainment estimates suffer from problems of species identification (green sturgeon where not identified until 1981 at the federal facility), and the estimates are expanded catches from brief sampling periods (CDFG 2002). Exotic species are an ongoing problem in the Sacramento-San Joaquin River and Delta systems (CDFG 2002).

Probably, the largest problems with exotic species are concerns about the replacement of food items (the exotic bivalve *Potamocorbula amurensis*, introduced in 1988, has become the most common food of white sturgeon and was found in the only green sturgeon so far examined (CDFG 2002). The overbite clam is known to bioaccumulate selenium, a toxic metal (CDFG 2002, Linville et al. 2004]. Green sturgeon may also experience predation by introduced species including striped bass. Sturgeon have high vulnerability to fisheries and the trophy status of large white sturgeon makes these fishes a high priority for enforcement to protect against poaching (CDFG 2002). Green sturgeon are caught incidentally in these white sturgeon fisheries. Pollution within the Sacramento River increased substantially in the mid-1970s when application of rice pesticides increased (USFWS 1995b). Estimated toxic concentrations for the Sacramento River during 1970-1988 may have deleteriously affected striped bass larvae (Bailey 1994). White sturgeon may also accumulate PCB and selenium (White et al. 1989), substances know to be detrimental to embryonic development. While green sturgeon spend more time in the marine environment than white sturgeon and therefore may have decreased exposure, the BRT concluded that some degree of risk probably also occurs for green sturgeon.

Discussion and Conclusions

The Sacramento River contains the only known green sturgeon spawning population in this DPS. There are no updated population trends data since the last status review. The BRT concluded that was almost certainly a substantial loss of spawning habitat behind Keswick and Shasta dams (USFWS 1995b, historical habitat data summarized in Lindley et al. 2004). Green sturgeon occur up to the impassible barrier at Keswick Dam (USFWS 1995b). It is unlikely that green sturgeon reproduced in their current spawning area under the historical temperature regime that occurred before the construction of Shasta and Keswick dams. At the present, water temperatures in the current spawning area are lower due to releases from Shasta Dam. Green sturgeon almost certainly spawned further up the mainstem that they do now. The BRT considers it possible that the additional habitat behind Shasta Dam in the Pitt, McCloud, and Little Sacramento systems would have supported separate populations or at least, a single larger population less vulnerable to catastrophes than one confined to a single mainstem, but were unable to be specific due to the paucity of historical information. The BRT expressed concern about the habitat limitation and potential threats that green sturgeon faced in the Sacramento River and again expressed particular concern about the high numbers of juveniles entrained prior to 1986.

The BRT concluded that a significant population of spawning green sturgeon no longer exists in the Feather River. A substantial amount of habitat in the Feather River was lost with the construction of Oroville Dam. CDFG (2002) concluded that the Feather River is the most likely loss of spawning habitat due to habitat blockage by Oroville Dam and from thermal barriers at the Thermaltio Afterbay facility. USFWS (1995b) stated that “Evidence also suggests that sturgeon reproduction occurs in both the Feather and Bear rivers.” in reference to white sturgeon. Again, the BRT assumed that a similar conclusion could be made for green sturgeon in the face of the paucity of data. Sturgeon (including some documented green sturgeon) still regularly occur in the Bear and Yuba rivers (CDFG 2002, Beamesderfer et al. 2004) and therefore must migrate through the Feather River. Threats to green sturgeon are similar to those faced in the Sacramento River.

The BRT concluded that there was not sufficient information to establish whether the San Joaquin River system had supported a viable green sturgeon population. There is no evidence of green sturgeon occurrence or spawning in the San Joaquin River (Beamesderfer et al. 2004, Adams et al. 2002, CDFG 2002). White sturgeon do occur in the San Joaquin River system, particularly in wet years (CDFG 2002) and the first record of white sturgeon spawning in San Joaquin system was made in 2003 (Beamesderfer et al. 2004). Moyle (2002) suggests that green sturgeon reproduction may have taken place in the San Joaquin River because adult green sturgeon were captured at Santa Clara Shoal and Brannan Island Recreational Area in the Delta. The potential threats faced by green sturgeon if they occurred in the San Joaquin system would be similar in nature to those faced in the Sacramento River, but would probably be more extreme.

The majority of the BRT concluded that the green sturgeon Southern DPS is likely to become endangered in the foreseeable future and only one member concluded that the Southern DPS is not danger of extinction or likely to become endangered in the foreseeable future. The likelihood votes ranged from currently in danger of extinction to not in danger of extinction likely to become endangered in the foreseeable future throughout all its range to not in danger of extinction in the foreseeable future, again reflecting the uncertainty associated with the lack of green sturgeon data. The BRT felt that the blockage of green sturgeon spawning from what were certainly historic spawning areas above Shasta Dam (although it is unclear whether these were separate populations) and the accompanying decrease in spawning area with the loss of the Feather River spawning area make green sturgeon in the Southern DPS at risk of extinction in the foreseeable future. The majority of the BRT also felt that potential threats faced by green sturgeon in this DPS were substantially greater in the Southern DPS than in the northern one, and this made the concentration of spawning adults into the Sacramento River an even greater risk factor.

Identifying what would constitute a “significant portion of the species’ range” would be even more difficult for this DPS because there is only one known spawning population. The BRT concluded that green sturgeon would have spawned above Shasta Dam and there may have been multiple historical populations in that area based on habitat characteristics (historical habitat evaluations summarized in Lindley et al. 2004). The BRT concluded that there was a more substantial probability of a historical spawning in the Feather River than was considered in the previous status review. There was, however, no consensus on how much more likely that was. Ultimately, the discussions on a significant portion were inconclusive due to lack of data and the habitat loss that the Southern DPS had already experienced.

CITATIONS

Adams, P.B., C.B. Grimes, J.E. Hightower, S.T. Lindley, and M.L. Moser. 2002. Status Review for the North American green sturgeon. NOAA, National Marine Fisheries Service, Southwest Fisheries Science Center, Santa Cruz, CA. 49 p.

Bailey, H.C., C. Alexander, C. DiGiorgio, M. Miller, S.I. Doroshov, and D.E. Hinton. 1994. The effect of agricultural discharge on striped bass (*Morone saxatilis*) in California's Sacramento-San Joaquin drainage. Ecotoxicology 3:123-142.

Beamesderfer, R., M. Simpson, G. Kopp, J. Inman, A. Fuller, and D. Demko. 2004. Historical and current information on green sturgeon occurrence in the Sacramento and San Joaquin rivers and tributaries. S.P. Cramer & Associates, Inc. 44 p.

Bremis, W. E. and B. Kynard. 1997. Sturgeon rivers: an introduction to acipenseriform biogeography and life history. Envir. Biol. Fishes 48: 167-183.

Birstein, V. J., A. I. Poletaev, and B. F. Goncharov. 1993. DNA content in Eurasian sturgeon species determined by flow cytometry. Cytometry 14(4): 377-383

Busby, P.J., T.C. Wainwright, G.J. Bryant, L.J. Lierheimer, R.S. Waples, F.W. Waknitz, and I.V. Lagomarsino. 1996. Status Review of West Coast Steelhead from Washington, Idaho, Oregon, and California. NOAA-NWFSC Tech. Memo. 27. 261 p.

California Department of Fish and Game (CDFG). 1992. Sturgeon in relation to water development in the Sacramento-San Joaquin Estuary. Entered by California Department of Fish and Game for the State Water Resources Control Board 1992 Water Rights Phase of the Bay-Delta Estuary Proceedings.

_____. 2002. California Department of Fish and Game Comments to NMFS Regarding Green Sturgeon Listing. 129 p

<u>Defenders of Wildlife v. Norton</u>, 258 F.3d 1136, 9th Cir. 2001

<u>EPIC et al. v. NMFS</u>, No. C-02-5401, N.D. Cal. Filed Mar. 3, 2004

Erickson, D.L. and J.E. Hightower. 2004. Oceanic distribution and behavior of green sturgeon (*Acipenser medirostris*). Unpub. ms. 29 p.

_____, J.A. North, J.E. Hightower, J. Weber and L. Lauck. 2002. Movement and habitat use of green sturgeon *Acipenser medirostris* in the Rogue River, Oregon, USA. J. Appl. Ichthyol. 18: 565–569

Farr, R. A., M. L. Hughes, and T. A. Rien. 2002. Green sturgeon population characteristics in Oregon. Annual Progress Report. Sport Fish Restoration Project F-178-R. 27 p.

Frank, B. Jr. 2002. Northwest Indian Fisheries Commission unpublished green sturgeon catch data.

Hillemeier, D. 2002. Yurok Tribe green sturgeon unpublished catch data. Yurok Tribe.

Houston, J. J. 1988. Status of green sturgeon, *Acipenser medirostris*, in Canada. Canadian Field-Naturalist 102: 286-290.

Israel, J.A., M. Blumberg, J. Cordes, and B. May. 2004. Geographic patterns of genetic differentiation among western U.S. collections of North American green sturgeon (*Acipenser medirostris*). North Amer. Journ. Fish. Man. 24:922-931.

Kautsky, G. 2004. Hoopa Tribe green sturgeon unpublished catch data. Hoopa Tribe.

Kohlhorst, D.W. 1976. Sturgeon spawning in the Sacramento River in 1973, as determined by distribution of larvae. California Fish and Game 62:32-40.

Lindley, S. T., R. Schick, B. P. May, J. J. Anderson, S. Greene, C. Hanson, A. Low, D. McEwan, R. B. MacFarlane, C. Swanson, and J. G. Williams. 2004. Population structure of threatened and endangered chinook salmon ESUs in California's Central Valley basin. NOAA TM NMFS SWFSC 360. 56 p.

Linville, R. G., S. N. Luoma, L. Cutter, and G. A. Cutter. 2002. Increased selenium threat as a result of invasion of the exotic bivalve *Potamocorbula amurensis* into the San Francisco Bay-Delta. Aquatic Toxicology 57: 51-64.

Mayfield, R.B. and J.J. Cech Jr. 2004. Temperature effects on green sturgeon bioenergetics. Trans. Amer. Fish. Soc. 133: 961-970.

Moyle, P.B. 2002. Inland fishes of California. Univ. of Calif. Press, Berkeley, CA. 109-113 p.

Moyle, P. B., P. J. Foley, and R. M. Yoshiyama. 1992. Status of green sturgeon, *Acipenser medirostris*, in California. Final Report submitted to National Marine Fisheries Service. 11 p. University of California, Davis, CA 95616.

Myers, J.M., R.G. Kope, G.J. Bryant, D. Teel, L.J. Lierheimer, T.C. Wainwright, W.S. Grant, F.W. Waknitz, K. Neely, S.T. Lindley, and R.S. Waples. 1998. Status review of chinook salmon from Washington, Idaho, Oregon, and California. NOAA-NWFSC Tech. Memo. 35. 443 p.

<u>National Association of Homebuilders v. Norton</u>, 340 F.3d. 835, 9th Cir. 2003

National Marine Fisheries Service (NMFS). 2001. 66 FR 64793 Endangered and Threatened Wildlife and Plants: 90-Day Finding for a Petition to List North American Green Sturgeon as Threatened or Endangered under the Endangered Species Act: Proposed Rule. *Federal Register* 66 pages 64793-64795. December 14, 2001.

_____. 2002. Biological opinion for the proposed license amendment for the Potter Valley project. Southwest Region, Long Beach, CA. 135 p.

______. 2003. 68 FR 4433: National Marine Fisheries Service. Endangered and Threatened Wildlife and Plants: 12-Month Finding on a Petition to List North American Green Sturgeon as Threatened or Endangered Species: Proposed Rule.   *Federal Register* 68 pages 4433-4441. January 29, 2003.

_____. 2004a. 69 FR 19975: Endangered and Threatened Species; Establishment of Species of Concern List, Addition of Species to Species of Concern List, Description of Factors for Identifying Species of Concern, and Revision of Candidate Species List Under the Endangered Species Act: Notice. *Federal Register* 69 pages 19975-19979. April 15, 2004.

_____. 2004b. 69 FR 34135: Endangered and Threatened Wildlife and Plants: Updated Status Review of the North American Green Sturgeon: Notice. *Federal Register* 69 pages 34135-34136. June 18, 2004.

National Research Council (NRC). 2004. Endangered and threatened fishes in the Klamath River Basin: causes of decline and strategies for recovery. Committee on Endangered and Threatened Fishes in the Klamath River Basin. National Academies Press, Washington, D.C. 424 p.

North, J. A., R. A. Farr, and P. Vescei. 2002. A comparison of meristic and morphological character of green sturgeon *Acipenser medirostris*. J. Appl. Icthyol. 18: 234-239.

Oregon Department of Fish and Wildlife (ODFW). 2002. Rogue Basin Fisheries Evaluation; Effects of reservoir releases on adult salmon during a drought year. Supplemental Report Number 1. 12 p.

Puckett, L. K. 1976. Observations on the downstream migrations of anadromous fishes within the Eel River system. California Department of Fish and Game. Memorandum Report. 35 p. California Department of Fish and Game, Eureka, CA.

Scheiff, A.J., J.S. Lang, and W.D. Pinnix. 2001. Juvenile salmonid monitoring on the mainstem Klamath River at Big Bar and mainstem Trinity River at Willow Creek 1997-2000. USFWS, AFWO, Arcata, CA 95521. 114 p.

Southwest Center for Biological Diversity v. Norton, LEXIS 13661, D.D.C. 2002

United States Fish and Wildlife Service (USFWS). 1981. Klamath River fisheries investigation program, Annual Report - 1980. Acrata, CA. 105 p.

______. 1994. Klamath River fisheries assessment program, Annual Report - 1992. Acrata, CA. 63 p.

_____. 1995a. Working paper on: habitat restoration actions to double natural production of anadromous fish in the Central Valley of California. Volume 2. May 9, 1995. Prepared for the U.S. Fish and Wildlife Service under the direction of the Anadromous Fish Restoration Program Core Group. Stockton, California. 293 p.

_____. 1995b. Working paper on restoration needs: habitat restoration actions to double natural production of anadromous fish in the Central Valley of California. Volume 3. May 9, 1995. Prepared for the U.S. Fish and Wildlife Service under the direction of the Anadromous Fish Restoration Program Core Group. Stockton, California. 544 p.

_____. and National Oceanic and Atmospheric Administration (NOAA). 1996. Policy Regarding the Recognition of Distinct Vertebrate Population Segments Under the Endangered Species Act. Federal Register 61(26) 4721 - 4725.

Washington Department of Fish and Wildlife (WDFW). 2002a. Letter to Ms. Donna Darm. 5 p. (plus enclosures, 28 p.)

_____. 2002b. Letter to Dr. Peter Adams. 5 p.

_____. 2004. Letter to Mr. James Lecky from R. Fuller. 4 p.

Weitkamp, L.A. T.C. Wainwright, G.J. Bryant, G.B. Milner, D. J. Teel, R.G. Kope, and R.S. Waples. 1995. Status Review of Coho Salmon from Washington, Oregon, and California. NOAA-NWFSC Tech Memo-24. 258 p.

White, J.R., P.S. Hoffmann, K.A.F. Urquhart, D. Hammond, and S. Baumgartner. 1989. Selenium verification study, 1987-1988. A report to the California State Water Resources Control Board from the California Department of Fish and Game, April 1989.

Yoshiyama, R.M., E.R. Gerstung, F.W. Fisher, and P.B. Moyle. 2001. Historical and present distribution of chinook salmon in the Central Valley Drainage of California. CDFG, Fish Bull. 179(1): 71-176.

Personal Communications

California Data Exchange Center. http://cdec.water.ca.gov/ California Department of Water Resources. Division of Flood Management.

S. Cannata. CDFG, Fortuna, CA, 95540. 11/5/04. Personal Communication.

S. Downie. CDFG, Fortuna, CA, 95540. 10/8/04. Personal Communication.

J. Israel and B. May. UC Davis, Dept. of Animal Science, Davis, CA, 95616. 11/5/04. Personal Communication.

D. Lane. Malaspina University, Nanaimo, BC. 12/6/04. Personal Communication.

S. Lindley and M. Moser. NOAA, SWFSC, Santa Cruz, CA, 95060. 11/22/04. Personal Communication.

J. McLain. NMFS, Sacramento, CA, 95814. 11/27/2004. Personal Communication.

R. Reisenbichler. USGS, West. Fish. Res. Cent., Seattle, WA, 88115. 11/18/04. Personal Communication.

T. Rien. ODFW, Clackamas, OR 97015. 11/16/04. Personal Communication.

Table 1. F_{ST} comparisons among green sturgeon samples. The analyses are based on nine loci. Significant values are noted with an asterisk that represents α values less than 0.003, which were calculated using a Bonferroni correction for multiple comparisons after 1500 permutations (J. Israel and B. May pers. comm.).

	Columbia	Rogue	San Pablo Bay	Sacramento	Umpqua
Klamath	0.055*	0.004*	0.049*	0.070*	0.002
Columbia		0.060*	0.002*	0.009*	0.050*
Rogue			0.052*	0.072*	0.002
San Pablo Bay				0.002	0.044*
Sacramento					0.065*

Table 2. Harvest of green sturgeon (Numbers) from California, Oregon, and Washington from 1985 to 2003. See footnotes for data sources.

	California			Oregon[c]						Washington[d]						
		Klamath[b]				Columbia River[c]			Willapa Bay			Greys Harbor				
Year	SF Bay[a]	Yurok	Hoopa[f]	Sport	Trawl	Sport	Comm.	Comm.	Sport	Treaty[e]	Comm.	Sport	Treaty[e]	Trawl	Other Treaty[e]	Total
1985	Few	351	10		726	533	1600	1289			227		5	348	67	5156
1986	Few	421	30	153	190	407	6000	925		1	626		3	142	167	9065
1987	Few	171	20	170	124	228	4900	877			770		8	52	349	7669
1988	Few	212	20	258	120	141	3300	1598	4		609	4	1	34	213	6514
1989	Few	268	30	202	210	84	1700	461	4		870	12	2	133	91	4067
1990	Few	242	20	157	143	86	2200	953	2		734	4	9	66	120	4736
1991	Few	312	11	366	242	22	3190	957	0		1527	0	3	99	59	6788
1992	Few	212	3	197	94	73	2160	1002	0		737	0	3	66	4	4551
1993	Few	417	36	293	250	15	2220	290	32		542	112	3	37	20	4267
1994	Few	293	6	160	154	132	240	268	13	6	17	25	22	5	1	1342
1995	Few	131	6	78	29	21	390	78	8		374	96	7	3	65	1286
1996	Few	119	8	210	182	63	610	129	24		137	70	132	1	7	1692
1997	Few	306	16	158	400	41	1614	16	4		316	105	198	6	19	3199
1998	Few	335	10	103	77	73	894	65	12	2	25	28	55	0		1692
1999	Few	204	28	73	21	93	967	9	5		0	29	58	4		1491
2000	Few	162	31	15	12	32	1224	224	5		0	38	50	3		1796
2001	Few	268	10	NA	17	50	342	106	9		0	27	32	1		862
2002	Few	273	5	NA	14	51	163	0	48		7	0	131	4		696
2003	Few	287	16	NA	17	52	46	43	NA		2	NA	46	5		514
2004			12	NA												

[a]CDFG 2002.
[b]USFWS 1994, Hillemeier 2002, Kautsky 2004.
[c]Farr et al. 2002, Rien 2004.
[d]WDFW 2002a,b.
[e]Frank 2002.
[f]Kautsky 2004

Table 3. Historical and current spawning status of green sturgeon within the Northern Distinct Population Segment, including specific threats to river systems (but excluding ocean and estuarine harvest, which is considered as a coastwide threat).

River System	Historical Spawning Status	Present Spawning Status	Threats / Changes
Fraser River	No evidence	No evidence[a]	Availability of appropriate habitat and degradation or alterations to the habitat[b] Local Harvest
Chehalis River	No evidence	No evidence[c]	Local Harvest
Umpqua River	Known spawning	Known spawning[d]	Local Harvest
Rogue River	Known spawning	Known spawning[e]	Common to Savage Rapids[e] and known to occur to Lost Creek Dam[f] Flow management and hydro effects[g] Local Harvest
Klamath River	Known spawning	Known spawning[h]	Increased temperatures[i] Reduced oxygen concentrations[j] Flow regime change[k] In-river harvest[l]
- Trinity River	Known spawning	Known spawning[m]	Reduced flows[n] See Klamath River Threats
- SF Trinity	Suspected spawning[o]	Suspected spawning[p]	1955 and 1964 floods[q] See Klamath River Threats
Eel River	Known spawning[r]	Suspected spawning[s]	1955 and1964 floods[t] Flow management and water transfers[u] Sediment and TMDL[v]

Footnotes

[a] Fraser River green sturgeon are from U.S. spawning populations, but do occur as far north as the Skeena River (D. Lane, pers. comm.).

[b]Houston 1987.

[c]WDFW (2004) notes potential habitat, and has investigated but found no evidence of green sturgeon above tidewater.

[d] Two juvenile green sturgeon (each approximately 10-cm long) were regurgitated from two smallmouth bass caught at river kilometer 134 (fresh water) on the Umpqua River, in June 2000 (T. Rien, pers. comm..).

[e]Erickson et al. (2002)

[f]R. Reisenbichler, pers. comm.

[g]ODFW 2002.

[h]Spawning to Ishi Pishi Falls (Moyle 2002). Juveniles taken annually at Big Bend (Scheiff et al. 2001).

[i]Increased summer temperatures due to lower flows (NRC 2004).

[j]Oxygen concentration decreased due to flow and degradable organic material below Irongate Dam (NRC 2004).

[k]Shift in peak flows from April to March (NRC 2004).

[l]Catch Information and Table 2.

[m]Spawning to Greys Falls (Moyle 2002). Juveniles taken in most years at Willow Creek (Scheiff et al. 2001).

[n]Trinity River flows reduced 88% (NRC 2004).

[o]1978 CDFG Letter (referenced in USFWS 1981, but not located).

[p]Willow Creek trap located down stream of S.F. Trinity confluence.

[q]Moyle et al. 1992.

[r]Juveniles sampled 1968 and 1969 (Plunkett 1976).

[s]Adults reported 1995 and 1996. S. Downey, pers. comm.

[t]Historic reductions to chinook populations from which they never recovered (Moyle 2002).

[u]Summer flows are lower and decrease earlier than historical flows (NMFS 2002).

[v]Loss of habitat due to sedimentation from land use practices and large scale floods (NMFS 2002).

Table 4. Historical and current spawning status of green sturgeon within the Southern Distinct Population Segment, including specific threats to river systems (but excluding ocean and estuarine harvest, which is considered as a coastwide threat).

River System	Historical Spawning Status	Present Spawning Status	Threats / Changes
Sacramento River	Known spawning	Known spawning[a]	Impassible barriers (Keswick and Shasta dams)[b] Adult migration barriers[c] Insufficient flow[d] Increased temperatures[e] Juvenile entrainment[f] Exotic species (e.g., striped bass)[g] Poaching[h] Pesticides and heavy metals[i] Local Harvest
Feather River	Suspected spawning	No evidence[j]	Impassible barriers (Oroville Dam)[k] See Sacramento River Threats
San Joaquin River	No evidence[l]	No evidence[m]	Impassible Barriers (Friant Dam)[n] Extreme low flow[o] See Sacramento River Threats

Footnotes

[a]Juvenile green sturgeon captured in most years at Glen Colusa Irrigation District and Red Bluff Diversion dams (Adams et al. 2002, Fig. 15).

[b]UFSWS 1995a

[c]Other barrier that are not impassible, RBBD and ACID (USFWS 1995b, CDFG 2002). Also, sturgeon attracted to stranding areas such as Yolo Bypass (J.McLain, pers. comm.).

[d]White sturgeon recruitment strength related to flow (CDFG 1992, USFWS 1995b).

[e]High water temperatures previous to winter-run chinook flow management (J. McLain, pers. comm.).

[f]Green sturgeon (age-0 fish) impinged in State and Federal water export facilities in the Sacramento-San Joaquin Delta (Adams et al. 2002).

[g]Replacement of food items and possible predation by striped bass (CDFG 2002).

[h]Take associated with white sturgeon poaching (CDFG 2002).

[i]Urban, agricultural, and trace metal contamination (USFWS 1995b).

[j]CDFG (2002) suggests that the Feather River is likely lost spawning habitat due to occurrence of adults. No juveniles or larvae have ever been observed in the Feather River.

[k]No evidence of spawning but continued presence of green sturgeon in the Feather and Yuba rivers suggest that they are trying to migrate into presumed spawning areas now blocked by Oroville Dam.

[l]Adult presence documented in Delta (Adams et al. 2002). Evidence of white sturgeon spawning in San Joaquin (Beamesderfer et al. 2004). Accounts of unspecified sturgeon sport catch in San Joaquin River as far as the Merced River (Kohlhorst 1976).

[m]Beamesderfer et al. 2004.

[n]San Joaquin River and tributaries block by dams (Yoshiyama et al. 2001).

[o]Vernalis flows as low as 17% of minimum targets (J. McLain, pers. comm.).

Figure 1. UPGMA dendrogram from green sturgeon samples was built using Nei's unbiased minimum genetic distance. The distance between each collection was calculated by bootstrapping 1000 times and node support represented as a percentage of the trees which displayed similar topology (J. Israel and B. May pers. comm.).

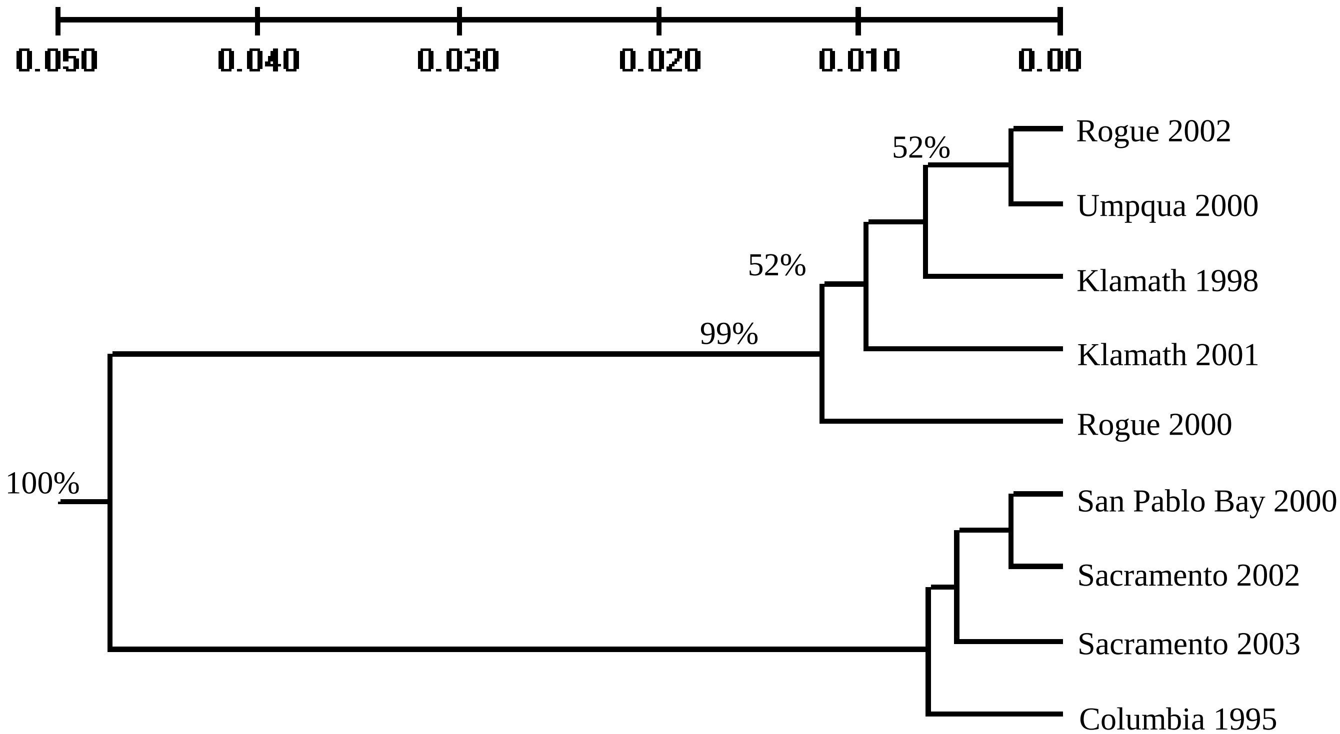

Figure 2. Locations of bottom-trawl sets made during 2000 (circles) and bottom-trawl sets that caught green sturgeon during 1993 - 2000 (crosses) along the Oregon and Washington coasts (from Erickson and Hightower 2004).

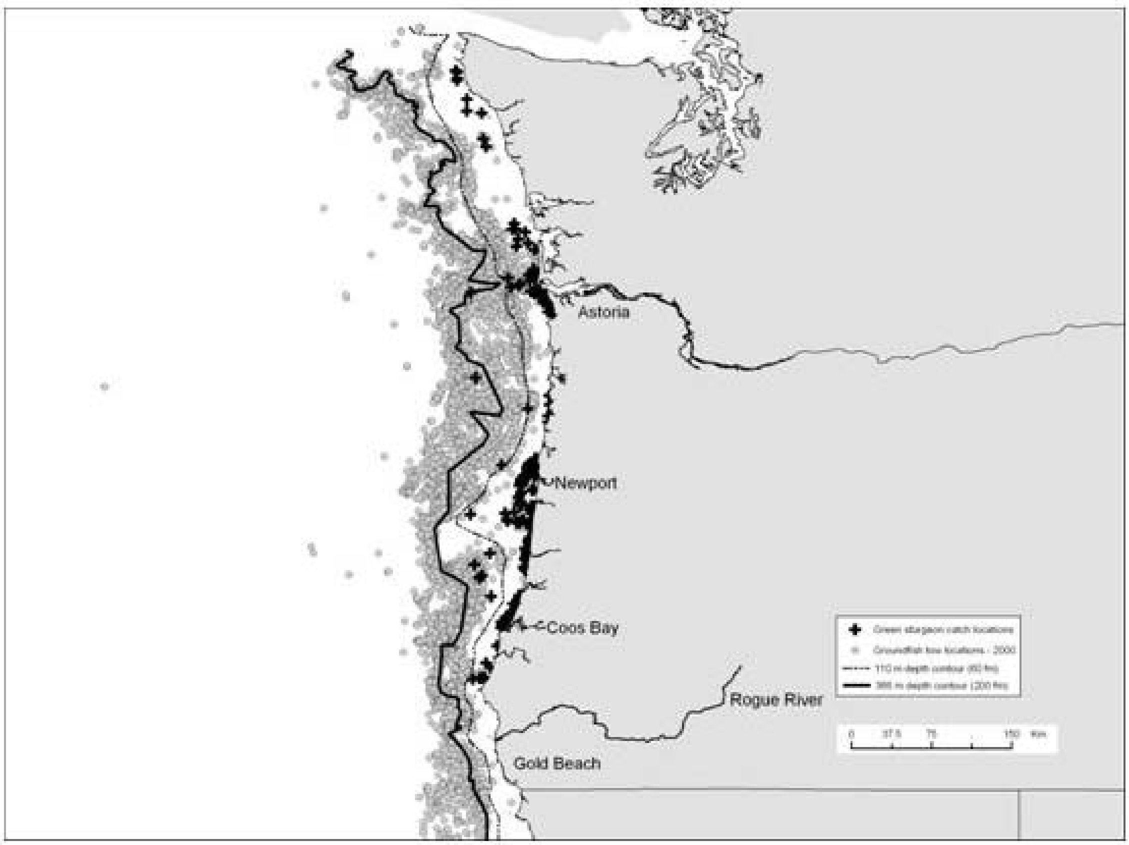

Figure 3. Green Sturgeon Distribution and Distinct Population Segments.