2014 Informal status review for the Northern Distinct Population Segment of the North American green sturgeon (*Acipenser medirostris*)

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Summary

This review examines new information about the Northern Distinct Population Segment (DPS) of green sturgeon (*Acipenser medirostris*) to assess its status as a Species of Concern (i.e., to verify whether its current position on the NMFS Species of Concern List is still appropriate). Based on the last status review in 2005, NMFS concluded that the Northern DPS did not warrant listing under the Endangered Species Act (ESA), but designated the species as a NMFS Species of Concern, due to concerns about fisheries harvest, alterations to freshwater habitat, and the lack of population data. The following summarizes our evaluation of and conclusions based on the new information that has become available since 2005 about the Northern DPS' abundance, productivity, distribution, life history characteristics, and threats.

Abundance, productivity, and life history characteristics:

The new information that has become available does not suggest that the status of the Northern DPS in terms of its abundance and productivity has changed since the last review. Recent studies are providing the first data upon which abundance estimates can be based in the future, and indicate that Northern DPS spawning populations are greater in abundance compared to the Southern DPS population. Continued monitoring in both the Klamath and Rogue rivers will provide insight on trends in abundance into the future. No new information on life history characteristics has become available since the last review. Overall, no change in status is suggested based on the information available about the Northern DPS' abundance, productivity, and life history characteristics.

Distribution:

New information has become available to increase our understanding of the distribution of Northern DPS green sturgeon within freshwater rivers and throughout the U.S. West Coast. Tagging and genetic studies uphold the distinction between Northern and Southern DPS spawning rivers, and also show continued gene flow between the Klamath and Rogue river populations within the Northern DPS. This gives the Northern DPS a degree of greater resiliency compared to the Southern DPS, which spawns in only the Sacramento River system. Within the Klamath and Rogue rivers, Northern DPS green sturgeon appear to occupy specific locations or holding areas, with migration and holding patterns influenced by flow and temperature. Temperature has also been found to affect the development and survival of early life stages, with varying tolerance ranges for embryos, larvae, and juveniles. The limited distribution of adults and the influence of flow and temperature on different life stages suggest a certain degree of vulnerability to threats such as poaching and alterations to freshwater habitat. Tagging and genetic

studies have also provided additional insight into the Northern DPS' migratory patterns and seasonal occupancy in coastal estuaries, where Northern DPS fish form mixed aggregations with Southern DPS fish and likely benefit from protections for the Southern DPS. Overall, there has been a substantial increase in information about the distribution, habitat use, and migratory patterns of the Northern DPS. This information indicates that the Northern DPS remains vulnerable to threats, but does not suggest a change in the degree of vulnerability or severity of threats. Thus, no change in status is suggested based on the information available about the Northern DPS' distribution.

Threats:

Non-tribal fisheries harvest of Northern DPS green sturgeon has decreased since the last review given that retention is no longer permitted in any State or Federal commercial or recreational fishery. Incidental catch continues to occur in these fisheries, but has been reduced and is not expected to increase in the future. Harvest in the Klamath River Yurok Tribal fishery still occurs, but increasingly strict fishery regulations have been implemented to constrain catch. Improvements to freshwater and estuarine habitat conditions have also been implemented or are likely in the near future. The removal of the Savage Rapids Dam on the Rogue River in 2009 could have a small, positive impact on green sturgeon in high flow years, and the potential removal of dams in the Klamath River is likely to result in long-term benefits by restoring historic temperature and flow profiles, although short-term increases in sediment load could have negatively affect green sturgeon. The use of carbaryl to control burrowing and mud shrimp populations in Washington estuaries has declined and is to be phased out in the near future, reducing the effects on green sturgeon prey resources and exposure of individual fish to this pesticide. Research is currently being conducted on the effects of imidacloprid (a proposed alternative to carbaryl) on green sturgeon. Dredging and the presence of Japanese eelgrass (*Zostera japonica*) and an invasive isopod in coastal estuaries may affect green sturgeon and their habitat, but additional research is needed to assess these impacts.

Other threats have been identified but have a great degree of uncertainty. For example, climate change impacts could alter flow and temperature regimes in freshwater rivers, but the predictions are highly uncertain, as are the mechanisms by which water flow and temperature influence green sturgeon spawning, recruitment, and rearing. The potential response of Northern DPS fish to changing ocean conditions is also difficult to evaluate given that green sturgeon adults and subadults use a wide range of temperature, salinity, and dissolved oxygen levels. Offshore and nearshore kinetic energy projects could result in mortality, habitat loss, or impacts on migration and habitat use due to sensitivity to low levels of electromagnetic fields; however, studies are just beginning to be conducted to evaluate these impacts. Overall, some threats have been reduced while several threats remain, indicating no change in status based on an evaluation of threats.

In summary, our understanding of the Northern DPS' abundance, distribution, habitat use, and migratory patterns has increased since the last review, but uncertainties remain. Concerns identified in the last status review regarding the lack of population data and the threats of fisheries harvest and alterations to freshwater habitat have been addressed to some degree. New research is yielding information upon which abundance estimates can be calculated and tracked, and continued monitoring is essential. The threat of fisheries harvest has been greatly reduced, but Northern DPS

fish continue to be incidentally captured in state, federal, and tribal fisheries.

Dam removals have been conducted or are likely to occur in the two spawning rivers. Thus, improvements have been made, but threats remain. Northern DPS green sturgeon face a number of other threats, including climate change impacts, chemical applications in feeding areas, and the possible impact of kinetic energy projects. Continued efforts to build upon the knowledge that has been gained about the Northern DPS' status and biology are needed to address the uncertainty in evaluating these threats. Overall, the new information that has become available since the last status review has added substantially to our understanding of the Northern DPS and shows a reduction in threats, particularly the threat posed by fisheries. However, remaining uncertainties about abundance and persistent threats continue to be concerns for the Northern DPS. Consideration of these factors led to the conclusion that a Species of Concern classification is still warranted. Thus, Northern DPS green sturgeon should remain on the NMFS Species of Concern list.

Background and Introduction

The North American green sturgeon, *Acipenser medirostris*, occurs along the west coast of North American from the Bering Sea, Alaska (Colway and Stevenson 2007) to Baja California, Mexico (Rosales-Casian and Almeda-Juaregui 2009). North American green sturgeon are infrequently encountered at the extremes of their range in Mexican and Alaskan waters. The population structure of green sturgeon is described below.

In 2002, a status review was conducted by a Biological Review Team (BRT) in response to a 2001 petition to list North American green sturgeon under the Endangered Species Act (Adams *et al.* 2002). The BRT identified the Northern and Southern DPS structure that is currently applied and concluded that green sturgeon in both DPSs should be placed on the Species of Concern list (then the Candidates species list) and their status reviewed within five years (Adams *et al.* 2002). In 2005, NMFS' Southwest and Northwest Fisheries Science Centers updated the Status Review as a 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" (BRT 2005). The BRT updated the review and concluded that the Northern DPS was not in danger of extinction now or likely to become endangered in the foreseeable future throughout all of its range. 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.

On April 7, 2006, NMFS published notification of the listing of the Southern DPS of North American green sturgeon as Threatened (71 FR 17757). The DPS structure for North American green sturgeon was originally defined as follows: (1) a Northern DPS consisting of populations in coastal watersheds northward of and including the Eel River (''Northern DPS''); and (2) a Southern DPS consisting of coastal and Central Valley populations south of the Eel River, with the only known spawning population in the Sacramento River (''Southern DPS'') (71 FR 17757; April 7, 2006). The definition was slightly revised for accuracy with the announcement of the critical habitat designation, as follows: (1) a Northern DPS consisting of populations originating from coastal watersheds northward of and including the Eel River (*i.e.,* the Klamath and Rogue rivers) ("Northern DPS"); and (2) a Southern DPS consisting of populations originating from coastal watersheds south of the Eel River, with the only known spawning population in the Sacramento River ("Southern DPS") (74 FR 52300; Oct. 9, 2009). In the April 7, 2006 listing notification (71 FR 17757), the

Northern DPS was identified as a NMFS Species of Concern, but was not listed under the ESA. NMFS stated that it would revisit the status of both DPSs in five years' time.

In the original status review (Adams *et al.* 2002), Northern DPS green sturgeon were placed on the Candidates list because of the considerable threats faced by the populations, including concentration of spawning, lack of population data, harvest concerns and loss of spawning habitat. In the 2005 update (BRT 2005), Northern DPS green sturgeon were designated as a Species of Concern based upon serious threats to the populations that were particularly worrisome given the lack of data to adequately monitor population status. The threats that were identified included those in Table 1. The BRT was encouraged by the fact that the Northern DPS consisted of two spawning rivers, green sturgeon catch had been decreasing, and improved data were available from Rogue River monitoring and concluded that the Northern DPS was not in danger of extinction now or likely to become endangered in the foreseeable future throughout all of its range.

In 2004, NMFS described the factors for identifying a species as a Species of Concern (69 FR 19975). When considering whether a species is a Species of Concern, NMFS considers demographic and genetic diversity concerns, as further elaborated by the following factors: abundance and productivity; distribution; and life-history characteristics. These factors are considered with regard to existing threats. The weight given to certain factors may differ among species.

This document serves as a review of the status of the Northern DPS of North American green sturgeon. The report is organized into sections corresponding to the factors used to designate a Species of Concern (69 FR 19975), namely the demographic and genetic diversity factors of abundance and productivity, distribution, life-history characteristics, and threats. Since no formal process is dictated for Species of Concern, the following process was used:

1) Survey literature published since 2005;
2) Contact experts (see list in Appendix I) for new information about Northern DPS green sturgeon;
3) Include a call for information about Northern DPS green sturgeon in the Federal Register (FR) notice regarding the 5 year status review for the ESA-listed Southern DPS of North American green sturgeon (77 FR 64595);
4) Synthesize findings from literature search, expert contact, and submitted FR notice comments into a report that considers the best available information for the relevant factors and threats to decide whether the Northern DPS should remain a Species of Concern; and
5) Conduct internal review to determine if the Species of Concern designation is appropriate.

Demographic and genetic diversity factors:

1) Abundance and productivity: magnitude of decline, natural rarity, and endemism

Northern DPS green sturgeon primarily spawn in the Rogue River in Oregon and Klamath- Trinity system in California and occupy coastal areas from Mexico to Alaska. Northern DPS green sturgeon can be considered naturally rare, since spawning is limited to certain rivers and specific habitats

within these river systems (Table 1; see additional habitat information in this and subsequent sections). The range of the Northern DPS has likely contracted, given historic accounts of spawning in some rivers and only limited recent records of occurrence in those systems (e.g., Eel River, South Fork of Trinity River; Table 1; Adams *et al.* 2002; BRT 2005).

As detailed in the last status reviews, population trends from fishery data indicated that the adult population in the Klamath River is fairly constant (Adams *et al.* 2002, 2007). Van Eenennaam *et al.* (2006) also suggested that the Klamath River has a potentially stable spawning population but that flow, temperature and other necessary habitat factors need to be characterized and protected. No new information collected for this review suggests a different conclusion than described in these studies.

Recent fisheries independent surveys are gathering the first numbers upon which an abundance estimate can be based in the future. Ethan Mora (UC Davis) used Dual Frequency Identification Sonar (DIDSON) surveys to estimate the number of adults in areas on the Klamath, Rogue and Sacramento rivers (Mora 2012). Numbers were higher in the years surveyed in the Klamath (2010: 349 ± 52; 2011: 471 ± 42) and Rogue (2010: 327 ± 50; 2011: 454 ± 46) Rivers as compared to the Sacramento (6/7/10: 164 ± 47; 7/6/10: 245 ± 64; 6/16/11: 220 ± 42) River. Given a spawning periodicity of every two to four years, these values do not represent the total spawning population, but only the spawning individuals detected in the areas of the river surveyed during that year. Mora (2012) noted that Northern DPS surveys were conducted on a limited time basis and in a two-week sampling period. In the Klamath River, 84 sample areas along the mainstem between the Klamath River estuary and the confluence with the Salmon River were surveyed and the study did not evaluate the Salmon or Trinity River. In the Rogue River, sampling occurred in areas between the estuary and Blossom Bar and generally occurred in the first two weeks of July. Green sturgeon were likely present in areas upstream of the upper boundary of the survey. As a result, the numbers of green sturgeon present in the Klamath and Rogue River basins are likely biased low. Additional years of survey data are necessary to fully characterize the spawning populations in these rivers, particularly given the spawning periodicity of two to four years.

Washington Department of Fish and Wildlife (WDFW) is working to generate an estimate of subadult and adult green sturgeon in Willapa Bay, Grays Harbor and the Columbia River based on tagging studies and subsequent analyses (WDFW 2013). Preliminary results of abundance vary from 4,027 to 65,274 individual subadult and adult green sturgeon, with most models estimates exceeding 20,000 individual green sturgeon (WDFW 2013). Based upon genetic information, 40% of these individuals would belong to the Northern DPS (WDFW 2013).

No new evidence suggests that the status of the Northern DPS in terms of its abundance and productivity has changed since the last review. Recent studies are providing the first data upon which abundance estimates can be based in the future. Continued monitoring of adults within the Klamath and Rogue Rivers will provide insight on trends in adult abundance.

2) *Distribution: Population connectivity, limited geographic range, and endemism*

2a) Freshwater Distribution and Behavior

As stated above and in the last status review, the Northern DPS of North America green sturgeon is known to spawn in two river systems: the Rogue River in Oregon and Klamath-Trinity system in

California (Adams *et al.* 2007). Spawning may also occur in the Eel and Umpqua rivers (Van Eenennaam *et al.* 2006; Adams *et al.* 2007). Lindley *et al.* (2011) indicated that spawning in the Umpqua River is rare, given that large green sturgeon have been detected in the estuary but not upstream from tidal influence. The Umpqua appears to support an important area for summer and autumn holding. In the Klamath, green sturgeon appear to be restricted to an area well below Iron Gate Dam (rkm 306.1), with an upstream limit of distribution of Ishi-Pishi Falls (rkm 108) (Hamilton *et al.* 2005). While some green sturgeon may presently migrate beyond the confluence of the Salmon and Klamath rivers, they are the exception rather than the rule. Green sturgeon may also occur in the Coos River (Farr and Kern 2005). No new information is available on green sturgeon in the Eel or Chehalis rivers or in the South fork of the Trinity River.

Recent work lends insight regarding spatial structure and population ecology within river systems. Northern DPS green sturgeon migrate into rivers in late winter to early summer and spawn with a peak in spring and early summer months (Van Eenennaam *et al.* 2006; Erickson and Webb 2007; Benson *et al.* 2007). Green sturgeon in the Rogue River mature at 145 cm TL (males) and 166 cm TL (females) (Erickson and Webb 2007). Outmigration from the Rogue generally occurs in the fall or early winter (Erickson and Webb 2007), while outmigration from the Klamath can occur at earlier times in the spring as well as in the fall (Benson *et al.* 2007). There are generally two or more years between spawning intervals, with two to four years a generally cited interval (Erickson and Webb 2007; Webb and Erickson 2007).

Benson *et al.* (2007) tagged 49 sexually mature Northern DPS green sturgeon with radio and/or sonic telemetry tags in the Klamath and Trinity Rivers during the upstream migration. The authors tracked the tagged animals in the Klamath, Trinity and Salmon Rivers from 2002 to 2004. The work identified four movement patterns, including upstream spawning migration, spring outmigration, summer holding, and fall outmigration after summer holding. The importance of flow and temperature in signaling migration of green sturgeon in the Klamath- Trinity system was detailed in the study. Increasing flows seemed to trigger outmigration in the spring while increased flow combined with temperatures of 10-12ºC triggered fall outmigration. McCovey *et al.* (2009, 2010) detailed tagging and receiver placement in and around Klamath River and movement of tagged individuals. The samples sizes were very small, so no generalizations could be made from the studies.

Erickson and Webb (2007) tagged 103 individual green sturgeon in the Rogue River between 2000 and 2004 with radio and/sonic telemetry tags, followed migrations for multiple years and conducted histological and visual examinations to look at maturity and spawning stage. Webb and Erickson (2007) used biological samples collected from animals captured in Erickson and Webb (2007) and performed studies on tissue and blood chemistry to confirm that Rogue River green sturgeon are reproductively active and spawning. Preliminary results from these studies were discussed in Adams *et al.* (2002). The migration of green sturgeon into the Rogue River appears to be correlated with water temperature. Green sturgeon entered the river and initiated spawning migrations when temperatures were 8.8 to 16.4ºC and all ripe individuals were caught when temperatures were ranged from 9.7 to 18.0ºC. Spawning at temperatures below 18ºC is consistent with the thermal optima for the survival of green sturgeon embryos in the laboratory (Van Eenennaam *et al*. 2005; see additional details below).

Outmigration during late-fall and early winter corresponded with increased flows and water temperatures dropping to near 10ºC. In addition to the findings cited above, the authors found that

migration distance upstream is positively correlated with increased water flow since green sturgeon migrated farther upriver in high flow years. The work calls attention to the fact that flow manipulation in the Rogue River could affect green sturgeon migration.

Temperature is also an important variable in the success of green sturgeon recruitment. Van Eenennaam et al. (2005) found that the hatching rate for green sturgeon eggs in the lab was slightly reduced when incubation temperatures were less than 11°C and that 17-18°C may be the upper thermal optima for embryogenesis. Laboratory studies found survival of green sturgeon larvae to be optimal at 18-20°C, sub-optimal at 22-26°C and lethal at 28°C (Linares-Casenave *et al.* 2013). Developmental abnormalities have been observed in green sturgeon larvae in laboratory conditions at 26°C (Werner *et al.* 2007). Optimal bio-energetic performance of age-0 and age-1 green sturgeon in the laboratory occurred at temperatures between 15-16°C, with an upper limit of 19°C (Mayfield and Cech 2004). Juvenile green sturgeon (mean age: 150 days) can handle elevated temperatures in the laboratory (up to 24°C tested) without showing compromised swimming performance, but temperatures above 19°C were correlated with higher expression of heat shock proteins (Allen *et al.* 2006).

A recent study by Allen *et al.* (2009) used trace element analysis to examine the age at which juvenile green sturgeon in the Klamath River system move from fresh to salt water. Juveniles appear to move to areas of moderate salinity (e.g. estuaries) between 6 months to 1.5 years of age. The study suggests that juvenile green sturgeon either remain in or regularly move back into seawater after their initial movement to the seawater environment. The ability to osmoregulate in seawater appears to develop around 1.5 years of age (Allen and Cech 2007).

The recent surveys conducted by Ethan Mora (UC Davis) mentioned above provide further information on the spatial occupancy of Northern DPS green sturgeon within the Klamath and Rogue rivers (Mora 2012). In the Klamath River, Mora (2012) conducted surveys in 84 different sampling locations in both 2010 and 2011. Green sturgeon were detected in nine of these locations in both years and in 14 and 16 locations in 2010 and 2011, respectively. In the Rogue River, green sturgeon were detected in 10 sampling locations in both years and 13 and 18 locations in 2010 and 2011, respectively. These data indicate that Northern DPS green sturgeon occur in limited areas of each river. A similar pattern was seen in data on the Southern DPS in the Sacramento River.

In 2011, Washington Department of Fish and Wildlife (WDFW) and Oregon Department of Fish and Wildlife (ODFW) found an age-0 green sturgeon in the Columbia River downstream of the Bonneville Dam (WDFW and ODFW 2012). This is the first time an age-0 green sturgeon had been observed in the Columbia River. Since the specimen was retained and preserved, genetic analysis could confirm its DPS of origin. Genetic analysis performed to date has confirmed that the animal is a green sturgeon but has not assigned the DPS of origin.

As noted in the 2005 review, green sturgeon are occasionally encountered in the Fraser River, Canada. Between 1999 and 2011, nine green sturgeon were recorded in the Lower Fraser in the Fraser River Conservation Society (FRCS) monitoring and assessment program database (all information below references pers. comm. with Troy Nelson, FRCS, December 17, 2013). Over 82,000 records are included in the database, over 34,000 of which are records of recapture events. There are likely to be a few more green sturgeon than those positively identified because positive identification to the species level is not always accomplished and not all sightings may be recorded in

the database. Most records are from the tidal section of the river, where most of the sampling effort took place. One of the nine green sturgeon observations was made by a First Nations fisherman while the others were made through the FRCS monitoring program or test fisheries conducted in the region.

2b) Oceanic and Coastal Distribution and Behavior

The 2005 Status Review update focused on the Erickson and Hightower (2007) study on green sturgeon tagging in the Rogue River. This paper detailed migrations of seven (7) green sturgeon that had been tagged in the Rogue River. All tagged sturgeon left the river and migrated north, with pop-off locations from Central Oregon coast to NW Vancouver Island, Canada. Depths occupied were 40-70m and all pop-off locations were inside the 110 m contour.

Erickson and Hightower (2007) reiterated the Status Review update information regarding archival tagging as this is the publication that describes the work mentioned in the update. The authors tagged seven (7) green sturgeon in the Rogue River during the autumn months of 2001 and 2002 with pop-up archival tags and used the data from these tags as well as data from trawl log-books to look at green sturgeon movement. Green sturgeon show congregating behavior in Oregon, Washington and NW Vancouver Island. The research also supports the fact that Northern DPS green sturgeon move between the Rogue and Klamath River.

Within the nearshore marine environment, North American green sturgeon prefer waters of less than a depth of 110 m (Erickson and Hightower 2007). Tagging data indicate that green sturgeon typically occupy depths of 20-70 m while in marine habitats (Erickson and Hightower 2007; Huff *et al.* 2011) and make rapid vertical ascents while in marine environments, often at night (Erickson and Hightower 2007). Temperatures occupied in the marine environment range from 7.3-16 °C, with a range of mean temperatures from 10.5-12.5 °C (Erickson and Hightower 2007; Huff *et al.* 2011). It should be noted that depth and temperature range preferences displayed by the individual green sturgeon studied was considerable.

Lindley *et al.* (2008) tagged 213 subadult and adult Northern and Southern DPS green sturgeon in the Columbia River estuary, Klamath River, Rogue River, San Pablo Bay (California), and Willapa Bay (Washington) with ultrasonic pingers and tracked the animals through arrays of automated hydrophones deployed along the North American west coast. The authors found that many green sturgeon migrate annually along the continental shelf, traveling from U.S. to Canadian waters in the fall and returning in the spring. The work corroborates earlier findings of concentrations of green sturgeon in the northwest Vancouver Island area during May through June and October through November and calls attention to the potential for green sturgeon to be affected by Canadian bottom trawl fisheries (see Catch Information section below). The work also noted detection of only one tagged green sturgeon in southeast Alaska, reinforcing the idea that green sturgeon only rarely travel into Alaskan waters. The DPS origin of the individual is unknown.

Expanding on this, Lindley *et al.* (2011) described the movements of 355 Northern and Southern DPS green sturgeon tagged with acoustic transmitters in the Columbia River estuary, the Klamath River, the Rogue River, San Pablo Bay, the Sacramento River, Willapa Bay, and Grays Harbor. The authors describe green sturgeon occurrence in estuarine and coastal sites (Columbia River estuary, Willapa Bay, Grays Harbor, and the estuaries of smaller rivers in Oregon, especially the Umpqua River estuary) in summer months as noted above. Green sturgeon from different natal rivers exhibited

different patterns of habitat use, with San Francisco Bay used only by Sacramento River fish and the Umpqua River estuary used mostly by fish from the Northern DPS Klamath and Rogue rivers. The Columbia River was visited by fish from the Rogue and Klamath River populations as well as the Sacramento, with the Northern DPS found in higher proportion to the Southern DPS in 2005 in the Columbia River estuary, and the Southern DPS found in higher proportion in 2006. Based on genetic analysis of samples collected in 1995, 1999, and 2004, Israel *et al.* (2009) found that Southern DPS green sturgeon occurred at higher frequency in the Columbia River in the three years sampled. As such, there may be substantial inter-annual variation in the use of some habitats. Relatively small sample sizes may have biased these results.

Lindley *et al.* (2011) further confirmed the green sturgeon DPS structure given that green sturgeon tagged in the Klamath or Rogue Rivers were not detected at the Golden Gate Bridge area and green sturgeon tagged in San Pablo Bay/Sacramento River area were not detected in the Rogue or Klamath Rivers. Green sturgeon tagged in the Klamath River were detected in the Rogue River, consistent with the idea that green sturgeon originating from the two rivers belong to one DPS. Movement between the two rivers was infrequent, however, suggesting that the Klamath and Rogue River should be managed separately. Northern DPS green sturgeon showed a high affinity for the Umpqua River estuary. New acoustic tagging studies in the Umpqua estuary found that only a small number of tagged fish (three of 20) were subsequently detected in the Sacramento River (WDFW and ODFW 2012).

As stated above, adult and subadult Northern and Southern DPS green sturgeon have been observed in large concentrations in the summer and fall within coastal bays and estuaries along the west coast of the US, including the Columbia River estuary, Willapa Bay, and Grays Harbor (Moser and Lindley 2007, Lindley *et al.* 2008, 2011; WDFW and ODFW 2012). Moser and Lindley (2007) used acoustic telemetry to examine behavior of green sturgeon that had been tagged in Willapa Bay and the Columbia River. The authors found that bay and estuary areas, particularly Willapa Bay, are likely used for foraging in the summer months and possibly as thermal refugia (Moser and Lindley 2007). Recent fieldwork indicates that green sturgeon generally inhabit specific areas of coastal estuaries near or within deep channels or holes, moving into the upper reaches of the estuary, but rarely into freshwater (WDFW and ODFW 2012). Green sturgeon in these estuaries may move into tidal flats areas, particularly at night, to feed (Dumbauld *et al.* 2008). The Northern and Southern DPSs both display intra-population level diversity in spatial and temporal use of coastal estuaries that somewhat corresponds to size and does not correspond perfectly with natal origin (Lindley *et al.* 2008, 2011). Intra- and inter- estuary movement of green sturgeon occurs, for example, within Willapa Bay and between Willapa Bay and the Columbia River (Moser and Lindley 2007; WDFW and ODFW 2012).

2c) Genetic Information

The last status review showed strong genetic division between North American green sturgeon in Northern DPS (Rogue, Klamath and Umpqua Rivers) and Southern DPS (Sacramento River plus San Pablo Bay areas plus the Columbia River). The reason behind the Columbia River fish grouping with the Southern DPS is presumed to be a result of study design or learned migratory or feeding behavior (e.g., Southern DPS green sturgeon use the Columbia River disproportionately more than Northern DPS fish).

Israel *et al*. (2009) detailed the genetic analysis of 20 collections of green sturgeon samples using 10

microsatellite loci to examine the DPS composition in different estuaries along the US west coast. The samples studied were collected from the Sacramento (N=266; 2002-2006), Klamath (N=124; 1998, 2001, 2003), and Rogue (N=113; 2000, 2002, 2004) River spawning populations as well as from non-spawning, estuary sites including San Pablo Bay (CA) (N=219; 2001,2004) in the south, and Winchester Bay (OR) (N=119; 2000, 2002), Columbia River (WA) (N=175; 1995, 1999, 2004), Willapa Bay (WA) (N=98; 2003), and Grays Harbor (WA) (N=82; 2005) in the north. The study upholds the distinction between Northern and Southern DPS spawning rivers.

The areas sampled differed in the composition of Northern and Southern DPS green sturgeon. Overall, the majority of individuals in northern estuaries originated from the threatened Southern DPS, except for in Winchester Bay and Grays Harbor. Winchester Bay had a large range in stock composition (0.16–0.55 originating from the Southern DPS) between years and sampling methods, so no generalization could be made. Grays Harbor had nearly equal proportions of Northern and Southern DPS green sturgeon, with slightly more Northern DPS (0.54–0.59) than Southern DPS green sturgeon. The Columbia River and Willapa Bay had more Southern (0.69– 0.88) than Northern DPS green sturgeon. San Pablo Bay samples were almost exclusively from Southern DPS green sturgeon. This mixed composition in northern estuaries means that conservation efforts must include all estuaries throughout the range of the North American green sturgeon.

2d) Distribution Summary

The information presented above on the distribution of Northern DPS green sturgeon indicates that green sturgeon are constrained in distribution during the freshwater stages of their life- history. While confirmed spawning mainly occurs in only two river systems, populations in these rivers are not genetically distinct from one another and there is gene flow between the populations. In comparison, the Southern DPS spawns in only one river system, so the resiliency of the Northern DPS is higher in comparison. Within the Klamath and Rogue Rivers, limited occupancy in specific locations or holding areas may contribute to the vulnerability of the Northern DPS. During the marine phase of their life-history, Northern DPS green sturgeon occur over a broader geographic area. The geographic constraint of Northern DPS green sturgeon during their freshwater phase suggests a certain degree of vulnerability, leading to the conclusion that the DPS should remain a Species of Concern.

3) *Life-history characteristics:*
Vulnerable life history strategies (e.g., low fecundity, late maturity, slow growth), resilience to environmental variability and catastrophes, and loss of unique life-history traits.

Like all sturgeons, Northern and Southern DPS green sturgeon have inherently vulnerable life history characteristics that include late maturity and non-annual reproduction. Both DPSs also rely upon specific habitats within rivers for spawning and require specific habitat characteristics (e.g., appropriate flow and temperature) for successful spawning and recruitment as detailed in the previous section. No additional new information on life-history characteristics is available. Based on this lack of new information, the status of the Northern DPS as a Species of Concern should remain unchanged.

4) *Threats:*
Extraction and harvest, habitat degradation and loss, disease, predation, and other natural or man-made factors

The 2005 review recognized loss of spawning habitat, water diversions and associated impacts of reduced flows, changed flow regimes, increased water temperatures and reduced oxygen concentrations as well as impacts from land-use changes and increased sedimentation as the major threats to the Northern DPS. Harvest was also a concern. Table 1 presents a summary of the threats recognized in the 2005 review as well as the updated information available and discussed in this review. Limited new information was available for this review on the impact of flow regimes, water temperatures, dissolved oxygen, land-use, and sedimentation. New threats identified in this review include incidental capture in estuary, coastal, and ocean environments and the impact of post-release mortality, chemical applications in Washington estuaries, climate change and its impact on flow and temperature in spawning rivers, and development of offshore and nearshore kinetic energy projects as described below. As in Adams *et al.* (2002, 2007) and BRT (2005), the lack of information on population abundance adds difficulty to assessing the impact of the threats outlined below.

4a) Extraction and Harvest

Past and present commercial and recreational fishing as well as poaching were recognized in the last review as factors that pose a threat to the green sturgeon. No estimate of an annual rate of mortality due to poaching has become available since the last review. The threat posed by commercial and recreational fishing has likely decreased given that intentional lethal take of green sturgeon has been prohibited through fishing regulations. Regulations prohibit retention of North American green sturgeon in California, Oregon, and Washington state fisheries and in federal fisheries in the US and Canada (see below for additional details on regulations). These regulations pertain to the range of both Southern and Northern DPS green sturgeon to address the possibility of capture of the threatened Southern DPS throughout the coast.

State fisheries

Retention of green sturgeon is not currently permitted in any state fishery. As of 2006, WDFW and ODFW prohibited the commercial retention and sale of green sturgeon in the Columbia River and WDFW subsequently made this commercial restriction effective state-wide. Oregon permitted the sale of green sturgeon incidentally caught during commercial ocean fisheries and coastal estuarine shad fisheries up until January 1, 2010. The retention of green sturgeon in the Columbia River recreational fisheries was prohibited effective January 1, 2007 and WDFW subsequently made this recreational restriction effective statewide. ODFW made the closure effective statewide in all waters outside the Columbia River on March 15, 2010. In California, take and possession of green sturgeon in the sport fishery has been prohibited since 2006 and commercial harvest of any sturgeon species has been prohibited since 1917, with prohibitions on and off from 1901-1916 (pers. comm. with Marty Gingras, CDFW, June 11, 2013 and November 16, 2013).

Although regulations prohibit retention and management measures have been established to minimize catch, green sturgeon are incidentally encountered in state fisheries. State officials performed observations of commercial fisheries in 2011 and 2012 in the lower Columbia River and Grays Harbor and Willapa Bay estuaries to detect rates of encounters with green sturgeon. Encounters

occurred mostly in the summer/fall period. Most encounters were observed in Willapa Bay (WDFW and ODFW 2012). Commercial fisheries in Grays Harbor and Willapa Bay likely encounter several hundred Northern DPS green sturgeon annually (pers. comm. with Kirt Hughes, WDFW May 28, 2013). Washington non-tribal marine commercial fisheries data (2003-2012) indicate a small number of green sturgeon incidentally encountered with no discernible pattern or trend among ports or years reported.

Agency statistics from self-reporting and direct observation give additional information about green sturgeon encounters in recreational fisheries in Washington and Oregon. In 2011, a total of 259 individual green sturgeon were encountered by recreational fisheries in the lower Columbia River (WDFW and ODFW 2012). This number is on the higher end of what is generally observed annually (see Table 2 in WDFW and ODFW 2012). A small number of green sturgeon (≤10) are still annually retained in this fishery due to misidentification (as white sturgeon). This number is far fewer than the number of animals that were retained before retention was prohibited in 2007 (up to 533 individuals in 1985). Of the 259 individuals encountered, 36 would be expected to be Northern DPS green sturgeon based on the higher range estimate of Israel *et al.* (2009).

In Washington recreational fisheries outside of the Columbia River, up to 64 Northern DPS green sturgeon may be encountered annually (pers. comm. with Kirt Hughes, WDFW May 28, 2013). Angler self-reported data from Oregon indicate encounters of green sturgeon at low but fluctuating levels, from a high of 209 individual green sturgeon in 1996 to a low of 12 individuals in 2010 and 0 in 2011 (in WDFW and ODFW 2012). Most of the captures occurred in Tillamook River and Bay and the Umpqua River and Bay sport catch areas. We are aware of one record of a green sturgeon caught and released in the Puget Sound bottomfish fishery in 2008 (unpublished WDFW RecFin data, from Eric Kraig, WDFW, January 7, 2014). No additional green sturgeon have been recorded in Washington coastal and Puget Sound recreational fisheries (outside of Willapa Bay and Grays Harbor) since the 2007 closure to retention, although anglers are only required to report fish kept, not those released.

New information indicates a correction is needed regarding historic and present fishing in Willapa Bay. The 2002 status review (Adams *et al.* 2002) and the 2005 update (BRT 2005) as well as Adams *et al.* (2007) makes reference to Treaty catch of green sturgeon in Willapa Bay in 1986, 1994 and 1998. After further investigation, it has been discovered that these catches did not occur in Willapa Bay (pers. comm. with Will Beattie, Northwest Indian Fisheries Commission, July 2, 2013). Treaty fisheries for green sturgeon have never occurred in Willapa Bay and do not occur at present. Thus, reference to tribal fisheries in Willapa Bay in the rule regarding take prohibitions for the Southern DPS (75 FR 30714; June 2, 2010) was erroneous.

Green sturgeon are encountered in the state-regulated California halibut bottom trawl fishery in coastal marine waters. From 2002 through 2010, an estimated 104 to 786 green sturgeon encounters occurred per year in the fishery (Al-Humaidhi *et al.* 2012). The majority of the green sturgeon encountered likely belong to the Southern DPS, based on the location of the encounters (primarily in coastal marine waters adjacent to San Francisco Bay) (Al-Humaidhi *et al.* 2012) and genetic data (NMFS 2012).

In Alaska, green sturgeon is listed as a "nominee" species in the State of Alaska Wildlife Action Plan and designated as a "Species of Greatest Conservation Need" under the Aquatic Habitat

Implementation Plan, which is part of the Comprehensive Wildlife Conservation Strategy. The Alaska Department of Fish and Game (ADFG) indicates that information about green sturgeon is limited to a few anecdotal reports of sightings and captures in Alaska waters, mostly in Alaska District 8 and District 11 (encompassing the mouths of the Stikine and Taku, respectively) driftnet fisheries. ADFG has received no reports of regular sightings of sturgeon or any indication of breeding activity in these areas.

Tribal and First Nations fisheries

Data from tribal catch of green sturgeon was used in the original assessment to understand the status of the Northern DPS. Catch data from the Yurok tribe did not show declining catch or CPUE in the last status review (Adams *et al.* 2007). Tribal catch of Northern DPS still occurs in the Klamath, and tribes outside of this river incidentally capture Northern DPS green sturgeon.

The Yurok Tribal fishery is conducted in a 44 mile stretch of the Klamath River from the mouth to above the confluence with the Trinity River (pers. comm. with Dave Hillimeier, Yurok Tribe, December 3, 2013). The seasonal (spring and fall) fishery for Northern DPS green sturgeon is regulated by a strict bag limit of one sturgeon per day in season. Green sturgeon larger than 6 feet total length must be released and any green sturgeon retained cannot be commercially sold. It is difficult to assess trends in abundance of the Northern DPS using recent data from the fishery because of increasingly strict fishery regulations that constrain catch. Tribal biologist have run a tagging program to study Northern DPS green sturgeon movements since 2002 (Benson *et al.* 2007; McCovey *et al.* 2009, 2010) and have been undertaking cooperative work using Dual Frequency Identification Sonar (DIDSON) surveys to obtain abundance estimates (Mora 2012).

Retention of green sturgeon in the Quinault Nation fisheries (Washington waters including Chehalis River and Grays Harbor) was prohibited in 2006. Green sturgeon are encountered in Quinault white sturgeon set and gillnet fisheries, primarily in summer, and are released alive (pers. comm. with Joe Schumacker, Quinault Tribe, December 18, 2013). Ghost fishing affects green sturgeon in this area and efforts are underway to remove derelict gear from area waters.

There are no additional new data available on other tribal or First Nations catch, outside of the one catch record in the Fraser River recorded by the FRCS monitoring database mentioned above.

National fisheries

In Canada, green sturgeon are occasionally encountered by commercial bottom trawlers, with most catches recorded off the north or southwest ends of Vancouver Island. Green sturgeon are also encountered in recreational hook and line white sturgeon and salmon gillnet and seine fisheries in the Fraser River at low encounter rates. Green sturgeon is listed as a species of Special Concern under Canada's Species at Risk Act (SARA) and is protected by the federal Fisheries Act. A Management Plan for the species is required under the Species at Risk Act, and is currently under development.

Currently, Canada prohibits retention of green sturgeon in recreational and commercial fisheries, and all commercial fisheries are required to release by-catch at sea with the least possible harm. The commercial groundfish bottom trawl fishery has 100% at-sea observer coverage, while the commercial hook and line/trap groundfish fisheries have 100% at-sea monitoring as either observers

or electronic monitoring. Dockside monitoring is also in place for groundfish (i.e., groundfish trawl, rockfish hook and line, sablefish, halibut, lingcod and dogfish). This monitoring, in addition to logbooks, enables more accurate accounting of green sturgeon by- catch in these fisheries. Habitat protection may be provided in the marine environment, secondarily, by fisheries closures established to protect large areas of significant bottom habitat (e.g., rockfish conservation areas and groundfish bottom trawl closures). Additionally, standard operating practices for industries and regulatory agencies with authority in the Fraser River have been developed to mitigate impacts to freshwater habitat for green sturgeon.

Directed take of green sturgeon in US fisheries was prohibited as a result of the 4(d) protective regulations issued in 2010 (75 FR 30714; June 2, 2010). Green sturgeon are, however, incidentally encountered in the west coast Pacific Groundfish fisheries, including the Limited Entry (LE) groundfish bottom trawl sector and the at-sea Pacific hake/whiting sector (at-sea hake sector) (Al-Humaidhi *et al.* 2012). Incidental catch of green sturgeon in these fisheries has varied over the years. The LE groundfish bottom trawl sector encountered an estimated 0 to 43 green sturgeon per year from 2002 through 2010 (Al-Humaidhi *et al.* 2012). Based on the location of the encounters and data on green sturgeon stock composition in marine and coastal estuarine waters, the majority of the green sturgeon encountered likely belong to the Southern DPS (NMFS 2012), but more extensive genetic sampling of encountered animals is needed. Most of the fish were released alive. In the at-sea hake sector, three green sturgeon were encountered from 1991 through 2011 and all had died (Al-Humaidhi *et al.* 2012; NMFS 2012). Data are not available to determine if the fish belonged to the Southern DPS or Northern DPS. The impact of these fisheries on green sturgeon populations is thought to be small (NMFS 2012).

The North Pacific Groundfish Observer Program, which observes Federal groundfish fisheries off Alaska, has recorded rare encounters with green sturgeon in trawl fisheries in the Bering Sea. Two green sturgeon were encountered in 2006 (Colway and Stevenson 2007) and one in 2009 (pers. comm. with Brian Mason, NMFS, June 4, 2009; NMFS 2012). All of the green sturgeon encountered were observed dead. It is unknown whether the green sturgeon encountered belonged to the Northern DPS or the Southern DPS.

4b) Incidental capture and conservation measures

As described above, while the retention of green sturgeon is currently prohibited in state and federal fisheries, by-catch and incidental take still occurs in state, federal, and tribal fisheries. Assessing the potential impact of by-catch handling of green sturgeon in commercial and recreational fisheries requires an understanding of by-catch mortality in different gear types. While immediate mortality can be more directly measured and detected and is expected to be low, some delayed mortality may occur. The issue of delayed, post-release mortality requires further study. An existing study suggests by-catch mortality estimates of 5.2% in commercial gillnet fisheries and 2.6% in recreational hook and line fisheries (Robichaud *et al.* 2006). By- catch mortality in commercial trawl fisheries has not been estimated. Efforts made by state and federal agencies to monitor, minimize, and evaluate the effects of fisheries capture of green sturgeon are ongoing and studies to better understand the circumstances under which by-catch mortality increases are needed to guide fishery management efforts.

Outreach by all state agencies has been undertaken regarding green sturgeon catch and handling regulations. State commercial and sport fishing rules pamphlets indicate prohibitions on green

sturgeon retention. These regulations as well as posters at boat launch and bank fishing sites also offer information on distinguishing between green and white sturgeon. WDFW requires commercial gillnet fishers in Willapa Bay and Grays Harbor to report all green sturgeon encounters. In 2012, WDFW deployed onboard commercial fishing vessel monitoring. All fishermen in the Willapa Bay and Grays Harbor region must also attend a Fish Friendly Best Fishing Practices class. Monitoring of commercial fisheries in the Columbia River has occurred annually since 2002 and has increased in scope in recent years. Since January 2004, the California Halibut trawl fishery has carried federal observers who record all green sturgeon encounters, although coverage rates have been fairly limited (Al-Humaidhi *et al.* 2012). The Federal groundfish fisheries are observed at higher rates and data indicate fewer encounters with green sturgeon as compared to the California Halibut fishery (Al-Humaidhi *et al.* 2012).

The ESA 4d Rule provides an exemption from take prohibitions for Southern DPS green sturgeon for commercial and recreational fisheries if state agencies submit a Fishery Management and Evaluation Plan (FMEP) (75 FR 30714; June 2, 2010). The FMEP has nine required elements, including setting maximum incidental take levels that will not reduce survival or recovery of the Southern DPS, effective monitoring and evaluation planning, enforcement, and education, and reporting of the amount of incidental take on a biannual basis (75 FR 30714; June 2, 2010). Washington has submitted a draft FMEP and Oregon and California may submit plans in the future. Through the FMEP process and the NOAA Fisheries observer programs recording of green sturgeon by-catch in certain fisheries, a more comprehensive understanding of the total by-catch of green sturgeon, and ways to mitigate it, will be available.

4c) Additional Threats

The application of chemicals and pesticides to control burrowing shrimp (i.e., ghost shrimp *(Neotrypaea californiensis)* and mud shrimp *(Upogebia pugettensis*)) populations in Washington estuaries may still pose a threat to green sturgeon. The chemical carbaryl has been used for this purpose in Willapa Bay and Grays Harbor because of the threat of burrowing shrimp to oyster aquaculture farming. Since green sturgeon feed on these shrimp, a potential negative impact from carbaryl application may occur through the limitation of prey availability, but the impact is thought to be small (Dumbauld *et al.*, 2008). Exposure to carbaryl also may make green sturgeon more vulnerable to predation (NMFS 2009). An out-of-court settlement in response to litigation on carbaryl application mandated a phase-out of carbaryl use (pers. comm. with Bruce Kauffman, WDFW, September 9, 2013). While use has been reduced, it has not been phased-out altogether (pers. comm. with Bruce Kauffman, WDFW, September 9, 2013). University of Washington researchers are studying the impacts on sturgeon of the chemical imidacloprid, a proposed alternative to carbaryl that may come into use in 2014, but information from this study was not yet available at the time of writing.

Climate change has the potential to impact green sturgeon in the future. Water flow and temperature are important factors influencing green sturgeon spawning and recruitment success and may be impacted by climate change. Changing ocean conditions could also impact green sturgeon since subadults and adults use ocean habitats for migration and potentially for feeding. Based on their use of coastal bay and estuarine habitats, subadults and adults can occupy habitats with a wide range of temperature, salinity, and dissolved oxygen levels (Kelly *et al.* 2007; Moser and Lindley 2007). Ocean acidification may also impact important components of the diet of green sturgeon (Dumbauld

et al. 2008). Climate change modeling predictions for the Klamath River basin suggest warming temperatures, decreased snowpack, and changes in vegetation cover over the next century (Barr *et al.* 2010). Flow regimes in rivers will also likely change with a changing climate (Moyle 2012). In the Klamath and Trinity Rivers, river flow may peak earlier in the spring and resulting changes in river flow and temperature could alter the timing of adult and juvenile entry and exit. Moyle *et al.* (2012) found that Northern DPS green sturgeon in the Klamath River could be highly vulnerable to the effects of climate change due to their limited temperature tolerance and dependence on flow regimes as well as other vulnerability factors assessed.

Investigations in recent years have focused on the impact of the removal of several dams in the range of the Northern DPS. Removal of four dams on the lower Klamath River will likely favorably impact green sturgeon over the long-term by restoring historic temperature and flow profiles (Hamilton *et al.* 2011). In the short-term, dam removal would increase sediment load in the river, which could adversely affect green sturgeon that remained in the mainstem of the Klamath River at the time of dam removal. However, much of the spawning and rearing habitat for green sturgeon occurs in an area where sediment concentrations are predicted to be lower and the timing of the dam removal will be such that the majority of the green sturgeon population in the Klamath River should not be in the river when the dams are removed (Hamilton *et al.* 2011).

The Savage Rapids Dam on the Rogue River was removed in 2009. Removal could have a small, positive impact on green sturgeon only in high flow years since most green sturgeon in the Rogue River generally spawn well below the area where the dam was removed (pers. comm. with Daniel Erickson, ODFW, December 17, 2013).

WDFW and ODFW (2012) noted two issues that may affect prey resources for green sturgeon in coastal bays and estuaries. Over the past five years, the presence of Japanese eelgrass (*Zostera japonica*) has increased in the upper intertidal mudflats in coastal estuaries of Northern California, Oregon, and Washington (in ODFW and WDFW 2012). This negatively impacts habitat for burrowing shrimp, which are a major component of the green sturgeon diet in these estuaries. Information is not yet available regarding the impacts of these changes on green sturgeon. An invasive isopod affecting blue mud shrimp (*U. pugettensis*) in northern estuaries (Chapman *et al.* 2012) could have an impact on green sturgeon prey resources, but the issue requires additional research to understand the impact (pers. comm. with Olaf Langness, WDFW, and Brett Dumbauld, USDSA-ARS, May 22, 2013).

An emerging threat is the development and operation of offshore and near shore kinetic energy projects. Impacts of such projects on green sturgeon could occur due to direct mortality or habitat loss and sensitivity to low levels of electromagnetic fields associated with the operations that could impact migration and habitat use (Nelson *et al.* 2008). A proposed wave energy project off of Reedsport, OR was being evaluated for impacts on green sturgeon migration and habitat use. Habitat use by green sturgeon in the area was to be tracked before and after the wave energy buoy installation occurred (pers. comm. with Daniel Erickson, ODFW, June 17, 2013). Unfortunately, the proposed project was terminated before this study was completed.

Additional kinetic energy projects have been proposed in the Columbia River and off the Oregon coast. Habitat use studies such as the one described above are needed to evaluate the impacts of these proposed projects on green sturgeon.

Dredging in rivers could have an impact on green sturgeon, but few studies have looked at specific impacts. Parsley (2009) used acoustic receivers to examine green sturgeon distribution in Baker Bay and the Ilwaco channel (Columbia River) during September and October when maintenance dredging was expected to occur. Both DPSs were present in the area during the period surveyed. Although green sturgeon were detected for only a short period, consistent with findings of earlier studies that green sturgeon make rapid and extensive intra-estuary movements, dredging in the area would need to consider impacts on green sturgeon.

Steller sea lions (*Eumetopias jubatus*) are known to feed on sturgeon in the Columbia River. Observations by the U.S. Army Corps of Engineers have recorded only white sturgeon being consumed (WDFW and ODFW 2012). In 2009, however, a photograph of a sea lion eating a green sturgeon was taken in the Rogue River. Researchers in Washington and Oregon have also reported puncture wounds and scrapes in green sturgeon consistent with a pinniped attack.

WDFW has also observed markings on green sturgeon that could be consistent with shark attack. The impact of predation on adult and subadult green sturgeon is unknown. Although sea lion abundance has increased, there is no new information to support that the threat of predation by sea lions or sharks has changed in severity since the last review.

4d) Threat summary

The new information summarized above indicates that some threats, such as harvest, have decreased in severity. New threats, such as chemical applications, climate change, and kinetic energy projects have been identified. Limited new information was available for this review on the impact of flow regimes, water temperatures, dissolved oxygen, land-use, and sedimentation and the impact of these threats on the Northern DPS. Overall, the new information suggests that the Northern DPS should remain on the Species of Concern list, given the number of threats identified and current lack of population abundance trend data.

Conclusion

The information presented in this review indicates that Northern DPS green sturgeon should remain a Species of Concern based on data about their abundance and productivity, distribution, and threats. Since the last status review, new information has become available to increase our understanding of the Northern DPS' biology, status, and threats and address the main concerns identified in the 2005 status review (i.e., the lack of population data and the threats of fisheries harvest and alterations to freshwater habitat). In general, the new information does not indicate an increase in the Northern DPS' vulnerability or in the severity of threats. Improvements have been made but threats and uncertainties remain. The Northern DPS primarily spawns in two river systems that are considerably geographically separated, adding resiliency. Within each river system, however, Northern DPS inhabit limited habitats with specific characteristics and depend upon appropriate water flow and temperature to reproduce and recruit, adding to their vulnerability. Marine phases of the life history occur over a broader geographic area than freshwater phases and may be less vulnerable. New research is yielding information upon which abundance estimates can be calculated and tracked and continued monitoring is essential.

Threats to Northern DPS green sturgeon, including water and land-use management practices, chemical applications, and climate change persist. The threat of extraction and harvest has decreased but incidental capture continues to occur in state, Federal, and Tribal fisheries and little is known about the impact of post-release mortality on green sturgeon. Overall, our understanding of the species' status and biology has increased substantially and threats such as fisheries harvest have been reduced; however, the limited geographic occupancy during some life stages, remaining uncertainty about abundance, and persistent threats indicate that a Species of Concern classification is still warranted.

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Table 1. Updated information on threats to the Northern DPS of green sturgeon. The first four columns are taken from the 2005 review and are also referenced in Adams *et al.* 2007. Any changes in spawning status are noted in a footnote. New information on threats is provided in the last column.

River System	Historical Spawning Status	Present Spawning Status	Threats/Changes 2005	Threats/Changes this review
Fraser River	No evidence	No evidence	Availability of appropriate habitat and degradation or alterations to the habitat; local harvest	Local fishing is catch and release only; efforts being made to mitigate habitat impacts
Chehalis River	No evidence	No evidence	Local harvest	Local directed harvest and retention not permitted.
Umpqua River	Known spawning	Known spawning	Current harvest	Local directed harvest and retention not permitted
Rogue River	Known spawning	Known spawning	Current harvest; flow management and hydro effects	Local directed harvest and retention not permitted; Savage Rapids Dam removal; no new additional information on flow management and hydro effects.
Klamath River	Known spawning	Known spawning	Increased temperatures; reduced oxygen concentrations, flow regime change, in-river harvest	Tribal harvest only; future dam removal may impact flow; no new additional information on other factors
- *Trinity River*	Known spawning	Known spawning	Reduced flows and threats identified for Klamath River	No new additional information
- *SF Trinity*	Suspected spawning	Suspected spawning	1955 and 1964 floods and threats identified for Klamath River	No new additional information
Eel River	Known spawning	Suspected spawning	1955 and 1964 floods; flow management and water transfers; sediment and TMDL	No new additional information

Appendix A: Outreach on green sturgeon 5 year status review

Email and phone contact was used to reach out to the following green sturgeon experts and people who might have information to contribute to the status review.

University

- UC Davis: Joe Cech, Dennis Cocherell, Fred Conte, Serge Doroshov, Nann Fangue, R. Kaufman, Peter Moyle, Michael Thomas, Joel Van Eenennaam, Pete Klimley, Ethan Mora (response from Cocherell, Fangue, Moyle, Thomas, Klimley, Mora)

Agency

- USDA-RDA: Brett Dumbauld (response)
- Oregon Department of Fish and Wildlife: Ruth Farr, Dan Erickson (response from ODFW, Erickson)
- Washington Department of Fish and Wildlife: Brad James, Phillip Dionne, Olaf Langness, Kirt Hughes (response from Langness, WDFW)
- National Marine Fisheries Service: Steve Lindley, Mary Moser, Jay Ogawa, John Carlos Garza, Colby Brady (response from Brady, Garza, Ogawa)
- USGS: Mike Parsley
- California Department of Fish and Wildlife: Russ Bellmer, Marty Gingras, Paul Riley (response from Bellmer, CDFW)
- US Bureau of Reclamation: Josh Israel (response from Israel, USBR)
- California Department of Water Resources: Alicia Seesholtz, Roger Churchwell (response from Seesholtz, DWR)
- USFWS: Richard Corwin, Bill Poytress, Zac Jackson, Bill Pinnix (response from Poytress, USFWS)
- Department of Fisheries and Oceans, Canada: Larry Hildebrand, Jonathan Thar, Murray Manson, Greg Workman (response from general DFO email, Manson, Workman)
- Glenn-Colusa Irrigation District: Dave Vogel
- Cramer Fish Sciences: Brad Cavallo, Ray Beamesderfer

Tribe

- Quinault Tribe: Joe Schumacker: (response)
- Shoalwater Bay Tribe: Steven Spencer (response))
- Quileute Tribe: Kris Northcut
- Yurok Tribe: Dave Hillemeier (response), Barry McCovey (response)

A letter was sent to the following contacts and agencies to solicit updated information on the status of Northern and Southern DPS green sturgeon.

- California Department of Fish and Wildlife: Charlton H. Bonham, Director, Sacramento, cc: Marty Gingras, Stockton; Russ Bellmer, Sacramento; Paul Reilly, San Diego; Tom Barnes, San Diego (response through submitted comments)
- Oregon Department of Fish and Wildlife: Roy Elicker, Director, cc: Tom Rein, Clackamas
- Washington Department of Fish Wildlife: Phil Anderson, Director, cc: Kirt Hughes, Montesano; Olaf Langness, Vancouver (response through submitted comments)
- Alaska Department of Fish and Game: Cora Campbell, Commissioner, cc: Jeff Regnart,

Director of the Division of Commercial Fisheries, Doug Vincent-Lang, Acting Director of the Division of Wildlife Conservation (response through submitted comments)

- California Department of Water Resources: Mark W. Corwin, Director, cc: Alicia Seesholtz, West Sacramento (response through submitted comments)
- Bureau of Reclamation; Donald R. Glaser, Regional Director, Mid Pacific Regional Office, Sacramento, cc: Robert Chase, Red Bluff; Sue Fry, Sacramento; Josh Israel, Sacramento; Frank Michny, Sacramento (response through submitted comments)
- USFWS (Region 8): Ren Lohoefener, Regional Director, Pacific Southwest Region (Region 8), Sacramento, cc: Dan Castleberry, Sacramento (response through submitted comments)
- USFWS (Region 1): Robyn Thorson, Regional Director, Pacific Region (Region 1), Portland (email response from Grant Canterbury with cc: to Marilet Zablan, Jana Grote, Larry Rabin)
- Bureau of Indian Affairs (Northwest Regional Office): Stanley M. Speaks, Regional Director, cc: Kris Northcut, Quileute Tribe; Joe Schumaker, Quinault Indian Nation, Steven Spencer, Shoalwater Bay Tribe; Russ Svec, Makah Indian Tribal Council
- Bureau of Indian Affairs (Pacific Regional Office): Amy Dutschke Regional Director, , cc: Toz Soto, Karuk Tribe; Dave Hillemeier, Yurok Tribal Fisheries Program; Barry McCovey, Yurok Tribal Fisheries Program; Stephen Kullman, Wiyot Tribe (response from Dale Morris)
- Northwest Indian Fisheries Commission: Billy Frank, Jr., Chairman,; cc: William Beattie, Olympia

Information obtained through peer and external review of the green sturgeon Southern DPS status review process was also used for this review. Agencies contributing to the review process are listed in the Southern DPS review.