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A comparison of meristic and morphometric characters of green sturgeon *Acipencer medirostris*

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Summary

The green sturgeon *Acipenser medirostris* is widely distributed along the coast of North America, with known spawning populations in the Klamath, Sacramento, and Rogue rivers. It also spawns in the Tumnin River, Russian Federation (formerly USSR) but is otherwise uncommon in Asia. Whether North American and Asian populations are conspecific has been debated; recent genetic analyses indicate these populations should likely be considered as distinct species. As part of a cooperative study aimed at determining the systematics of sturgeons of the North Pacific, meristic and morphometric data were collected from 50 green sturgeon harvested from the Columbia River, Oregon, USA in August 1999. Our meristic data expand the observed range for lateral scutes, ventral scutes, and gill rakers and confirm the published range for dorsal scutes. We found considerable overlap in meristic counts of Asian and North American populations of green sturgeon. Morphometric data showed considerable differences between populations, especially measures related to snout length; however, a lack of raw data precluded statistical comparison. Specific detailed procedures for collecting sturgeon morphometric and meristic characters should be established to facilitate comparison of data.

Introduction

The green sturgeon *Acipenser medirostris* is a widely distributed yet relatively uncommon anadromous species occurring along the Eastern Pacific coast of North America from southern California to the Bering Sea (Miller and Lea 1972). Along the Western Pacific coast, this species has been reported from the Amur River south to the Sea of Japan (Soldatov 1915; Masuda et al. 1984). Current spawning populations are known only in the Sacramento, Klamath, and Rogue rivers of North America and in the Tumnin River, Russian Federation (formerly USSR). Targeted research has, until recently, been virtually nonexistent (Nakamoto et al. 1995; Van Eenennaam et al. 2001; Erickson et al. 2002; T. Rien, Oregon Department of Fish and Wildlife, personal communication; R. Shaffter, California Department of Fish and Game, personal communication), resulting in a weak understanding of the population status, biology and habitat needs of this species. Species classification has been equally confusing: at various times, Asian populations of the green or 'Sakhalin' sturgeon have been classified as *A. mikadoi* (Hilgendorf 1892; Okada and Matsubara 1938; Matsubara 1955; Birstein 1993), *A. medirostris* (Berg 1948; Andriyashev and Panin 1953; Masuda et al. 1984; Artyukhin and Andronov 1990), and *A. medirostris mikadoi* (Lindberg and Legeza 1965). Recent genetic comparisons of Asian and North American populations of green sturgeon provide evidence for separate species classification (Birstein et al. 1993; Blacklidge and Bidwell 1993; Birstein and Bemis 1997).

The objective of this study was to collect a representative sample of meristic and morphometric measurements from a population of North American green sturgeon to further ongoing comparisons with Asian populations of this species. This report documents the specific methods we used to measure morphometric and meristic characters, and compares our results with data for other green and white sturgeon, *A. transmontanus*, populations. We were unable to complete a statistical comparison of our findings with results for other green sturgeon populations as comparable raw data for other studies could not be obtained.

Materials and methods

Six meristic and 12 morphometric characters reported in Artyukhin and Andronov (1990) were collected from 50 green sturgeon [125–170 cm total length (TL)] harvested from the Columbia River estuary near Astoria, Oregon, USA during a 4–5 August 1999 commercial gillnet fishery. Fish were iced in plastic totes and refrigerated overnight prior to sampling. Data was also collected from a single adult (198 cm TL) green sturgeon captured on 27 July 2000 at river kilometer 24.0 on the Rogue River, Oregon.

Definitions of most counts and measurements were obtained from Hubbs and Lagler (1958), Scott and Crossman (1973), Birstein et al. (1997), and personal communication with Martin Hochleithner (Aqua Tech, Kitzbühel, Austria). A few measurements (maximum body depth and snout width at mouth) were subject to some interpretation because published descriptions could not be obtained or lacked exact methodologies. For example, we did not include dorsal scutes when measuring maximum body depth. Detailed descriptions of the counts and measurements collected are defined in Table 1 and Fig. 1.

Measurements of TL, head length, snout length to eye, postorbital distance, depth of head at eye, maximum body depth, and pectoral fin length were made to the nearest millimeter (except TL = cm) along the left lateral side. Measurements of snout to barbels and barbels to mouth were measured along the mid-ventral surface. Inter-orbital distance, snout width at barbels, and snout width at mouth were transverse measurements. Measurements relative to the mouth were recorded to a transverse line through the mouth in a closed position rather than to the anterior edge of the oral cavity as this point was not clearly defined. Lateral scutes, ventral scutes, and gill

Table 1
Definitions of morphometric measurements and meristic counts collected from green sturgeon harvested in the Columbia River, Oregon, August 1999. All measurements are linear distance to the nearest mm except total length (cm)

Total length: The anterior tip of the rostrum to the end of the upper lobe of the caudal fin in its natural position.
Head length: The anterior tip of the rostrum to the posterior margin of the operculum including the fleshy margin.
Snout length to eye: The anterior tip of the rostrum to the center of the eye.
Post-orbital distance: The posterior margin of the eye to the posterior margin of the operculum including the fleshy margin.
Inter-orbital distance: The distance between dorsal margins of the orbits.
Depth of head at eye: With the fish placed in a natural, upright position on a flat surface, the maximum depth of the head from the surface on a plane through both eyes.
Maximum body depth: With the fish laying in a natural, upright position on a flat surface, the maximum depth of the body from the surface to the most dorsal body-trunk point between scutes. Moderate manual lateral compression was applied as this measurement was taken to compensate for dorsal compression caused by the weight of the fish on the table.
Pectoral fin length: The anterior origin of the pectoral fin to the most distal margin.
Snout length to barbels: The anterior tip of the rostrum to the midpoint between the anterior insertion of the center barbels.
Barbels to mouth: The midpoint between the posterior insertion of the center barbels to a transverse plane through the center of the closed mouth.
Snout width at barbels: Snout width on a transverse plane through the barbel insertion row.
Snout width at mouth: Snout width on a transverse plane through the center of the mouth in a closed position.
Dorsal scutes: The number of large, dorsal scutes between the head and the anterior insertion of the dorsal fin, excluding small, unhooked plates (scutelet) that occasionally occurred in pairs immediately anterior of the dorsal fin. The first anterior dorsal scute was counted if it was independent of the cranial plate structure.
Lateral scutes: The number of left-side lateral scutes and scutelets beginning with the first anterior scute not connected to the pectoral girdle (cleithrum), posterior to the last lateral scutelet anterior to the point where the lateral line turns upward into the upper lobe of the caudal fin.
Ventral scutes: The number of left-side ventral scutes with keels anterior to the pelvic fin terminating under the pectoral fin. Scutelets were not observed.
Gill rakers: The combined number of complete and rudimentary gill rakers on both limbs of the first gill arch (not the pseudobranch).

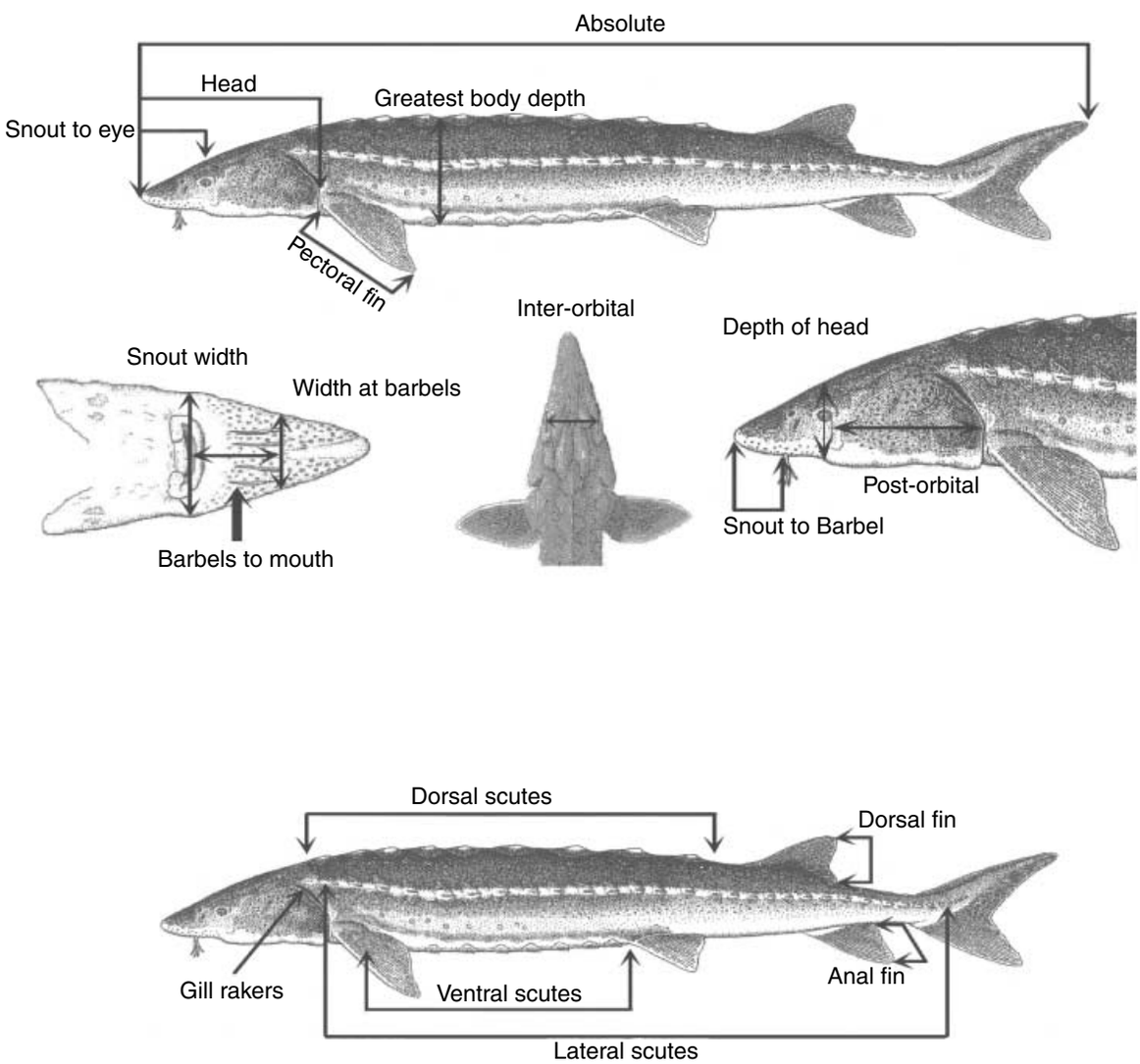

Fig. 1. Morphometric and meristic characters collected from green sturgeon harvested in the Columbia River, Oregon, August 1999. Drawings by Paul Vescei

rakers were enumerated from the left side of fish. Dorsal scute counts excluded small, keel-less scutelets often observed in pairs immediately anterior to the dorsal fin. Data for dorsal and anal fin ray counts of Columbia River specimens are not presented because we mistakenly enumerated only principal rays rather than counting all fin rays. All measurements represent a straight line along the left side or midline of the fish. Measurements were collected with calipers or dividers and a metric ruler, except that head and body depth were measured with two, inter-locked combination squares.

Table 2
Summary of four meristic characters collected from 50 Columbia River green sturgeon, August 1999

Character	Mean	Range	SE	SD
Total length (cm)	148	125–170	2.1	14.6
Dorsal scutes	9.4	7–12	0.2	1.1
Lateral scutes	28.5	22–33	0.4	2.8
Ventral scutes	9.2	7–12	0.2	1.1
Gill rakers	19.0	15–26	0.4	2.5

Results

Mean values of meristic characters are summarized in Table 2. A comparison with references citing original and undocumented data for green sturgeon, as well as some common references for white sturgeon, are provided in Table 3. Our meristic data expand published ranges for several characters of this species including lateral scutes (22; minimum), ventral scutes (12; maximum), and gill rakers (26; maximum). Because we sampled significantly more fish than previous studies, our data confirms other original data for dorsal scutes (7–12) and gill rakers (15 minimum). Inclusion of data from 28 references that could not be authenticated as being original (rather than references to other work) would increase the maximum range of lateral scutes to 36 (Matsubara 1955; Masuda et al. 1984) and extend the lower range for anal fin rays to 18 (Dumeril 1870). Considering the absolute of published ranges provided in Table 3, there appears to be little difference in meristic characters between Asian and North American populations of green sturgeon. There is also an overlap in ranges of several meristic characters between green and white sturgeon, especially ventral scutes and anal fin rays. Lateral scute count was the only character we identified without overlap between species. Summaries of characteristics observed by the authors

Table 3
Summary of documented ranges for six meristic characters of Asian and North American (NA) populations of green sturgeon. Several references for white sturgeon are included for comparison

Source	Origin	Dorsal scutes	Lateral scutes	Ventral scutes	Dorsal rays	Anal rays	Gill rakers	n
Green Sturgeon								
Artyukhin and Andronov (1990)	Asian	8–11	26–33	5–10	29–44	19–27	18–21	10[a]
Hilgendorf (1892)	Asian	10	30–31		39–43			?[b]
Jordan and Snyder (1906)	Asian	7–8	34	9	35–44	28–31		1[c]
Ueno and Abe (1966)	Asian	10–11	28–34		35–39	26–27		2[d]
Ayres (1854)	NA	11–12	25–27	10–11	35	24		1[e]
Deng (2000)	NA	8–10	24–28	5–6	40–44	26–32		5[f]
Norris (1957)	NA	9	28	9	40–42	28–29		1[g]
ODFW (this report)	NA	7–12	22–33	7–12			15–26	50[h]
ODFW (this report)	NA	9	25	8	37	25	25	1[i]
Schreiber (1959)	NA		23–30		35–40	21–27	15–19	4[j]
Snyder (1908)	NA	11	27	9				1[k]
28 undocumented references[l]	Both	7–11	22–36	5–10	33–42	18–30	18–20	?
Documented absolute ranges for green sturgeon								
Asia		7–11	26–34	5–10	29–44	19–31	18–21	= 13
North America		7–12	22–33	5–12	35–44	21–32	15–26	= 63
All		7–12	22–34	5–12	29–44	19–32	15–26	= 76
White Sturgeon								
Hart (1973)	NA	11–14	38–48	9–12	44–48	28–31		
Miller and Lea (1972)	NA	11–14	38–48	9–12	44–48	28–31		
Schreiber (1959)	NA		36–46		42–53	27–32	23–30	31[j]
Scott and Crossman (1973)	NA	11–14	38–48	9–12	44–48	28–30	34–36	
Absolute ranges for white sturgeon								
North America		11–14	36–48	9–12	42–53	27–32	23–36	

[a] Adults from Tumnin (Datta) River estuary, Russian Federation (formerly USSR).
[b] Unknown life stage from northern waters of Japan.
[c] Preserved specimen from unknown location.
[d] One juvenile from Konbumori and one from near the mouth of the Ishikari River, Japan.
[e] Juvenile from unknown location. Text refers to one specimen but states range for counts.
[f] Young-of-year progeny from adults collected in Klamath River, California, USA.
[g] Juvenile from Point Vicente, Los Angeles County, California, USA.
[h] Adults from Columbia River estuary, Oregon, USA.
[i] Adult from Rogue River, Oregon, USA.
[j] Young-of-year from Old, Sacramento, or Eel rivers, California, USA.
[k] Adult from Klamath River estuary, California, USA.
[l] Dumeril (1870); Kirsch and Fordice (1889); Berg (1911); Snyder (1912); Okada and Matsubara (1938); Schultz (1938); Berg (1948); Matsubara (1955); Dees (1961); Migdalski (1962); Vladykov and Greeley (1963); Clemens and Wilby (1967); Bane and Bane (1971); Miller and Lea (1972); Bond (1973); Fry (1973); Hart (1973); Scott and Crossman (1973); Moyle (1976); Carl et al. (1977); Bond and Beardsley (1978); Wydoski and Whitney (1979); Morrow (1980); Masuda et al. (1984); Wang (1986); Conte et al. (1988); Moyle et al. (1995); PSMFC (1996).

Table 4
Guidelines for field identification of green and white sturgeon in North America

Characteristic	White Sturgeon	Green Sturgeon
Color	Gray	Dark or olive green
Dorsal scutes	11–14	7–12 (usually sharp)
Lateral scutes[a]	36–48	22–33 (usually sharp)
Ventral scutes	9–12	5–12 (usually sharp)
Dorsal fin rays	42–53	35–44
Barbels	Equidistant between mouth and tip of snout or closer to snout	Equidistant between mouth and tip of snout or closer to mouth
Longitudinal stripes[a]	None	Olive green, two lateral from pectorals to pelvics; one on the anterior ventral surface
Position of anus[a]	Posterior of anal fin insertion	Anterior to anal fin insertion
Scutes between anal fin and pelvic fin	Two rows of 4–8 scutes each	One or two rows of 1–4 scutes each
Scutes between dorsal and caudal fin	Not present	May be present
Snout	Generally less pointed	Generally more pointed

[a] Most useful in field.

and reported in literature (Berg 1948; Migdalski 1962; Clemens and Wilby 1967; Bond 1973; Fry 1973; Moyle 1976; Carl et al. 1977; Morrow 1980; Wang 1986; Artyukhin and Andronov 1990; Lane 1991; Moyle et al. 1995) that can be used for field identification of green and white sturgeon are provided in Table 4.

Comparative morphometric data indicate that Asian green sturgeon may have a longer, narrower head than the fish we examined (Table 5). This difference appears to be driven by the length of the snout anterior to the eyes. Measurements of head, snout, snout to barbels, and barbels to mouth length show little or no overlap, whereas post- and inter-orbital length, depth of

Table 5
Summary of 12 morphometric characters of Asian (Artyukhin and Andronov 1990) and North American (North et al. this report) green sturgeon

Character		Artyukhin and Andronov 1990[a]	North et al. this report[b]	North et al. this report[c]
Total length (cm)	n	8	50	1
	range	148–180	125–170	198
	mean (±SE)	163 (4.0)	148 (2.1)	198
Head length	n	8	50	1
	% of TL	22.4–24.3	16.2–21.6	19.2
	mean (±SE)	23.3 (0.3)	18.8 (0.2)	19.2
Snout length to eye	n	8	50	1
	% of TL	10.0–12.0	5.0–9.9	7.6
	mean (±SE)	10.9 (0.2)	7.4 (0.2)	7.6
Post-orbital distance	n	8	50	1
	% of TL	10.9–12.1	10.2–12.3	10.7
	mean (±SE)	11.3 (0.1)	11.2 (0.1)	10.7
Inter-orbital distance	n	7	50	1
	% of HL	30.3–37.1	34.1–42.8	37.1
	mean (±SE)	34.1 (1.0)	38.5 (0.3)	37.1
Depth of head at eye	n	7	50	1
	% of TL	5.6–6.4	5.4–7.8	5.2
	mean (±SE)	6.0 (0.1)	6.5 (0.1)	5.2
Greatest body depth	n	8	50	1
	% of TL	11.9–16.9	9.2–13.0	10.2
	mean (±SE)	13.5 (0.5)	10.2 (0.1)	10.2
Pectoral fin length	n	7	50	1
	% of TL	11.5–13.5	10.7–15.4	10.2
	mean (±SE)	12.5 (0.2)	12.7 (0.1)	10.2
Length of snout to barbels	n	7	50	1
	% of HL	26.2–30.7	12.4–24.8	22.1
	mean (±SE)	27.7 (0.8)	19.2 (0.4)	22.1
Barbels to mouth	n	7	50	1
	% of HL	17.8–21.3	21.3–29.3	16.6
	mean (±SE)	19.4 (0.5)	26.0 (0.3)	16.6
Snout width at barbels	n	7	50	1
	% of HL	28.7–35.1	27.2–36.6	27.9
	mean (±SE)	31.6 (1.0)	31.9 (0.3)	27.9
Snout width at mouth	n	7	50	1
	% of HL	35.7–45.4	43.7–59.6	35.5
	mean (±SE)	40.6 (1.5)	50.1 (0.4)	35.5

[a] Tumnin (Datta) River green sturgeon (Asian) collected in 1986 and 1987.
[b] Columbia River green sturgeon (North American) collected in August 1999.
[c] Rogue River green sturgeon (North American) collected in July 2000.

head, snout width at barbels, and width of the head were similar. Data for the single specimen collected from the Rogue River was similar to mean values for Columbia River fish.

Discussion

Collection of morphometric data was an extremely tedious procedure, but the importance of collecting a large sample was clearly evident. As more fish were examined, individual differences became readily apparent, reaffirming the need to collect a representative sample. Meristic characters were much easier to evaluate and seem to be advantageous because most counts can be collected from live fish. However, meristic data alone may not provide the detail necessary to discern dissimilarities between different populations of the same species. Being the only mutually exclusive character of green and white sturgeon, the lateral scute count is a useful method for differentiating between these two, often co-existing, species.

Although it is difficult to collect a large sample of morphometric measures from live fish, it is also important for dead specimens to be in good condition so that measurements are representative. We observed minor deformities in some fish as a result of their overnight storage on ice. Measurements of head depth and maximum body depth of some dead specimens may have been slightly biased because the ventral body wall seemed less firm than those of live fish. To compensate for the effects of gravity, we applied moderate manual lateral compression during the measurements. This method seemed reasonable, but we do recognize the potential for bias. All meristic data and most other measurements were likely not affected.

We had some difficulty discerning the exact procedures to measure some characters because comprehensive methods detailing precise collection specific to sturgeon are not readily available (Hubbs and Lagler 1958; Schreiber 1959; Birstein et al. 1997). We attempted to duplicate measurements recorded by Artyukhin and Andronov (1990) but found that many characters were subject to interpretation. It is important for researchers to investigate existing methodologies prior to conducting sampling and to report precise definitions of methods used to collect data. Specific, detailed procedures for measuring morphometric and meristic characters of sturgeon should be established to facilitate comparison of data from different studies.

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References

Andriyashev, A. P.; Panin, K. I., 1953: Discovery of a Pacific sturgeon (*Acipenser medirostris* Ayres) in the Bering Sea. Zoologicheskii Zhurnal **32,** 932–936 (In Russian).

Artyukhin, E. N.; Andronov, A. E., 1990: A morphobiological study of the green sturgeon, *Acipenser medirostris* (Chondrostei, Acipenseridae), from the Tumnin (Datta) River and some aspects of the ecology and zoogeography of Acipenseridae. J. Ichthyol. **30** (7), 11–22.

Ayres, W. O., 1854: Descriptions of the Sturgeons. Proc. California Academy of Science, Vol. 1, 2nd edn. Academy Publishing, San Francisco, CA, pp. 14–16.

Bane, G. W.; Bane, A. W., 1971: Bay Fishes of Northern California. Mariscos Publications, Hampton Bays, New York. 143 pp.

Berg, L. S., 1911: Fishes (Marsipobranchii and Pisces). Fauna of Russia and adjacent countries. Vol. 3, Vypusk 1. Izdatelstvo Akademii Nauk, St. Petersburg. 337 pp, (In Russian).

Berg, L. S., 1948: Freshwater fishes of the U.S.S.R. and adjacent countries. Academy of Science U.S.S.R. Zoological Institute. (Translations from Russian by Israel Program for Scientific Translations, Jerusalem, 1962.) Guide to Fauna of the U.S.S.R. **27**(1) 4th edn. 504 pp.

Birstein, V. J., 1993: Sturgeons and paddlefishes: threatened fishes in need of conservation. Conservation Biol. **7,** 773–787.

Birstein, V. J.; Bemis, W. E., 1997: How many species are there within the genus *Acipenser*? Environ. Biol. Fishes **48,** 157–163.

Birstein, V. J.; Poletaev, A. I.; Goncharov, B. F., 1993: DNA content in Eurasian sturgeon species determined by flow cytometry. Cytometry **14,** 377–383.

Birstein, V. J.; Bemis, W. E.; Waldman, J. R., 1997: The threatened-status of acipenseriform species: a summary. Environ. Biol. Fishes **48,** 427–435.

Blacklidge, K. H.; Bidwell, C. A., 1993: Three ploidy levels indicated by genome quantification in Acipenseriformes of North America. J. Hered. **84,** 427–430.

Bond, C. E., 1973: Key to Oregon freshwater fishes. Agricultural Experiment Station Oregon State University, Corvallis, Oregon. Tech. Bull. **58** (revised).

Bond, C. E.; Beardsley, A. J., 1978: Field guide to common marine and bay fishes of Oregon. Oregon State University Extension Service Sea Grant Marine Advisory Program and Oregon State Univ. Agricultural Experiment Station, Corvallis, OR. Extension Manual 4/November 1978.

Carl, G. C.; Clemens, W. A.; Lindsey, C. C., 1977: The freshwater fishes of British Columbia. Handbook No. 5. British Columbia Provincial Museum, Victoria. 192 pp.

Clemens, W. A.; Wilby, G. V., 1967: Fishes of the Pacific Coast of Canada. Fish. Res. Board Can. Bull. **68,** 2nd edn. Ottawa. 443 pp.

Conte, F. S.; Doroshov, S. I.; Lutes, P. B.; Strange, E. M., 1988: Hatchery manual for the white sturgeon (*Acipencer transmontanus* Richardson) with applications to other North American Acipenseridae. Publ. #3322. Division of Agriculture and Natural Resources, Univ. California, Oakland, CA. 104 pp.

Dees, L. T., 1961: Sturgeons. Fishery Leaflet 526. U. S. Fish and Wildl. Serv. Bureau of Commercial Fisheries. 8 pp.

Deng, X., 2000: Artificial reproduction and early life stages of the green sturgeon (*Acipencer medirostris*). Master's Thesis. Univ. California, Davis, CA. 62 pp.

Dumeril, A., 1870: Histoire naturelle poissons, Vol. II. Atlas, 1865, Paris, 1–624.

Erickson, D. E.; North, J. A.; Hightower, J. E.; Weber, J.; Lauck, L., 2002: Movement and habitat use of green sturgeon *Acipenser medirostris* in the Rogue River, Oregon, USA. Proceedings of the 4th International Sturgeon Symposium. H. Rosenthal (Ed.). J. Appl. Ichthyol. (this volume).

Fry, D. H., Jr. 1973: Anadromous fishes of California. Calif. Dept. Fish and Game, Res. Agency, Sacramento, CA. 112 pp.

Hart, J. L., 1973: Pacific Fishes of Canada. Fish. Res. Board Can. Bull. No.180, Ottawa. 740 pp.

Hilgendorf, F., 1892: Über eine neue Stör-Art aus Nord-Japan (*Acipencer mikadoi*). Sitzungsber. Ges. naturf. Freunde, Berlin, **7,** 98–100.

Hubbs, C. L.; Lagler, K. F., 1958: Fishes of the Great Lakes Region. Univ. Michigan Press, Ann Arbor, MI. 213 pp.

Jordan, D. S.; Snyder, J. O., 1906: A synopsis of the sturgeons (Acipenseridae) of Japan. Proc. U.S. Nat. Museum **24** (1265), 567–593.

Kirsch, P. H.; Fordice, M. W., 1889: A review of the American species of sturgeons (Acipenseridae). Proc. Acad. Nat. Sci. Phila. **41,** 245–257.

Lane, D. E., 1991: Status of the white sturgeon, *Acipenser transmontanus*, in Canada. Can. Field-Nat. **105**(2), 161–167.

Lindberg, G. U.: Legeza, M. I., 1965: Fishes of the Sea of Japan and Adjacent Areas of the Okhotsk and Yellow Seas, Part 2. Nauka Publishers, Moscow and Leningrad, Russia. 391 pp, (In Russian).

Masuda, H.; Amaoka, K.; Araga, C.; Ueno, T.; Yoshino, T., 1984: The Fishes of the Japanese Archipelago. Tokai Univ. Press, Japan. 137 pp.

Matsubara, K., 1955: Fish Morphology and Hierarchy, parts 1-2-3. 135 plates. Ishizaki-Shoten, Tokyo, Japan. 1,605 pp.

Migdalski, E. C., 1962: Anglers Guide to Freshwater Sport Fishes. Ronald Press, New York. 431 pp.

Miller, D. J.; Lea, R. N., 1972: Guide to the coastal marine fishes of California. Calif. Fish and Game Bull. **157,** 249 pp.

Morrow, J. E., 1980: The freshwater fishes of Alaska. Alaska Northwest Publ. Corp., Anchorage, Alaska. 248 pp.

Moyle, P. B., 1976: Inland Fishes of California. Univ. California Press, Berkeley, Los Angeles, CA. 405 pp.

Moyle, P. B.; Yoshiyama, R. M.; Williams, J. E.; Wikramanayake, E. D., 1995: Fish Species of Special Concern in California, 2nd edn. Calif. Dept. Fish and Game, Inland Fisheries Division, Contract No. 2128IF, Rancho Cordova, CA. 272 pp.

Nakamoto, R. J.; Kisanuki, T. T.; Goldsmith, G. H., 1995: Age and growth of Klamath River green sturgeon (*Acipenser medirostris*). Ann. Rep. U.S. Fish and Wildl. Serv., Proj. 93-FP-13. Klamath River Resource Office, Eureka, CA. 28 pp.

Norris, K. S., 1957: Second record of the green sturgeon in southern California. Calif. Fish and Game **43**(4), 317.

Okada, Y.; Matsubara, K., 1938: Keys to the fishes and fish-like animals of Japan. Tokyo–Osaka. pp. 1–584, plates 1–113.

PSMFC (Pacific States Marine Fish Commission), 1996: Green sturgeon fish facts. Retrieved on 3 August 2000 from the World Wide Web: http://www.psmfc.org/habitat/edu_gsturg_fact-html.

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.

Schultz, L. P., 1938: Keys to the fishes of Washington, Oregon, and closely adjoining regions. Univ. Washington Publ., Seattle, Washington **2**(4), 103–228.

Scott, W. B.; Crossman, E. J., 1973: Freshwater fishes of Canada. Fish. Res. Board Can. Bull. **184**. 966 pp.

Snyder, J. O., 1908: The fishes of coastal streams of Oregon and northern California. Bull. U.S. Bureau Fish. **27,** 153–189.

Snyder, J. O., 1912: Japanese shore fishes collected by the U.S. Bureau of Fisheries steamer Albatross expedition of 1906. Proc. U.S. Nat. Museum pp. 399–450, figure 1, plates 51–61.

Soldatov, V. K., 1915: A study of the sturgeons of the Amur. Materials for an evaluation of the Russian fishing industry, Part 2 **3**(12), 95–114.

Ueno, T.; Abe, K., 1966: On rare or newly found fishes from the water of Hokkaido (1) and (2). Jpn. J. Ichthyology **13,** 220–236.

Van Eenennaam, J. P.; Webb, M. A. H.; Deng, X.; Doroshov, S. I., 2001: Artificial spawning and larval rearing of Klamath River green sturgeon. Trans. Amer. Fish. Soc. **130,** 159–165.

Vladykov, V. D.; Greeley, J. R., 1963: Order Acipenseroidei. Fishes of the western North Atlantic. Memorial Sears Found. Mar. Res. **1**(3), 24–60.

Wang, J. C. S., 1986: Fishes of the Sacramento-San Joaquin estuary and adjacent waters, California: A guide to the early life histories. Tech. Rep. 9. Inter agency ecological study program for the Sacramento-San Joaquin estuary. Calif. Dept. Water Res., Calif. Dept. Fish and Game, U.S. Bureau of Reclamation, and U.S. Fish and Wildl. Serv.

Wydoski, R. S.; Whitney, R. R., 1979: Inland Fishes of Washington. Univ. Washington Press, Seattle, WA. 220 pp.

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