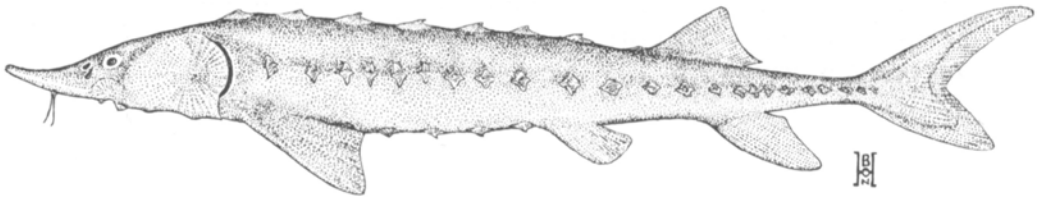
COSEWIC
Assessment and Update Status Report

on the

Green Sturgeon
Acipenser medirostris

in Canada



SPECIAL CONCERN
2004

COSEWIC
COMMITTEE ON THE STATUS OF
ENDANGERED WILDLIFE
IN CANADA

COSEPAC
COMITÉ SUR LA SITUATION
DES ESPÈCES EN PÉRIL
AU CANADA

COSEWIC status reports are working documents used in assigning the status of wildlife species suspected of being at risk. This report may be cited as follows:

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Green sturgeon — Line drawing by D.R. Harriott. Source: Pacific Fishes of Canada, by J.L. Hart, Fisheries Research Board of Canada, Bulletin 180; Ottawa, 1973; FS 94-180.

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COSEWIC
Assessment Summary

Assessment Summary – November 2004

Common name
Green Sturgeon

Scientific name
Acipenser medirostris

Status
Special Concern

Reason for designation
The number of individuals in Canadian waters is unknown, but is undoubtedly not large. This species is globally at risk and is of concern in Canada because of exploitation and habitat loss due to damming of rivers.

Occurrence
British Columbia

Status history
Designated Special Concern in April 1987. Stats re-examined and confirmed in November 2004. Last assessment based on an update status report.

COSEWIC
Executive Summary

Green Sturgeon
Acipenser medirostris

Species Information

The green sturgeon (*A. medirostris*) is easily distinguished from other families of fish by a combination of features including four barbels in front of a subterminal mouth, five rows of bony scutes, a heterocercal tail, an elongate snout, a single fleshy dorsal fin located near the caudal peduncle, and a largely cartilaginous endoskeleton. Green sturgeon are generally dark olive green with a white belly. Due to range overlap and similar appearance, green sturgeon can be easily confused with the white sturgeon (*A. transmontanus*). The green sturgeon spawns in freshwater but spends the majority of its lifecycle in the marine environment and is reported to reach a maximum length and weight of 2.3 m and 159 kg.

There are conflicting genetic studies regarding the relatedness of the North American and Asian forms of green sturgeon. There is more evidence suggesting that they should be considered separate species; however, further study is required to address this issue. Discrete northern and southern populations have been identified for the green sturgeon in North America by the National Marine Fisheries Service (NMFS), with the latitudinal boundary being found at Eel River, CA. The northern population is likely the source population of individuals found in Canada; however, as green sturgeon undertake large northern migrations and the genetic population structure of individuals in Canada is unknown, this cannot be confirmed at this time.

Distribution

Green sturgeon are found along the Pacific Coast of North America extending from the northern Mexico border up to southern Alaska. There are no known spawning populations located in Canada and green sturgeon are principally found in marine waters. Although rare, reports of freshwater captures in the lower Fraser, Nass, Stikine, Skeena, and Taku rivers have been documented. Known spawning populations are restricted to three rivers found in the US: the Rogue and Klamath rivers in Oregon, and the Sacramento River system in California. Green sturgeon are frequently caught up and down the coast and are thought to be present in limited numbers in most estuaries.

Habitat

Green sturgeon have diverse habitat needs ranging from freshwater streams, rivers, estuarine habitat as well as marine waters depending upon their life stage. The specific habitat requirements for green sturgeon are poorly understood but are thought to resemble those of white sturgeon. Green sturgeon spawning is thought to occur in deep pools in areas of large cobbles, but can range from clean sand to bedrock in turbulent river mainstreams. The larger eggs and higher growth rates of developing green sturgeon in comparison to white sturgeon suggest that a higher oxygen demand may be required for proper embryonic development. Therefore, green sturgeon may subsequently require colder, cleaner water for spawning relative to white sturgeon. Marine residents utilize benthic habitat to feed on various invertebrates and fish species.

Biology

Green sturgeon are anadromous, slow growing and mature slowly. The first 1 to 4 years are spent in freshwater and juveniles gradually adapt to waters of higher salinity as they grow older. After leaving freshwater, green sturgeon migrate and forage for benthic invertebrates and fish in estuaries and marine areas. Adults return to natal spawning sites and can spend up to six months in freshwater and migrate up to 300 km upriver. Maximum size is reported to be 230 cm and 159 kg. Males mature slightly earlier than females at 15 years, whereas females reach maturity in the range of 17 to 25 years (Adams *et al.* 2002). Generation time is between 27 and 32 years; however precision and accuracy of aging techniques is still considered poor. Green sturgeon have the largest egg size of any sturgeon species and consequently have a lower relative fecundity than other anadromous species of sturgeon. Fecundity ranges from 51 000 to 224 000, eggs which are less adhesive and have a much thinner chorionic membrane than white sturgeon suggesting that better water quality is needed for successful green sturgeon reproduction in comparison to white sturgeon.

Population sizes and trends

A paucity of information is available to estimate population sizes and trends in both Canada and the US. In Canada, green and white sturgeon were not differentiated in catch statistics until 1996 with the inception of the fisheries observer program. Limited anecdotal survey data are available prior to this date and when compared to the Department of Fisheries and Oceans (DFO) observer catch information, the possibility of a substantial decline in green sturgeon abundance exists. However, because the DFO data are of such a short time series, and the accuracy and precision of an anecdotal survey are questionable, this claim cannot be made with certainty.

Limiting factors and threats

Sturgeon exhibit a combination of morphological, life history and habitat requirements that make them highly susceptible to negative impacts from human

activities. Green sturgeon are rarely captured in freshwater in Canada with the majority of sightings being in estuaries and marine waters. Therefore, negative anthropogenic impacts are mostly limited to those affecting prey species and fishery impacts. As no spawning of green sturgeon has been observed in Canada and freshwater utilization is thought to be limited, freshwater impacts may be more generally limited to spawning and rearing habitats in the US.

Special significance of the species

Green sturgeon are among the largest and longest living species found in freshwater, living up to 70 years, reaching 2.3 m in length, and weighing up to 159 kg. Literally surviving contemporaries of the dinosaurs, green sturgeon are one of the world's most ancient species, having remained virtually unchanged since they appeared in the fossil record more than 200 million years ago. The reported disagreeable taste and rarity of green sturgeon has limited its utilization in Canada. The majority of fish are captured as bycatch and are frequently discarded. However, there is a tribal fishery in the US located on the Klamath River, OR.

Existing protection or other status designations

Green sturgeon was given the status rank of rare by COSEWIC in 1987 and has been reclassified to the status rank of Special Concern due to a change in the ranking definitions. In BC, green sturgeon has a status of red indicating it is a candidate for extirpation, endangerment, or threatened status. It is illegal to retain green sturgeon while fishing in both marine and freshwater in Canada.

In the US, green sturgeon has Federal Species of Concern status. In Oregon, Washington, and Alaska it has no special protection. In California, it is classified as a species of special concern but has no protection under the California Endangered Species Act. There are fishing regulations such as size, bag and slot size limits in these states.

IUCN assessed the green sturgeon in 1996 and classified it as Vulnerable (A1ac). The Sturgeon Specialist Group considered them to be facing a high risk of extinction in the wild in the medium-term future, based on direct observation and a decline in area of occupancy resulting in a reduction of population size of at least 20% over the last three generations. CITES listed green sturgeon under Appendix II in June 1997 and they remain listed.

COSEWIC HISTORY

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) was created in 1977 as a result of a recommendation at the Federal-Provincial Wildlife Conference held in 1976. It arose from the need for a single, official, scientifically sound, national listing of wildlife species at risk. In 1978, COSEWIC designated its first species and produced its first list of Canadian species at risk. Species designated at meetings of the full committee are added to the list. On June 5th 2003, the *Species at Risk Act* (SARA) was proclaimed. SARA establishes COSEWIC as an advisory body ensuring that species will continue to be assessed under a rigorous and independent scientific process.

COSEWIC MANDATE

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assesses the national status of wild species, subspecies, varieties, or other designatable units that are considered to be at risk in Canada. Designations are made on native species for the following taxonomic groups: mammals, birds, reptiles, amphibians, fishes, arthropods, molluscs, vascular plants, mosses, and lichens.

COSEWIC MEMBERSHIP

COSEWIC comprises members from each provincial and territorial government wildlife agency, four federal agencies (Canadian Wildlife Service, Parks Canada Agency, Department of Fisheries and Oceans, and the Federal Biodiversity Information Partnership, chaired by the Canadian Museum of Nature), three non-government members and the co-chairs of the species specialist and the Aboriginal Traditional Knowledge subcommittees. The Committee meets to consider status reports on candidate species.

DEFINITIONS (NOVEMBER 2004)

Wildlife Species	A species, subspecies, variety, or geographically or genetically distinct population of animal, plant or other organism, other than a bacterium or virus, that is wild by nature and it is either native to Canada or has extended its range into Canada without human intervention and has been present in Canada for atleast 50 years.
Extinct (X)	A wildlife species that no longer exists.
Extirpated (XT)	A wildlife species no longer existing in the wild in Canada, but occurring elsewhere.
Endangered (E)	A wildlife species facing imminent extirpation or extinction.
Threatened (T)	A wildlife species likely to become endangered if limiting factors are not reversed.
Special Concern (SC)*	A wildlife species that may become a threatened or an endangered species because of a combination of biological characteristics and identified threats.
Not at Risk (NAR)**	A wildlife species that has been evaluated and found to be not at risk of extinction given the current circumstances.
Data Deficient (DD)***	A wildlife species for which there is inadequate information to make a direct, or indirect, assessment of its risk of extinction.

* Formerly described as “Vulnerable” from 1990 to 1999, or “Rare” prior to 1990.
** Formerly described as “Not In Any Category”, or “No Designation Required.”
*** Formerly described as “Indeterminate” from 1994 to 1999 or “ISIBD” (insufficient scientific information on which to base a designation) prior to 1994.

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The Canadian Wildlife Service, Environment Canada, provides full administrative and financial support to the COSEWIC Secretariat.

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COSEWIC Status Report

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2004

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SPECIES INFORMATION

Name and Classification

Class:	Actinopterygii
Order:	Acipenseriformes
Family	Acipenseridae
Genus:	*Acipenser*
Scientific name	*Acipenser medirostris* Ayers 1854
Common names	
English	Green Sturgeon
French	
Canada/France	*esturgeon vert*
Salish First Nations	*K'toyethen*
Mexico	*Esturión verde*
Japan	*Chôzame*
Russian Federation	*Sterlyad*
Asia	Sakhalin Sturgeon
Synonyms:	*A. medirostris mikado*, *A. acutirostris* (Froese and Pauly 2003)

Sturgeons are classified in the family Acipenseridae which consists of four genera: *Acipenser, Huso, Scaphirhynchus*, and *Pseudoscaphirhynchus* (Helfman *et al*. 1997). The green sturgeon (*A. medirostris*) was first described in 1854 from a specimen caught in San Francisco Bay (Ayres 1854, Adams *et al*. 2002). Asian populations (regionally named "Sakhalin" sturgeon) were initially considered to be conspecifics due to meristic count overlap to North American populations and were classified as either *A. mikadoi* or *A. medirostris mikado*. Zhang *et al*. (2001) and Fain *et al*. (2000) both conducted genetic analysis examining mitochondrial DNA sequences of Asian and North American green sturgeon and determined that the two forms of green sturgeon should be considered a single species. However, other genetic evidence (Birstein *et al*. 1993, 1997; Birstein and DeSalle 1998) and morphometric studies (North *et al*. 2002) suggest that the Asian and North American forms should be considered separate species (*A. mikadoi* and *A. medirostris* respectively). Further work is required to address this disagreement.

Description

Sturgeon are easily distinguished from other families of fish by a combination of features including four barbels in front of a subterminal mouth, five rows of bony scutes, a heterocercal tail, an elongate snout, a single fleshy dorsal fin located near the caudal peduncle, and a largely cartilaginous endoskeleton, including an unconstricted notochord that extends into the tail (Figure 1; Helfman *et al.* 1997; Echols 1995).

The green sturgeon is anadromous but spends more time in the marine environment than any other species of sturgeon (Adams *et al.* 2002). The first record of

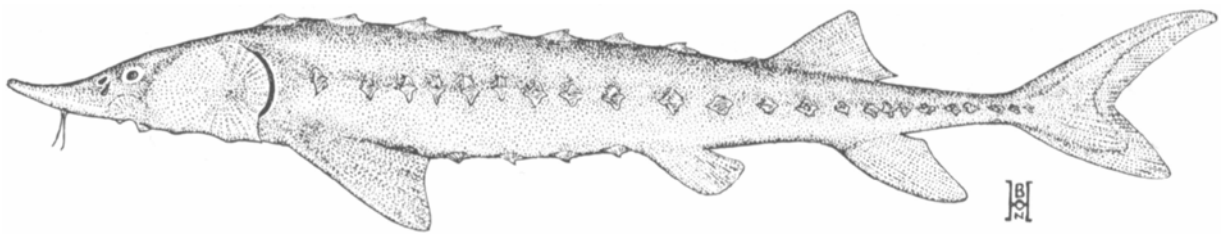

Figure 1. Illustration of a green sturgeon (*Acipenser medirostris*), 107 cm. Alaska. BC 63-1064 (from Scott and Crossman 1973, art 1973).

green sturgeon captured in Canada was on August 30th, 1908. The specimen was 34 cm in length and was caught near Victoria, BC (Clemens and Wilby, 1961). Green sturgeon can reach a maximum length and weight of 2.3 m and 159 kg (Scott and Crossman 1973).

Green sturgeon have a dark olive green dorsal surface and a white ventral surface with longitudinal and olive-green stripes between the lateral and ventrolateral plates and on the midventral surface extending the length of the body (Scott and Crossman 1973). The colouration pattern on its ventral surface resembles an arrow pointing towards its snout terminating anterior to its pectoral fins (Figure 2). There is anecdotal evidence that a colour variant of the species may exist. There have been reports of brown to golden coloured green sturgeon captured in San Francisco Bay and the Sacramento River. However, no “golden sturgeon” have been reported in Canada and whether this second morphotype is due to genetic or environmental influences is currently unknown (CDFG 2000 cited in EPIC 2001).

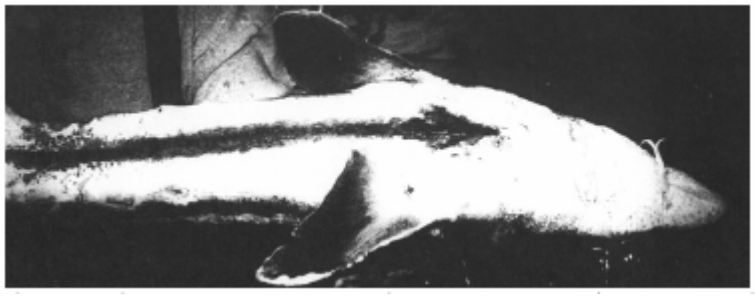

Figure 2. Photo of ventral surface of green sturgeon showing the arrow pattern terminating anterior to the pectoral fins (Photo courtesy Terry Slack).

Due to range overlap and morphometric similarity, the green sturgeon can be confused with the white sturgeon (*A. transmontanus*), however they can be easily distinguished by a lateral line scute count; green sturgeon having 23-30 bony plates and the white sturgeon 38-48 (Scott and Crossman 1973). In addition, the position of the anal vent differs between the species, with the anal vent of the green sturgeon located directly between the posterior insertions of the pelvic fins compared to the white sturgeon where it is found posterior to the pelvic fins (Slack and Stace-Smith 1996;). Furthermore, the green sturgeon has two rows of 4 to 8 post vent scutes while the white sturgeon has a single row of 1 to 4 scutes extending from the pelvic fins to the anal fin (Figure 3).

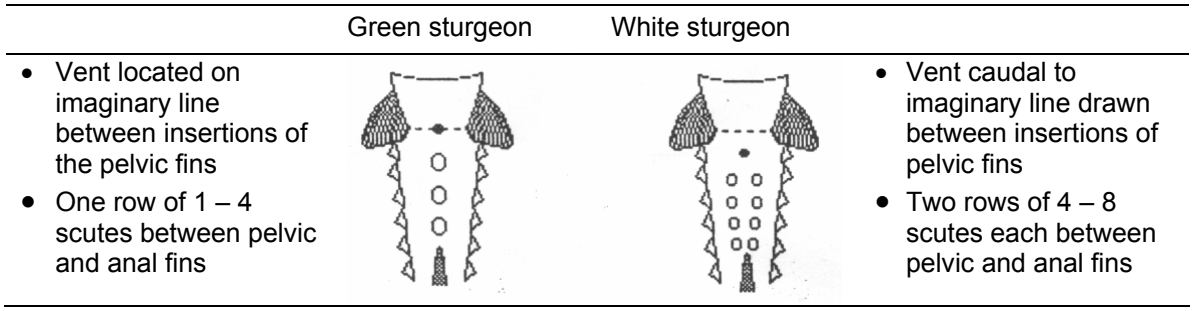

Figure 3. Differences between green and white sturgeon vent location, and placement and number of ventral scutes (adapted from Eddy and Underhill 1978).

Unlike all other sturgeon species, green sturgeon larvae lack a direct swim-up or post-hatching stage (Deng 2000; Cech *et al.* 2000). They can also be distinguished from white sturgeon larvae by their larger size, lighter pigmentation, and size and shape of yolk sac (Adams *et al.* 2002; Cech *et al.* 2000).

North *et al.* (2002) conducted a study examining meristic and morphometric characteristics of green sturgeon captured in the Columbia River (Table 1). These individuals are likely representative of green sturgeon found in Canadian waters due to geographic proximity, and there is no evidence that morphometrics significantly vary between Distinct Population Segments (DPS).

Designatable units

Within North America, the National Marine Fishery Service (NMFS) has identified northern and southern Discrete Population Segments (DPS) for green sturgeon with the latitudinal boundary located at Eel River, CA (40º 42'N) (Adams *et al*. 2002). Israel *et al*. (2002) conducted a preliminary population genetic study indicating that green sturgeon found in the Rogue River, Oregon, and the Klamath River are distinct from those from San Pablo Bay, California. However, green sturgeon collected from the Columbia River appeared to be a mixture of other populations suggesting that there are currently unknown spawning populations or this result may be an artifact of low sample sizes and differences among years of specimen collection. As the specimens from the

Columbia River and the northern DPS are closest to Canada, there is a greater likelihood that individuals found in Canadian waters are from these populations.

Table 1. Comparison of selected meristic characteristics (mean ± standard deviation) from 50 green sturgeon collected from the Columbia River in August 1999 and white sturgeon (North *et al.* 2002). Values for white sturgeon are absolute ranges cited in North *et al.* (2002) from Scott and Crossman (1973), Schreiber (1959), Miller and Lea (1972) and Hart (1973).

Character	Green Sturgeon			White Sturgeon
	Mean	Range	S.D.	Range
Total Length (cm)	148	125-170		n.a.
Dorsal Scutes	9.4	7-12	± 1.1	11-14
Lateral Scutes	28.5	22-33	± 2.8	36-48
Ventral Scutes	9.2	7-12	± 1.1	9-12
Gill Rakers	19	15-26	± 2.5	23-36

DISTRIBUTION

Global range

There is debate over whether the Asian and North American forms of green sturgeon should be considered separate species; therefore the range of the Asian form (Sakhalin sturgeon (*A. mikadoi*)) is included here. The Sakhalin sturgeon has been extirpated throughout Japan, Korea, and China and is reduced in range in Russia to the Tummin River where it is supported by a hatchery (EPIC 2001). Historically, the species ranged from the Sea of Japan and the southwest coast of Korea, north to the Amur River in Siberia and northeast to the Bering Sea, Alaska (McPhail and Lindsey 1970). Further genetic study regarding the relatedness of Asian and North American forms will clarify the global range.

The North American form of green sturgeon is found on the western coast of North America from Mexico to southeastern Alaska, however, they are rarely found below 30^{o} (S) latitude and their greatest abundance is between the 40^{th} and 60^{th} parallels (EPIC 2001; Moyle 2002; Figure 4). Mecklenburg *et al* (2002) give the Alaskan range as along the panhandle and north to the Bering Sea based on a 1964 reference to a record off Unalaska Island, as well as older records from the Bering Sea, and a questionable record of 2 specimens in 1897 from the Copper River (Gulf of Alaska, northwest of Controller Bay).

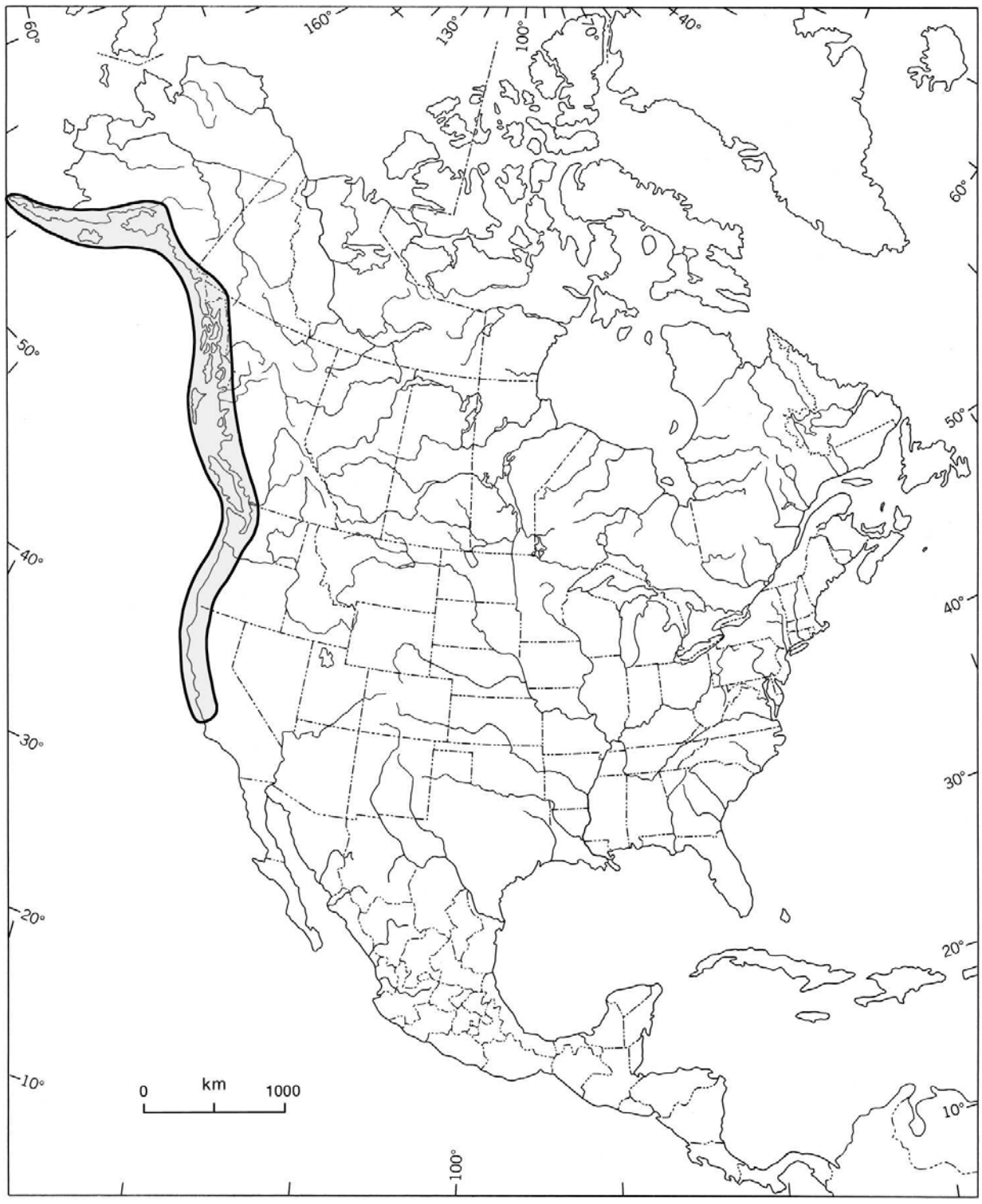

Figure 4. Range map for green sturgeon (*A. medirostris)*; Asian form range excluded as it is currently restricted to one river and relatedness is in debate.

Large concentrations of green sturgeon are still found in coastal estuaries, but their range in freshwater has been restricted by damming in some rivers. For example, green sturgeon were historically observed hundreds of kilometres upstream in the Sacramento and Columbia rivers, but are currently restricted in the Columbia River to the lower 60 km downstream of the Bonneville Dam (Moyle 2002). Spawning is presently known to occur in only three rivers in North America, all of which are in the United States: the Rogue River in Oregon, and the Klamath and Sacramento river systems in California (EPIC 2001, Adams *et al*. 2002, Moyle *et al*. 1994). Spawning populations have been extirpated from the San Joaquin, Eel, South Fork Trinity rivers and possibly the Umpqua River (EPIC 2001).

Canadian range

The range of green sturgeon in Canada spans the entire length of the Pacific Coast (Houston 1988, Scott and Crossman 1973). Green sturgeon are rarely captured in freshwater, preferring estuaries and marine environments. Reports of green sturgeon caught in the lower Fraser, Nass, Stikine, Skeena and Taku rivers are extremely rare but have been documented (FISS 2003). The extent of utilization of freshwater is unknown, but is thought to be limited as there is no evidence that spawning has ever occurred in Canadian rivers.

Green sturgeon have reportedly always been rare in freshwater in Canada (McPhail and Carveth 1993). Incidents are generally limited to irregular reports from sport fishers and researchers conducting white sturgeon tagging programs. In 1985 and 1986, a tagging study captured two green sturgeon (not positively identified) in the process of tagging approximately 500 white sturgeon 50 to 90 km upstream from the Fraser River mouth (Houston 1988). Conversely, a tagging study from 1995 to 1999 in a similar area (78 to 154 kilometres from the river mouth (rKm)) failed to report any occurrences of green sturgeon (Adams *et al.* 2002). The lower Fraser River has had more reports of green sturgeon; however, they continue to be rare. Nearly 13 000 white sturgeon have been tagged from the beginning of 2000 to present and 12 to 15 possible green sturgeon have been reported (T. Nelson, Fraser River Sturgeon Conservation Society, Crescent Beach, BC; pers. comm. 2003).

Green sturgeon have been caught incidentally in large bottom trawler hauls off the west coast of Vancouver Island, the Straight of Georgia, and coastal northern BC and in salmon gillnets at the mouths of rivers along the southern coast of BC (Anonymous 1954; Slack and Stace-Smith 1996; Houston 1988; Echols 1995).

Detailed distribution maps for green sturgeon were not developed by DFO until 1996, when the department began differentiating green and white sturgeon in their catch statistics. However, a local BC fisherman who was concerned that green sturgeon populations were declining conducted a survey of fishermen regarding historical catches back to 1960 (Slack and Stace-Smith 1996). The groups surveyed included members of the commercial trawl, gillnet, longline and sport fishing industry and the results suggested that freshwater reports of green sturgeon have always been

uncommon; however, large marine catches have historically occurred. For example, Hart (1973) reported 75 fish weighing a total of 952 kg in one day off Kyuquot Sound. Responses to the survey, however, were sparse and the earliest report occurred in 1960 and therefore may not fully account for the historical range of green sturgeon. Commercial trawl fishing data collected by DFO from 1996 to 2002 recorded green sturgeon bycatch as far north and west as 54° latitude and 131° longitude respectively, which is consistent with the historical range estimations given by Slack and Stace-Smith (1996). Marine range has been estimated based on the recent DFO catch information to be 12 000 to 30 000 km^2 or 2.6 to 6.6% of Canadian Pacific waters (B. Lucas, Research Biologist, Department of Fisheries and Oceans, Nanaimo, BC; pers. comm. 2002). Limited information makes an area of occupancy estimate difficult due to the low number of catches and the short time series of catch records.

The small number of recent freshwater sightings of green sturgeon suggest that the species is still rare in freshwater in Canada. The few recorded historical sightings and the rarity of green sturgeon make it impossible to firmly establish whether any range contraction has occurred. Green sturgeon do not seem to have undergone any large-scale range contraction in marine waters as the recent DFO data is consistent with the survey catch data collected by Slack and Stace-Smith (1996). However, the survey by Slack and Stace-Smith likely did not include all incidents of historical green sturgeon catches and therefore, marine range contraction cannot be ruled out entirely.

HABITAT

Habitat requirements

Green sturgeon inhabit a range of environments throughout their life cycle, including freshwater streams, rivers, estuarine habitat, and marine waters (Figure 5). The specific habitat requirements of green sturgeon are poorly understood but they are thought to resemble those of white sturgeon (Moyle *et al.* 1992). There are no known spawning populations of green sturgeon in Canada and they have been rarely caught in freshwater environments. Instead, incidental catches in the commercial trawl and salmon gillnetting fishery suggest that marine and estuarine environments are the main habitats utilized by green sturgeon in Canada. However, not much effort has been made to understand the extent and nature of its presence in Canadian waters and it is possible that Canadian (spawning) populations are too small to be detected, as is their presence in freshwater. In order to provide a holistic assessment of the habitat requirements of green sturgeon throughout its life cycle, its freshwater habitat requirements in the US are included here.

Green sturgeon spawning is thought to primarily occur in deep pools in areas of large cobbles, but has also been observed in areas of clean sand or bedrock in turbulent river mainstreams (Moyle *et al*. 1992). Adults in the Sacramento River spawn in temperatures ranging from 8°C to 14°C (EPIC 2001). Optimal temperature for larval growth is estimated to be 15°C (Cech *et al*. 2000) and growth is substantially reduced

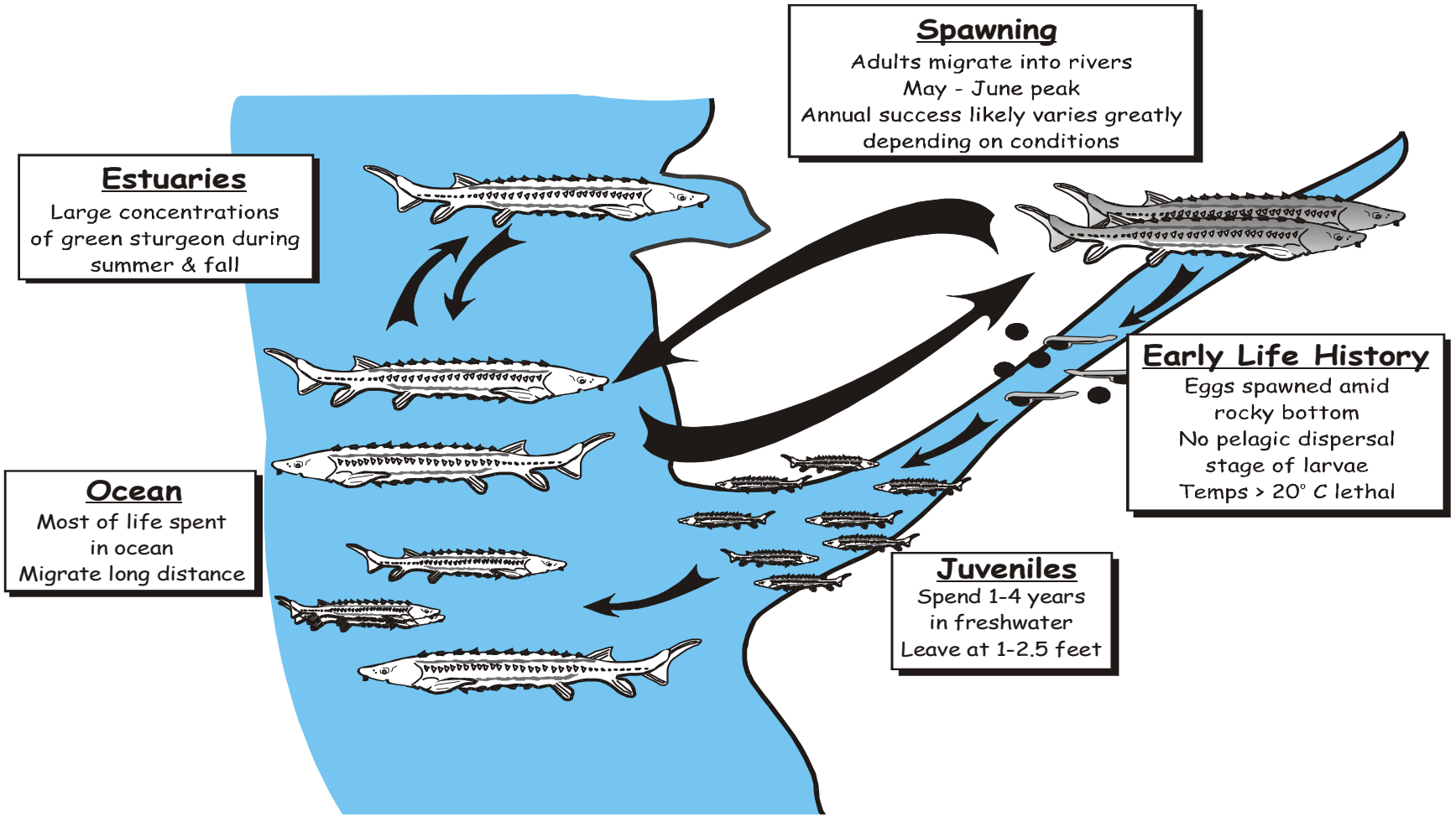

Figure 5. Conceptual Model of green sturgeon life cycle with limiting factors (Beamesderfer and Webb 2002 used with permission).

outside the 11°C to 19°C range. Temperatures above 20°C are lethal to green sturgeon embryos, and temperatures above 24°C cause a significant reduction in larval growth (Cech *et al*. 2000). Minimum and maximum pH tolerance and dissolved oxygen requirements of eggs and larvae for green sturgeon are unknown. Green sturgeon eggs are adhesive and are broadcast over substrate where they settle and stick on the bottom in breaks in the substrate (Deng 2000; Cech *et al*. 2000). Their eggs do not form a thick jelly coat as do white sturgeon eggs and subsequently exhibit poor adhesion to substrate (Deng 2000; Cech *et al*. 2000). The comparatively lower adhesiveness of green versus white sturgeon eggs suggests that a higher turbidity load may be more detrimental to green sturgeon spawning in comparison to white sturgeon, since the increased turbidity may interfere with adhesion to the substrate (Moyle *et al*. 1994; Moyle 2002). Furthermore, the larger eggs and higher growth rates of developing green sturgeon in comparison to white sturgeon suggests that a higher oxygen demand may be required for proper embryonic development. Therefore, green sturgeon may subsequently require colder, cleaner water for spawning relative to white sturgeon (USFWS 1995b).

During the 1 to 4 years of freshwater residence, juveniles gradually move to deeper and more saline areas as they grow (Beamesderfer and Webb 2002). As juveniles grow, they exhibit greater tolerance to salinity and achieve seawater tolerance at 7 months or sooner (Allen and Cech 2003). Juveniles are frequently captured in off-channel, low flow habitats and in estuaries (Nakamoto *et al.* 1995).

After migrating from freshwater, green sturgeon are captured both offshore and in estuaries. DFO trawl fishery catch statistics between 1996 and 2002 recorded green sturgeon at a maximum depth of 610 m (mean=82 m). After spending over 15 years in the marine environment and estuaries, adults return to freshwater and can travel significant distances up rivers to spawn. Green sturgeon have been reported to spawn up to 160 km upstream in the Klamath and Rogue rivers, and over 300 km upstream in the Sacramento River (Beamesderder and Webb 2002). Tagged adults from the Rogue River spent upwards of 6 months in freshwater; contrary to previous information indicating that adult green sturgeon spend limited amounts of time in freshwater (Erickson *et al.* 2002). Furthermore, green sturgeon preferred specific sites that were deep (>5m), low gradient reaches, or off-channel coves. Tagged green sturgeon emigrated to sea after spawning from late autumn to early winter when temperatures dropped below 10°C and flows increased above 100 m^3s^{-1} (Erickson *et al.* 2002).

Trends

Green sturgeon are generally encountered in marine and estuarine environments in Canada, thus habitat quality and restriction in these areas is of most concern. Estuaries in BC are used for log storage and can be the eventual sinks to freshwater pollutants. An assessment of the quality of the lower Fraser River ecosystem was done in 1993 to 1994 by Healey *et al.* (1994) to determine whether species assemblages had substantially shifted since a similar survey was done by Northcote *et al.'s* (1976) in 1973 to 1974. A 2.5 fold increase in species density was found in the 1993 to 1994 survey and no dramatic changes in species assemblages were determined to have occurred

over the 21 years between the studies. The BC Ministry of Water, Land and Air Protection assessed commercial and public usage of 51 BC estuaries and found that usage had increased from 2.1 to 4.7% from 1986 to 2001 of the total area assessed. Area managed for conservation also increased from 23 to 69% over the same time period with 80% of the increase being accounted for by conservation efforts on the Fraser River estuary (MWLAP 2002). The increase in estuary protection and the results from Healey *et al.* (1994) suggest that estuarine habitat loss that may effect green sturgeon is likely not substantial in Canada.

In the US, where all known spawning populations occur, green sturgeon have lost spawning habitat to poor land use practices and habitat alteration through water management projects (EPIC 2001). This has caused a decline in general water quality in some areas through increased sedimentation as well as the loss of deep pools which green sturgeon are known to prefer. Furthermore, damming of river systems can block previously available spawning habitat, affect natural flow regimes, potentially reduce areas of thermal refugia, and change sediment transport characteristics of the river which may cascade and impact sturgeon by modifying ecosystem community structure (EPIC 2001).

Freshwater environments are still available to green sturgeon in Canada with no damming occurring in the lower portions of rivers where they have been historically observed. There is the possibility that some areas have been lost due to pollution from agriculture and industry. A die-off of white sturgeon in the Fraser River occurred in 1993 to 1994 and thirty-four dead “huge sturgeon”, mostly females, were found (MELP 1997). Pollution, thermal stress and the consumption of decomposing sockeye were suggested causes of the die-off. Although no green sturgeon were reported, the possibility that some green sturgeon could have been affected exists as all affected sturgeon may not have been found.

Protection/Ownership

Green sturgeon are subject to protection from harmful alteration, disruption or destruction of fish habitat by Section 35 of the federal Fisheries Act.

BIOLOGY

General

Green sturgeon are anadromous, long-lived, slow growing and reach sexual maturity at an advanced age (Houston 1988). In comparison to other sturgeon species, green sturgeon invest a greater amount of their reproductive resources into individual eggs, thus having the largest egg size of any sturgeon species and a resultant lower fecundity in comparison to other anadromous sturgeon (Van Eenennaam *et al.* 2001). A distinct characteristic of green sturgeon is that their fertilized eggs have a thin chorion layer and show poor adhesion, which is not observed in either white or Atlantic sturgeon (Van Eenennaam *et al.* 2001).

Reproduction

There are no known green sturgeon spawning populations in Canada; however, they are currently known to spawn in the Rogue and Klamath rivers in Oregon and the Sacramento River system in California (Moyle *et al.* 1994).

Green sturgeon eggs and larvae are comparatively larger than those of other sturgeon species. For example, Cech *et al.* (2000) reported an egg diameter of 4.34, 3.40 and 2.62 mm for green, white, and Atlantic sturgeon (*A. oxyrinchus*) respectively indicating that green sturgeon have eggs which have a volume twice that of white and over four times that of Atlantic sturgeon. Consequently, green sturgeon have a relatively lower fecundity in comparison to other similar-sized sturgeon species as reproductive energy is more heavily invested in egg size rather than egg number (Van Eenennaam *et al.* 2001; Cech *et al.* 2000)

Similar to white sturgeon, artificially spawned green sturgeon captured from the Klamath River larvae hatch after 7 to 9 days at 15°C (Van Eenennaam *et al.* 2001). Cech *et al.* (2000) reported that temperatures above 20°C are lethal to embryos and temperatures above 24°C significantly reduce five-day larval growth rates. Larvae begin to feed at 10 days post hatch and complete metamorphosis into juveniles at 45 days (Adams *et al.* 2002). Nakamoto *et al.* (1995) reported that fish from the Klamath River reach 30 cm in length within the first year and 60 cm after 2 to 3 years. In contrast, green sturgeon reared under hatchery conditions can grow to 40 cm in the first six months after hatching (Deng 2000). Growth rates under normal conditions of both sexes is approximately 7 cm $year^{-1}$ until sexual maturation when growth rates reduce in response to the energetic demands of reproduction (USFWS 1982; Nakamoto *et al.* 1995).

The maximum size of green sturgeon is reported to be 2.3 m and 159 kg (Scott and Crossman 1973). Similarly aged males are generally smaller than females with males from the northern DPS achieving a maximum size of 168 cm (Adams *et al.* 2002). Sexually mature males and females from southern DPS range in size from 139 to199 cm and 157 to 223 cm, respectively (Adams *et al.* 2002). Maximum age has been estimated to be 42 years (Nakamoto *et al.* 1995); however, there is some debate that this may be an underestimate with maximum age approaching 70 years (Moyle 2002). Estimating longevity precisely for green sturgeon is difficult due to reduced growth rates of older fish and poor formation of spawning checks caused by long marine migrations and adverse environmental conditions (Nakamoto *et al.* 1995). Variability in age estimation may also be a product of a seasonal pattern of alternating winter feeding and summer fasting which has been observed in other sturgeon species (Sulak and Randall 2002) but has not been confirmed for green sturgeon.

Green sturgeon are oviparious broadcast spawners. Similar to other sturgeon species, males reach sexual maturity before females (Nakamoto *et al.* 1995). Males reach sexual maturity around 15 years and females slightly later at 17 years (Adams *et al.* 2002). Spawning peaks in mid-April to mid-June but is spread from March to July (Moyle *et al.* 1992) and occurs every three to five years (Adams *et al.* 2002) with males

generally spawning more frequently. Spawning occurs in the mainstem of large rivers in relatively fast water flows (Emmet *et al.* 1991). Long sperm motility (100% motility for 5 minutes) has been observed in artificial spawning studies (Van Eenennaam *et al.* 2001) and may be an adaptive fertilization strategy when spawning in fast moving water. The growth rate of larval green sturgeon is much greater than white sturgeon with Wang *et al.* (1987) reporting five-day-old green sturgeon larvae to be almost twice the weight of white sturgeon larvae of the same age (65 vs 34 mg; (cited in Cech *et al.* 2000). The faster growth rate is likely due to the larger egg size of green sturgeon (Cech *et al.* 2000).

Fecundity has been reported to range from 51 000 to 224 000 eggs per female (mean of 127 500; n=26) for fish caught in the Klamath River (USFWS 1982) with quantity being largely dependent upon the age and subsequent size of the fish. Using these figures, a fecundity estimate of approximately 2800 eggs per kilogram bodyweight for green sturgeon can be calculated. This is approximately half that of white sturgeon, which has a fecundity estimate of 5648 eggs per kilogram bodyweight (Moyle 2002).

Detailed age structure analysis of green sturgeon is not available for fish captured in Canadian waters. Preliminary age structure data of the 1999 to 2000 Klamath spawning run indicated an age range of spawners to be 17 to 33 with most being 25- to 31-years-old (Van Eenennaam and Doroshov 2001). However, this short time series may not be representative for the species.

Generation time, the average age of parents in the current cohort, reflects the turnover rate of breeding individuals in the population (COSEWIC). For green sturgeon, females mature at a later age than males (seventeen vs. fifteen years; Adams *et al.* 2002), and generation time is calculated as the mean age of female parents. Generation time is estimated as the age at which 50% of females are mature + 1/M, where M is the instantaneous rate of natural mortality. Neither age of maturity nor spawning frequency, however, has been firmly established (Williamson 2003). Furthermore, natural mortality of juveniles and adults is unknown but is estimated to be below 10% (Beamesderfer and Webb 2002). Therefore, a minimum generation time is approximated to be 17 + 1/10% = 27 years. However, age of reaching sexual maturity for females has also been estimated to be between 20 to 25 years (Beamesderfer and Webb 2002). Therefore, taking the average age of maturity of 22.5 years and maintaining the estimated 10% mortality value, generation time would be 22.5 + 1/10% = 32.5 years. Taking these values as a range, generation time is estimated to be between 27 to 33 years. As the precision and accuracy of aging green sturgeon is questionable, this estimate should be used with caution.

Survival

Green sturgeon have few known predators other than humans and some marine mammals (Fitch and Lavenburg 1971; Emmet *et al.* 1991). Larval and young green sturgeon are likely preyed upon by other species present in spawning areas. Adults have relatively few direct threats from natural predators, which is due to a life history design based on achieving large size and possibly using freshwater as refugia from predators.

Year class failure is not uncommon for sturgeon populations (Sulak and Randall 2002). A study examining age class structure of gulf sturgeon (*A. oxyrinchus desotoi*) reported that population age class structure can be highly dynamic and unstable with strong and weak recruitment and persistent recruitment failures in populations under low exploitation (Sulak and Randall 2002). Furthermore, other long-term data series of sturgeon species indicate periodic, widely spaced successful year classes with periodic year class failures (Sulak and Randall 2002). Therefore, green sturgeon are likely able to handle occasional year class failures and still maintain overall population stability

Physiology

Of all sturgeon species, the green sturgeon is the most widely distributed and spends the most time in marine waters (EPIC 2001). The development of anadromy in some sturgeon species enables them to exploit otherwise unavailable rich benthic invertebrate resources in estuarine and marine habitats (Sulak and Randall 2002).

A common trait among anadromous sturgeon is the tendency for adults and sub adults to fast in freshwater and feed only in marine and estuarine environments (Sulak and Randall 2002). Although green sturgeon fasting is not a confirmed behaviour, adult green sturgeon stomachs are frequently found to be empty during their presence in freshwater during some estuarine summer concentrations (USFWS 1982; Beamesderfer and Webb 2002).

The preferred temperatures and upper and lower lethal ranges for adult green sturgeon are unknown. A radio tagging study by Erickson *et al.* (2002) suggested that green sturgeons emigrate to sea once temperature dropped below 10°C. This temperature was also associated with a flow rate greater than 100 m^3s^{-1}, however, which may have been the actual trigger for migration out of the system.

Optimal embryonic growth rates are reached at 15°C and upper lethal temperature threshold for developing embryos was determined to be 20°C. Growth of larval green sturgeon is significantly reduced at 24°C (Cech *et al.* 2000).

Movements/Dispersal

Green sturgeon in Canada are thought to originate from spawning populations in the US as there is no record of green sturgeon ever spawning in Canada. However, the frequent misidentification and rarity may result in underestimation of habitat use in Canada. Green sturgeon are the most widely distributed of sturgeon species with their range extending from Mexico to Alaska (Adams *et al*. 2002).

Green sturgeon spend their first 1 to 4 years in freshwater gradually exposing themselves to estuarine environments as they get older (Beamesderfer and Webb 2002). During their marine sub-adult phase, green sturgeon are frequently observed in estuarine concentrations at major river systems where spawning is not known to occur. Concentrations have been observed in the Columbia River estuary during the late

summer and early fall (Adams *et al.* 2002). Green sturgeon migrate along the coast of Oregon and are thought to be present in most open estuaries (Williamson 2003). Reasons for these concentrations are unclear as spawning does not occur in the Columbia River and there is no evidence of feeding during these concentrations (Adams *et al.* 2002). An explanation of this behaviour is suggested in the evolutionary life history of sturgeon species. As an anadromous lifestyle is a secondary adaptation of sturgeon, their physiology is most closely adapted to, and least stressed, in lower salinity waters (Sulak and Randall 2002). Furthermore, marine mammals are predators of adult green sturgeon and presence close to freshwater may offer access to areas of predator refugia during summer marine mammal migrations.

When green sturgeon enter their marine migratory phase they either occupy estuarine holding areas or undergo a northern migration (Adams *et al.* 2002). Limited tagging studies exist; however, tagged individuals from the Columbia River have been recaptured off the west coast of Vancouver Island (Adams *et al.* 2002).

As mentioned previously, two distinct population segments were identified by NMFS with the Eel River being the north/south boundary between the Oregon and California populations. Unique alleles not present in the other spawning populations, however, were found at low frequencies in the sampled Columbia River population. Israel *et al.* (2002) suggested that the presence of these alleles might indicate the existence of a currently unknown spawning population(s) or may be an artifact of low sample sizes and sampling methodology. Further study is needed to clarify this issue.

Nutrition and Interspecific Interactions

Juveniles are opportunistic benthic feeders with a diet consisting of various invertebrates and fish (EPIC 2001; Moyle 2002). Stomach content analysis indicates that green sturgeon have a marine diet consisting of various benthic invertebrates including shrimp, crabs, worms, amphioids, and isopods (EPIC 2001) but have also been observed feeding on sand lances (*Ammodytes hexapterus*) and other fish.

Behaviour/Adaptability

Sturgeons are generally not known as a schooling fish; however, a high level of group cohesion is observed in green sturgeon during migration and summer concentrations in seasonal holding areas. Summer estuarine concentrations and irregular large catches by fishing vessels in marine waters (one haul in Canadian waters in January 2000 was over 1000 kg and one catch in 1960 off the west coast of Vancouver Island was reportedly 9000 kg (Slack and Stace-Smith 1996) suggest that green sturgeon have a level of group cohesion above most other sturgeon species. Schooling behaviour may allow individuals to acquire learned behaviour and/or to chemically imprint upon habitat sites (Sulak and Randall 2002). Therefore, a minimum population size including older individuals may be necessary to maintain a behavioral and habitat “knowledge base” within the species.

Larvae of green sturgeon are nocturnal and do not have a direct swim-up or post-hatching stage which is uncharacteristic to other sturgeon species (Van Eenennamm *et al.* 2001).

POPULATION SIZES AND TRENDS

A comprehensive population size and trends analysis has not been done for the green sturgeon population in Canada. The first COSEWIC report in 1987 classified the species as rare due to a lack of information on the habitat requirements and biology of the species in addition to a paucity of information on its population status (Houston 1988). Unfortunately, this has not substantially improved. Information on the green sturgeon found in Canada is largely anecdotal prior to 1996; as DFO catch statistics only began differentiating green and white sturgeon with the implementation of 100% fisheries observer coverage for the domestic trawl fishery after this date. No spawning populations in Canada are known, and there is no evidence that any existed historically. The lack of studies on the green sturgeon in Canada is largely due to its rarity, its low commercial value and the relative ease of misidentification with the more common white sturgeon. However, the absence of evidence is not evidence of absence and a few green sturgeon have been caught in areas where spawning might occur. While there has been intensive sampling for white sturgeon, the same is not the case for the green surgeon, and no specific attempts have been made to look for adults, let alone young-of-the-year or juveniles. Work by Israel *et al.* (2002) suggests that there may be a discrete spawning population yet to be discovered; it is considered unlikely, but not impossible that this population is spawning in Canada despite the lack of evidence.

The vast majority of information regarding the habitat needs, biology and population status and trends of green sturgeon comes from the US. where all currently known spawning populations are located

Canadian Assessment

Green sturgeon are generally restricted to marine environments in Canada; however, there is anecdotal evidence that suggests that they may have historically utilized the lower portions of the Fraser, Skeena, and Nass rivers (McPhail and Carveth 1993). Due to their similarity to white sturgeon, there is the possibility that green sturgeon may have been substantially impacted during the collapse of the unregulated white sturgeon fishery in the late 1800s when the white sturgeon fishery was declared “practically commercially extinct” by a fisheries inspector in 1902 (EPIC 2001). Because of their similarity and range overlap with white sturgeon, green sturgeon were likely caught in the fishery and discarded or sold without being reported in landing statistics. The possible impact on the population will likely never be known as historical catch statistics differentiating between sturgeon species do not exist. There is the possibility that they may have been somewhat protected due to their disagreeable taste and low market value. Large marine catches, summer estuarine concentrations, and a possible negative attitude towards releasing the fish alive due to the feeling that they may be

displacing white sturgeon habitat makes it impossible to assess the relative impact that green sturgeon may have suffered during the unregulated white sturgeon fishery.

Green sturgeon have been encountered in freshwater in Canada through white sturgeon tagging studies. In 1986, a tagging study captured and tagged 500 white sturgeon, and two green sturgeon (which were not positively identified but simply appeared as "different" from white sturgeon) between approximately 50 to 90 km upstream from the Fraser River mouth (Houston (1988). A similar study, which overlapped a portion of the original study area spanning the years 1995 to 1999, tagged 414 white sturgeon between Mission (rKm 78) and Bristol Island (rKm 154) but failed to find any green sturgeon. An additional 1429 white sturgeon were captured during the study farther upstream from this area with no green sturgeon being found (Adams *et al.* 2002). The lower Fraser River has had more reports of green sturgeon; however, they continue to be rare. Nearly 13 000 white sturgeon have been tagged from the beginning of 2000 to June 2003, and 12 to 15 possible green sturgeon have been reported (Nelson pers. comm.). However, as green sturgeon in Canadian waters are generally marine residents, freshwater encounters were likely always rare with the majority of catches being restricted to marine commercial fishing vessels. The first documented catch of green sturgeon on the coast of BC occurred in 1954 off Spring Island near Kyuquot Sound. Seventy-five green sturgeon were caught in one trawl haul at a depth of 78.6 m. The average length and weight of these fish was 119.4 cm (range 94 to 203 cm) and 12.7 kg, respectively (Anonymous 1954).

A survey was conducted in 1995 by Slack and Stace-Smith (1996) due to a concern over the absence of data about the population status and a concern that the population was on the decline. The survey included local commercial, longline, gillnet and sport fishers who were asked about any current or historic encounters with green sturgeon. The survey used notices posted at fishing docks at Stevenston and False Creek, calls at fishers' meetings and a notice in The West Coast Fisherman magazine. The results of the survey indicated that in the early 1980s, some large trawlers off the west coast of Vancouver Island caught and released large numbers of green sturgeon; however, large catches were not observed from 1988 to 1995. Furthermore, since 1985, the Pacific Salmon Commission has only found one green sturgeon in all test fisheries that were conducted, and it was unconfirmed (J. Gable, Racial Identification Group, Pacific Salmon Commission; pers. comm. 2003). In the bottom trawl fishery, large single hauls of green sturgeon reaching 9000 kg were reported in 1960 and catches from 1737 to 4500 kg were being landed between 1989 and 1992. Moreover, green sturgeon were incidentally caught in salmon gillnets at the mouths of large rivers (Table 2). In addition to the observations reported in Table 3, deliveries to a fish processing company in Port Hardy reported some small catches (2 to 6 per boat) between January 1994 to June 1995, which were sold dockside or taken home by the crew.

Table 2. Results from surveys done by Slack and Stace-Smith (1996), not including qualitative reports of green sturgeon catches. Weights are catches from single large bottom trawls and individuals were caught from either gillnets or longline. Individuals are reported at an estimated weight of 30 kg (Houston 1988).

	Region			
Year	Northern BC and midcoast mainland (Kg)	West coast Vancouver Island (Kg)	Juan de Fuca Strait, Georgia Strait, Johnston Strait, and Fraser River	Total (kg)
1960	-	9000	-	9000
1962	-	-	2 in gillnets	60
1972 – 1989	-	-	2 – 3 per year in gillnets	60 – 90
1989	-	3600	-	3600
1990	-	4500	-	4500
1991	-	3500	3 in gillnets	3590
1992	508	1737	-	2245
1993	8	286	-	294
1994	23	239	3 in gillnets	352
1995	-	12 individuals (longline)	-	360

The survey conducted by Slack and Stace-Smith (1996), although anecdotal and incomplete, is the only substantial source of information regarding historic catch sizes of green sturgeon prior to 1996. The survey suggests that green sturgeon catches may have declined since the early 1960s. The survey data, however, needs to be viewed cautiously and is of limited value for stock assessment purposes. For instance, the data does not reflect the overall decline in total commercial fisheries which has occurred since the 1960s. This would result in lower effort and likelihood of sturgeon captures. Additionally, there is no method to ascertain the accuracy or precision of catch weight estimation or whether the survey information incorporates all green sturgeon catches, as fishers who had left the fishery or not responded to the survey would be omitted. Furthermore, temporal standardization of fishing effort is absent. Therefore, the catch statistics formulated through this survey of single abnormally large catches do not reflect total annual catches of green sturgeon.

A method to develop historical catch estimations of green sturgeon is possible by estimating species composition of undifferentiated sturgeon catches between those in marine and freshwater. As green and white sturgeons are generally marine and freshwater residents respectively in Canadian waters, by observing catch location, it may be possible to develop a historical time series of green sturgeon catches. Estimations would include a degree of error as white sturgeon have been caught in marine waters and green sturgeon in freshwater. Furthermore, the data is currently not readily available in electronic form and would be difficult to compile (J. Echols, Selective Fishing Co-coordinator, Department of Fisheries and Oceans, Vancouver, BC; pers. comm. 2003).

Quantitative data on green sturgeon catches in Canada is limited as DFO only started differentiating between green and white sturgeon in their catch statistics after 1996 with the initiation of 100% observer coverage for the domestic trawl fishery. Catches of green sturgeon are rare and single catches generally make up a substantial portion of the entire yearly catch as can be seen from the upper range of the biomass per trawl (Table 3). In each year, a single haul accounts for 25 to 52% of the total yearly catch.

Table 3. Summary of annual catch statistics of green sturgeon aboard bottom trawl vessels in Canadian Pacific waters (DFO catch statistics).

Year	Number of sets	Total Fishing Time (h:mm)	Range of green sturgeon biomass per trawl (Kg)	Total Yearly green sturgeon Catch (Kg)
1996	10	17:55	6.8 – 127.0	460
1997	7	21:40	13.6 – 294.8	562
1998	15	42:06	4.5 – 158.8	623
1999	8	11:42	4.5 – 113.4	259
2000	27	78:33	13.6 – 1063.7	3274
2001	12	29:25	2.26 – 762.4	2832
2002	33	90:45	0.45 – 952.5	3212
Total	112	292:06	0.45 – 1063.7	11222

From 1996 to 2002, the catches were composed of 171 green sturgeon (mean weight = 65.6 kg). A total of 151 138 sets were recorded for the fishery over this time indicting that green sturgeon were caught in only 0.07% of catches (Levings and Nelson 2002). The low incidences of green sturgeon over the span of the data set indicate that green sturgeon catches are rare. Catch data is not standardized for overall fishery effort or gear selectivity which may have changed over the time series, making the data presented here of limited value. Standardized data, however, would be of little use in determining population sizes and trends due to the short time series and relatively small and highly variable catch sizes. Therefore, making any reasonable quantitative assessment of the status and trends of green sturgeon found in Canadian waters is not practical at this time.

The reports of large single catches up to 9000 kg and many significantly over 1000 kg as reported by Slack and Stace-Smith (1996) have not been observed since 100% observer coverage for the domestic trawl fishery was instituted in 1996. This may be an indication that the green sturgeon population has suffered a decline over the past few decades; however, this claim cannot be made with certainty.

U.S. Assessment

The National Marine Fisheries Service (NMFS) recently conducted a status review of green sturgeon (Adams *et al*. 2002) to determine if the species should be listed as an endangered or threatened species under the US Federal Endangered Species Act

Table 4. White and green sturgeon caught during San Pablo Bay tagging program. Green sturgeon estimates are calculated by multiplying ratio of recaptures of tagged green and white sturgeon against the white sturgeon population estimate (CDFG 2002 cited in Adams *et al*. 2002).

Year	White sturgeon captured	>102 cm green sturgeon captured	Green captures/ White captures	White population estimate	Green abundance
1954	961	17	0.018	11200	198
1967	1612	26	0.016	114700	1850
1968	1080	28	0.026	40000	1037
1974	713	7	0.01	20700	203
1979	1368	26	0.145	100300	1906
1984	2551	24	0.009	117600	1106
1985	2419	19	0.008	107800	847
1987	982	6	0.006	97800	598
1990	701	15	0.021	75600	1618
1991	546	9	0.016	72700	1198
1993	534	2	0.004	46700	175
1994	593	0	0	0	0
1997	1321	12	0.009	141900	1289
1998	1469	7	0.005	144400	688
2001	855	60	0.07	120000	8421

(EPIC 2001). The status review determined that neither the northern, nor the southern green sturgeon DPSs warranted listing as threatened or endangered at this time (Adams *et al*. 2002); although it was acknowledged that the northern DPS could be in the foreseeable future (Adams *et al*. 2002). The best evidence available seems to indicate that the green sturgeon has undergone significant range contraction and in turn has likely suffered a substantial decline in abundance.

Asian Population of Sakhalin Sturgeon

The Sakhalin population of green sturgeon has been extirpated throughout Japan, Korea, and China and is reduced in range in Russia to the Tummin River where a hatchery maintains its population (EPIC 2001). It is listed as endangered on the IUCN red list (IUCN 2002). The taxonomic relationship between the North American and Asian form (the Sakhalin sturgeon) of green sturgeon is still in debate.

LIMITING FACTORS AND THREATS

Sturgeon exhibit a combination of morphology, life history and habitat requirements that make them highly susceptible to negative impacts from human activities (Boreman 1997). Anthropogenic activities known to impact sturgeon include: exploitation (*see* Population Sizes and Trends), blockage of available freshwater

spawning habitat through diking, damming causing inadequate flow regimes, channelization, elimination of backwater areas, dewatering of streams, destruction of thermal refugia, loss of deep pools, inundation of habitat by reservoirs, and exposure to bioaccumulating industrial and municipal pollution, (Boreman 1997, EPIC 2001, Adams *et al.* 2002). It is illegal to retain green sturgeon caught in both marine and freshwater in Canada (DFO fishing regulations 2003). No assessment of mortality incurred by trawl caught green sturgeon has been done.

The long life span and late age of maturity make sturgeon vulnerable to chronic and acute effects of bioaccumulation. A fish contaminant survey of the Columbia River Basin between 1996 to 1998 found white sturgeon to have the greatest contaminant concentrations compared to all other species tested, of which various salmonids, two sucker species, walleye, pacific lamprey and eulachon (USEPA 1999). White sturgeon also had the highest whole body concentrations of hexachlorobenzene (19 µg/kg), DDT (787 µg/kg), p,p'DDE (620 µg/kg), Aroclors (173 µg/kg), and dioxins were an order of magnitude higher in concentration than all other species tested. Although green sturgeon are less exposed to anthropogenic contaminants due to their marine migratory phase, there is the potential for exposure when entering freshwater to spawn and during estuarine concentrations.

There is a possibility of disease transfer from hatchery-raised sturgeon and wild sturgeon, however there is no evidence that this has ever occurred. There was a die off of white sturgeon in the Fraser River in 1993 to 1994. Thirty-four "huge sturgeon", mostly females, were found (MELP 1997). Although no green sturgeon were reported, the possibility that some green sturgeon could have been affected exists as all affected sturgeon may not have been found.

SPECIAL SIGNIFICANCE OF THE SPECIES

Green sturgeon are among the largest and longest-living species found in freshwater, living up to 70 years, reaching 2.3 m in length, and weighing up to 159 kg. Literally surviving contemporaries of the dinosaurs, green sturgeon are one of the world's most ancient species, having remained virtually unchanged since they appeared in the fossil record more than 200 million years ago. The rarity and reported disagreeable taste of green sturgeon has limited its utilization in Canada, with the majority of fish captured as bycatch being frequently discarded as unmarketable. However, there is a tribal fishery on the Klamath River in Oregon that has existed for more than one thousand years and is considered an integral part of the tribe's culture (Van Eenennaam *et al.* 2001).

Sturgeon are of biological and commercial significance. Biologically they have been of interest to science because of their ancestry leading back to the dinosaurs. Commercially, they are valued to some extent for their flesh, which is usually smoked and brings a high price per kg, but more so for the highly valued caviar. Trade in sturgeon, their parts and derivatives is international and regulated by The Convention

on International Trade in Wild Flora and Fauna (CITES). Caviar is the most valuable fish product in the world and suppliers will go to great lengths to procure a supply. Roe is worth up to $550/kg in legal markets (MD 2003) and processed caviar can bring well in excess of $1000/kg in the domestic market (CITES World 2001). Given the demand for caviar and the scarcity of the wild resource; such prices encourage the development and support of illegal practices, including poaching.

There is no information on the extent of illegal exploitation of green sturgeon, but poaching activity on white sturgeon in the lower Fraser River is a concern (Ptolemy and Vennesland 2003). Some recent investigations have linked sturgeon poaching to organized crime, and an organized poaching ring, known to be operating in the Pacific Northwest, has provided large quantities of sturgeon caviar to retailers, much of it marketed to the public as beluga caviar (Waldman 1995; Ptolemy and Vennesland 2003).

EXISTING PROTECTION OR OTHER STATUS

Green sturgeon were given the status of Special Concern by COSEWIC in 1987 due to a lack of information regarding population sizes and trends of the species (Houston 1988). In British Columbia, green sturgeon has a status of red indicating it is a candidate for extirpation, endangerment, or threatened status (BCCDC, 2003). It is illegal to retain green sturgeon while sport fishing in both marine and freshwater in Canada (DFO fishing regulations 2003).

In the United States it has federal species of concern status; however, this offers no regulatory or conservation protection (EPIC 2001). In Oregon, Washington, and Alaska it has no special protection. In California, it is classified as a species of special concern but has no protection under the California Endangered Species Act (EPIC 2001). However, there are fishing regulations such as size, bag and slot limits in these states.

IUCN assessed the green sturgeon in 1996 using the 1994 Categories & Criteria (version 2.3) and classified it as “VU A1ac” (vulnerable due to suspected reduction over 20% in the last 10 years or three generations from direct observation and a decline in area of occupancy) (IUCN 2002). CITES listed green sturgeon under Appendix II in June 1997 and it remains listed (CITES 2003).

TECHNICAL SUMMARY

Acipenser medirostris
Green sturgeon Esturgeon vert
Range of Occurrence in Canada: British Columbia

Extent and Area Information	
• *Extent of occurrence (EO)in Canada* [Estimated from Figure 4]	<500 000 km^2
• *specify trend:*	Unknown, possible decline
• *are there extreme fluctuations in EO (> 1 order of magnitude)?*	Unknown
• *Area of occupancy (AO)* [Estimate of author]	Data limited; maximum 12 000 – 30 000 km^2
• *specify trend:*	Unknown, possible decline
• *are there extreme fluctuations in AO (> 1 order magnitude)?*	Yes, summer concentrations
• *Number of extant locations*	Unknown in marine, at least 2 in freshwater
• *specify trend in # locations:*	Unknown
• *are there extreme fluctuations in # locations (>1 order of magnitude)?*	Unknown
• *habitat trend:*	Stable
Population Information	
• *generation time:*	27 to 33 years
• *number of mature individuals (capable of reproduction) in the Canadian population:*	Unknown
• *total population trend:*	Unknown, possibly declining
• *if decline, % decline over the last/next 10 years or 3 generations, whichever is greater:*	Unknown
• *are there extreme fluctuations in number of mature individuals (> 1 order of magnitude)?*	Unknown
• *is the total population severely fragmented?*	No
• *list each population and the number of mature individuals in each*	Not Applicable
• *specify trend in number of populations: (decline, stable, increasing, unknown)*	Unknown
• *are there extreme fluctuations in number of populations ?*	Unknown
Threats (actual or imminent threats to populations or habitats)	
Anthropogenic activities known to impact sturgeons include: blockage of available freshwater spawning habitat through diking, damming causing inadequate flow regimes, channelization, elimination of backwater areas, dewatering of streams, destruction of thermal refugia, loss of deep pools, inundation of habitat by reservoirs, exposure to bioaccumulating industrial and municipal pollution, and overfishing. With the exception of overfishing, the majority of these impacts are restricted to the freshwater phases of green sturgeon life history. As green sturgeon are rarely captured in freshwater in Canada, negative anthropogenic impacts outside fishing may be more limiting to individuals utilizing spawning and rearing habitat in the US.	
Rescue Effect (immigration from an outside source)	**Moderate**
• *does species exist elsewhere (in Canada or outside)?*	Yes
• *status of the outside population(s)?*	Possibly declining
• *is immigration known or possible?*	Yes
• *would immigrants be adapted to survive here?*	Unknown
• *is there sufficient habitat for immigrants here?*	Yes
Quantitative Analysis	**Not Applicable**

Existing Status
Nature Conservancy Ranks
Global – G3
National
US – N3
Canada N3N
Regional
US – Alaska – S4N, California S2S2, Oregon S3, Washington S3N
Canada – BC S3N

IUCN – Vulnerable
US Endangered Species Act – Candidate species
CITES – Appendix II
COSEWIC – SC 1987

Status and Reasons for Designation

Status: Special Concern	**Alpha-numeric code:** Not Applicable
Reasons for Designation The number of individuals in Canadian waters is unknown, but is undoubtedly not large. This species is globally at risk and is of concern in Canada because of exploitation and habitat loss due to damming of rivers.	
Applicability of Criteria **Criterion A** (Declining Total Population**)** – Not applicable, no evidence of population decline. **Criterion B (**Small distribution, and Decline or Fluctuation) – Not applicable, AO and EO larger than threshold values and there is no evidence of decline or fluctuation. **Criterion C** (Small Total Population Size and Decline) – Not applicable, population size and trends not known. **Criterion D** (Very Small Population or Restricted Distribution) – Not applicable, although the Canadian population is undoubtedly small, the number of mature individuals is unknown, the area of occupancy is certainly larger than the threshold value, and the number of locations at which the species is found is uncertain. **Criterion E** (Quantitative Analysis) – Not applicable - no data.	

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INFORMATION SOURCES

Adams, P.B., C.B. Grimes, J.E. Hightower, S.T. Lindley, and M.L. Moser. June 2002. Status Review of North American Green Sturgeon, *Acipenser medirostris*. National Marine Fisheries Service (NMFS), Santa Cruz.

Allen, P.A., and J.J. Cech Jr. 2003. Ontogeny of salinity tolerance in juvenile green sturgeon (*Acipenser medirostris*). Presented at the 2003 WDAFS & Cal-Neva Annual Meeting. San Diego, CA, April 14 – 17, 2003.

Anonymous. 1954. An unusual catch of green sturgeon. Fish. Res. Board Can. Pac. Prog. Rept. 100:19.

Ayres, W.O. 1854. Descriptions of three new species of sturgeon from San Francisco. Proceedings of the California Academy of Natural Sciences 1: 14-15 (1854-1857).

BC Conservation Data Centre (BCCDC). 2003. Ministry of Sustainable Resource Management. http://srmwww.gov.bc.ca/cdc/

Beamesderfver, R.C.P., and M.A.H. Webb. 2002. Green sturgeon status review information. S.P. Cramer and Associates, Gresham, Oregon. 44 p.

Birstein, V.J., R. Hanner, and R. DeSalle. 1997. Phylogeny of the Acipenxeriformes: cytogenetic and molecular approaches . Environ. Biol. Fishes 48: 127-155.

Birstein, V.J., A.I. Poleaev, and B.F. Goncharov. 1993. DNA content of Eurasian sturgeon species determined by flow cytometry. Cytometry 14: 377-383.

Birstein, V.J. and R. DeSalle. 1998. Molecular phylogeny of Acipenserinae. Molecular Phylogentics and Evolution. 9: 141 – 155.

Boreman, J. 1997. Senstitivity of North American sturgeon and paddlefish to fishing mortality. Environmental Biology of Fishes. 48: 399 – 405.

California Department of Fish and Game (CDFG). 2000. California Department of Fish and Game green sturgeon files. Produced by Dave Kohlhorst in response to a California Public Records Act request. Available from the California Department of Fish and Game, Sacramento, California.

Cech, J.J. Jr., S.I. Doroshov, G.P. Moberg, B.P. May, R.G. Schaffter and D.M. Kohlhorst. 2000. Biological assessment of green sturgeon in the Sacramento-San Joaquin watershed (phase 1). Final Report to the CALFED Bay-Delta Program. Project # 98-C-15, Contract #B-81738.

CITES World. 2001. A new focus for *CITES World* – Strugeons, significant trade and the "Paris Agreement". CITES World 8 (December 2001): 1-16.
Clemens W.A. and G.V. Wilby. 1961. Fishes of the Pacific Coast of Canada. 2nd ed. Bull. Fish. Res. Board Can. 68. 443 pp.
Committee on the Status of Endangered Wildlife in Canada (COSEWIC). Government of Canada.
Convention on International Trade in Endangered Species and Wild Fauna and Flora (CITES). 2003. Appendices I, II and III. http://www.cites.org/eng/append/latest_append.shtml
Deng, X. 2000. Artificial reproduction and early life stages of the green sturgeon (*Acipenser medirostris*). Unpub. Ph.D. thesis. University of California, Davis.
Deng, X. 2000. Presentation at green sturgeon workshop. March 22 – 23, 2000. Weitchpec, CA. http://www.krisweb.com/krisweb_kt/biblio/klamath/yurok/2000greensturgeon.pdf
Department of Fisheries and Oceans (DFO). 2003. Tidal Waters Sport Fishing Guide. http://www-comm.pac.dfo-mpo.gc.ca/pages/sfg/tables_e.htm
Echols, J.C. 1995. Review of Fraser River White Sturgeon (*Acipenser transmontanus*). Department of Fisheries and Oceans, Vancouver, BC.
Eddy, S., J.C. Underhill. 1978. How to know the freshwater fishes. McGraw-Hill, Boston.
Emmett, R.L., S.L. Stone, S.A. Hinton, and M.E. Monaco. 1991. Distribution and abundance of fishes and invertebrates in west coast estuaries, Volume II: species life history summaries. 329 p. Rockville, MD, Strategic Environmental Assessments Division.
Environmental Protection Information Center, Center for Biological Diversity, and Waterkeepers Northern California (EPIC). 2001. Petition to list the North American Green Sturgeon (*Acipenser medirostris*) as an endangered or threatened species under the Endangered Species Act. 62 pp.
Erickson, D.L., J.A. North, J.E. Hightower, J. Weber, and L. Lauck. 2002. Movement and habitat use of green sturgeon *Acipenser medirostris* in the Rogue River, Oregon, USA. J. Appl. Ichthyol. 18: 565 – 569.
Fain, S.R., J.P. LeMay, J. Shafer, R.M. Hoesch and B.H. Hamlin. 2000. The Development of a DNA Procedure for the Forensic Identification of Caviar. National Fish and Wildlife Forensics Laboratory, 1490 East Main Street, Ashland, OR, 97520, USA.
Fisheries Information Summary System (FISS). 2003. Ministry of Sustainable Resource Management, Aquatic Information Branch. http://www.bcfisheries.gov.bc.ca
Fitch, J.E. and R.J. Lavenberg. 1971. Marine food and game fishes of California. University of California Press, Berkley, CA, 179 pp.
Froese, R. and D. Pauly. Editors. 2003. Fishbase. World Wide Web electronic publication. www.fishbase.org, version 26 May 2003.
Hart, J.L. 1973. Pacific fishes of Canada. Fisheries Research Board of Canada, Bulletin 180:82.
Healey, M., J. Richardson, Lissimore, T. Rempel, and P. Dymond. 1994. Biophysical Analysis of the main lower Fraser River. Institute for Resources and the Environment. http://www.ire.ubc.ca/ecoresearch/

Helfman, G.S, B.B Collette, and D.E. Facey. 1997. Diversity of Fishes. Blackwell Science Inc., Malden, Massachusettes. 507 p.

Houston, J.J.P. 1987. COSEWIC status report on the green sturgeon *Acipenser medirostris* in Canada. Committee on the Status of Endangered Wildlife in Canada. 15 pp..

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

Israel, J., M. Blumberg, J. Cordes, and B. May. 2002. A preliminary report on the development and use of molecular genetic markers for North American green sturgeon (*Acipenser medirostris*). Unpub. Draft. 24 p. University of California, Davis.

International Union for Conservation of Nature and Natural Resources (IUCN) 2002. 2002. IUCN Red List of Threatened Species. http://www.redlist.org/

Levings, C.D., and W.A. Nelson. Review of critical habitats for estuarine and nearshore coastal species in Pacific region: a contrast of white sturgeon (*Acipenser transmontanus*) and northern abalone (*Haliotis kamtschatkana*). Draft working paper presented at DFO National Science Workshop "Quantifying critical habitat for aquatic species at risk", Montreal, Dec 3 – 6, 2002.

MD. 2003. Fact sheet – Atlantic sturgeon, *Acipenser oxyrhinchus*. Maryland State Fisheries Education Web Site accessed 24 March 2004;

Mecklenburg, C.W., T.A. Mecklenburg, and L.K. Thorsteinson. 2002. Fishes of Alaska. American Fisheries Society, Bethesda, Maryland. 1037 pp.

Ministry of the Environment, Lands and Parks. 1997. White sturgeon, habitat alteration and declining water quality threaten the survival of this species in British Columbia. Fisheries Branch, BC Environment. http://wlapwww.gov.bc.ca/wld/documents/sturgeon.pdf

Ministry of Water, Land and Air Protection. 2002. Environmental Trends in British Columbia: Area Under License for Use or Managed for Conservation in 51 Coastal Estuaries. http://wlapwww.gov.bc.ca/soerpt/3habitat/estuaries.pdf

McPhail, J.D., and C.C. Lindsey. 1970. Freshwater Fishes of Northwestern Canada and Alaska. Fisheries Research Board of Canada. Bulletin 173: 60 – 61.

McPhail, J.D., and R. Carveth. 1993. Field Key to the Freshwater Fish of British Columbia. Fish Museum, Department of Zoology, University of British Columbia, Canada. 239 pp.

Miller, D.J. and R.N. Lea. 1972. Guide to the Coastal Marine Fshes of California. Calif. Fish and Game Bull. 157, 249 pp.

Moyle, P.B., P.J. Foley, and R.M. Yoshiyama. 1992. Status of green sturgeon, *Acipenser medirostris*, in California. Final Report Submitted to National Marine Fisheries Service, Terminal Island, CA.

Moyle, P.B., P.J. Foley, and R.M. Yoshiyama. 1994. Status and Biology of the Green sturgeon, *Acipenser medirostris*. The Sturgeon Quarterly. Vol. 2, No. 1:7. 1 p.

Moyle, P.B. 2002. Inland Fishes of California (second edition). Davis, CA: University of California Press.

Nakamoto, R.J., T.T. Kisanuki, and G.H. Goldsmith. 1995. Age and growth of Klamath River green sturgeon (*Acipenser medirostris*). U. S. Fish and Wildlife Service, Project # 93-FP-13, Klamath River Fishery Resource Office, Yreka, CA.

North, J.A., R.A. Farr, and P. Vescei. 2002. A comparison of meristic and morphometric characteristics of green sturgeon, *Acipenser medirostris*. J. Appl. Ichthyol. 18: 234 – 239.

Northcote, T.G., N.T. Johnston, and K. Tsumura. 1976. Benthic, epibenthic and drift fauna of the lower Fraser River. Westwater Research Centre, Technical Report No. 11.

Ptolemy Juanita, and Ross Vennesland. 2003. Update COSEWIC status report on the white sturgeon, *Acipenser transmontanus,* in Canada. Committee on the Status of Endangered Wildlife in Canada (COSEWIC). Ottawa. vii + 57 pp.

Scott, W.B. and E.J. Crossman. 1973. Freshwater Fishes of Canada. Bulletin 184 of the Fisheries Research Board of Canada, Ottawa, ON.

Schreiber, M.R. 1959. Study of sturgeon and striped bass: observations on the systematics and food habits of juvenile white sturgeon (*Acipenser transmontanus*) and green sturgeon (*Acipenser medirostris*). Calif. Dept. Fish and Game Inland Fish Admin. Report 60(15): 1 – 5.

Slack, T. and D. Stace-Smith. 1996. Distribution of the green sturgeon rarely seen in British Columbia waters. Journal of British Columbia Natural History 3(1): 39-43.

Sulak K.J., and M. Randall. 2002. Understanding sturgeon life history: Enigmas, myths, and insights from scientific studies. J. Appl. Ichthyol. 18: 519 – 528.

US Environmental Protection Agency (USEPA). 1999. Columbia River Basin Fish Contaminant Survey: 1996 – 1998. Region 10. Seattle, Washington. EPA 910-R-02-006.

U.S. Fish and Wildlife Service (USFWS). 1982. Klamath River Fisheries Investigation Program. Annual Report 1981. Fisheries Assistance Office, Arcata, California.

U.S. Fish and Wildlife Service (USFWS). 1995b. Working Paper on Restoration Needs: Habitat Restoration Actions to Double Natural Production of Anadromous Fish in the Central Valley of California, Vol. 2. USFWS, Stockton. 78 pp.

Van Eenennaam, J.P., and S.I. Dorsohov. 2001. Reproductive conditions of Klamath River green sturgeon (*Acipenser medirostris*). Proceedings of the International Symposium on Sturgeon, Wisconsin. (In press).

Van Eenennaam, J.P., M.A.H. Webb, X. Deng, and S.I. Doroshov. 2001. Artificial Spawning and Larval Rearing of Klamath River Green Sturgeon. Transactions of the American Fisheries Society 130:159-165.

Waldman, J.R. 1995. Sturgeons and paddlefishes: a convergence of biology, politics and greed. Fisheries 20(9): 20, 21, 49.

Wang, Y.L., R.K. Buddington, and S.I. Doroshov. 1987. Influence of temperature on yolk utilization by the white sturgeon *Acipenser transmontanus*. Journal of Fish Biology 30: 263 – 271.

Williamson, D.F. 2003. Caviar and Conservation. Status, Management, and Trade of North American Sturgeon and Paddlefish. World Wildlife Fund. TRAFFIC, North America.

Zhang S., Q. Wu, and Y. Zhang. 2001. On the taxonomic status of the Yangtze sturgeon, Asian and American green sturgeon based on mitochondrial control region sequences. Acta Zoologica Sinica. 47(6): 632 – 639.

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Gable, J. 2003. Head, Stock Identification Group. Pacific Salmon Commission, 600-1155 Robson Street. Vancouver, B.C. Canada V6E 1B5

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