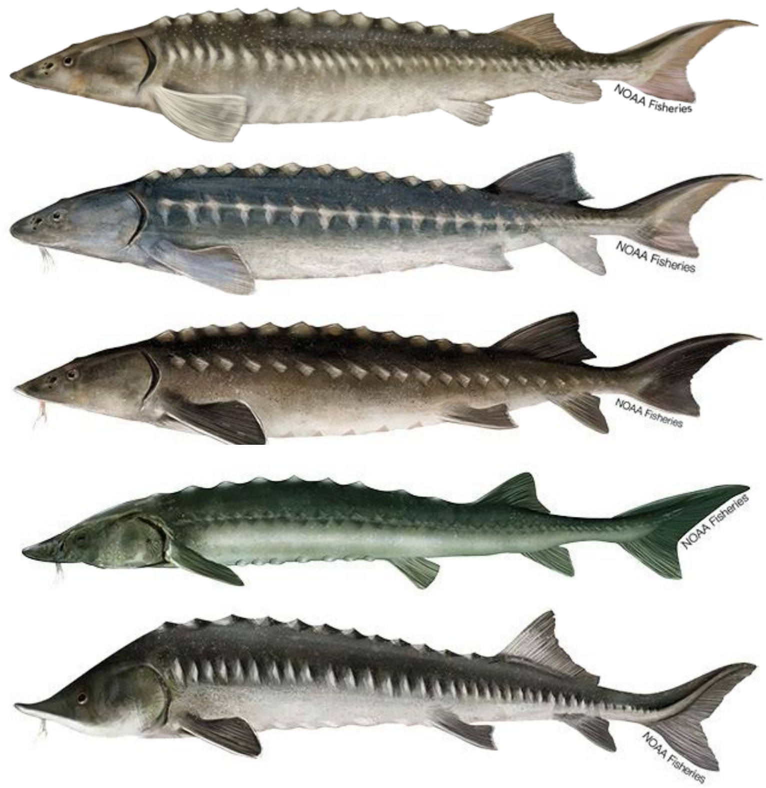
Adriatic Sturgeon (*Acipenser naccarii*), European sturgeon (*Acipenser sturio*), Chinese sturgeon (*Acipenser sinensis*), Sakhalin sturgeon (*Acipenser mikadoi*), Kaluga sturgeon (*Huso dauricus*)

5-Year Review: Summary and Evaluation

2021



National Marine Fisheries Service
Office of Protected Resources
Silver Spring, MD

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1.0 GENERAL INFORMATION

1.1 Reviewers

NMFS Office of Protected Resources: Adrienne Lohe, 301-427-8442

1.2 Methodology used to complete review

The purpose of the Endangered Species Act of 1973, citation as amended (ESA; 16 U.S.C. 1531 *et seq*.) is to provide a means to conserve the ecosystems upon which endangered and threatened species depend, to provide a program for the conservation of endangered and threatened species, and to take appropriate steps to recover endangered and threatened species. One of our responsibilities under the ESA is to conduct a review of each listed species at least every 5 years to determine whether its endangered or threatened status should be changed or removed (i.e., 5-year review, 16 U.S.C. 1533(c)(2)). The ESA requires us to make these determinations solely on the basis of the best scientific and commercial data available (16 U.S.C. 1533(b)(1)(A)). In 2014, the National Marine Fisheries Service (NMFS) listed the following five sturgeon species as endangered after reviewing their status (the Status Review; Meadows and Coll 2013): Adriatic Sturgeon (*Acipenser naccarii*), European sturgeon (*Acipenser sturio*), Chinese sturgeon (*Acipenser sinensis*), Sakhalin sturgeon (*Acipenser mikadoi*), and Kaluga sturgeon (*Huso dauricus*) (79 FR 31222; June 2, 2014; listing effective July 2, 2014). On September 16, 2020, we initiated this 5-year review for these five foreign sturgeon species (85 FR 57832).

To compile the best available scientific and commercial data on these species, we first reviewed the Status Review (Meadows and Coll 2013), which was based on the best available scientific and commercial data available at that time. We then searched for relevant new information on the five sturgeon species, their biology and habitat, and threats to their existence. Specifically, we searched for published literature using scientific search engines (including Clarivate's Web of Science, ScienceDirect, BioOne Complete, ProQuest's Aquatic Sciences and Fisheries Abstracts, JSTOR, EBSCO Academic Search and Environment Complete, and Google Scholar) and NMFS' scientific literature database. We solicited relevant information from other Federal agencies, States, Territories, Tribes, foreign governments, academia, nonprofit organizations, industry groups, and individuals by publishing a request in the Federal Register (85 FR 57832; September 16, 2020). We also solicited information from subject matter experts and individuals with expertise on particular species. We compiled, reviewed, and evaluated available data, including information from one response to our Federal Register notice. We did not conduct new empirical studies because the ESA requires the use of the best *available* scientific and commercial information.

After compiling the data, we considered the biology and habitat of the five sturgeon species. We identified information that has become available since the publication of the Status Review in 2013. We also reviewed the best available information on abundance and trends, genetics, and spatial distribution.

We also assessed threats to each of the species by identifying and evaluating the ESA section 4(a)(1) factors (i.e., the five factor analysis; 16 U.S.C. 1533(a)(1)):

1. Present or threatened destruction, modification, or curtailment of habitat or range
2. Overutilization for commercial, recreational, scientific, or educational purposes
3. Disease or predation
4. Inadequacy of existing regulatory mechanisms
5. Other natural or manmade factors affecting its continued existence

Because the abundance and trends present a manifestation of past threats, we focused on present threats. For each factor, we evaluated its likely impact and magnitude, as well as the vulnerability and exposure of each species.

We synthesized the above information to assess the status of each species. We identified the factors that weighed most heavily in our evaluation. We also described areas of high confidence, remaining uncertainties, and their relevance to our overall assessment. Based on this information, we provide a recommendation on the status of each of the sturgeon species.

1.3 Background

1.3.1 FRN Notice citation announcing initiation of this review

FR notice: 85 FR 57832
Date published: September 16, 2020
Purpose: NMFS gave notice of our initiation of a 5-year review of five foreign sturgeon species: Adriatic Sturgeon (*Acipenser naccarii*), European sturgeon (*Acipenser sturio*), Chinese sturgeon (*Acipenser sinensis*), Sakhalin sturgeon (*Acipenser mikadoi*), and Kaluga sturgeon (*Huso dauricus*); we requested relevant information from the public.

1.3.2 Listing History

<u>Original Listing</u>
FR notice 79 FR 31222; June 2, 2014
Date listed: July 2, 2014
Entity listed: Adriatic Sturgeon (*Acipenser naccarii*), European sturgeon (*Acipenser sturio*), Chinese sturgeon (*Acipenser sinensis*), Sakhalin sturgeon (*Acipenser mikadoi*), and Kaluga sturgeon (*Huso dauricus*)
Classification: Endangered

1.3.3 Review History

- On March 12, 2012, NMFS received a petition from WildEarth Guardians and Friends of Animals to list 15 species of sturgeon, including *Acipenser naccarii*, *Acipenser sturio*, *Acipenser sinensis*, *Acipenser mikadoi*, and *Huso dauricus*, as threatened or endangered under the ESA. As the other ten species of sturgeon were determined not to be marine or anadromous, the U.S. Fish and Wildlife Service (FWS) conducted the required listing analyses for those ten species. On August 27, 2012, NMFS found that the petition presented substantial scientific information indicating that listing the five marine or anadromous species may be warranted (77

FR 51767) and subsequently conducted the Status Review (Meadows and Coll 2013).

1.3.4 Species' Recovery Priority Number at start of 5-year review

Not applicable.

1.3.5 Recovery Plan or Outline

Recovery plans were not prepared for these five species. This is in accordance with NMFS' August 2, 2019 finding that a recovery plan would not promote their conservation as they all occur entirely under the jurisdiction of other countries. Therefore, any conservation actions for the five sturgeon species that would bring them to the point that the measures of the ESA are no longer necessary would need to be implemented by foreign nations.

2.0 REVIEW ANALYSIS

2.1 Application of the 1996 Distinct Population Segment (DPS) policy

2.1.1 Are the species under review vertebrates?

__x__**Yes**
_____**No**

2.1.2 Are the species under review listed as DPSs?

_____**Yes**
__x__**No**

2.1.3 Is there relevant new information for these species regarding the application of the DPS policy?

_____**Yes**
__x__**No**

2.2 Recovery Criteria

2.2.1 Do these species have final, approved recovery plans containing objective, measurable criteria?

_____**Yes**
__x__**No** (see section 1.3.5)

2.3 Updated Information and Current Species Status

2.3.1 Adriatic sturgeon

2.3.1.1 Biology and life history:

The Adriatic sturgeon is a large, long-lived anadromous species that spawns in freshwater after a period of growth in marine habitat, typically at the mouth of rivers (Bronzi *et al.* 2011). Male and female Adriatic sturgeon mature at 6-7 and

8-12 years of age, respectively (Mandelli 2016), and the species has a lifespan of approximately 40-50 years (Giovannini, pers. comm., as cited in Congiu *et al*. 2011). Adults spawn every other year or more rarely (Boscari *et al.* 2014b) and spawning was historically observed in May and June along river banks in the middle and lower reaches of the Po River (Paccagnella 1948).

2.3.1.2 Abundance, population trends (e.g. increasing, decreasing, stable), demographic features (e.g., age structure, sex ratio, family size, birth rate, age at mortality, mortality rate, etc.), or demographic trends:

Adriatic sturgeon were relatively common up to 50 years ago in the Po River and its tributaries, although overfishing, habitat degradation, and pollution have since resulted in dramatic population declines (Boscari *et al.* 2015). At the time of the 2013 Status Review, *A. naccarii* was estimated to have declined by at least 80% (and possibly 100%) over the last three generations (Bronzi *et al.* 2011). Habitat alteration has led to the loss of natural connections between freshwater and marine habitats, although the species can complete its entire life cycle in freshwater as evidenced by the landlocked Ticino River population (Boscari and Congiu 2014; Guarniero *et al.* 2017). The last known natural spawning event occurred in Italy in the 1980s and in Albania in 1990, and Bronzi *et al.* (2011) conclude that both of these wild populations are most likely extinct. There have been reports of natural reproduction in the wild in the Ticino River and the Livenza River in the last decade, though they are unconfirmed (L. Congiu, pers. comm. 2021). For these reasons, the survival of the species depends on captive breeding and restocking practices.

A single captive broodstock of wild origin (F0) exists, originally collected and transferred to the Azienda Agricola V.I.P. aquaculture plant (Orzinuovi, Brescia, Italy) in the 1970s (Boscari *et al.* 2014b). Of 50 wild individuals collected, only 13 individuals remain (Boscari and Congiu 2014). All Adriatic sturgeon reared in Europe descend from this stock directly (Boscari *et al.* 2014b). Other stocks of potential breeders are located in other aquaculture facilities, each consisting of about 100 F1 animals (first generation offspring of F0 parents) (Guarniero *et al.* 2017). Since recovery plans were put in place in the 1980s, over 430,000 captive F1 animals have been reintroduced to the wild (Arlati *et al.* 1999). However, successful reproduction in the wild has not been confirmed (Bronzi *et al.* 2011; Congiu *et al.* 2011). Few individuals released during restocking events have been recaptured (Guarniero *et al.* 2017). The high mortality rate of released individuals may be due to inadequate rearing and release protocols (L. Congiu, pers. comm. 2021), or reduced fitness of stocked individuals in the wild (Guarniero *et al.* 2017). Boscari and Congiu (2014), however, report that individuals are occasionally recaptured after several years in good condition, suggesting that adaptation to natural conditions is possible. Moreover, a gravid female was found dead on the shores of the Po River in 2018, signifying that the environment is suitable for the species to mature (P. Bronzi, pers. comm. 2021).

In sum, we find that the abundance of the species is perilously low, and its survival depends on captive rearing and release.

2.3.1.3 Genetics, genetic variation, or trends in genetic variation (e.g., loss of genetic variation, genetic drift, inbreeding, etc.):

Genetic variation is critical to the evolutionary potential and long-term survival of a species because it provides the raw material for adaptation by natural selection. As the conservation of *A. naccarii* is so heavily dependent on the success of captive breeding programs, breeding with the goal of minimizing genetic relatedness is important in retaining the genetic diversity within the captive stock.

In an analysis of two broodstocks (one captive and one released) reared from wild-originating individuals involved in conservation activities of the landlocked Ticino River population, only a small fraction of genetic variability observed in the F0 stock was observed in the F1 stocks (Boscari and Congiu 2014). Both F1 stocks at Ticino River Park showed a 50% decrease in haplotype diversity compared to the F0 stock (from 6 to 3 haplotypes) (Boscari and Congiu 2014). Two other diversity indices showed decreases from F0 to F1 stocks: frequencies of the families in which a given parent was involved, which evaluates how many parents were crossed to produce the observed familiar groups, and the frequencies of the offspring having a given breeder as a parent (Boscari and Congiu 2014). The loss of genetic diversity is due to 15 years of random breeder selection, and underscores the importance of careful captive breeding to maintain high levels of genetic variation (Boscari and Congiu 2014).

The stocks at the Azienda Agricola V.I.P. plant, however, appear to be a source of genetic variability for the species. Although there has been an important loss of mitochondrial genetic variability with two of seven haplotypes identified in the F0 stock absent in the F1 stock and a third lost after a poisoning incident at the plant in 2003, there are no significant differences in number of alleles at microsatellites between F0 and F1 stocks (Boscari *et al.* 2014b). The probability of selecting two related individuals for reproduction in the V.I.P. F1 stock is very low (5.6%) compared to the estimated probability of 35% in the stock reared at Ticino River Park (Boscari *et al.* 2014b).

Another issue of concern in facilities that rear multiple sturgeon species or hybrids is accidental introduction of other species to the stock (Boscari *et al.* 2014b). The presence of hybrids or other species in the V.I.P. F1 stock was detected using species-specific single nucleotide polymorphisms (SNPs) in two genes, and breeding plans proposed excluding these hybrids (Boscari *et al.* 2014b).

Overall, loss of genetic variation in captive stocks of *A. naccarii* is apparent and concerning. Boscari *et al.* (2014b) present a breeding plan for Adriatic sturgeon that is "family-based" rather than "individual-based," as adults only reproduce every other year or more rarely, and a certain individual may not be reproductively active when an individual-based breeding plan may require them to breed. Their plan includes the breeding of the 13 remaining F0 individuals. As most of these animals have never been mated before, their reproduction would represent important contributions to the diversity of the captive stock (Boscari *et al.* 2014b). It is possible that these 13 individuals haven't bred yet because they have low reproductive potential (Boscari *et al.* 2014b), or due to suboptimal rearing environments for some individuals.

2.3.1.4 Taxonomic classification or changes in nomenclature:

The taxonomic classification for the species has not changed since the 2013 Status Review. It remains as follows:

Kingdom: Animalia
Phylum: Chordata
Class: Actinopterygii
Order: Acipenseriformes
Family: Acipenseridae
Genus: *Acipenser*
Species: *naccarii*
Common name: Adriatic sturgeon

2.3.1.5 Spatial distribution, trends in spatial distribution (e.g. increasingly fragmented, increased numbers of corridors, etc.), or historical range (e.g. corrections to the historical range, change in distribution of the species within its historical range, etc.):

As reported in the Status Review, the species was historically found in fresh waters in northern Italy and the eastern coasts of the Adriatic Sea including Greece, Albania, Montenegro, and Croatia (Tortonese 1989; Bronzi *et al.* 2011). The species has been more recently recorded in the Po River and its inflow rivers (Ticino, Adda, Oglio, Mincio) and in the Adige, Livenza, Piave, Tagliamento rivers (Bronzi *et al.* 2011). Since the early 1960s, the Isola Serafini Dam had prevented migratory movements of the species, reducing suitable spawning grounds in the Po River and its tributaries to an area of less than 10 km^2 (Bronzi *et al.* 2011). However, construction of a fish passage at Isola Serafini under Life Programme Project Con.Flu.Po (Life11NAT/IT/188, https://www.life-conflupo.eu/index.php?lang=it) has proven successful in restoring connectivity for migratory species in the Po River. Monitoring by cameras has verified about 30,000 passages by at least 16 different species, although as of 2018, Adriatic sturgeon have not been identified as using the passage.

2.3.1.6 Five-Factor Analysis (threats, conservation measures, and regulatory mechanisms):

Present or threatened destruction, modification or curtailment of its habitat or range:

As mentioned in section 2.3.1.5 above, the construction of the Isola Serafini hydroelectric power plant and dam in the early 1960s interrupted the migration of Adriatic sturgeon between freshwater and marine habitats. As a result, wild populations experienced drastic population declines and are now potentially extinct in the wild, according to Bronzi *et al.* (2011). Although there is now a fish passage at the dam designed to accommodate the species, it is unclear if released Adriatic sturgeon have used it to access upstream spawning areas. The dam continues to modify the habitat of the Adriatic sturgeon to such an extent that there is no confirmed record that the species has naturally reproduced in Italy since the 1980s. We conclude that habitat modification reduces productivity, spatial distribution, and abundance of the species and poses a serious threat to the survival of the species.

Overutilization for commercial, recreational, scientific, or educational purposes:

The legal caviar trade for the species is only allowed in captive-bred specimens under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). A molecular testing method has been developed to identify *A. naccarii* with 100% accuracy, which is significant as the species had previously been indistinguishable from *Acipenser gueldenstaedtii*, *Acipenser baerii* and *Acipenser persicus* (Boscari *et al.* 2014a). The identification tool will allow for better regulation and monitoring of the legal and illegal caviar trades.

The 2013 Status Review finds that bycatch and recreational fishing of the species are contributing to its overuse. Recreational fishermen are known to illegally catch and release large adults (50-60 kg and about 2 meters long) in places that extant adults are known to congregate, which may threaten these individuals in the long-term (L. Congiu, pers. comm. 2021). Beyond this, we did not find any new information on either bycatch or recreational fishing of the species. It is unclear to what degree overutilization is currently threatening the species.

Disease or predation:

Captive breeding operations for sturgeon may lead to increased susceptibility to bacterial infections and disease. Recent molecular evidence has confirmed that two genotypes of iridovirus (Namao virus and Acipenser iridovirus-European) infect Adriatic sturgeon, causing skin leisons, local secondary infections mainly due to *Flavobacterium* sp. fungus, and increased mortality rates (Bigarré *et al.* 2016). It is unclear to what degree disease impacts the Adriatic sturgeon population, though management specific to preventing the spread of disease in sturgeon farming facilities is important.

The 2013 Status Review reports that the Wels catfish, *Silurus glanis*, is a potential predator of the Adriatic sturgeon, and may also compete with the species for habitat. We did not find any information indicating that predation is currently influencing the status of the species.

Inadequacy of existing regulatory mechanisms:

Inadequate regulatory measures can leave sturgeon vulnerable to a wide range of anthropogenic impacts, including overharvest and habitat degradation. The migratory life history of sturgeon exposes them to these threats across multiple habitat types, and in some cases, across different countries and jurisdictions. For this reason, regulatory and conservation mechanisms at several different scales are needed for adequate protection. Below is a summary of regulatory and conservation measures that apply to Adriatic sturgeon. We conclude that there are many regulatory and conservation mechanisms being implemented to protect the Adriatic sturgeon from threats of overutilization, and to some extent, habitat degradation. However, damming continues to be a threat to Adriatic sturgeon as it hinders their ability to migrate and reproduce, and we therefore conclude that existing regulatory mechanisms are inadequate as they fail to protect or restore the connectivity of habitat required by this migratory species.

Fishing for the species is banned throughout its range (DPR 08/09/1997, n.357) and several restoration activities are being carried out with the goal of protecting the species, but no coordinated basin-wide efforts are in place (Friedrich *et al.* 2018). The EU's LIFE (L'Instrument Financier pour l'Environnement) Programme, a funding instrument for environment and climate actions, has co-funded several projects focused on restoring connectivity between marine and freshwater habitats in the Po River, and also on breeding, releasing, and monitoring captive-reared Adriatic sturgeon.

Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)

CITES is an international convention that aims to ensure that international trade in animals and plants does not threaten their survival. CITES affords varying degrees of protection to over 37,000 species and is legally binding for Parties. CITES only regulates international trade, and does not regulate take or trade within a country. There are 183 Parties to CITES as of July 2021.

The Adriatic sturgeon is listed on Appendix II of CITES, meaning that trade in specimens of the species (including parts and products such as caviar) is allowed when the trade is determined to be non-detrimental to the survival of the species. Parties to CITES adopted a resolution on the conservation of sturgeon and paddlefish (Resolution Conf. 12.7; https://cites.org/sites/default/files/document/E-Res-12-07-R17.pdf) under which range countries must declare annual catch and export quotas, cooperate regionally, abide by a universal caviar labeling system, and take other actions to ensure sustainability of trade in the species.

Convention on the Conservation of Migratory Species of Wild Animals (CMS)

CMS is an environmental treaty of the United Nations aiming to conserve migratory species and their habitats and migration routes. CMS establishes obligations for each State joining the Convention and promotes collaboration among range states. As of July 2021, there are 132 Parties to CMS.

The Adriatic sturgeon was included in Appendix II of CMS in 1999. Appendix II species are those that have an unfavorable conservation status and that require international agreements for their conservation and management, as well as those that have a conservation status which would significantly benefit from the international cooperation that could be achieved by an international agreement. For Appendix II species, CMS acts as a framework through which other instruments are developed and implemented.

Bern Convention on the Conservation of European Wildlife and Natural Habitats
The Bern Convention is a binding legal instrument aiming to conserve wild flora and fauna and their natural habitats, and to promote European cooperation towards this aim. All countries that have signed the Convention must promote national conservation policies, promote measures against pollution, promote educational and informative measures, coordinate efforts to protect migratory species, and establish legislative and administrative measures. As of July 2021 there are 50 countries plus the European Union that have ratified the Convention.

Adriatic sturgeon is listed as a strictly protected fauna species on Appendix II of the Convention, meaning the following is prohibited: all forms of deliberate capture, keeping, and killing; the deliberate damage to or destruction of breeding or resting sites; deliberate disturbance, particularly during breeding, rearing, and hibernation period; the deliberate destruction or taking of eggs from the wild or keeping these eggs even if empty; and the possession of and internal trade in these animals, alive or dead.

In November 2018, a Pan-European Action Plan for Sturgeons (Friedrich *et al.* 2018) was adopted under the Convention with an intended lifespan of 2019-2029. The plan aims to restore all existing European sturgeon populations to the status of "least concern" under the IUCN or "favorable" under the EU Habitats Directive (see below), and reestablish self-sustaining sturgeon populations and habitat in their historical range to an extent that ensures species survival. The plan identifies an urgent need for coordinated efforts in conservation of Adriatic sturgeon, specifically a coordinated restoration plan and monitoring throughout its range.

Council Directive 92/43/EEC on the Conservation of Natural Habitats and of Wild Fauna and Flora (EC Habitats Directive)
The EC Habitats Directive was adopted by the European Community in May 1992, and aims to promote the maintenance of biodiversity, taking account of economic, social, cultural and regional requirements. It targets the protection of approximately 200 habitats and 1,000 animal and plant species listed in the Directive's Annexes, of which Adriatic sturgeon are included. The provisions in the Directive require Member States to introduce a range of measures including protecting species listed in the Annexes, surveillance of habitats and species, and producing a report every six years on the implementation of the Directive. The first complete set of country data was reported in 2007. The Directive led to the establishment of a network of Special Areas of Conservation (SAC) that, together with the existing Special Protection Areas classified under the separate EC Birds Directive, form a network of protected areas known as Natura 2000. A SAC for

Acipenser naccarii spawning areas in the Ticino River (from Pavia to the confluence with the Po River) has been proposed as part of the LIFE project Ticino Biosource (LIFE15NAT/IT/000989, http://ticinobiosource.it/en/home-eng/). Additional information on the EC Habitats Directive is available at http://ec.europa.eu/environment/nature/legislation/habitatsdirective/index_en.htm.

Other natural or manmade factors affecting its continued existence:

Climate change

To evaluate the impact of climate change on the species, we used the best available data, which includes the Intergovernmental Panel on Climate Change (IPCC) Special Report on Oceans and Cryosphere (IPCC 2019). The Revised Guidance for Treatment of Climate Change in NMFS' ESA Decisions (NMFS 2016) requires us to use climate indicator values projected under the IPCC Representative Concentration Pathway (RCP) 8.5 when data are available. RCP8.5 reflects a continued increase of greenhouse gas emissions and assumes that few mitigation measures will be implemented.

The IPCC (2019) reports that the global ocean has warmed unabated since 1970 and has taken up more than 90% of the excess heat in the climate system (high confidence). It is virtually certain that the ocean will continue warming throughout the 21st century and by 2100, the top 2000 m of the ocean will very likely take up 5 to 7 times more heat under RCP8.5 than observed heat uptake since 1970 (IPCC 2019). The melting of glaciers and ice sheets resulting from increased surface air temperature is the primary driver of sea level rise, which has accelerated in recent years (very high confidence; IPCC 2019). By 2100 (relative to 2005), global mean seal level is projected to rise 0.84 m with a likely range of 0.61 to 1.1 m, where likely refers to 66% to 100% probability (IPCC 2019). Sea level rise has caused intrusion of salt water into estuaries, which may reduce suitable habitat for estuarine communities (medium confidence; IPCC 2019). Further, increased nutrient loads in estuaries from human development exacerbate the effects of warming on bacterial respiration, causing expansion of hypoxic areas (high confidence; IPCC 2019). Ocean warming and sea level rise are projected to result in further expansion of areas of higher salinity and hypoxia in estuaries (high confidence; IPCC 2019).

Exposure to warmer, more hypoxic conditions has been shown to result in developmental impairment and reduced survival of early life stage European sturgeon (see section 2.3.2.6; Delage *et al.* 2020), and can be expected to impact Adriatic sturgeon and other species in this review in a similar way. As spawning, hatching, and embryonic survival are influenced by exposure to specific temperature ranges in sturgeon (Delage *et al.* 2020; Wang *et al.* 2020), productivity (i.e., reproductive potential) of the Adriatic sturgeon and other species in this review is likely to be negatively impacted by rising water temperatures resulting from climate change.

There is evidence that increased salinity of estuarine habitat will also have negative impacts on the species. Adriatic sturgeon larvae and juveniles are able to survive salinities of 10‰ and 20‰ respectively, and exposure to higher salinity can result in mortality (Cataldi *et al.* 1999). McKenzie *et al.* (2001) found that young-of-the-year Adriatic sturgeon acclimated to a salinity of 11‰ had lower survival and growth rates than their siblings maintained in freshwater. Therefore, increased intrusion of salt water into estuaries as a result of sea level rise may present a concern for the survival and fitness of early life stages of the species.

As reported in the 2013 Status Review, modeling by Lassalle and Rochard (2009) indicates that climate change would result in the decreased abundance of *A. naccarii* in the Po River and the disappearance of the species in the southern Italian basins, with populations potentially remaining stable in the eastern Adriatic Sea. Although we did not find any new species-specific studies or projections of the impact of climate change, we find that the best available information indicates that climate change is likely to negatively impact the spatial distribution, productivity, and abundance of the species.

2.3.1.7 Synthesis:

The 2013 Status Review found the Adriatic sturgeon to be at high risk of extinction based on reduced spatial distribution and population size, habitat destruction and degradation, the species' low productivity life history, and potential competition with hybrids and a catfish species. The final rule to list the Adriatic sturgeon as an endangered species was published June 2, 2014 and became effective July 2, 2014 (79 FR 31222).

Currently, the species has extremely low abundance in the wild, and recovery is dependent on a captive stock that only contains 13 remaining individuals of wild origin. The genetic diversity of most captive stocks is very limited, which reduces the adaptive capacity of the population and increases the species' extinction risk. Habitat degradation and fragmentation have reduced the species' capacity to naturally reproduce, and the last known natural spawning event occurred in Italy in the 1980s and in Albania in 1990. Though a fish passage has been constructed at the Isola Serafini dam to reconnect the marine and freshwater habitats used by the species, we found no indication that any Adriatic sturgeon have used it to this point. The species has extremely low abundance, decreased genetic variability, late age of maturity, and low productivity. On top of these demographic threats, the species faces threats of habitat modification and curtailment, climate change, and possibly overutilization due to fisheries bycatch and recreational fishing. For these reasons, *A. naccarii* continues to be at risk of extinction presently and we conclude that the status of the species should remain endangered.

2.3.2 European sturgeon

2.3.2.1 Biology and life history:

The European sturgeon is a long-lived anadromous species that reproduces in rivers after a period of growth in marine environments. The last remaining population of European sturgeon occurs in the Gironde-Garonne-Dordogne basin in France. Juveniles migrate from their natal rivers (Garonne and Dordogne) to the Gironde estuary in their first year of life, where they remain and grow over several years before heading to sea (Rochard *et al*. 2001). Males and females mature at 8-12 years and 13-16 years, respectively (Chassaing *et al.* 2018). Available studies indicate that males reproduce every other year, while females only reproduce every 3 or 4 years (Gessner *et al.* 2010). When they are ready to reproduce, they return to the river from the marine environment (Chassaing *et al*. 2016) and spawn from March through August among gravel and stones in the lower to middle reaches of rivers (Billard and Lecointre 2001). The generation time for European sturgeon is estimated to be between 38.4 and 52.2 years (Jarić and Gessner 2013).

2.3.2.2 Abundance, population trends, demographic features or demographic trends:

The European sturgeon historically bred in all large rivers in Europe, and occupied a very wide range including the North and Eastern North Atlantic and Mediterranean coasts of Europe, as well as the Black Sea (Gesner *et al.* 2010). At the time of the Status Review, one population remained in the Gironde-Garonne-Dordogne basin in France and the population size was estimated at between 20-750 wild, mature individuals (Gesner *et al.* 2010). The population was declining due to overharvest and the destruction of spawning sites. The species last spawned in 1994 in the Garonne River (Gesner *et al.* 2010) and genetic research suggests that the 1994 cohort is considered to have originated from just one mating pair (Ludwig *et al.* 2004). The 2018 Pan-European Action Plan for Sturgeons (Friedrich *et al.* 2018) reports that the wild mature population is considered to be below 800 individuals, though no detailed population estimates are available.

As the wild population has such low abundance, a captive breeding and stocking program is critical to the survival of the species. Conservation measures, including the release of juveniles, are currently supported by national action plans in the Gironde estuary in France and the Elbe in Germany (Brevé *et al.* 2019). A captive broodstock was established by France's National Research Institute of Science and Technology for the Environment and Agriculture (now known as the National Research Institute for Agriculture, Food, and Environment, INRAE) at the Saint Seurin-sur-l'Isle research station from both wild and artificially bred individuals. From the controlled reproductions, over 1.7 million juveniles have been bred and released into the Garonne and Dordogne rivers since 1995 (Delage *et al.* 2020). Genetic testing of 193 juvenile and adult European sturgeon captured in the Gironde estuary revealed that 91.2% were descendants of captive stock, and that reintroduction of captive born individuals to the wild has been successful (Roques *et al.* 2016). There is some indication of reproduction in the wild, though further study is needed to confirm this (Roques *et al.* 2016). The presence of mature individuals in the Dordogne River was reported by fishermen who accidentally caught these individuals in 2020 and 2021 during the spawning migration (the sturgeon were immediately released; Gessner, pers. comm. 2021).

A second *ex situ* stock is maintained at the Leibniz Institute for Freshwater Ecology and Inland Fisheries in Berlin, Germany, to be used for intensified releases under the German National Action Plan once the fish are mature (Gessner, pers. comm. 2021). Roughly 20,000 European sturgeon have been stocked in the Elbe River in Germany since 2008 under the German National Action Plan (Gessner, pers. comm. 2021). In 2021 the first adult sturgeon has been witnessed in the Elbe River mouth (Gessner, pers. comm. 2021). Reduced reproduction in the French brood stock after 2014 has led to a pause in releases in France and Germany since 2015 (Visser *et al.* 2020).

The long life cycle and late maturity of the species makes management challenging. As it will take at least 15 years for released juveniles to begin reproducing, recovery is a slow process that may take a minimum of 30-50 years (Jarić and Gessner 2013).

2.3.2.3 Genetics, genetic variation, or trends in genetic variation:

Genetic variation is critical to the evolutionary potential and long-term survival of a species because it provides the raw material for adaptation by natural selection. Ludwig *et al.* (2004) demonstrated the low genetic variability and high degree of relatedness of individuals of the Gironde population of European sturgeon, concluding that only one male and one female participated in the last known natural reproduction in 1994. A nuclear genetic study by Chassaing *et al.* (2018) reveals higher past allelic diversity in the Mediterranean and Adriatic seas compared to Atlantic and Black Sea samples, the Atlantic region having been colonized from the Mediterranean and Adriatic seas after the last glaciation. Analysis of five microsatellite loci of 22 contemporary, 42 museum (originating in the 19th early 20th centuries) and 38 archeological (originating 250–2,500 years before present) specimens reveal much higher diversity in archeological samples than in contemporary samples of the Gironde population (Chassaing *et al.* 2018). Genetic diversity in the current population is assessed to be low (Chassaing *et al.* 2016; Chassaing *et al.* 2018) which increases the extinction risk to the species.

2.3.2.4 Taxonomic classification or changes in nomenclature:

The taxonomic classification for the species has not changed since the 2013 Status Review. It remains as follows:

Kingdom: Animalia
Phylum: Chordata
Class: Actinopterygii
Order: Acipenseriformes
Family: Acipenseridae
Genus: *Acipenser*
Species: *sturio*
Common name: European sturgeon

2.3.2.5 Spatial distribution, trends in spatial distribution, or historical range:

The last remaining population of European sturgeon occurs in the Gironde-Garonne-Dordogne basin in France. Juveniles migrate from their natal river to the Gironde estuary in their first year of life where they remain and grow for several years before heading to sea (Rochard *et al.* 2001). The species has recently been sighted in the marine environment along the French Atlantic coast, the British Isles, and the Baltic Sea (Chassaing *et al.* 2018).

As discussed in section 2.3.2.2, the release of juveniles is currently supported by national action plans in the Gironde estuary in France and the Elbe in Germany. The potential for a reintroduction effort in the Rhine River, on the border of Germany and the Netherlands, has been explored (Brevé *et al.* 2019). The Rhine Sturgeon Project, aiming to restore European sturgeon populations in the Rhine River, is in its early experimental research phases right now as described in the June 2020 Action Plan (Visser *et al.* 2020).

2.3.2.6 Five-Factor Analysis:

Present or threatened destruction, modification or curtailment of its habitat or range:

Juvenile European sturgeon of the Gironde population spend several years of their development in the estuary and are subject to pollution from urban wastewater, former mining and ore processing, industrial waste, and agricultural activities (Acolas *et al.* 2020). A study of 87 juveniles captured in the estuary in 2014 found low levels of inorganic metal contamination, mainly the following: zinc (< 5 microgram/milliliter (μg/mL)), iron (< 1.5 μg/mL), copper (< 0.8 μg/mL), selenium (< 0.8 μg/mL), arsenic (< 0.25 μg/mL), cobalt (< 0.14 μg/mL), and manganese (< 0.03 μg/mL). Concentrations of organic contaminants including polychlorinated biphenyls, organochlorine pesticides, and polybrominated diphenyl ethers were generally low (Acolas *et al.* 2020). No acute toxicity was found, though further study is needed to determine the impact of detected contaminants on European sturgeon that spend time in the Gironde estuary.

Historical alterations to the European sturgeon's habitat summarized by Williot and Castelnaud (2011) include gravel extraction from the riverbed and damming of the Dordogne and Garonne Rivers, resulting in the decrease in number of accessible spawning grounds by 33% in the Dordogne and 88% in the Garonne. Gravel extraction has since been banned in the Gironde estuary (Lepage *et al.* 2000). The Bergerac Dam on the Dordogne, constructed in 1851, and the Golfech Dam on the Garonne, constructed in 1971, are the furthest downstream dams, and European sturgeon have access to approximately 20 suitable spawning habitats below these dams (Gessner *et al.* 2010; Ministère de la Transition Ecologique et Solidaire 2019). The facilitation of fish passage at the dams was considered, but was not carried out due to the marginal benefit, and potential detriment, that would result from dispersing the small current breeding population over a larger number of spawning sites (Gessner, pers. comm. 2021). Flow regulation resulting from the dams contributes to habitat alteration and changes to water temperature regimes, negatively affecting the productivity of the species (Gessner *et al.* 2010).

In sum, modification of European sturgeon habitat has contributed to the low abundance and reduced spatial distribution of the species in the Gironde-Garonne-Dordogne basin. The current number of mature breeders is so low that availability of spawning habitat does not appear to be an immediate challenge to the species survival at this time, though pollution and flow regulation by dams have the potential to reduce the productivity of the species.

Overutilization for commercial, recreational, scientific, or educational purposes:

The European sturgeon has a high susceptibility to even very low levels of fishing mortality, and population recovery requires complete protection from harvest (Jarić *et al.* 2011; Jarić and Gessner 2013). Modeling shows that historically, even at low fishing mortality, targeted removal of spawning migrants in the Elbe River significantly reduced the abundance of adult sturgeon (Gessner and Jarić 2014).

Fishing is banned throughout the species' range. Since 2004, the French Fisheries Association has carried out communications efforts in collaboration with neighboring countries, resulting in increased compliance and sturgeon releases upon being bycaught (Gessner, pers. comm. 2021). In the current range of the species, mortalities due to fishing activity have been limited to occasional accidental instances (Gessner, pers. comm. 2021). However, bycatch in commercial benthic trawls and gillnet fisheries threatens reintroduction efforts and is considered to be the main threat to the remaining population (OSPAR Commission 2020), and a main obstacle for the species' recovery (Jarić and Gessner 2013; Friedrich *et al.* 2018).

Despite increases in compliance with fisheries prohibitions, fisheries bycatch remains a threat to the abundance and productivity of the species, particularly if mature individuals with high reproductive potential are removed.

Disease or predation:

Predation has been confirmed as a main cause of mortality for stocked fish across several different species, typically occurring within the first few days after release (Carrera-García *et al.* 2017). It has been suggested that predation by cormorants (*Phalacrocorax carbo*), herons (*Ardea spp.*) and the European catfish (*Silurus glanis*) was the main reason for the disappearance of 30.7% of tagged released juvenile European sturgeon in the Dordogne River, France, though this was not confirmed (Carrera-García *et al.* 2017). Based on this limited information, we conclude that predation of stocked juvenile European sturgeon may be a potential threat to the recovery of the species.

Captive breeding operations for sturgeon may lead to increased susceptibility to bacterial infections and disease, though we did not find any specific information to suggest that disease is currently threatening the species.

Inadequacy of existing regulatory mechanisms:

Inadequate regulatory measures can leave sturgeon vulnerable to a wide range of anthropogenic impacts, including overharvest and habitat degradation. The migratory life history of sturgeon exposes them to these threats across multiple habitat types, and in some cases, across different countries and jurisdictions. For this reason, regulatory and conservation mechanisms at several different scales are needed for adequate protection. Below is a summary of regulatory and conservation measures that apply to European sturgeon. In all, we find that there are many measures being implemented to protect the species from habitat degradation, as well as restore the species to its historical range, though regulatory mechanisms appear to be inadequate to protect the species from the ongoing threat of fisheries bycatch.

In France, fishing, trade, and transportation of the species have been strictly prohibited since 1982 (Billard and Lecointre 2001), although bycatch in commercial benthic trawl fisheries reduces the efficacy of reintroduction efforts (Friedrich *et al.* 2018). Several national action plans for the conservation of the species are in place, including for France, Germany, and the Netherlands. Financial efforts to recover the species are made through the European Commission LIFE program as well as national and local authorities and funding instruments.

Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)

The European sturgeon is listed on Appendix I of CITES, which includes species threatened with extinction. International trade in specimens of the species is permitted only in certain circumstances, and commercial international trade in the species is prohibited. For more information on this Convention see section 2.3.1.6.

Bern Convention on the Conservation of European Wildlife and Natural Habitats

The European sturgeon is listed as a strictly protected fauna species on Appendix II of the Bern Convention. See section 2.3.1.6 for more information on this instrument, and the 2018 Pan-European Action Plan for Sturgeons (Friedrich *et al.* 2018), which identifies an urgent need to secure long-term coordinated efforts and reduction of bycatch for the species. The Action Plan for the conservation and restoration of the European Sturgeon (Rosenthal *et al.* 2007) was also developed under the Bern Convention.

Convention on the Conservation of Migratory Species of Wild Animals (CMS)

The European sturgeon was included in Appendix II of CMS in 1999. It was added to Appendix I, which lists migratory species in danger of extinction, in 2005. CMS Parties that are range states work to strictly protect Appendix I species by prohibiting take, conserving or restoring their habitat, mitigating obstacles to migration, and reducing or eliminating other threats. For more information on this Convention see section 2.3.1.6.

Council Directive 92/43/EEC on the Conservation of Natural Habitats and of Wild Fauna and Flora (EC Habitats Directive)

The European sturgeon is listed among the animals of community interest (Annex II and IV) whose conservation requires the designation of Special Areas of Conservation (SAC). Implementation takes place nationally and is reported to the EU. For more information on the Habitats Directive, see section 2.3.1.6.

Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR Convention)

Through OSPAR, the EU and 15 European governments (Belgium, Denmark, Finland, France, Germany, Iceland, Ireland, Luxembourg, The Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and United Kingdom) coordinate to protect the marine environment of the North-East Atlantic. OSPAR is the result of the 1992 unification of the Oslo Convention against dumping and the Paris Convention against land-based sources of pollution and offshore industry. OSPAR is implemented through the adoption of decisions (which are legally binding) and recommendations, both of which set out actions to be taken by the Contracting Parties. The European sturgeon was added to the OSPAR list in 2003, and Recommendation 2014/1 on furthering the protection and conservation of the common or European sturgeon (*Acipenser sturio*) in Regions II, III1 and IV of the OSPAR maritime area was adopted in 2014. The purpose of the recommendation is to strengthen protections for all life stages of the species to recover the population, and it recommends Contracting Parties to introduce new legislation, implement action plans, designate marine protected areas, promote monitoring of the species, take actions to address threats, and other actions focused on the conservation of the species. Contracting Parties are requested to report regularly on their implementation of the Recommendation.

Other natural or manmade factors affecting its continued existence:

Climate change

Climate change has the potential to impact the species as described in section 2.3.1.6. Lassalle *et al.* (2010) modeled habitat suitability for the European sturgeon under future climate change scenarios, concluding that although future climatic suitability does not appear to constrain species rehabilitation actions in the Elbe or Gironde basins by 2050, a moderate decrease in suitability was predicted for the end of the 21st century. More recently, the effects of warming and decreased oxygen saturation on the development of early life stage European sturgeon were investigated. The optimal temperature for development of European sturgeon embryos and larva is 20°C indicated by maximum survival, hatching success and routine metabolism capacities, as well as minimum malformation frequency (Delage *et al.* 2020). At 26°C, over 75% hatching failure was observed by Delage *et al.* (2020), and at 30°C, no embryos survived. Embryos that were subjected to hypoxic conditions had significantly lower swimming speeds as larvae (Delage *et al.* 2020). With observed warming water temperatures and more intense and frequent hypoxic events expected to continue as a result of climate change, European sturgeon will experience reduced survival and recruitment if they do not shift their breeding period temporally or spatially (farther north) so the most vulnerable life stages are not subjected to these stressors (Delage *et al.* 2020). The availability of food, interaction with pollutants, and maturation of adults are also impacted by climate change and are expected to indirectly affect European sturgeon (Delage *et al.* 2020). We therefore find that the best available information indicates that climate change is likely to negatively impact the spatial distribution, productivity, and abundance of the species.

Competition
As reported in the 2013 Status Review, *A. sturio* experienced competition with escaped *Acipenser baerii* in the Gironde estuary. The 2020 OSPAR Commission Status Assessment on the species also reports that an increased abundance of nonnative sturgeon species in the species' range potentially threatens European sturgeon through competition for food (OSPAR Commission 2020). We did not find any further information on the threat posed by nonnative sturgeon species and it is unclear to what degree competition affects the status of the European sturgeon at this time.

2.3.2.7 Synthesis:
The 2013 Status Review found the European sturgeon to be at high risk of extinction at that time based on reduced spatial distribution and population size, habitat destruction and degradation, pollution, dredging, dams, historical harvest, bycatch, inadequate regulations, the species' low productivity life history, and potential competition with introduced sturgeon. The final rule to list the European sturgeon as an endangered species was published June 2, 2014 and became effective July 2, 2014 (79 FR 31222).

Currently, there are no detailed population estimates for the species, though the wild, mature population is considered to consist of fewer than 800 individuals (Friedrich *et al.* 2018). Genetic diversity in the population is low (Chassaing *et al.* 2018), and the last confirmed natural reproduction occurred in 1994 with just one breeding pair (Ludwig *et al.* 2004). The species currently faces threats of bycatch in commercial trawls and gillnets, pollution, climate change, and potentially competition with introduced sturgeon and predation. Although compliance with fishing prohibitions has increased in recent years and limited the amount of mortalities due to fisheries activities (Gessner, pers. comm. 2021), bycatch is still considered a main threat to the recovery of the species (Friedrich *et al.* 2018; OSPAR Commission 2020). The long life cycle and late maturity of the species (at 15 years) makes recovery a slow process that may take a minimum of 30-50 years (Jarić and Gessner 2013). Although there have been indications that restoration activities, including restocking of artificially bred individuals, have been successful in the Gironde estuary and the Elbe River, we do not find that the status of the species has changed since it was originally listed as endangered. We find that *A. sturio* continues to be at risk of extinction presently, and conclude that the status of the species should remain endangered.

2.3.3 Chinese sturgeon

2.3.3.1 Biology and life history:

The Chinese sturgeon is an anadromous species that spends most of its life at sea and migrates to spawn in the Yangtze River. Males and females mature at approximately 8 years and 14 years, respectively (Zhang *et al.* 2018a), and adults spawn about every four years (Zhang 1998 and Wei 2003, as cited in Zhuang *et al.* 2016). Adults approach the Yangtze River Estuary in June or July and swim upstream to spawning areas (Zhang *et al.* 2018a). They spend up to 18 months in the middle reaches of the river as their gonads mature, and begin spawning in October or November of the next year (Chang *et al.* 2017; Zhang *et al.* 2018a). Their spawning substrate includes coarse gravel in the middle reaches of rivers (Billard and Lecointre 2001). After spawning, adults return to the sea and their larvae begin to drift down the river towards the estuary. Juveniles spend about three months adapting to increased salinity and foraging in shallow coastal waters of the estuary before entering the Yellow and East China Seas (Wang *et al.* 2018). Chinese sturgeon are benthic predators, and their dominant prey includes annelids, crustaceans, molluscs, fishes and aquatic insects (Wang *et al.* 2018; Sun *et al.* 2019). Stable isotope analysis shows that juveniles shift their diet from low trophic-level food in riverine habitats to higher trophic-level food in the estuarine habitat (Wang *et al.* 2018).

2.3.3.2 Abundance, population trends, demographic features, or demographic trends:

The spawning population of Chinese sturgeon was estimated at 10,000 individuals in the 1970s, and was reduced by 97.5% due to habitat degradation and overfishing to just 203-257 individuals in 2005-2007 (Qiwei 2010). Between 2006-2014, the spawning population was counted at 57-188 individuals (Wu *et al.* 2015). Huang and Wang (2018) estimate the total adult abundance at 2,569 in 2015, reduced from 6,000 in 2010 and 32,260 before 1981. Overall, the wild population of Chinese sturgeon has experienced a drastic decrease in abundance and continues to decline.

Construction of the Gezhouba Dam in 1981 blocked access to the Chinese sturgeon's upstream spawning areas, and the species began using a new spawning ground 3.85 km below the dam in 1982 (Wu *et al.* 2015). Spawning at this site was observed every year through 2012 (Wu *et al.* 2015). Although no spawning activity was recorded below the Gezhouba Dam in 2013 or 2014, four juveniles were found in April 2015 at one of the Yangtze Estuary monitoring stations, indicating that spawning had occurred in 2014. Over 3,000 juveniles were found in the Yangtze Estuary between May and September 2015, though they were smaller and arrived earlier than those captured in previous years (Wu *et al.* 2015). It is unclear where the specimens originated but it is thought that they were born further downstream than the known Gezhouba Dam spawning site (Wu *et al.* 2015; Zhuang *et al.* 2016). Zhuang *et al.* (2016) are optimistic that the species is able to change its spawning site and adapt to environmental change. Survey data from the spawning ground and the estuary indicates that the species failed to breed in 2013, 2015, 2017, 2018, and possibly 2019 (Zhuang *et al.* 2016; Shen *et al.* 2020). Over 9 million captive-reared juveniles were released into the Yangtze River between 1983 and 2007, however, the contribution to wild stocks is considered to be less than 10% (Qiwei 2010; Zhang *et al.* 2017). Huang and Wang (2018) predict that the natural population of Chinese sturgeon will be extinct in 10-20 years.

2.3.3.3 Genetics, genetic variation, or trends in genetic variation:

Genetic variation is critical to the evolutionary potential and long-term survival of a species because it provides the raw material for adaptation by natural selection. Measures of genetic diversity are also used to infer inbreeding, which may increase the extinction risk of a species. As described below, inbreeding and loss of genetic diversity are often linked, and both often result from reduced population size. While inbreeding may occur within a single generation, it may take several generations of reduced population size to diminish genetic diversity.

As discussed in section 2.3.3.2, the species failed to spawn in 2013, 2015, 2017, 2018, and possibly 2019. Spawning in 2014 allowed for the collection of samples and genetic analyses. Evaluating the mitochondrial DNA (mtDNA) genome and 21 nuclear microsatellite loci, Shen *et al.* (2020) revealed that the 15 juveniles captured in 2015 were sired and spawned in 2014 by 11 males and 11 females; seven pairs parented only one offspring, and four pairs parented two offspring. Liu *et al.* (2018) analyzed the mtDNA control region (421 base pairs) and 115,982 genome-wide single nucleotide polymorphisms of 462 larvae collected in 2015, identifying 15 different haplotypes (i.e., at least 15 spawning females) and low effective female population size. Both studies found evidence for inbreeding, which may increase the risk of extinction in the species: FIS = 0.066±0.1430 (Shen *et al.* 2020) and FIS = 0.148 (Liu *et al.* 2018). Given the small number of breeding adults and evidence for inbreeding, we might also expect a reduction in genetic diversity. Sequencing the mtDNA control region of 106 adult sturgeon samples collected between 1995 and 2000, Zhang *et al.* (2003) estimated haplotype diversity to be 0.949±0.010. More recently, Liu *et al.* (2018) estimated haplotype diversity at the mtDNA control region to be 0.8047±0.0094, and Shen *et al.* (2020) estimated haplotype diversity to be (0.876±0.0035) across the mtDNA genome. These data may reflect a slight decline in haplotype diversity over time; however, the recent values are based on one larval or juvenile cohort, and the earlier values are based on samples collected from adults over numerous years, which would be expected to demonstrate higher diversity. Given the diminished population size and evidence for inbreeding, it is somewhat surprising that genetic diversity remains relatively high. Shen *et al.* (2020) attribute this resilience to the species' complex genetic makeup, which includes mtDNA genome size polymorphism and tetraploidy (four, rather than two alleles at each nuclear locus). Thus, not enough time has elapsed since the building of the dams and resulting population decline to significantly reduce the genetic diversity of this species. Regardless of its current genetic diversity, the species is at risk of extinction due to its small abundance, a risk that is further exacerbated by inbreeding.

In addition to the concerning state of the wild population, Chinese sturgeon in hatcheries have been subject to random mating without genetic management of parents, increasing the possibility of inbreeding and reduced genetic diversity in future generations (Xu *et al.* 2019).

2.3.3.4 Taxonomic classification or changes in nomenclature:

The taxonomic classification for the species has not changed since the 2013 Status Review. It remains as follows:

Kingdom: Animalia
Phylum: Chordata
Class: Actinopterygii
Order: Acipenseriformes
Family: Acipenseridae
Genus: *Acipenser*
Species: *sinensis*
Common name: Chinese sturgeon

2.3.3.5 Spatial distribution, trends in spatial distribution, or historical range:

Historically found in southwest Korea, western Kyushu, Japan, and in the Yellow, Yangtze, Pear, Mingjiang, and Qingtang rivers in China, the species now only occurs below the Gezhouba dam in the Yangtze River, and the Yellow and East China Seas (Qiwei 2010). The construction of the Gezhouba Dam reduced the Chinese sturgeon's migratory distance by 1,175 km (Huang and Wang 2018) and length of spawning grounds from 600 km to 30 km, a 95% reduction (Wang *et al.* 2012).

2.3.3.6 Five-Factor Analysis:

Present or threatened destruction, modification or curtailment of its habitat or range:

Dams

Several dams have been constructed on the main channel of the Yangtze River since the 1980s, including the Gezhouba in 1981, the Three Gorges in 2003, the Xiangjiaba in 2012, and the Xiluodu in 2013 (He *et al.* 2020). Two new dams will soon begin operations: the Baihetan and Wudongde (He *et al.* 2020). The primary impact of the Gezhouba Dam's construction in 1981 was the dramatic reduction in spawning area available to the species (Jiao *et al.* 2019). The effective breeding population was reduced to 24.1% of its original size, and the environmental carrying capacity of the new spawning ground below the dam was reduced to 6.5% of the original as a result of the Gezhouba Dam's construction (Huang and Wang 2018). The effective breeding population size is estimated to have been reduced to 0-4.5% of the original by subsequent construction of other dams on the Yangtze, primarily the Three Gorges Dam and the Xilodu Dam (Huang and Wang 2018).

Beyond reducing spawning area, dams and reservoirs also significantly alter the hydrology and ecology of downstream river habitat. The operation of reservoirs in the upper reaches of the Yangtze River and the Three Gorges Reservoir (TGR, constructed in 2003) alters water flow and temperature regimes, including by delaying temperature changes in the rivers (He *et al.* 2020; Wang *et al.* 2020). The species begins spawning when the water temperature drops to 20.5°C, typically in October, however, modeling shows that water temperature does not reach 20.5°C until the beginning of November, delaying the start of spawning for the species by 2-3 weeks (Wang *et al.* 2020). With more reservoirs operating, the effects on delayed temperature changes are more dramatic (Wang *et al.* 2020). Zhang *et al.* (2019) found that the suitable spawning temperature has been delayed by 29 days in the period 2003-2016. The average frequency of active spawning cohorts declined from 1.8 per season in the period 1984-2003 to 1.1 per season in the period 2004-2012, meaning that after the TGR impoundment, only one cohort typically spawned each year rather than two (Wu *et al.* 2015; Gao *et al.* 2016). Temperature shifts may also affect gonad development as this process is correlated with water temperature in winter and early spring (Zhang *et al.* 2019).

Dams and reservoir operation also influence flow rates, water level, and sediment level. Significant trapping of sediments by reservoirs impacts spawning as the species is rather sensitive to sediment condition, and Yu *et al.* (2019) find that sediment condition downstream of the Three Gorges Dam has not been suitable for Chinese sturgeon spawning since 2006. Habitat suitability modeling reveals that Chinese sturgeon prefer to spawn at depths of 13.33-20.33 meters and velocities of 1.06-1.56 meters/second (m/s), and that habitat suitability reaches its highest value at a discharge of 16,000 cubic meters per second (m^3/s) (Yi *et al.* 2016). Wang *et al.* (2017) and Zhou *et al.* (2014) report similar discharge preferences for spawning and hatching of between 13,100 m^3/s to 24,200 m^3/s and 10,000 m^3/s and 17,000 m^3/s, respectively. Prior to the impoundment of the Gezhouba Dam in the period 1960-1969, average discharge during spawning season at Yichang Station was between 11,000 m^3/s and 20,000 m^3/s (Yi *et al.* 2016). Between 1982 and 1998, after operations of Gezhouba Dam began and before the impoundment of the Three Gorges Reservoir, average discharge was between 8,500m^3/s and 17,000m^3/s (Yi *et al.* 2016). In the period 2003-2012, after the filling of the Three Gorges Reservoir, average discharge fell to between 9,000 m^3/s and 12,300 m^3/s (Yi *et al.* 2016).

In all, we conclude that dams are a major threat to the abundance, productivity, and spatial distribution of the Chinese sturgeon.

Pollutants

Effluents from rapid urbanization and industrial activities are discharged into the Yangtze River estuary, resulting in heavy metal contamination (Feng *et al.* 2017). Although zinc and copper are essential nutrients for physiological function, exposure to high concentrations can cause reduced fitness and mortality in juvenile Chinese sturgeon (Feng *et al.* 2017). Specifically, Feng *et al.* (2017) found that juveniles exposed to increased copper concentrations resulted in accumulation of copper in the liver, liver damage, secretion of excess mucus covering the gills, and mortality (Feng *et al.* 2017). Safe copper and zinc concentrations for juveniles of the species were found to be 0.00217 and 0.1200 milligrams per liter (mg/L) respectively, and the average concentrations in the Yangtze River estuary between 2005 and 2008 were 0.01448 and 0.0275 mg/L, respectively (Feng *et al.* 2017). As juveniles use the Yangtze River estuary for growth and development prior to entering the sea, copper contamination in the estuary poses a concern for recruitment into the adult population.

Also of concern is the accumulation of persistent organic pollutants, including polybrominated diphenyl ethers, polychlorinated biphenyls, and perfluorinated compounds, in Chinese sturgeon and their eggs (Jianxian *et al.* 2015). For example, exposure to triphenyltin, used as a pesticide and as an ingredient in antifouling paint, is the likely cause of ocular and morphological malformation of larval Chinese sturgeon and can be transferred from female sturgeon to their eggs (Hu *et al.* 2009). Further study is needed to understand the impacts of these pollutants on the species.

Based on the available information, we conclude that pollution in the Yangtze River and estuary threatens the productivity of the species as the youngest life stages use these habitats for their growth and development.

Overutilization for commercial, recreational, scientific, or educational purposes:

Chinese sturgeon were historically overfished, though commercial fishing has been prohibited since 1983 (Billard and Lecointre 2001). Illegal fishing and the use of illegal fishing gears are cited as reasons for the species' continued drastic population decline, and past studies have estimated that 5,000 individuals are removed by fishermen each year (Cheng *et al*. 2005, as cited in Wang *et al.* 2011). Although the current magnitude of fishery mortality is unknown, given the low abundance and poor status of the species, we conclude that illegal fishing is a serious threat to the species.

Disease or predation:

The rapid increase in captive breeding operations and high stock density for the species has led to susceptibility to bacterial infections, including by *Streptococcus iniae* (Muhammad *et al*. 2020), *Mycobaterium* species (Zhang *et al.* 2015; Zhang *et al.* 2018b), *Pseudomonas alcaligenes* (Xu *et al.* 2015), and *Aeromonas hydrophila* and *Aeromonas veronii* (Di *et al.* 2018). Muhammad *et al.* (2020) determined that a 2016 outbreak of infection by HMN-1 *S. iniae* in Chinese sturgeon living in Hebei aquaculture experimental station, Shijiazhuang China, caused cumulative mortality of between 40% and 100%. As *S. iniae* is resistant to many antibiotics, this bacterial infection presents a concern for the species in aquaculture facilities (Muhammad *et al.* 2020). An outbreak of fatal haemorrhagic septicaemia, caused by *A. hydrophila* and *A. veronii*, in a sturgeon hatchery at

Jingzhou City, Hubei Province, China led to mortality rates of 20% (Di *et al.* 2018). Mycobacteriosis in *A. sinensis* results in muscle ulceration, accumulation of fluid in the peritoneal cavity, and eventually death (Zhang *et al.* 2018b). Bacterial infections pose health risks not only to stocks of the species in aquaculture facilities, but also to wild populations that may be exposed via restocking activities. Though disease is not currently a main threat to the species, management specific to preventing the spread of disease in sturgeon farming facilities is important as outbreaks could pose serious dangers to the population.

Inadequacy of existing regulatory mechanisms:

Inadequate regulatory measures can leave sturgeon vulnerable to a wide range of anthropogenic impacts, including overharvest and habitat degradation. The migratory life history of sturgeon exposes them to these threats across multiple habitat types, and in some cases, across different countries and jurisdictions. For this reason, regulatory and conservation mechanisms at several different scales are needed for adequate protection. Below is a summary of regulatory and conservation measures that apply to Chinese sturgeon.

The Chinese sturgeon is a Class I state protected animal in China. Commercial fishing for the species has been banned in China since 1983 (Billard and Lecointre 2001), and fishing for all purposes (including scientific) has been prohibited since 2009 (Zhang *et al.* 2018a). China has established several nature reserves specifically for the protection of *A. sinensis* including the Yangtze Provincial Nature Reserve for Chinese Sturgeon, established in 1996 (Zhang *et al.* 2017), and the Shanghai Yangtze Estuarine Wetland Nature Reserve for Chinese Sturgeon, established in 2002 (Wang *et al.* 2018). The Chinese government has designed an action plan for the conservation of Chinese sturgeon for the years 2015-2030, which includes *in situ* and *ex situ* conservation actions (Zhang *et al.* 2017). A new regulation (effective June 6, 2020) in Shanghai prohibits capturing, killing, producing, selling, purchasing, transporting and eating food containing Chinese sturgeon and its products. The regulation also directs the fishery administrative department to carry out research, carry out and monitor artificial breeding and release, and strengthen enforcement (Shanghai Municipal People's Government 2020). On January 1, 2020, a 10-year fishing moratorium for all species in the waterways of the Yangtze took effect with the goal of recovering fish stocks. In 2021, the ban was extended to tributaries and the Yangtze estuary (Stanway 2020). The species is also listed on Appendix II of CITES and Appendix II of CMS. For more information on these Conventions see section 2.3.1.6.

In terms of conservation efforts, collaborative monitoring of Chinese sturgeon spawning has been carried out since the 1980s by The Yangtze River Fisheries Research Institute of the Chinese Academy of Fisheries Sciences, the Institute of Hydrobiology of the Chinese Academy of Sciences, the Institute of Hydro-ecology of the Ministry of Water Resources of China, and the Chinese Sturgeon Research Institute of the Three Gorges Group. In addition, the East China Sea

Fisheries Research Institute of the Chinese Academy of Fisheries Sciences has been monitoring migrating juveniles in the Yangtze Estuary since the early 2000s.

While we find that there are many existing national and international regulatory mechanisms, they do not adequately protect or restore the health and connectivity of habitat required by this migratory species, do not adequately protect against introduction of nonnative sturgeon species, and may not effectively protect from the effects of overutilization. New measures targeting overutilization have recently been implemented, and adequacy of these measures should be assessed in the future.

Other natural or manmade factors affecting its continued existence:

Climate change

Climate change has the potential to impact the species as described in section 2.3.1.6. Chinese sturgeon spawn when water temperatures drop to 20.5°C, and most suitable temperature range is 18-20°C (Zhuang *et al.* 2016; Wang *et al.* 2020). Water temperature increase caused by climate change is likely to delay the onset of spawning in Chinese sturgeon and narrow the spawning window, and the effect is exaggerated in combination with negative effects on water temperature caused by operation of the Three Gorges Dam (Zhang *et al.* 2021). We conclude that climate change is likely to threaten the species by reducing productivity.

Competition

As reported in the 2013 Status Review, *A. sinensis* experienced competition with introduced exotic sturgeon in the Yangtze River. Heavy rains and flooding of the Qingjiang River Basin in July 2016 caused the escape of 9,800 tonnes of non-native sturgeon (including *A. schrenckii*, *A. baerii*, *H. dauricus*, *A. gueldenstaedtii*, the American paddlefish *P. spathula* and some hybrids of these species) from farming facilities in the Qingjiang Reservoir, Hubei Province, and introduction to the Yangtze River (Li *et al.* 2019b). An analysis of the diets of farm-escaped nonnative sturgeon in the Yangtze found that escaped sturgeon may compete with native sturgeon for food (Li *et al.* 2019b). The introduced sturgeon may also compete with *A. sineisis* for spawning habitat, and pose threats to the genetic integrity of *A. sinensis* through hybridization (Ju *et al.* 2020, Appendix S1). We conclude that competition with introduced sturgeon remains a threat to the Chinese sturgeon.

2.3.3.7 Synthesis:

The 2013 Status Review found the Chinese sturgeon to be at high risk of extinction at that time based on reduced spatial distribution and population size, habitat destruction and degradation, water pollution, dams, historical harvest, inadequate regulations, the species' low productivity life history, and potential competition with introduced exotic sturgeon. The final rule to list the Chinese sturgeon as an endangered species was published June 2, 2014 and became effective July 2, 2014 (79 FR 31222).

The species continues to have low and declining abundance: Huang and Wang (2018) estimated adult abundance at 2,569 individuals in 2015, reduced from 6,000 in 2010 and 32,260 before 1981. Genetic variation has remained relatively high, although evidence of inbreeding increases the risk of extinction in the species (Liu *et al.* 2018; Shen *et al.* 2020). The reduction of available spawning area due to damming of the Yangtze River has resulted in a drastically reduced breeding population size, and breeding was not observed in 2013, 2015, 2017, 2018, and possibly 2019 (Shen *et al.* 2020). The species also faces serious threats of altered water flow and water temperature regimes due to damming, pollution, disease, illegal fishing, competition with introduced sturgeon species, climate change, and inadequate regulatory mechanisms. Based on the severity of the threats facing the species, as well as demographic factors including late age at maturity, long breeding interval, low and declining abundance, and indications of inbreeding, we find that *A. sinensis* continues to be at risk of extinction presently and we conclude that the status of the species should remain endangered.

2.3.4 Sakhalin sturgeon

2.3.4.1 Biology and life history:

Sakhalin sturgeon remain poorly studied and much of the data on the biology of the species is now several decades old. They are a rare anadromous species that feed in waters of oceanic salinity and migrate to spawn in freshwater in the spring (Koshelev *et al.* 2012). They appear to only use river systems with estuaries, and it is thought that estuaries provide nursery habitat for the species (Shmigirilov *et al.* 2007). Maturity is reached at body length of 135 cm and body weight of 15 kg (Koshelev *et al.* 2012). For females, maturity is estimated to be reached at 10-12 years (Shilin 1995, as cited in Shmigirilov *et al.* 2007).

2.3.4.2 Abundance, population trends, demographic features, or demographic trends:

At the time of the 2013 Status Review, the Sakhalin sturgeon was thought to have declined 80% over 45 years, with an estimated 10 to 30 individuals entering the Tumnin River each year to spawn (Mugue 2010). The main method of maintaining Sakhalin sturgeon abundance is artificial reproduction and release of juveniles into the Tumnin River and Lake Tunaicha (Koshelev *et al.* 2012). The best available information indicates that the abundance of the species continues to be extremely low.

2.3.4.3 Genetics, genetic variation, or trends in genetic variation:

Genetic variation is critical to the evolutionary potential and long-term survival of a species because it provides the raw material for adaptation by natural selection. A recent study of the mitogenome of Sakhalin sturgeon suggests that the species' extremely low abundance has not impacted the diversity of mtDNA variants (Shedko 2017). The seven wild individuals examined represented six different haplotypes, allowing the authors to estimate gene diversity at 0.82 (93% of the maximum possible value for a sample this size) (Shedko 2017). Analysis of a larger sample size is required for a more complete understanding of the species' genetic variation.

2.3.4.4 Taxonomic classification or changes in nomenclature:

For many years, the species was thought to be conspecific with green sturgeon *Acipenser medirostris,* occurring along the Pacific coast of North America (Shmigirilov *et al.* 2007). The taxonomic separation of *A. mikadoi* from *A. medirostris* was recently reaffirmed, however, the time since the divergence of the two species is now estimated at 0.16 million years rather than 9.6 million years (Shedko 2017).

The taxonomic classification for the species has not changed since the 2013 Status Review. It remains as follows:

Kingdom: Animalia
Phylum: Chordata
Class: Actinopterygii
Order: Acipenseriformes
Family: Acipenseridae
Genus: *Acipenser*
Species: *mikadoi*
Common name: Sakhalin sturgeon

2.3.4.5 Spatial distribution, trends in spatial distribution, or historical range:

The Sakhalin sturgeon's historical breeding distribution included small coastal rivers of the Russian Federation (Suchan, Adzemi, Koppi, Tumnin, Viakhtu, and Tym rivers), and the Ishikari and Teshio Rivers of Hokkaido, Japan (Shmigirilov *et al.* 2007; Mugue 2010). Currently the species is only known to breed in the Tumnin River no further than 100 km upstream of the estuary, and feed in the Sea of Japan from the Amur Liman and the Tatar Strait south to the Tumen River (Mugue 2010; Shedko 2017). One mature male was caught in the Viakhtu River, Sakhalin in 2011 (Koshelev *et al.* 2012).

2.3.4.6 Five-Factor Analysis:

Present or threatened destruction, modification or curtailment of its habitat or range:

As discussed briefly in the 2013 Status Review, Sakhalin sturgeon habitat is degraded by pollution from oil production, agriculture, and mine operations (Shmigirilov *et al.* 2007). We did not find any new information on specific threats to the habitat of *A. mikadoi*, or information to suggest that threat of pollution has been mitigated.

Overutilization for commercial, recreational, scientific, or educational purposes:

The species occurs in estuaries and bays, where it is bycaught by commercial fixed nets and gill nets targeting salmon and other fish (Shedko 2017). Shmigirilov *et al.* (2007) report that the species is also illegally fished primarily during its spawning migration. Koshelev *et al.* (2016), however, report that *A.*

mikadoi has not been a target of fishermen except for a small number of catches in the coastal waters of Sakhalin Island at the beginning of the last century. Though we did not find any new information on the specific level of fishing mortality from bycatch or targeted catch, given the species' demographic risks, any additional mortality due to bycatch or poaching further poses a serious threat to the survival of the species.

Disease or predation:

We did not find any information indicating that disease or predation currently threaten the species.

Inadequacy of existing regulatory mechanisms:

Inadequate regulatory measures can leave sturgeon vulnerable to a wide range of anthropogenic impacts, including overharvest and habitat degradation. The migratory life history of sturgeon exposes them to these threats across multiple habitat types, and in some cases, across different countries and jurisdictions. For this reason, regulatory and conservation mechanisms at several different scales are needed for adequate protection. The Sakhalin sturgeon is listed in the Red Data Book of the Russian Federation under the status of an endangered species (Category I) (Shedko 2017) which provides a complete ban on fishing. The species is listed on Appendix II of CITES and Appendix II of CMS (for more information on these Conventions, see section 2.3.1.6). We find existing regulatory mechanisms inadequately protect the species from threats of pollution, illegal harvest, and fisheries bycatch.

Other natural or manmade factors affecting its continued existence:

Climate change has the potential to impact Sakhalin sturgeon as described in section 2.3.1.6, though we found no studies specific to the impact on this species.

2.3.4.7 Synthesis:

The 2013 Status Review of the Sakhalin sturgeon found it to be at high risk of extinction at that time based on reduced spatial distribution and population size, habitat destruction and degradation, pollution, dams, historical harvest and poaching, bycatch in a salmon fishery, inadequate regulations, and the species' low productivity life history. The final rule to list the Sakhalin sturgeon as an endangered species was published June 2, 2014 and became effective July 2, 2014 (79 FR 31222).

Very little new information is available on the biology, status, or threats to the species. The best available data indicates that the abundance of the Sakhalin sturgeon remains extremely low, with an estimated 10 to 30 individuals entering the Tumnin River each year to spawn (Mugue 2010). One study of seven wild individuals provides evidence that the diversity of mtDNA variants has not been reduced due to low abundance, though further study is required to understand the level of genetic variation of the species as a whole (Shedko 2017). The species currently only occurs in the Tumnin River and the Sea of Japan, and experiences threats of pollution, illegal and incidental catch, and inadequate regulatory mechanisms. Based on the limited available information, we conclude that *A. mikadoi* continues to be at risk of extinction presently and we conclude that the status of the species should remain endangered.

2.3.5 Kaluga sturgeon

2.3.5.1 Biology and life history:

Kaluga sturgeon are a semi-anadromous, predatory species that mature late in life (at 14-23 years), spawn every 3-5 years (Cuiyun *et al.* 2014), and live to 80 years (Shmigirilov *et al.* 2007). The species is endemic to the Amur River basin on the border of Russia and China. Breeding migrations from the Amur estuary to the river take place between mid-May to mid-June and mid-August to late September, though the majority of mature individuals migrate during the spring (Koshelev *et al.* 2014b). The species displays a preference for lower salinity waters, though larger individuals are often caught in higher salinity areas (Koshelev *et al.* 2014a). For this reason, it is thought that salinity tolerance may increase with age and size in this species (Koshelev *et al.* 2014a). They are an active predator and eat freshwater and marine fishes, including smelt, salmon, and herring (Shmigirilov *et al.* 2007).

2.3.5.2 Abundance, population trends, demographic features, or demographic trends:

At the time of the 2013 Status Review, the population had declined more than 80% between the end of the 19th century and 1992 as evidenced by reductions in annual catch (Ruban and Qiwei 2010). The population decline was largely driven by overfishing, both legal and illegal, in the Amur River (Ruban and Qiwei 2010). Based on drift net sampling at seven stations, the total abundance of *H. dauricus* in the Lower Amur and the Amur Estuary in 2011 was estimated to be 345,100 individuals at a biomass of 7,110.9 tons, and the spawning stock was estimated to be 6,800 individuals at a biomass of 445 tons (Koshelev *et al.* 2014a). Significant declines in abundance are indicated by the Lower Amur population dropping from 40,000 individuals in the 1990s to 19,100 in 2011, resulting from the overfishing of spawners (Koshelev *et al.* 2014a).

Maintenance of the species by natural reproduction alone has been shown to be inadequate, and therefore the release of hatchery-reared juveniles is necessary to restore the abundance and distribution of the species (Krykhtin and Gorbach 1994, as cited in Koshelev *et al.* 2014a). Captive breeding operations began in 1995 at the Central Heat and Power Plant-1 in the city of Amursk, Russia, 600 km from the mouth of the river (Koshelev *et al.* 2014a). Two other hatcheries are now operational: the Anyui hatchery, 750 km upstream of the river mouth, and the Vladimirskii hatchery, 975 km upstream (Koshelev *et al.* 2014a). In 2011, a total of 800,000 juvenile kaluga were released into the Amur River, and between 1995 and 2011, 2.5 million juveniles were released (Koshelev *et al.* 2014a).

Selective poaching of large mature females has likely led to the observed shift from relatively equal sex ratios to a highly male-skewed sex ratio; for example, the sex ratio of kaluga sampled during migrations upstream from the Amur Estuary between 2005 to 2009 was 1 female to 1.6 males. Reduced relative abundance of females has resulted in a significant reduction in fecundity: the average absolute individual fecundity in the period 2005-2008 was 492.7 ± 14.36 thousand eggs as compared to 977.4 ± 23.69 thousand eggs in the 1960s-1990s (Koshelev *et al.* 2014b).

2.3.5.3 Genetics, genetic variation, or trends in genetic variation:

Genetic variation is critical to the evolutionary potential and long-term survival of a species because it provides the raw material for adaptation by natural selection. Shedko *et al.* (2015) evaluated 819 base pairs of the mitochondrial control region in 122 wild-caught kaluga sturgeon. Compared to the Amur sturgeon, kaluga exhibit fewer haplotypes (27) and less haplotype (0.927) and nucleotide diversity (0.0044). The authors suggest that this would be expected from the kaluga sturgeon, a top predator that has relatively low long-term abundance and little population substructure. However, the authors caution that the recent, sharp decline in kaluga sturgeon, while not as dramatic as the Amur sturgeon decline, may be contributing to the relatively lower genetic diversity. The relatively low genetic diversity increases the extinction risk of the species.

Further, risks of hybridization between kaluga and the sympatric Amur sturgeon, both in natural reproduction and artificial reproduction and subsequent release to the wild, threatens the genetic integrity of both species (Boscari *et al.* 2017).

2.3.5.4 Taxonomic classification or changes in nomenclature:

The species is referred to as both *Huso dauricus* and *Acipenser dauricus* in recent literature. The use of the genus *Acipenser* is informed by the revision of the validity of the genus *Huso* by Vasil'eva *et al.* (2009). Molecular and cytogenetic studies reveal that the genus *Huso* is not monophyletic, and through morphological comparisons of 22 species of the order Acipenseriformes, Vasil'eva *et al.* (2009) find only two morphological features combining *Huso huso* and *H. dauricus*: the shape of the mouth, and the attachment of gill membranes to the isthmus in adults. The authors suggest that all sturgeon species should be combined in the genus *Acipenser*. According to many other sources, the genus *Huso* remains valid until further morphological and molecular data support a hypothesis for the phylogenetic relationships of all acipenserids (Dyldin and Orlov 2016; Kovalchuk and Hilton 2017; Warth *et al.* 2017; Fricke *et al.* 2021; Froese and Pauly 2021). We therefore consider the classification to remains as follows:

Kingdom: Animalia
Phylum: Chordata
Class: Actinopterygii
Order: Acipenseriformes

Family: Acipenseridae
Genus: *Huso*
Species: *dauricus*
Common name: Kaluga sturgeon

2.3.5.5 Spatial distribution, trends in spatial distribution, or historical range:

The Kaluga sturgeon inhabits the Amur River from the estuary to the upper reaches and tributaries (Ruban and Qiwei 2010). The species also inhabits marine areas of the Sea of Okhotsk and the Sea of Japan (Koshelev *et al.* 2014a). Three individuals have been recorded in the Viakhtu River on the west coast of Sakhalin Island (Mikodina *et al.* 2015). It is thought that immature kaluga use this area for foraging as the river does not currently support ecological conditions for breeding (Mikodina *et al.* 2015), which include calm waters of 15-20°C and gravel bottoms (Billard and Lecointre 2001). The largest kaluga occur in the Amur estuary as well as the Sea of Okhotsk, while those found in the Amur River are mainly juveniles (Koshelev *et al.* 2014a). Analyses of length, weight, and pectoral spines of kaluga caught in the Fuyuan reaches of the Amur River show that juveniles of one to six years of age are present here (Li *et al.* 2019a).

The Amur River Estuary is estimated to provide foraging habitat for 94% of the population, and the spawning stock is thought to almost completely originate in this area (Koshelev *et al.* 2014a). In surveys of the Amur Estuary in June and July 2011, aggregation density along the western coast reached 472.3 individuals per km^2 upstream of the village of Puir, 186.0 individuals per km^2 in a shoal off Cape Uarke, 288.7 individuals per km^2 off Bol'shoi Chome island, and 174.3 individuals per km^2 off Malyi Chome island (Koshelev *et al.* 2014a). High densities were also observed at the Sakhalin coast off Cape Chinkhoi (298.2 individuals per km^2) and in a shoal near the Sakhalin fairway (289.2 individuals per km^2) (Koshelev *et al.* 2014a). Kaluga were more rarely recorded in the central and southeastern parts of the estuary (Koshelev *et al.* 2014a). Kaluga are likely more common in coastal waters of the Amur Estuary because they prefer the low salinity water found here due to river inflows (Koshelev *et al.* 2014a).

In the lower Amur River, kaluga are most abundant near the village of Troitskoe (Koshelev *et al.* 2014a). The distribution of kaluga in the Amur River in 2011 has changed significantly since surveys in the 1960s, when the species was found to be fairly abundant throughout the Lower Amur; the recorded aggregation densities at almost all stations has decreased (Koshelev *et al.* 2014a). In the middle and upper Amur River, only 17 kaluga have been caught over a 5 year period (2006-2010), likely due to overharvest of spawners in the section of river marking the Russian-Chinese border (Koshelev *et al.* 2014a).

2.3.5.6 Five-Factor Analysis:

Present or threatened destruction, modification or curtailment of its habitat or range:

Although the main channel of the Amur River has not been dammed, several large dams regulate the flow of its main tributaries: the Zeya Dam, operating on the

Zeya River since 1984, the Bureya Dam, operating 174 km from the mouth of the Bureya River since 2003, and the Lower Bureya Dam, operating 85 km from the mouth of the Bureya since 2017 (Nikitina *et al.* 2020). The function of the dams is to generate electricity and to protect the human population from catastrophic flooding. Severe flooding in 2013 led to the announcement of plans to build four to ten new dams in Russia, but these plans have not yet been implemented (Nikitina *et al.* 2020). Nikitina *et al.* (2020) note that the operation of these dams has altered water flow regimes, and since the construction of the Zeya Dam, kaluga have disappeared from the Zeya Reservoir. It is likely that the proposed dams on the main tributaries of the Amur River will have further negative impacts to kaluga spawning and migratory habitat.

The 2013 Status Review reports that pollution of the Amur River had been increasing in recent years, including by heavy metals, oil products, phenol, mineral fertilizers and gold mining byproducts. However, because studies on the effects of pollution on the species were not available, the Status Review concluded that effects of pollution on the species' recovery were unclear. We did not find any new information on the impacts of pollution to kaluga, and therefore conclude that further study is required to determine the extent to which pollution threatens the species.

Overutilization for commercial, recreational, scientific, or educational purposes:

Commercial fishing of kaluga was prohibited in the Soviet Union in 1958, and the species has since only been collected for hatchery breeding and to monitor the status of the population (Koshelev *et al.* 2014a). Despite protections, poaching in Russia and legal commercial harvest in China continue to threaten the species (Koshelev *et al.* 2014a; Koshelev *et al.* 2016). Poaching of the largest individuals (mature females are often targeted) has resulted in an 89 cm reduction of average fork length between 1929-1930 and 2005-2011 (Koshelev *et al.* 2014a). Selective poaching of large, mature females has also resulted in the population's highly male-skewed sex ratio and resulting decline in fecundity, as discussed above in section 2.3.5.2. For this reason, poaching threatens the survival of the species by reducing not only the abundance, but importantly, the productivity of the species.

Disease or predation:

Captive breeding operations for sturgeon may lead to increased susceptibility to bacterial infections and disease, although we did not find any specific information to suggest that disease is currently threatening the species.

We did not find any information indicating that predation currently threatens the species.

Inadequacy of existing regulatory mechanisms:

Inadequate regulatory measures can leave sturgeon vulnerable to a wide range of anthropogenic impacts, including overharvest and habitat degradation. The migratory life history of sturgeon exposes them to these threats across multiple habitat types, and in some cases, across different countries and jurisdictions. For this reason, regulatory and conservation mechanisms at several different scales are needed for adequate protection. Commercial fishing for the species was banned in the Soviet Union in 1958, though illegal fishing in Russia and legal commercial fishing in China continue to threaten the species (Koshelev *et al.* 2014a). The species is listed on Appendix II of CITES and Appendix II of CMS (for more information on these Conventions see section 2.3.1.6). We find that regulatory mechanisms summarized here inadequately protect kaluga from overutilization and pollution.

Other natural or manmade factors affecting its continued existence:

Climate change

Climate change has the potential to impact sturgeon as described in section 2.3.1.6, though we found no studies specific to the impacts on this species.

2.3.5.7 Synthesis:

The 2013 Status Review of the Kaluga sturgeon found it to be at high risk of extinction at that time based on reduced population size, habitat destruction and degradation, water pollution, historical harvest, inadequate regulations, the species' low productivity life history, a parasite, and potential competition with hybrids. The final rule to list the kaluga sturgeon as an endangered species was published June 2, 2014 and became effective July 2, 2014 (79 FR 31222).

The best available information indicates that *H. dauricus* has low abundance and relatively low genetic diversity. Though commercial fishing for the species in Russia is prohibited, enforcement of regulatory mechanisms is inadequate and the selective poaching of mature females has resulted in a highly male-skewed sex ratio, reduced fecundity, and reduced average fork length (Koshelev *et al.* 2014a; Koshelev *et al.* 2014b). For this reason, poaching of mature females severely reduces the productivity of the species. Other potential threats facing the species include climate change and habitat degradation from dams and pollution. The species' low abundance, decreased genetic variability, and late age of maturity, in combination with poaching pressure on mature females, put it at risk of extinction presently. We therefore conclude that the status of the species should remain endangered.

3.0 RESULTS

3.1 Recommended Classification

_____**Downlist to Threatened**

_____**Uplist to Endangered**

_____**Delist** *(Indicate reason for delisting per 50 CFR 424.11):*

_____*Extinction*

_____ *Species does not meet the definition of an endangered or threatened species*

_____ *Listed entity does not meet the definition of a species* __x__**No change is needed**

3.2 New Recovery Priority Number

Brief Rationale: N/A, these five species do not currently have a recovery priority number.

4.0 RECOMMENDATONS FOR FUTURE ACTIONS

We recommend the following actions prior to the next 5-year review:

- Improve understanding of biological and life history of sturgeon species where it is lacking, e.g., for Sakhalin sturgeon;
- Continue to implement captive breeding and restocking programs that emphasize maintenance of genetic diversity for each species;
- Improve understanding of efficacy of restocking programs and how captive breeding operations can produce sturgeon with a high likelihood of survival and reproduction in the wild;
- Develop and implement techniques to mitigate effects of existing dams on sturgeon migration and reproduction;
- Maintain existing prohibitions on fishing;
- Improve enforcement of existing regulatory measures to decrease poaching of wild sturgeon where this is an issue;
- Develop and implement regulatory mechanisms and conservation measures at the regional level to ensure adequate protection for all five species throughout their migratory life history;
- Assess the impacts of climate change on each of the five species, and if necessary and possible, develop and implement techniques to mitigate its effects.

5.0 REFERENCES

Acolas M-L, Davail B, Gonzalez P, Jean S, Clérandeau C, Morin B, Gourves P-Y, Daffe G, Labadie P, Perrault A, et al. 2020. Health indicators and contaminant levels of a critically endangered species in the Gironde estuary, the European sturgeon. Environmental Science and Pollution Research 27:3726-3745.

Arlati G, Poliakova L, Granata A. 1999. Esperienze di reintroduzione ittifaunistica dello storione autoctono cobice (Acipenser naccarii) nelle acque lombarde. Anni 1988-1997. Quaderni ETP 28:23-27.

Bigarré L, Lesne M, Lautraite A, Chesneau V, Leroux A, Jamin M, Boitard PM, Toffan A, Prearo M, Labrut S, et al. 2016. Molecular identification of iridoviruses infecting various sturgeon species in Europe. Journal of Fish Diseases 40:105-118.

Billard R, Lecointre G. 2001. Biology and conservation of sturgeon and paddlefish. Reviews in Fish Biology and Fisheries 10:355-392.

Boscari E, Barmintseva A, Pujolar JM, Doukakis P, Mugue N, Congiu L. 2014a. Species and hybrid identification of sturgeon caviar: a new molecular approach to detect illegal trade. Molecular Ecology Resources 14:489-498.

Boscari E, Barmintseva A, Zhang S, Yue H, Li C, Shedko SV, Lieckfeldt D, Ludwig A, Wei QW, Mugue NS, et al. 2017. Genetic identification of the caviar-producing Amur and Kaluga sturgeons revealed a high level of concealed hybridization. Food Control 82:243-250.

Boscari E, Congiu L. 2014. The need for genetic support in restocking activities and ex situ conservation programmes: the case of the Adriatic sturgeon (Acipenser naccarii Bonaparte, 1836) in the Ticino River Park. Journal of Applied Ichthyology 30:1416-1422.

Boscari E, Pujolar JM, Dupanloup I, Corradin R, Congiu L. 2014b. Captive breeding programs based on family groups in polyploid sturgeons. PLoS One 9:e110951.

Boscari E, Vidotto M, Martini D, Papetti C, Ogden R, Congiu L. 2015. Microsatellites from the genome and the transcriptome of the tetraploid Adriatic sturgeon, Acipenser naccarii (Bonaparte, 1836) and cross-species applicability to the diploid beluga sturgeon, Huso huso (Linnaeus, 1758). Journal of Applied Ichthyology 31:977-983.

Brevé NWP, Vis H, Houben B, Breukelaar A, Acolas ML. 2019. Outmigration pathways of stocked juvenile European sturgeon (Acipenser sturio L., 1758) in the Lower Rhine River, as revealed by telemetry. Journal of Applied Ichthyology 35:61-68.

Bronzi P, Congiu L, Rossi R, Zerunian S, Arlati G. 2011. Acipenser naccarii (errata version published in 2020). The IUCN Red List of Threatened Species. https://www.iucnredlist.org/species/224/175973332.

Carrera-García E, Rochard E, Acolas ML. 2017. Effects of rearing practice on post-release young-of-the-year behavior: Acipenser sturio early life in freshwater. Endangered Species Research 34:269-281.

Cataldi E, Barzaghi C, Di Marco P, Boglione C, Dini L, McKenzie DJ, Bronzi P, Cataudella S. 1999. Some aspects of osmotic and ionic regulation in Adriatic sturgeon Acipenser naccarii. I: Ontogenesis of salinity tolerance. Journal of Applied Ichthyology 15:57-60.

Chang T, Gao X, Danley PD, Lin P, Li M, Liu H. 2017. Longitudinal and temporal water temperature patterns in the Yangtze River and its influence on spawning of the Chinese sturgeon (Acipenser sinensis Gray 1835). River Research and Applications 33:1445-1451.

Chassaing O, Desse-Berset N, Hänni C, Hughes S, Berrebi P. 2016. Phylogeography of the European sturgeon (Acipenser sturio): A critically endangered species. Molecular Phylogenetics and Evolution 94:346-357.

Chassaing O, Desse-Berset N, Hänni C, Hughes S, Berrebi P. 2018. Microsatellite diversity of a critically endangered sturgeon, Acipenser sturio L. 1758, assessed from museum and archaeological tissue remains. Journal of Biogeography 45:1043-1053.

Congiu L, Pujolar JM, Forlani A, Cenadelli S, Dupanloup I, Barbisan F, Galli A, Fontana F. 2011. Managing Polyploidy in Ex Situ Conservation Genetics: The Case of the Critically Endangered Adriatic Sturgeon (Acipenser naccarii). PLoS One 6:e18249.

Cuiyun L, Qianqian Y, Lei C, Ying G, Chao L, Xiaowen S. 2014. Development and characterization of eighteen microsatellites for endangered fish Huso dauricus. Conservation Genetics Resources 6:361-365.

Delage N, Couturier B, Jatteau P, Larcher T, Ledevin M, Goubin H, Cachot J, Rochard E. 2020. Oxythermal window drastically constraints the survival and development of European sturgeon early life phases. Environmental Science and Pollution Research 27:3651-3660.

Di J, Zhang S, Huang J, Du H, Zhou Y, Zhou Q, Wei Q. 2018. Isolation and identification of pathogens causing haemorrhagic septicaemia in cultured Chinese sturgeon (Acipenser sinensis). Aquaculture Research 49:3624-3633.

Dyldin Y, Orlov A. 2016. Ichthyofauna of Fresh and Brackish Waters of Sakhalin Island: an Annotated List with Taxonomic Comments: 1. Petromyzontidae–Clupeidae Families. Journal of Ichthyology 56:534-555.

Feng G, Yao Z, Shi X, Zhang L, Zhuang P. 2017. Copper and Zinc Toxicity Estimates for Juvenile Chinese Sturgeon Acipenser sinensis in the Yangtze River Estuary. International Journal of Agriculture and Biology 19:539-544.

Fricke R, Eschmeyer WN, Van der Laan R. 2021. Eschmeyer's Catalog of Fishes. https://researcharchive.calacademy.org/research/ichthyology/catalog/fishcatmain.asp.

Friedrich T, Gessner J, Reinartz R, Striebel-Greiter B. 2018. Pan-European Action Plan for Sturgeons. Strasbourg: Council of Europe, Convention on the Conservation of European Wildlife and Natural Habitats. p. 85. https://rm.coe.int/pan-european-action-plan-for-sturgeons/16808e84f3.

Froese R, Pauly D. 2021. FishBase. Huso dauricus (Georgi 1775). https://fishbase.mnhn.fr/summary/Huso-dauricus.html.

Gao X, Lin PC, Li MZ, Duan ZH, Liu HZ. 2016. Impact of the Three Gorges Dam on the spawning stock and natural reproduction of Chinese sturgeon in the Changjiang River, China. Chinese Journal of Oceanology and Limnology 34:894-901.

Gesner J, Williot P, Rochard E, Freyhof J, Kottelat M. 2010. Acipenser sturio. The IUCN Red List of Threatened Species. https://www.iucnredlist.org/species/230/13040963.

Gessner J, Jarić I. 2014. A life-stage population model of the European sturgeon (Acipenser sturio L., 1758) in the Elbe River. Part II: assessment of the historic population decline. Journal of Applied Ichthyology 30:267-271.

Gessner J, Tautenhahn M, von Nordheim H, Borchers T. 2010. Nationaler Aktionsplan zum Schutz und zur Erhaltung des europäischen Störs (Acipenser sturio). Bonn: Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit und Bundesamt für Naturschutz.

Guarniero I, Mandelli M, Stancampiano L, Cariani A, Govoni N, Parmeggiani A, Barboni D, Mordenti O. 2017. Genotyping, pedigree reconstruction and endocrinological characterization of Acipenser naccarii (Bonaparte, 1836) using microsatellite markers and plasma steroid levels. Aquaculture Research 48:5550-5560.

He TF, Deng Y, Tuo YC, Yang YJ, Liang NS. 2020. Impact of the Dam Construction on the Downstream Thermal Conditions of the Yangtze River. International Journal of Environmental Research and Public Health 17.

Hu J, Zhang Z, Wei Q, Zhen H, Zhao Y, Peng H, Wan Y, Giesy JP, Li L, Zhang B. 2009. Malformations of the endangered Chinese sturgeon, Acipenser sinensis, and its causal agent. Proceedings of the National Academy of Sciences 106:9339-9344.

Huang Z, Wang L. 2018. Yangtze Dams Increasingly Threaten the Survival of the Chinese Sturgeon. Current Biology 28:3640-3647.e18.

IPCC. 2019. Summary for Policymakers. In: IPCC Special Report on the Ocean and Cryosphere in a Changing Climate. https://www.ipcc.ch/srocc/chapter/summary-for-policymakers/.

Jarić I, Gessner J. 2013. A life-stage population model of the European sturgeon (Acipenser sturio) in the Elbe River. Part I: general model outline and potential applications. Journal of Applied Ichthyology 29:483-493.

Jarić I, Knežević-Jarić J, Cvijanović G, Lenhardt M. 2011. Population Viability Analysis of the European Sturgeon (Acipenser sturio L.) from the Gironde Estuary System. In: Williot P, Rochard E, Desse-Berset N, Kirschbaum F, Gessner J, editors. Biology and Conservation of the European SturgeonAcipenser sturioL. 1758: The Reunion of the European and Atlantic Sturgeons. Berlin, Heidelberg: Springer Berlin Heidelberg. p. 603-619.

Jianxian S, Hui P, Jianying H. 2015. Temporal trends of polychlorinated biphenyls, polybrominated diphenyl ethers, and perfluorinated compounds in Chinese sturgeon (Acipenser sinensis) eggs (1984-2008). Environmental Science and Technology 49:1621-30.

Jiao W, Zhang P, Chang J, Tao J, Liao X, Zhu B. 2019. Variation in the suitability of Chinese sturgeon spawning habitat after construction of dams on the Yangtze River. Journal of Applied Ichthyology 35:637-643.

Ju R-T, Li X, Jiang J-J, Wu J, Liu J, Strong DR, Li B. 2020. Emerging risks of non-native species escapes from aquaculture: Call for policy improvements in China and other developing countries. Journal of Applied Ecology 57:85-90.

Koshelev V, Shmigirilov A, Ruban G. 2014a. Current status of feeding stocks of the kaluga sturgeon Huso dauricus Georgi, 1775, and Amur sturgeon Acipenser schrenckii Brandt, 1889, in Russian waters. Journal of Applied Ichthyology 30:1310-1318.

Koshelev VN, Mikodina EV, Mironova TN, Presnyakov AV, Novosadov AG. 2012. New data on biology and distribution of Sakhalin sturgeon Acipenser mikadoi. Journal of Ichthyology 52:619-627.

Koshelev VN, Ruban G, Shmigirilov A. 2014b. Spawning migrations and reproductive parameters of the kaluga sturgeon, Huso dauricus (Georgi, 1775), and Amur sturgeon, Acipenser schrenckii (Brandt, 1869). Journal of Applied Ichthyology 30:1125-1132.

Koshelev VN, Shmigirilov AP, Ruban GI. 2016. Distribution, abundance, and size structure of Amur kaluga Acipenser dauricus and Amur sturgeon A. schrenckii in the Lower Amur and Amur Estuary. Journal of Ichthyology 56:235-241.

Kovalchuk O, Hilton E. 2017. Neogene and Pleistocene sturgeon (Acipenseriformes, Acipenseridae) remains from southeastern Europe. Journal of Vertebrate Paleontology 37:e1362644.

Lassalle G, Crouzet P, Gessner J, Rochard E. 2010. Global warming impacts and conservation responses for the critically endangered European Atlantic sturgeon. Biological Conservation 143:2441-2452.

Lassalle G, Rochard E. 2009. Impact of twenty-first century climate change on diadromous fish spread over Europe, North Africa and the Middle East. Global Change Biology 15:1072-1089.

Lepage M, Rochard E, Castelnaud G. 2000. Atlantic sturgeon Acipenser sturio L., 1758 restoration and gravel extraction in the Gironde estuary. Boletin Instituto Espanol de Oceanografia 16:175-179.

Li L, Zhang J, Wang N, li N, Jin H, Ma B. 2019a. Age structure of juvenile Amur sturgeon Acipenser schrenckii and kaluga Huso dauricus in the Fuyuan reach of the Amur River, Northeast China. Journal of Applied Ichthyology 35:821-824.

Li W, Zhu B, Li CC. 2019b. Diet of farm-escaped sturgeon in the Yangtze River. Journal of Applied Ichthyology 35:831-834.

Liu J, You X, Xu P, Zhuang P, Zheng Y, Zhang K, Wang M, Lv Y, Xu G, Zhao F, et al. 2018. Assessing the genetic diversity of the critically endangered Chinese sturgeon Acipenser sinensis using mitochondrial markers and genome-wide single-nucleotide polymorphisms from RAD-seq. Science China Life Sciences 61:1090-1098.

Ludwig A, Williot P, Kirschbaum F, Lieckfeldt D. 2004. Genetic variability of the Gironde population of Acipenser sturio. BfN-Skripten 101:54-72.

Mandelli M. 2016. Studies on the reproductive Physiology of two critically endangered species of the North Adriatic Sea: Adriatic sturgeon (Acipenser naccarii) and European eel (Anguilla anguilla). http://amsdottorato.unibo.it/7459/.

McKenzie DJ, Cataldi E, Romano P, Owen SF, Taylor EW, Bronzi P. 2001. Effects of acclimation to brackish water on the growth, respiratory metabolism, and swimming performance of young-of-the-year Adriatic sturgeon (Acipenser naccarii). Canadian Journal of Fisheries and Aquatic Sciences 58:1104-1112.

Meadows DW, Coll H. 2013. Status Review Report of five foreign sturgeon. Report to the National Marine Fisheries Service, Office of Protected Resources. https://repository.library.noaa.gov/view/noaa/16217.

Mikodina EV, Novosadov AG, Koshelev VN. 2015. On biology of Kaluga sturgeon Acipenser dauricus (Acipenseridae) from the Viakhtu River (Northwestern Sakhalin). Journal of Ichthyology 55:567-575.

Ministère de la Transition Ecologique et Solidaire. 2019. Plan national d'actions en faveur de l'esturgeon européen Acipenser sturio 2020-2029.

Mugue N. 2010. Acipenser mikadoi. The IUCN Red List of Threatened Species. https://www.iucnredlist.org/species/241/13045375.

Muhammad M, Zhang T, Gong S, Bai J, Ju J, Zhao B, Liu D. 2020. Streptococcus iniae: A Growing Threat and Causative Agent of Disease Outbreak in Farmed Chinese Sturgeon (Acipenser sinensis). Pakistan Journal of Zoology 52.

Nikitina OI, Dubinina VG, Bolgov MV, Parilov MP, Parilova TA. 2020. Environmental Flow Releases for Wetland Biodiversity Conservation in the Amur River Basin. Water 12:2812.

OSPAR Commission. 2020. 2020 Status Assessment: European Sturgeon. https://oap.ospar.org/en/ospar-assessments/committee-assessments/biodiversity-committee/status-assesments/european-or-common-sturgeon/.

Paccagnella B. 1948. Osservazioni sulla biologia degli storioni del Bacino Padano. Archivi di Oceanografia e Limnologia 5:141-154.

Qiwei W. 2010. Acipenser sinensis. The IUCN Red List of Threatened Species. https://www.iucnredlist.org/species/236/13044272.

Rochard E, Lepage M, Dumont P, Tremblay S, Gazeau C. 2001. Downstream migration of juvenile European sturgeonAcipenser sturio L. in the Gironde estuary. Estuaries 24:108-115.

Roques S, Berrebi P, Chèvre P, Rochard E, Acolas ML. 2016. Parentage assignment in the critically endangered European sturgeon (Acipenser sturio) based on a novel microsatellite multiplex assay: a valuable resource for restocking, monitoring and conservation programs. Conservation Genetics Resources 8:313-322.

Rosenthal H, Bronzi P, Gessner J, Moreau D, Rochard E. 2007. Action Plan for the conservation and restoration of the European sturgeon. Council of Europe, Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention). https://awsassets.panda.org/downloads/6_20yy_action_plan_a_sturio_eu_1.pdf.

Ruban G, Qiwei W. 2010. Huso dauricus. The IUCN Red List of Threatened Species. https://www.iucnredlist.org/species/10268/3186676.

Shanghai Municipal People's Government. 2020. Announcement of the Standing Committee of Shanghai Municipal People's Congress No. 36. http://www.shanghai.gov.cn/nw48050/20201123/f276bb8da8ae45a3888b83ec6c38c48f.html.

Shedko SV. 2017. The low level of differences between mitogenomes of the Sakhalin sturgeon Acipenser mikadoi Hilgendorf, 1892 and the green sturgeon A. medirostris Ayeres, 1854 (Acipenseridae) indicates their recent divergence. Russian Journal of Marine Biology 43:176-179.

Shedko SV, Miroshnichenko IL, Nemkova GA, Shedko MB. 2015. On the population genetic portrait of kaluga, Acipenser dauricus georgi, 1775: Analysis of sequence variation in the mitochondrial dna control region. Russian Journal of Genetics 51:877-885.

Shen Z-Y, Yu D, Gao X, Zhang F-T, Liu H-Z. 2020. Genetic diversity and reproductive success of a wild population of Chinese sturgeon (Acipenser sinensis) from the Yangtze River inferred from juveniles born in 2014. Zoological Research 41:423-430.

Shmigirilov AP, Mednikova AA, Israel JA. 2007. Comparison of biology of the Sakhalin sturgeon, Amur sturgeon, and kaluga from the Amur River, Sea of Okhotsk, and Sea of Japan biogeographic Province. Environmental Biology of Fishes 79:383-395.

Stanway D. 2020. China to extend fishing ban to Yangtze estuary in 2021. Reuters. https://www.reuters.com/article/us-china-environment-fishing/china-to-extend-fishing-ban-to-yangtze-estuary-in-2021-idUSKBN28108H.

Sun L, Zhao F, Wang S, Wang Y, Yang G, Zhuang P. 2019. Growth and feeding ecology of juvenile Chinese sturgeon, Acipenser sinensis, in the Yangtze Estuary. Journal of Applied Ichthyology 35:47-53.

Tortonese E. 1989. Acipenser naccarii Bonaparte, 1836. In: Holcik J, editor. The Freshwater Fishes of Europe. Vol. 1 (2). General Introduction to Fishes. Acipenseriformes. Wiesbaden: AULA-Verlag. p. 285-293.

Vasil'eva ED, Vasil'ev VP, Shedko SV, Novomodny GV. 2009. The revision of the validity of genus Huso (Acipenseridae) based on recent morphological and genetic data with particular reference to the Kaluga H. dauricus. Journal of Ichthyology 49:861.

Visser S, de Bruijne W, Houben B, Roels B, Brevé N. 2020. First Action Plan for the European Sturgeon (Acipenser sturio) for the Lower Rhine. https://openarchivaris.nl/blob/ee/97/5c003fbd1dc4b85a890c0f98041d.pdf.

Wang J, Wei Q, Zou Y. 2011. Conservation strategies for the Chinese sturgeon, Acipenser sinensis: An overview on 30years of practices and future needs. Journal of Applied Ichthyology 27:176-180.

Wang P, Shen Y, Wang C, Hou J, Qian J, Yu Y, Kong N. 2017. An improved habitat model to evaluate the impact of water conservancy projects on Chinese sturgeon (Acipenser sinensis) spawning sites in the Yangtze River, China. Ecological Engineering 104:165-176.

Wang S, Zhang T, Yang G, Wang Y, Zhao F, Zhuang P. 2018. Migration and feeding habits of juvenile Chinese sturgeon (Acipenser sinensis Gray 1835) in the Yangtze Estuary: Implications for conservation. Aquatic Conservation Marine and Freshwater Ecosystems 28:1329-1336.

Wang Y, Xia Z, Wang D. 2012. Characterization of hydraulic suitability of Chinese sturgeon (Acipenser sinensis) spawning habitat in the Yangtze River. Hydrological Processes 26:3489-3498.

Wang Y, Zhang N, Wang D, Wu J. 2020. Impacts of cascade reservoirs on Yangtze River water temperature: Assessment and ecological implications. Journal of Hydrology 590:125240.

Warth P, Hilton E, Naumann B, Olsson L, Konstantinidis P. 2017. Development of the skull and pectoral girdle in Siberian sturgeon, Acipenser baerii, and Russian sturgeon, Acipenser gueldenstaedtii (Acipenseriformes: Acipenseridae). Journal of Morphology 278.

Williot P, Castelnaud G. 2011. Historic Overview of the European Sturgeon Acipenser sturio in France: Surveys, Regulations, Reasons for the Decline, Conservation, and Analysis. In: Williot P, Rochard E, Desse-Berset N, Kirschbaum F, Gessner J, editors. Biology and Conservation of the European SturgeonAcipenser sturioL. 1758: The Reunion of the European and Atlantic Sturgeons. Berlin, Heidelberg: Springer Berlin Heidelberg. p. 285-307.

Wu JM, Wang CY, Zhang H, Du H, Liu ZG, Shen L, Wei QW, Rosenthal H. 2015. Drastic decline in spawning activity of Chinese sturgeon Acipenser sinensis Gray 1835 in the remaining spawning ground of the Yangtze River since the construction of hydrodams. Journal of Applied Ichthyology 31:839-842.

Xu J, Zeng X, Jiang N, Zhou Y, Zeng L. 2015. Pseudomonas alcaligenes infection and mortality in cultured Chinese sturgeon, Acipenser sinensis. Aquaculture 446:37-41.

Xu N, Shao K, Yan S, Shi F, Zhu B, Chang J. 2019. Partitioning kin groups of broodstock in the critically endangered Chinese sturgeon, Acipenser sinensis Gray 1835. Journal of Applied Ichthyology 35:87-93.

Yi Y, Sun J, Zhang S. 2016. A habitat suitability model for Chinese sturgeon determined using the generalized additive method. Journal of Hydrology 534:11-18.

Yu M, Yang D, Liu X, Li Q, Wang G. 2019. Potential Impact of a Large-Scale Cascade Reservoir on the Spawning Conditions of Critical Species in the Yangtze River, China. Water 11:2027.

Zhang DF, Ji C, Zhang XJ, Li TT, Li AH, Gong XN. 2015. Mixed mycobacterial infections in farmed sturgeons. Aquaculture Research 46:1914-1923.

Zhang H, Kang M, Wu J, Wang C, Li J, Du H, Yang H, Wei Q. 2019. Increasing River Temperature Shifts Impact the Yangtze Ecosystem: Evidence from the Endangered Chinese Sturgeon. Animals 9:583.

Zhang H, Li J, Wang C, Wang C, Wu J, Du H, Wei Q, Kang M. 2018a. Acoustic Target Strength of the Endangered Chinese Sturgeon (Acipenser sinensis) by Ex Situ Measurements and Theoretical Calculations. Applied Sciences 8:2554.

Zhang H, Li JY, Wu JM, Wang CY, Du H, Wei Q, Kang M. 2017. Ecological effects of the first dam on Yangtze main stream and future conservation recommendations: A review of the past 60 years. Applied Ecology and Environmental Research 15:2081-2097.

Zhang P, Qiao Y, Grenouillet G, Lek S, Cai L, Chang J. 2021. Responses of spawning thermal suitability to climate change and hydropower operation for typical fishes below the Three Gorges Dam. Ecological Indicators 121:107186.

Zhang S-M, Wang D-Q, Zhang Y-P. 2003. Mitochondrial DNA variation, effective female population size and population history of the endangered Chinese sturgeon, Acipenser sinensis. Conservation Genetics 4:673-683.

Zhang S, Huang J, Di J, Du H, Xu Q, Zhou Q, Congiu L, Wei Q. 2018b. The genome sequence of a new strain of Mycobacterium ulcerans ecovar Liflandii, emerging as a sturgeon pathogen. Aquaculture 489:141-147.

Zhou J, Zhao Y, Song L, Bi S, Zhang H. 2014. Assessing the effect of the Three Gorges reservoir impoundment on spawning habitat suitability of Chinese sturgeon (Acipenser sinensis) in Yangtze River, China. Ecological Informatics 20:33-46.

Zhuang P, Zhao F, Zhang T, Chen Y, Liu J, Zhang L, Kynard B. 2016. New evidence may support the persistence and adaptability of the near-extinct Chinese sturgeon. Biological Conservation 193:66-69.

NATIONAL MARINE FISHERIES SERVICE
5-YEAR REVIEW

Adriatic Sturgeon *(Acipenser naccarii),* European sturgeon *(Acipenser sturio),* Chinese sturgeon *(Acipenser sinensis),* Sakhalin sturgeon *(Acipenser mikadoi),* Kaluga sturgeon *(Huso dauricus)*

Current Classification: Endangered

Recommendation resulting from the 5-Year Review

____ Downlist to Threatened
____ Uplist to Endangered
____ Delist
_x__ No change is needed

Review Conducted By: Adrienne Lohe, Office of Protected Resources

LEAD OFFICE APPROVAL:

Director, Office of Protected Resources, NOAA Fisheries

MARZIN.CATHERINE.G.1365836082 Digitally signed by MARZIN.CATHERINE.G.1365836082 Date: 2021.07.14 15:03:21 -04'00'

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HEADQUARTERS APPROVAL:

Assistant Administrator, NOAA Fisheries

ROBINSON.CARRIE.DIANE.1365872135 Digitally signed by ROBINSON.CARRIE.DIANE.1365872135 Date: 2021.07.19 10:22:42 -04'00'

_____Concur _____ Do Not Concur

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