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The Lake Sturgeon, *Acipenser fulvescens* (Chondrostei: Acipenseridae): An Annotated Bibliography

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1992

THE LAKE STURGEON, Acipenser fulvescens (CHONDROSTEI: ACIPENSERIDAE): AN ANNOTATED BIBLIOGRAPHY

by

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A total of 296 literature references on lake sturgeon covering the period 1817 (the first description of the species by Rafinesque) to 1991 are referenced in this bibliography. Of these, 24 are book articles, 102 constitute the 'gray' literature and 167 are primary publications. In addition, 3 theses on lake sturgeon are referenced. Most of the studies are on the population biology and natural history of lake sturgeon. Excerpts from general references (e.g., books) have not been referenced unless they provide novel information. Sources of reference include Biological Abstracts, Zoological Record, Cambridge Life Sciences Abstracts Compact Disc for 1986-1991, Aquatic Sciences and Fisheries Abstracts Compact Disc 1988-1990, Science Citation Compact Disc 1987-1991 and cross-references from other publications. The bibliography is preceded by an introduction, a table and key of the world species of sturgeon, and maps showing the distribution of the various species of acipenseriforms.

Key words: lake sturgeon; Acipenser fulvescens; bibliographies.

RÉSUMÉ

Dick, T.A., and A. Choudhury. 1992. The lake sturgeon, Acipenser fulvescens (Chondrostei: Acipenseridae): an annotated bibliography. Can. Tech. Rep. Fish. Aquat. Sci. 1861: iv + 69 p.

La présente bibliographie compte au total 296 références bibliographiques sur l'esturgeon de lac portant sur la période de 1817 (première description de l'espèce par Rafinesque) à 1991. Elle comprend 24 articles de livre, 102 références de littérature "grise" et 167 articles de publications primaires. De plus, elle compte 3 thèses sur l'esturgeon de lac. La plupart des études portent sur la biologie des populations et l'histoire naturelle de l'esturgeon de lac. Seuls les extraits d'ouvrages généraux (p. ex. livres) qui apportaient des éléments d'information nouveaux ont été énumérés dans la bibliographie. Parmi les sources des références, on trouve les Biological Abstracts, le Zoological Record, le Cambridge Life Sciences Abstracts Compact Disc de 1986-1991, l' Aquatic Sciences and Fisheries Abstracts Compact Disc de 1988-1990, le Science Citation Compact Disc de 1987-1991 et des références croisées d'autres publications. La bibliographie est précédée d'une introduction, d'un tableau et d'une clé d'identification des espèces d'esturgeon décrites dans le monde ainsi que de cartes indiquant la distribution des diverses espèces d'acipensériformes.

Mots clés : esturgeon de lac; Acipenser fulvescens; bibliographies.

INTRODUCTION

Among the Osteichthyes the order Acipenseriformes stands out as ancient, and widely distributed in the northern hemisphere with the distribution limited to north of the 20°N latitude (Fig. 1). However, it is in the temperate regions of the world that this group once flourished with large populations of both marine and freshwater forms (Fig. 1). Table 1 outlines the species and common names of the worlds' acipenseriformes. The main characteristics which separate each species are given in the key at the end of the introduction. Recent environmental events, ranging from overfishing, polluted waters, and modification of natural habitats for spawning and nurseries areas have drastically reduced populations from most regions of the world. Indeed, some species are designated as distribution reduced, endangered, rare, threatened, and close to extinction (Table 1). Ten of the 26 species of Acipenser fall within one of the above designations (Table 1). The status of the Chinese species of acipenserids (Table 1) is thought to be related to the construction of dams on the Chang Jian (Yang Xe) river. Lake sturgeon from North America is designated, in general, as having a reduced distribution but in parts of its range has been extirpated and in other areas it is considered to be endangered.

Figure 1 illustrates the distribution of all known sturgeon species of the world and Fig. 2 and 3 illustrate the individual species distribution in North America. There are eight species of Acipenseriformes in North America, with the lake sturgeon having by far the greatest distribution (Fig. 2 and 3). Eurasia is well represented by 13 species of acipenseriformes, although most of the species fall within designations indicating the populations are in trouble, particularly in Europe (Table 1). The distribution of the Eurasian species is illustrated in Fig. 4, 5 and 6. The distribution of the East Asian species of Acipenser spp. is illustrated in Fig. 7.

Most species of the genus Acipenser exhibit anadromy. Some species, i.e., A. brevirostrum, A. gueldenstaedti, A. nudiventris, A. transmontanus establish non-anadromous populations, in landlocked hydro-lakes. Two species are known to be exclusively or predominately freshwater; A. fulvescens, from North America and A. ruthenus from Eurasia. The Siberian sturgeon, A. baeri, may be also considered predominantly freshwater. A. dabryanus from China is probably freshwater since they have been reported only from the Chang Jian river.

This annotated bibliography deals with A. fulvescens, the lake sturgeon of North America which at one time was widely distributed on the continent. Considering the many publications on lake sturgeon (mostly in the gray literature) there has been remarkably little new information added to the biological knowledge of this species in our time. Numerous studies have estimated the size of local populations of sturgeon throughout much of its range in Canada and most of these studies have been predictable in terms of the approach taken. There is even information on radio tagging using airplanes and varying levels of analyses of this data but very little solid information on spawning sites or nursery areas. Indeed, most of the studies dealing with assessment or impact studies have added little to our knowledge of lake sturgeon biology and the relationship of sturgeon to the culture and livelihood of aboriginal peoples of Canada.

The destruction of lake sturgeon populations was noted as early as the mid 1800s and causes for these declines were documented in some of these reports (Prince 1905; Smith 1914; Tower 1909). The publication by Prince (1905) is an excellent review outlining the problems of the lake sturgeon fishery in Canada. As early as the late 1800s a few enlightened souls (Tower 1909) suggested that preserves be set aside to protect the lake sturgeon and a few individuals had a good appreciation of the importance of this fish species in the lives of aboriginal peoples. With the exception of the reports from the Alberta Fisheries department there are few long term reportings on sturgeon populations and even the Alberta reports are restricted to questionnaires to anglers and contain limited biological data. Nevertheless, this information is valuable as there is a consistency in the way the data was collected and presented. This literature review certainly pointed out the extensive gaps in the knowledge of lake sturgeon biology; early development and growth, habitat requirements (especially nursery areas), nutrition, physiology, and disease and immunology. In addition, little is known on the survival of local populations when isolated due to hydro-electric developments and whether or not these isolated stocks show genetic differences. The minimum number of reproducing individuals to sustain a population is unknown, even without exploitation.

Undoubtedly, the most revealing aspect of this literature review is that biologists and resource managers are saying the same things about a dwindling species that was being said nearly a century ago. Moreover, not only was much of the literature repetitious but often the solutions for enhancement were identical, be it separated by geographical distance or time. For example, reduce or eliminate the commercial harvest and implement a higher value sport fishery is frequently suggested. But often these same managers admit they do not clearly understand their local fishery regulations concerning lake sturgeon and their knowledge of sturgeon biology is limited. As there is usually no "before studies" and if there are the studies are usually inadequate, on the migrating patterns of lake sturgeon the effects of dams are essentially unknown. The Winnebago Lake population is the only system with adequate information to use as a model and even with this population there seems to have been a stronger population base to start from than many of the local populations which are in trouble in other parts of North America. When basic population estimates are attempted they are usually incomplete. Age to maturity is quite variable among studies and part of this variability is due to a lack of knowledge on how to stage eggs in order to predict the proportion of females that will spawn in subsequent years. If the next 100 years sees as

little progress in our understanding of the biology of lake sturgeon, as the past century has, its future does not look too bright.

ACKNOWLEDGMENTS

The authors wish to thank the following people who have contributed towards this manuscript: Mr. Frank Bishop, Department of Natural Resources (Fisheries), province of Alberta for giving us all their reports. This was particularly appreciated as it was difficult to acquire all the gray literature; Chief Willie Wilson, Manitou Rapids (Rainy River Band) for allowing access to his personal files on sturgeon; Mr. Ken Kansas, Manitoba Department of Natural Resources (Fisheries) for allowing access to his collection of lake sturgeon literature; Dr. E. Raikova, Institute of Cytology, St. Petersburg, Russia for translating some of the French publications; and the staff of the University of Manitoba interlibrary loans unit and the reference branch of the science library for their perseverance in sleuthing out incomplete and occasionally incorrect reference citations. We are indebted to Mr. Eric Marshall, Chief Librarian and Ms. Mary Layton, Librarian, Freshwater Institute, Department of Fisheries and Oceans, Winnipeg, for the speed and thoroughness with which they reviewed the preparation of this manuscript. We also greatly appreciate the efforts of Mr. Mike Papst, Divisional Manager, Fisheries Research, Central and Arctic Region, Department of Fisheries and Oceans, Winnipeg, for his encouragement of this project and financial assistance for its publication through the Department of Fisheries and Oceans.

WORLD SPECIES OF ACIPENSERIFORMES

NORTH AMERICA	EURASIA	FAR EAST ASIA
	ACIPENSERIDAE	
ACIPENSERINAE		
West Coast		
Acipenser medirostris R (Green)	A. baeri (Siberian)	A. dabryanus (Yang Xe)
A. transmontanus V (White)	A. gueldenstaedti V (Danube)	A. medirostris (Green)
	A. naccari E (Adriatic)	A. multiscutatus
	A. nudiventris DR (Schip)	A. schrenki (Amur)
Central	A. persicus E (Persian)	A. sinensis (Chinese)
A. fulvescens DR (Lake)	A. medirostris (Green)	
	A. stellatus (Stellate)	
	A. sturio E (European)	
East Coast	Huso huso (Beluga)	
A. brevirostrum R-E (Shortnose)	H. dauricus (Kaluga)	
A. oxyrhynchus (Atlantic)		
SCAPHIRHYNCHINAE		
Scaphirhynchus platorynchus (Shovelnose)	Pseudoscaphirhynchus fedtschenkoi R (Syr-Darya)	
	P. herdmanni R (Little Amu-Darya)	
S. albus (Pallid)	P. kaufmanni R (Amu-Darya)	
	POLYODONTIDAE	
Polyodon spathula (Paddlefish)		Psephurus gladius R-V

DR = Distribution Reduced; E = Endangered; R = Rare; V = Vulnerable; * = Close to extinction
(Data from Lelek 1989, and Sokolov and Berdichevskii 1989, see bibliography).

KEY TO THE WORLD SPECIES OF ACIPENSERIFORMES

Order Acipenseriformes.
Osteichthyes, Actinopterygii, body fusiform, caudal fin heterocercal, skeleton predominantly cartilaginous, intestine with spiral valve. Worldwide distribution in northern hemisphere.

1. Body covered with 5 rows of bony scutes (one dorsal, two lateral, two ventral, all 5 rows seen on young individuals), snout conical or dorsoventrally flattened but always narrowing in a triangular shape with the anterior tip forming the apex, ventral surface of snout with barbels, mouth ventral, jaws protrusible, anadromous and freshwater .....Family Acipenseridae.....(3 & 4).

2. Body not covered with rows of bony scutes, snout elongated sword-like or spatulate, barbels absent, jaws wide and not protrusible, operculum with posterior elongated spine, freshwater .....Family Polyodontidae.....(5).

3. Snout conical with round edges in adults, well developed spiracle, pseudobranchiae present .....Subfamily Acipenserinae.....(7 & 8).

4. Snout dorsoventrally flattened with sharp edges, triangular, spiracle absent or poorly developed, pseudobranchiae reduced, freshwater .....Subfamily Scaphirhynchinae.....(9 & 10).

5. Snout spatulate, mouth gape wide, planktivorous filter feeder, North America, Mississippi drainage .....Polyodon spathula.

6. Snout narrow sword shaped, piscivorous, China; Yang Xe River .....Psephurus gladius.

7. Gill membranes free from isthmus, joined to each other .....Genus Huso.....(11 & 12).

8. Gill membranes attached to isthmus, not joined to each other ..Genus Acipenser.....(13 & 14).

9. Spiracle absent, rudimentary pseudobranchiae, North America; Mississippi drainage .....Genus Scaphirhynchus.....(40 & 41).

10. Spiracle absent, pseudobranchiae absent, freshwater, USSR; Amu-Darya and Syr-Darya rivers .....Genus Pseudoscaphirhynchus.....(42 & 43).

11. Barbels without foliate appendages, Amur basin .....Huso dauricus.

12. Barbels with foliate appendages, basins of Adriatic, Black and Caspian seas ..... Huso huso.

13. Lower lip continuous and not indented medially .....Acipenser nudiventris.

14. Lower lip indented medially, snout less than 60% of total head length ..... (16 & 17).

15. Lower lip indented medially, snout greatly elongated and > 60% of head length ...A. stellatus.

16. Barbels clearly fimbriate, > 50 lateral scutes .....A.ruthenus.

17. Barbels not fimbriate or inconspicuously so, < 50 lateral scutes .....(18 & 19).

18. Gill rakers fan like, terminated by several tubercles .....A. baeri.

19. Gill rakers not fan like, terminated by single tip.....(20).

20. More than 30 gill rakers .....(22).

21. Less than 30 gill rakers .....(28 & 29).

22. More than 48 dorsal fin-rays, freshwater China .....A.dabryanus.

23. Less than 48 dorsal fin-rays .....(24 & 25).

24. Snout very broad, rounded at tip, Adriatic Sea .....A.naccari.

25. Snout stout and sub-conical .....(26 & 27).

26. Plates between dorsal and caudal fin and between anal and caudal fin .....A. fulvescens.

27. Plates described in 26 absent ..... A. transmontanus.

28. Dorsal finrays $\geq$ 54 .....A. sinensis.

29. Dorsal finrays $\leq$ 52 .....(30 & 31).

30. Barbels nearer tip of rostrum than mouth .....(32 & 33).

31. Barbels nearer mouth than tip of rostrum .....(36 & 37).

32. Snout broad, rounded tip .....(34 & 35).

33. Snout short, subconical, blunt .....A.brevirostrum.

34. Broad snout straight and relatively short, dorsum golden brown, ventrum yellowish white .....A.gueldenstaedti.

35. Snout massive, curved downward, dorsum greyish blue, ventrum white .....A. persicus.

36. Elongate snout, narrowing to pointed tip, 4 smaller plates between anal fin and caudal fulcrum .....(38 & 39).

37. Snout blunt, rounded but sharp, only one larger plate between anal fin and caudal fulcrum .....A.medirostris.

38. Anal fin-rays 26-28 .....A. oxyrhynchus.

39. Anal fin-rays 22-26 .....A. sturio.

40. Belly naked, dorsal fin-rays ≥ 37, anal finrays 24 .....Scaphirhynchus albus.

41. Belly covered with small scales, dorsal finrays < 36, anal finrays < 23 .....S. platorynchus.

42. Dorsal scutes 9-14, spines frequently present at tip of snout.....(44 & 45).

43. Dorsal scutes 15-22, no spines at tip of snout .....Pseudoscaphirhynchus fedtschenkoi.

44. Well developed cercus in adult, 1-5 sharp spines on tip of snout, no fold along outer edge of pectoral fin .....P. kaufmanni.

45. Cercus spines absent or weakly .developed, fold along outer edge of pectoral fin .....P. herdmanni.

The description of Acipenser multiscutatus (Japanese Archipelago) available to the authors, was incomplete. Consequently the species could not be accommodated in this key. It is considered similar in the number of fin-rays to A. schrenki but differs from it in possessing a short blunt snout (Lindberg 1967). For other morphological features of this anadromous species, the reader is referred to Lindberg (1967) and Masuda et al. (1989).

It is felt (Gardiner 1984) that the characters separating the Russian genus Pseudoscaphirhynchus and the North American Scaphirhynchus are "trivial" and consequently the two genera should be combined. (For complete references of the above citations, please see bibliography).

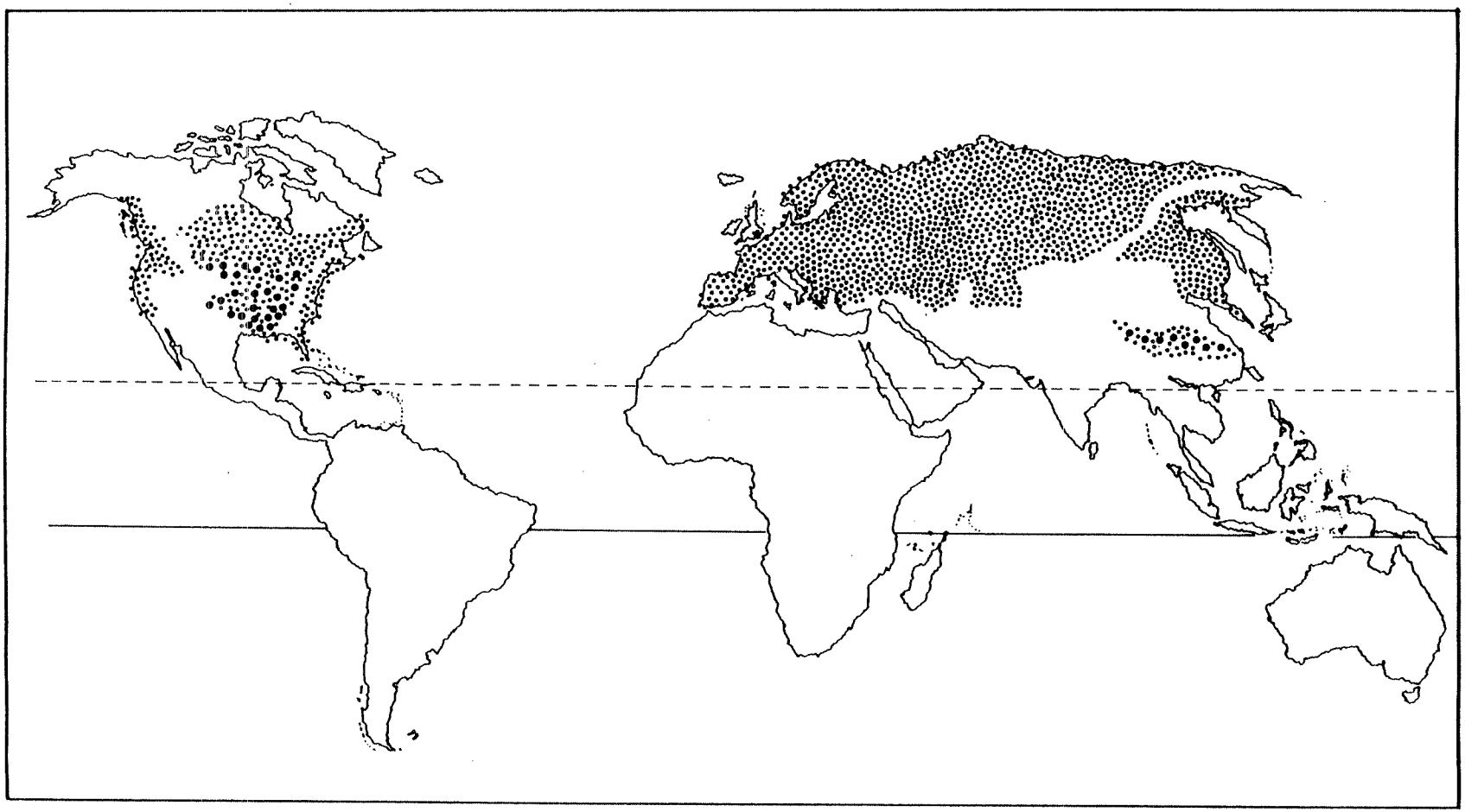

Fig. 1. Map of the world illustrating the distribution of Acipenseriformes: Acipenseridae (•••)and Polyodontidae (••).

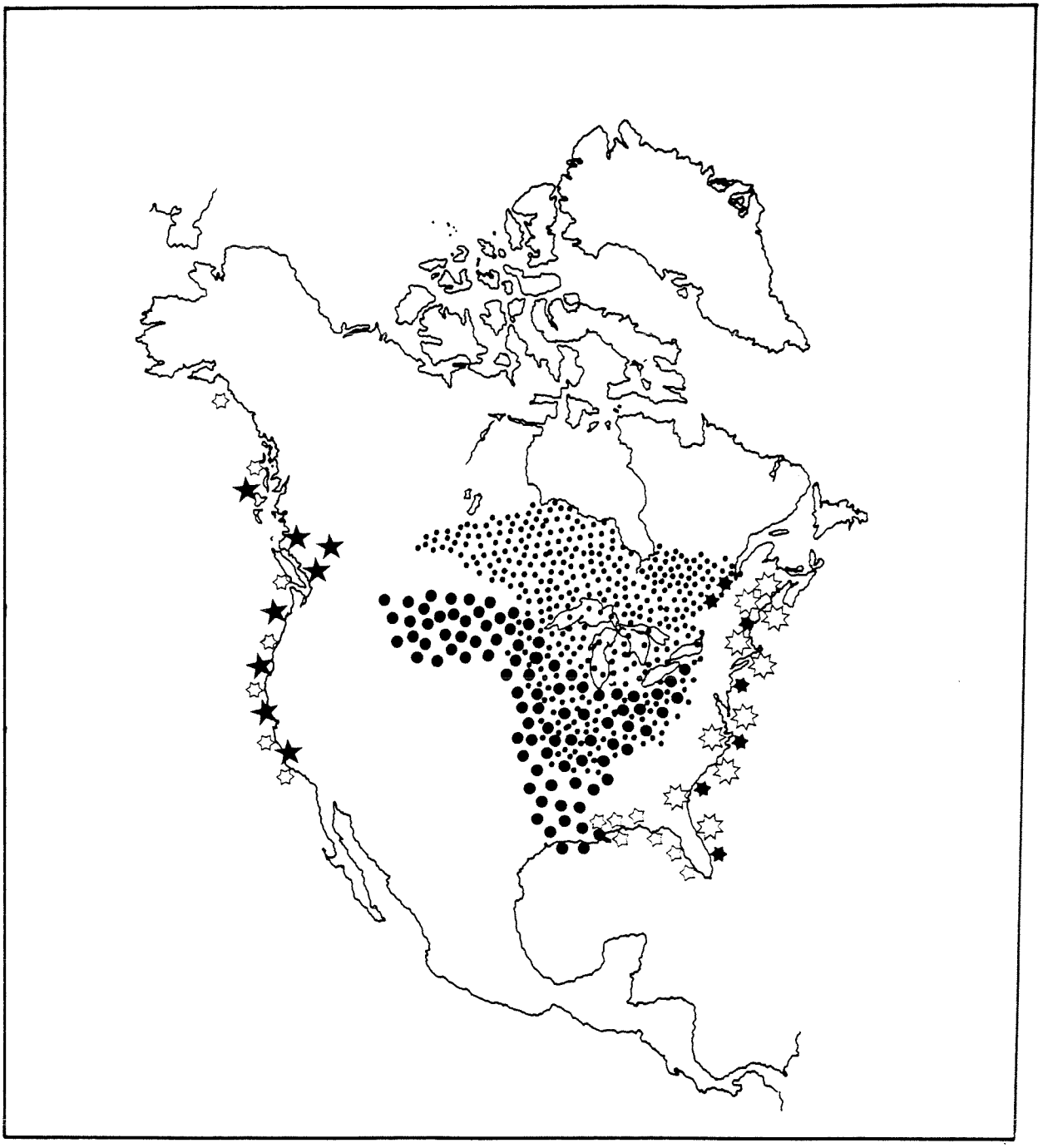

Fig. 2. Map of North America illustrating the distribution of Acipenseriformes: Acipenser brevirostrum (★); A. fulvescens (••); A. medirostris (☆); A. oxyrhynchus oxyrhynchus (✡); A. o. desotoi (✡); A. transmontanus (★); Polyodon spathula (●●).

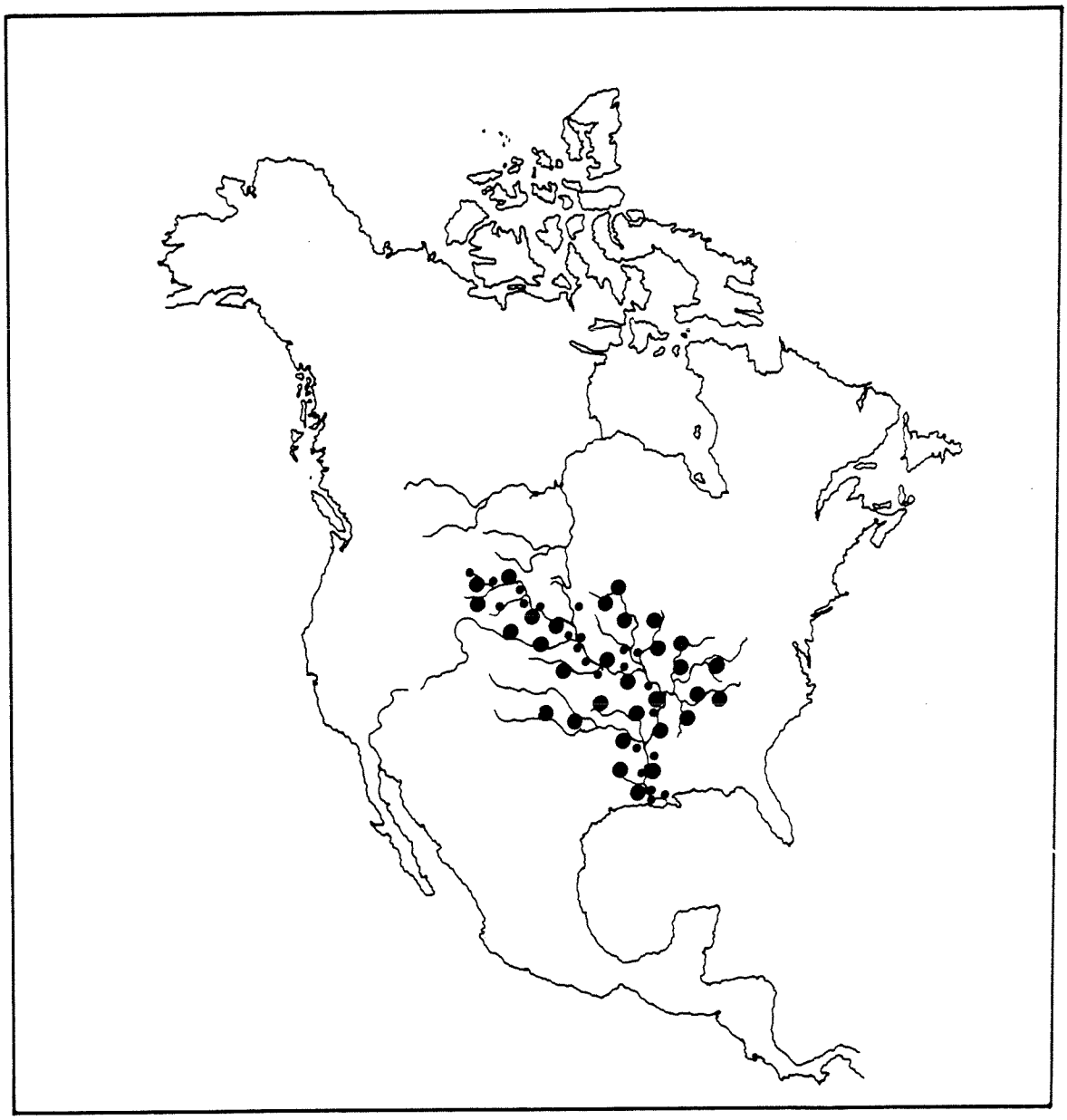

Fig. 3. Map of North America illustrating the distribution of Acipenseriformes: Scaphirhynchus albus (••) and S. platorynchus (●).

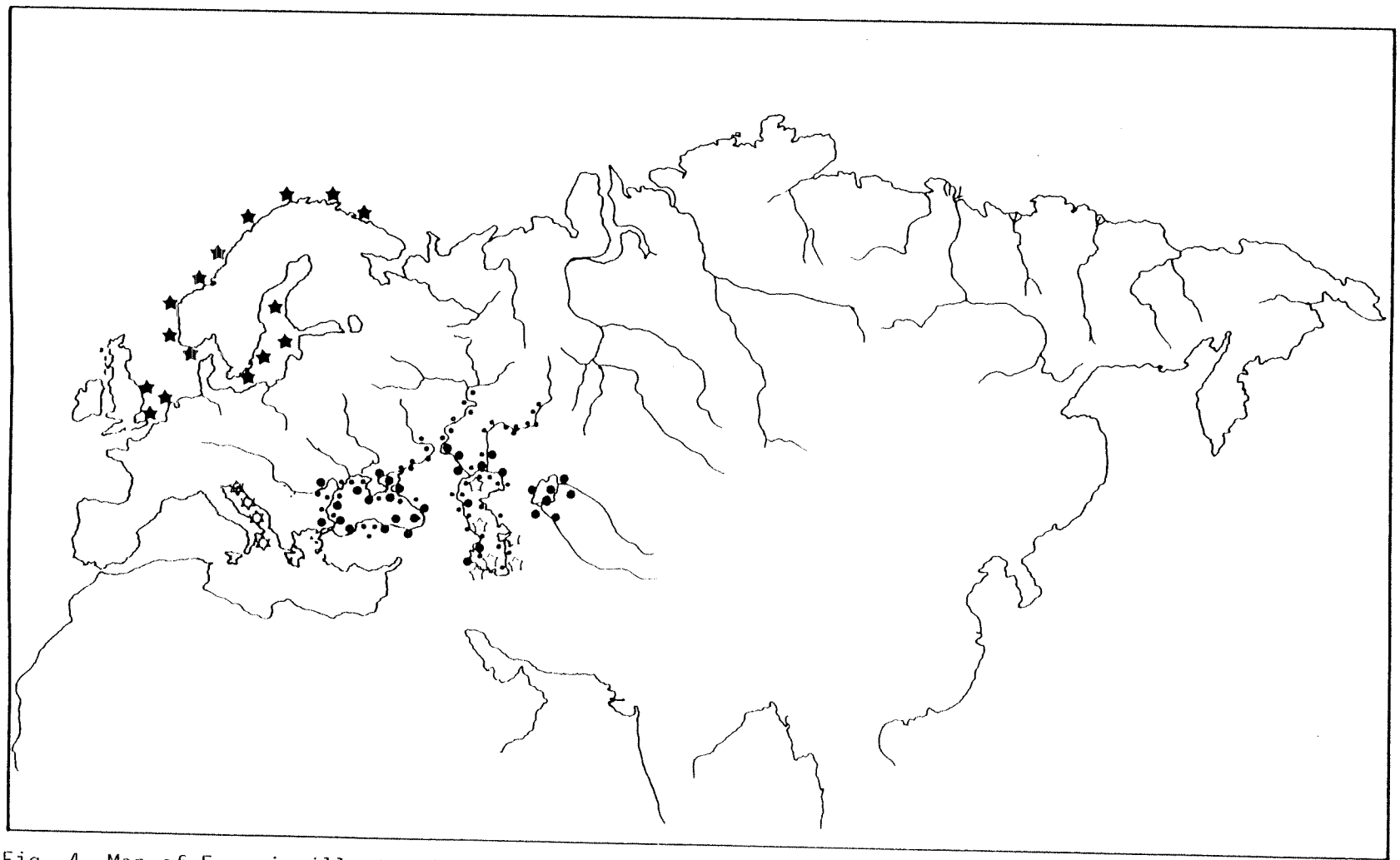

Fig. 4. Map of Eurasia illustrating the distribution of Acipenseriformes: Acipenser gueldenstaedti (••); A. naccari (✡); A. nudiventris (●●); A. persicus (☆); A. sturio (★).

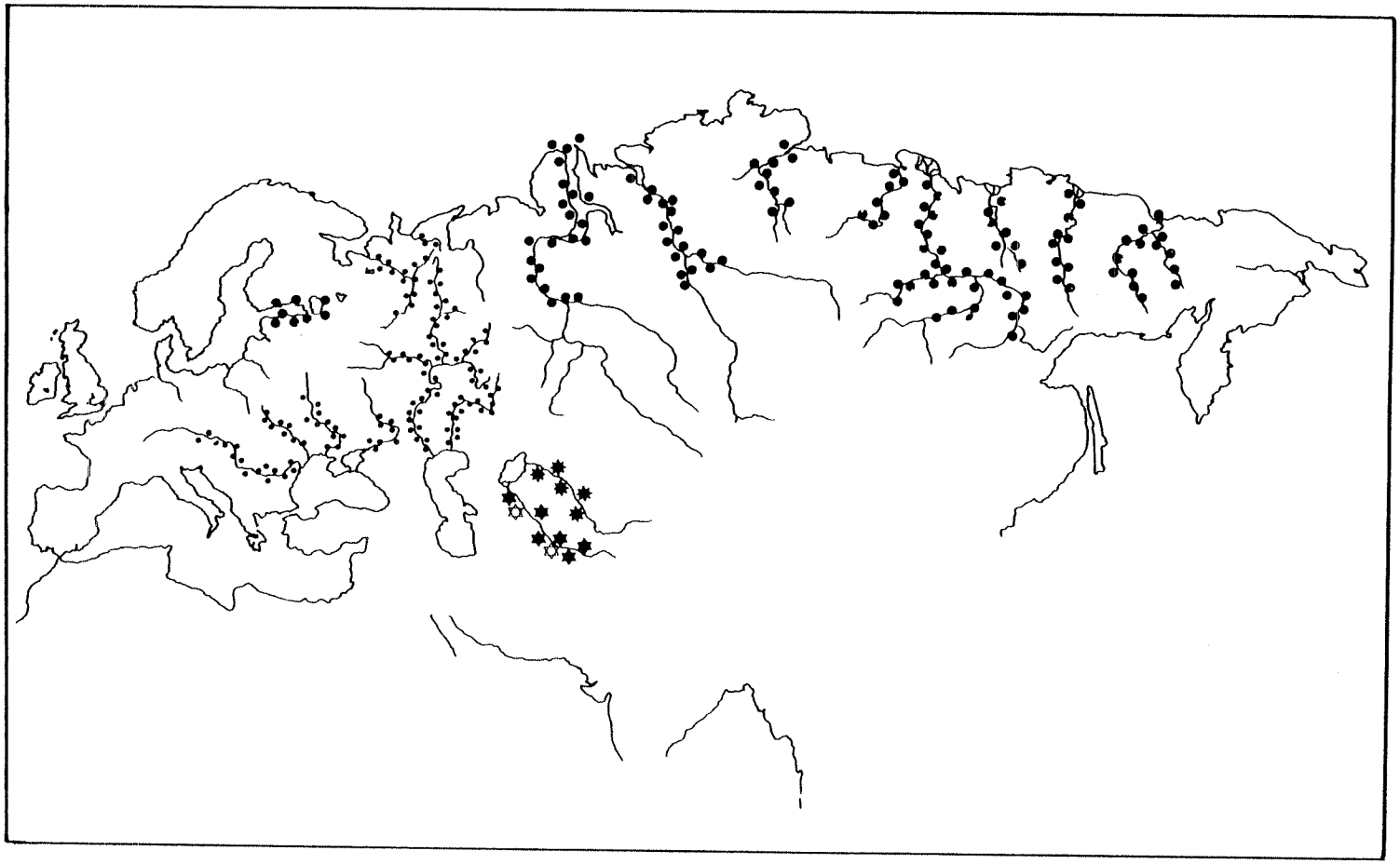

Fig. 5. Map of Eurasia illustrating the distribution of Acipenseriformes: Acipenser baeri (••); A. ruthenus (••); Pseudoscaphirhynchus fedtschenkoi (✸); P. hermanni (✡); P. kaufmanni (✸).

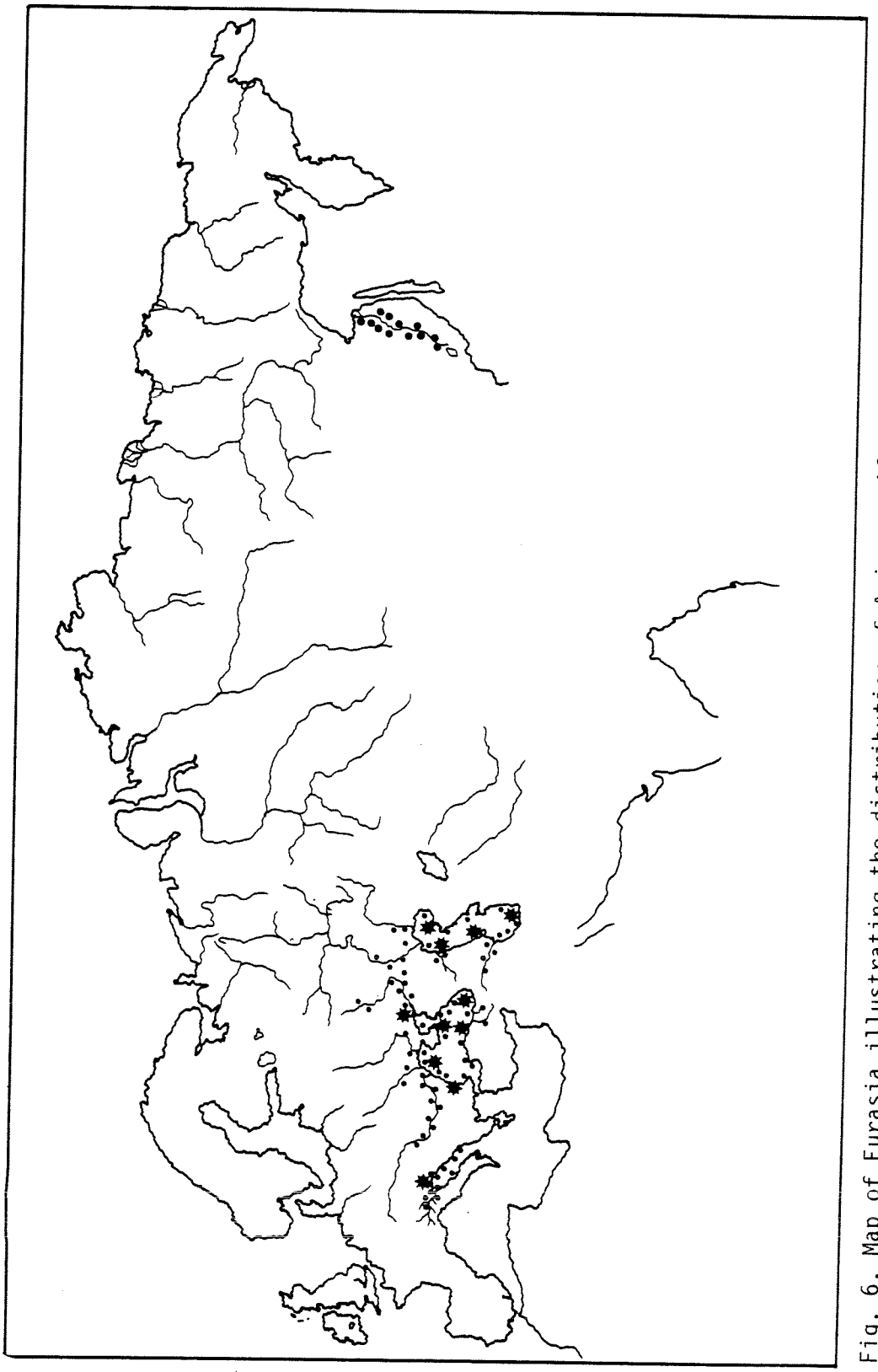

Fig. 6. Map of Eurasia illustrating the distribution of Acipenseriformes: Acipenser stellatus (✸); Huso dauricus (••); H. huso (••).

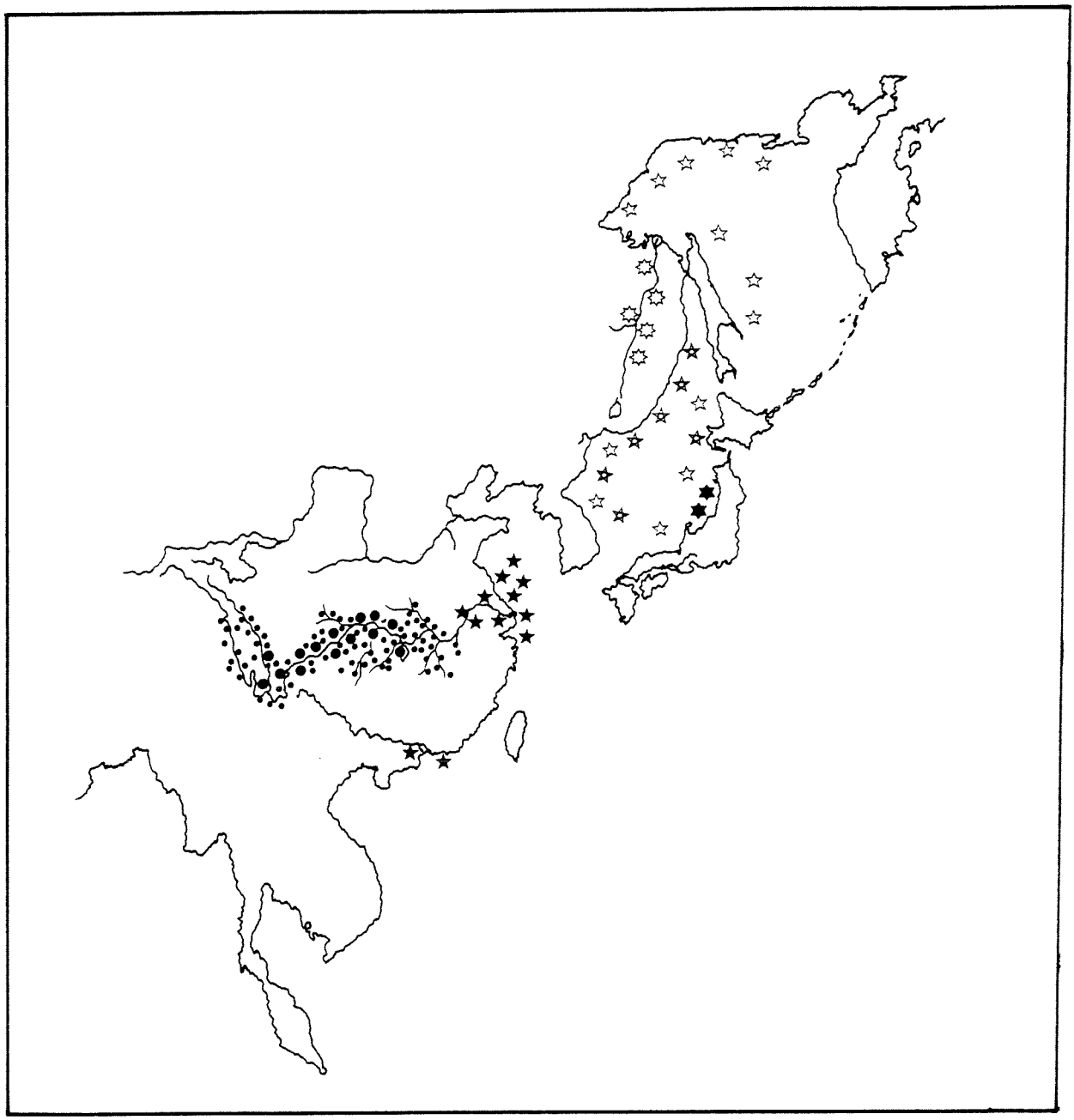

Fig. 7. Map of far East Asia illustrating the distribution of Acipenseriformes: Acipenser dabryanus (●●); A. medirostris (☆); A. multiscutatus (★); A. schrenki (⛭); A. sinensis (★); Psephurus gladius (••).

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(References preceded by asterisks were unavailable for annotation).

ADAMSTONE, F.B. 1923. The distribution and economic importance of Mollusca in Lake Nipigon. Univ. Toronto Stud. Biol. Ser. 21, Publ. Ont. Fish. Res. Lab. 14: 69-118.

A section of this paper deals with the value of molluscs as fish food. An examination of sturgeon digestive tracts showed "conclusively" that the sturgeon subsists to a large extent on molluscs ingesting almost all the smaller gastropods and bivalves. A total of 16 species of molluscs are listed from lake sturgeon stomachs represented by the genera Lymnaea (four spp.), Valvata (two spp.), Amnicola (two spp.), Planorbis (three spp.) and Physa (two spp.) as well as three species of Sphaeridae. It is hypothesised that molluscs may even constitute 100% of the diet.

ADAMSTONE, F.B. 1924. The distribution and economic importance of the bottom fauna of Lake Nipigon. Univ. Toronto Stud. Biol. Ser. Publ. Ont. Fish. Res. Lab., 24: 33-100.

The study by Harkness on the food of lake sturgeon in Lake Nipigon is discussed. The main food taken by sturgeon include chironomids, molluscs and ephemerids. Crayfish are also considered to be important in the diet in certain areas.

AGASSIZ, L. 1850. Lake Superior. Its physical character, vegetation and animals, compared with those of other similar regions. Gould, Kendall and Lincoln, Boston, Massachusetts. 428p.

In this book, the author describes three new species of sturgeon, all from Lake Superior: Acipenser laevis (p. 267); A. carbonarius (p. 271) and A. rhynchaeus (p. 276). All three species were subsequently synonymized with the lake sturgeon, Acipenser rubicundus, by Kirsch and Fordice (1889) (see in this bibliography).

AMEMIYA, C.T., and G.W. LITMAN. 1991. Early evolution of immunoglobulin genes. Am. Zool. 31: 558-569.

This paper reviews the immunoglobulin genes from evolutionarily primitive vertebrates including cartilaginous fishes, chondrosteans and holosteans. Immunoglobulin genes of the lake sturgeon, Acipenser fulvescens, were also studied by cDNA from erythrocytes followed by genomic analyses. Preliminary data is presented and shows that all actinopterygians probably possess heavy chain gene organizations similar to those of tetrapods, including mammals.

ANDERSON, E.R. 1984. Artificial propagation of lake sturgeon (Acipenser fulvescens Rafinesque), under hatchery conditions in Michigan. Mich. Dept Nat. Res. Fish. Res. Rep. 1898: 32p.

The author discusses the results of experiments carried out on the artificial fertilisation of lake sturgeon eggs, their culture, and growth and survival of young under hatchery conditions. Adult sturgeon were collected with long-handled dip nets while on their spawning migration in the upper Black River of Michigan. Milt was collected first, by drawing it into a 50 cc syringe while stripping, and then storing on ice for 30 min prior to use. The caesarian section technique was used to obtain a total of 2.1 l (39,900) of eggs from two ripe and running females. Eggs flowed freely from the incision and fertilisation was started within five minutes of collection. Eggs and milt were mixed for 10 minutes and a suspension of bentonite clay powder was added several minutes later to prevent clumping. Fertilized eggs were incubated at 15°C, initially in MacDonald jars and later in vertical flow incubators with decreased flow rates, prior to hatching which occurred nine days post-fertilisation and was complete in 24 hrs. Hatching success was 72% (for Michigan eggs) and 76% (for Wisconsin eggs), with a corresponding 26% and 24% egg mortality due to fungal infection. Hatched sturgeon larvae transferred to holding tanks, were negatively phototactic and swam constantly. The change from endogenous (yolk) to exogenous feeding, was a accompanied by a behaviourial change from negative to positive phototaxis and a general decrease in activity. Diet studies were carried out with sturgeon fry 16 days and 31 days post hatching. Two artificial semi-moist diets, OMP and Biodiet, were compared with a natural diet of zooplankton and an aquatic annelid species. The artificial diet treatments were divided into direct switch and weaned (i.e., gradually off their pre-treatment diet of zooplankton), while the natural diet treatment was only direct. Survival across treatments could not be compared with confidence since artificial diet fed sturgeon fry died by the 5th week while the survival of natural diet fed sturgeon was 54% (Wisconsin sturgeon) - 75% (Michigan sturgeon). Growth of sturgeon raised on the natural diet was greatest amongst all treatments with Biodiet second best, for any sampling point. At the termination of the experiment by week nine, natural diet fed sturgeon grew to an average of 84 cm (2.3 gm). Comparisons of growth across all treatments is only possible at the three week mark; the OMP -raised sturgeon grew least (averaging about 28 cm, 0.07 gm) compared to Biodiet (averaging about 29 cm, 0.08 gm) and natural diet (averaging about 38 cm, 0.25 gm).

ANDERSON, E.R. 1985. A partial bibliography of the sturgeon family Acipenseridae. Mich. Dept Nat. Res. Fish. Div. Fish. Res. Rep. 1936: 22p.

The bibliography contains 288 references

divided into 6 sections; systematics and distribution, biology, management, morphology, physiology and health aspects of the acipenserids. The biology and management sections are further divided into subsections. The biochemical and parasite literature of sturgeons is not covered in detail. Some aspect of nearly all the species are covered by at least one reference.

ANDERSON, E.R. 1986. Sturgeon: king of freshwater fish. Minn. Volun. 49(288): 58-62.

This is an account of the natural history of lake sturgeon in Minnesota where sturgeon spawn from late April to early June above or below clear rapids. Females reportedly mature between 24-28 years and have a 4-6 year interval between spawning. Males mature at 14-16 years and spawn in alternate years. The collapse of sturgeon fisheries and the attempts of the Michigan Department of Natural Resources to culture lake sturgeon is recounted. After years of trial, a five-year project was initiated in 1984 to restore lake sturgeon in the St. Louis River near Duluth. In 1985, 5000 5-7 inch sturgeon were released which were wire tagged for future reference.

ANDERSON, E.C. 1987. Lake Sturgeon (Acipenser fulvescens) management and culture in Minnesota and Michigan. Ont. Fish. Tech. Rep. Ser. 23: 84.

A three year study in Michigan on lake sturgeon included observations of pre and post spawning sturgeon and the collection of gametes. Eggs were removed by caesarian section and milt was removed with a syringe. Fry were fed zooplankton, aquatic annelids and artificial diets but results were poor on the artificial diets. As part of a reestablishment program over 5,000 1-18 cm fingerlings were stocked into the St. Louis River. All of these fingerlings were code-wire tagged.

ANDERSON, J. 1956. The vanishing sturgeon. Ohio Cons. Bull. 20: 13 and 32.

The declining numbers of lake sturgeon in Ohio waters is discussed and closing of the fishing season indefinitely as the sole management strategy is considered of little use. It is felt that clear water conditions (prevention of pollution and soil draining into the waters) have to be restored to give the sturgeon a chance at successful spawning.

ANDERSON, P.J. 1971. The carboxy-terminal region of sturgeon muscle aldolase. Can. J. Biochem. 49(3): 372-375.

Unmodified muscle aldolase is capable of cleaving fructose 1,6-diphosphate (FDP) 20 times faster than fructose 1-phosphate (F-1-P). Digestion with carboxypeptidase causes the immediate release of tyrosine residues and a decreased ability to digest FDP compared to little effect on F-1-P. Results indicate that lake sturgeon muscle aldolase is different in its carboxy-terminal region from rabbit liver and brain aldolase.

ANDERSON, P.J. 1972. The number, location and reactivity of the cysteine residues of sturgeon muscle aldolase. Can. J. Biochem. 50(2): 111-119.

Each subunit of lake sturgeon muscle aldolase contains six cysteine residues which apparently occur in homologous positions to six cysteine residues of rabbit enzyme. Four of these six carboxymethylcysteine containing peptides are homologous with corresponding peptides in rabbit aldolase. Three residues react with iodoacetic acid in the absence of denaturing agents causing the inactivation of the enzyme. The presence of substrates protects one residue and no activity is lost. Results indicate that the loss of activity is due to addition of modifying groups rather than loss of sulphydryl groups. It is considered unlikely that cysteine residues have a direct or an auxiliary catalytic role in aldolase activity.

ANON. 1933. Mystery of sturgeon 41 solved. Fisherman 2(7): 12.

A 75 lb sturgeon branded with the number 41 was caught at the Newaygo Dam, Lake Michigan, Michigan. A letter from a certain Charles Trost informed officials that he had branded the sturgeon at Lake St. Clair, 28 years prior to its capture at the dam. It then weighed 41 lbs and hence its brand.

ARNOLD, D.E. 1971. Lake Erie alive but changing. Conservationist 25(3): 25-30.

This is, to use the author's own words, a "dispassionate analysis" of the existing conditions of Lake Erie. The natural phenomenon of eutrophication following pollution is reviewed and the author discusses the geological past and future trends affecting this lake. The lake waters are characterised by heavy sedimentation loads, resulting from pollution by silt, domestic sewage and industrial waste, the latter including thermal, mercury and radioactive waste. An increase in Ca, Mg, SO_4, Na + K, Si, Cl, NO_3, PO_4, soluble P, organic N_2, and total solids is documented with actual values. An increase in total sedimentary P and ammonia nitrogen is also quantified. Some valuable commercial fishes have been extirpated from commercial catches including the lake sturgeon. However, the decline of the lake sturgeon is attributed mainly to systematic destruction by fishermen when it was considered a nuisance fish and it's worth as a food fish was unknown. Restocking and restoring the polluted waters to

a former pristine state are advocated as the means of returning the lake to its former status.

ATKINSON, J. 1987. Management of lake sturgeon (Acipenser fulvescens) as a sport fish in Ontario. Ont. Fish. Tech. Rep. Ser. 23: 91-94.

Recommendations for the management of lake sturgeon as a sport fish are presented. The daily creel limit of one fish per angler per day should be reassessed. Female sturgeon have the potential to spawn 3-4 times between age 20-40 and spawn less regularly than males and thus a minimum size limit is urged. Since sturgeon are still concentrated and readily caught when the season opens, the opening date should be delayed to enable sturgeon to disperse. Other recommendations include the need for more data on the biology of lake sturgeon, a survey to assess its popularity, its promotion as a trophy fish, experimental trials of size limits on selected populations and consideration given to stocking through intensive culturing.

AUER, N.A. 1982. Identification of larval fishes of the Great Lakes Basin with emphasis on the Lake Michigan drainage. Gr. Lakes Fish. Comm. Spec. Publ. 82-3: 42-43.

There is a two page (42-43) section on lake sturgeon larvae with illustrations of a yolk-sac larva, a 18.5 mm larva and a 22 mm larva (dorsal and ventral aspects). The 18.5 mm larva shows prominent pectoral fins, a mouth bordered by fleshy lips and anteriorly by barbels. The 22 mm larva was the distinctive shape of the adult sturgeon.

AVELALLEMANT, S., D.J. CZESKLEBA, and T. THUEMLER. 1983. Artificial spawning and rearing of lake sturgeon at the Wild Rose State Hatchery, Wisconsin. Wis. Dept Nat. Res. Madison, Fish Cult. Note. 7p.

Eggs and sperm were collected from actively spawning fish captured by dip netting. Milt was removed with a syringe and eggs were recovered following caesarean section. Eggs were fertilized immediately, returned to the hatchery, treated to remove clumps and then incubated at 13° and 16° C. Hatching success was 63.5% at 13 C after eight days and 55% at 16 C and maybe related to lower fungal levels at 13 C. Newly hatched fry were negatively phototactic up to 10 days post-hatch and then became positively phototactic. Fry preferred live brine shrimp over dry feed. Frozen Daphnia and brine shrimp are marginally acceptable foods. Some of the fry that hatched were stocked and the remaining fry were reared in tubs. Fry produced gas bubbles in tubs at 21 days and were moved to raceways with a water flow of 12.5 gal/min. Fry and fingerlings were treated with chloramine-T-hydrate at concentrations increasing from 10ppm to 16ppm. Wild fingerlings captured in the Wolf River grew faster than hatchery-reared fingerlings.

BAJKOV, A.D. 1933. Report on Fisheries Investigations, Sturgeon- Pigeon River. Man. Dept Mines Nat. Res. MS. Rep. 15p.

The Pigeon River was investigated for sturgeon distribution from the river mouth to Sturgeon Falls 14 miles upstream. Seventy five 10-12 inch mesh nets were set two weeks prior to May 27th. A total of fourteen sturgeon were caught of which 12 were males and two were unripe females. There was evidence for illegal fishing and sturgeon stocks were thought to be considerably depleted. The report is accompanied by photographs showing sturgeon spawning sites on the Pigeon River and some fishing in action.

BAJKOV, A.D., and F. NEAVE. 1930. The sturgeon and sturgeon industry of Lake Winnipeg. Canadian Fisheries Manual. p. 43-47.

The distribution, biology and fishery production are outlined. There are suggestion of dimorphism in lake sturgeon populations based on snout shape. The sturgeon at this time occurred in Lake of the Woods, Lake Winnipeg system, and Winnipeg, Saskatchewan, Nelson rivers. They also occurred in the Red and Assiniboine basins but were absent from the western shores of Lake Winnipeg, Winnipegosis, Dauphin and St. Martin. The authors suggest that sturgeon prefer water not strongly alkaline (pH of not more than 8.0). In lake Winnipeg sturgeon were caught in shallow water (4-5 ft) in June but are found later in the summer in water up to 7 fathoms deep. Some evidence suggests that fish feeding in shallow water are the darker coloured blunt-nosed sturgeon. They have been seen feeding amongst wild rice in 1-2 ft of water. Food items are variable with the fish fly Hexagenia limbata being the most common. Females grow faster than males and females lose about a third of their weight after spawning (roe and fat). The decrease of sturgeon populations in North America is due to extensive fishing coupled with slow growth. Prohibition of fishing, even for ten years, would only delay the collapse of a fishery. The authors give an example of 100 fish caught only six females contained roe. They recommend the protection of young as well as the remaining large individuals and the creation of special reserves comprising spawning grounds and lakes, with total prohibition of fishing in such areas.

BAKER, J.P. 1980. The distribution, ecology and management of the lake sturgeon (Acipenser fulvescens Rafinesque) in Michigan. Mich. Dept Nat. Res. Fish. Res. Rep. 1883: 95p.

Sturgeon populations in the following lakes and waterways of Michigan were investigated; Burt,

Mullet, and Black lakes, Lake St. Clair, and the Menominee and St. Clair rivers, where the populations are significant and in Otter, Manistique, Indian, Brevort, and Monacle lakes which harbour remnant landlocked populations of lake sturgeon. The population of lake sturgeon 48.6 inches and larger in Black lake was estimated to be 1599 in 1975 with a 2.1% exploitation in 1976 and the natural mortality rate was calculated to be 0.076 using a standard exploitation rate of 2.5%. The mean annual recruitment to the fishable stock was 4.5% with the age at entry into the fishery held constant at 22 years. The maximum catch limit was calculated to be 77 fish.The growth rates of sturgeon from Black and Mullet lakes and the Menominee river were very similar. Recommendations for protecting sturgeon stocks include strict enforcement of poaching regulations, prohibition of sturgeon fishing statewide during May and June and the season creel limit reduced from two to one fish.

BAKER, J.P. 1982a. Yield per recruitment of inland stocks of lake sturgeon (Acipenser fulvescens Raf.) in Michigan. Mich. Acad. 14(4): 415-425.

This is a report on the analysis of harvest data of sturgeon from the Black and Mullet Lakes and the Menominee River of Michigan. The parameters for the von Bertalanffy equation for Michigan sturgeon were calculated as: L_a = 69.6411 inches, k = 0.0558 and x_0 = - 0.8815. The length -weight relationship was given by the equation InW = -8.8949 + 3.1393 InL. Rates of instantaneous total mortality were determined by analyzing the catch curves for the Black Lake and Menominee rivers separately. Instantaneous total mortality was 0.102 and 0.098 for Black Lake and the Menominee River respectively. The annual total mortality (0.097 and 0.093) for these two systems were similar. Based on the yield model total biomass of an unharvested spawning population is 70,276 pounds per 1000 age-1 recruits. With an exploitation rate of 2.5% with 22 years as the age at entry into the fishery, the total biomass shows a 32% decline. The annual mortality rate of sturgeon is considered to be very small. Considering the annual recruitment rate into the fishery of Black lake to be 4.8%, the annual exploitation rate seems to have a safety margin. The continued close monitoring of sturgeon fisheries is urged to prevent overfishing since recovery from over-exploitation by sturgeon is very slow.

BAKER, J.P. 1982b. The fish with the golden egg. Mich. Nat. Res. Mag. 51(6): 50-57.

This popular article gives a general account of the history of sturgeon fishing in North America and describes the life history of this acipenserid. It is reported that the best known sturgeon populations in Michigan occur in Burt, Mullett and Black Lakes and in the Cheboygan River system of the northern Lower Peninsula. Smaller sturgeon populations are also present in the Otter, Manistique, Indian, Brevort and Monacle lakes. It is urged that the remaining feeding and spawning habitats of lake sturgeon be carefully protected, poaching be strictly controlled and artificial propagation methods be employed to revive sturgeon stocks. The article contains on its first page, an impressive colour photograph of a swimming lake sturgeon (spanning two pages).

BALDWIN, N.S., R.W. SAALFELD, M.A. ROSS and H.J. BUETTNER. 1979. Commercial fish production in the Great Lakes 1867-1977. Gr. Lakes Fish. Comm. Tech. Rep. 3: 187p.

A year by year breakdown of commercial lake sturgeon production from the first to the last recorded harvest is provided in tabular form, separately for each of the 5 Great Lakes; Ontario, Erie, St. Clair, Michigan and Superior. Furthermore, a breakdown is provided for separate catch records for U.S. and Canada, and in some cases for U. S. states. In Lake Ontario, 546,000 pounds were harvested in 1879, the year of the first harvest record, of which Canada produced only 1000 pounds. Canadian productions did not exceed 100,000 pounds except in 1882 (103,000 pounds). The highest total production was obtained in 1890 (581,000 pounds) followed by a decline, and after 1908 the harvest did not exceed 20,000 pounds except in 1930 (24,000 pounds). In 1977, the total harvest was 4000 pounds. In lake Erie, 1879 produced a total of 2,112,000 pounds, of which Canada (Ontario) contributed 142,000 pounds. Separate statistics for four different states (N.Y., Pennsylvania, Ohio and Michigan) is available for the first time in 1885. The combined harvest also reached its highest point that year, 5,187,000 pounds, of which N.Y. state contributed 3,723,000 pounds and Canada 459,000 pounds. One million pounds was reached only once more in 1893, after which the fishery declined. In 1908, the total catch was 170,000 pounds. Commercial sturgeon fishing was banned in Canadian waters from 1920-1921 and in Michigan waters from 1929-1950. In 1968, Ohio closed its fishery. The Canadian harvest exceeded 500,000 pounds only once in 1890 and the combined harvest did not reach 100,000 pounds after 1916 and remained under 50,000 pounds since 1929. In 1977, 5000 pounds of sturgeon were harvested from Lake Erie. In Lake St. Clair, the highest production was attained in the first year of record (1879, 1,091,000 pounds). The harvest dropped to 278,000 pounds in 1885 and did not exceed 100,000 pounds since 1893. No catches have been reported since 1969 (harvest of 17,000 pounds for the year) when discovery of mercury contamination in fish resulted in closure of the fishery. Canada's contribution was always under 80,000 pounds except in 1879, the high-point of the fishery. Statistics are available for Saginaw Bay in Michigan, Georgian Bay and North Channel in Ontario and Lake Huron proper separately for Michigan and Ontario. Highest harvest levels

were reached in 1885 (1,041,000 pounds), after which production declined steadily and did not exceed 100,000 pounds after 1904. Commercial fishing was prohibited from Michigan waters from 1928-1950 and did not exceed 2000 pounds thereafter. The Canadian contribution exceeded that of the U.S. after 1892 and all of the 9000 pounds harvested in 1977 came from Canadian waters. There are no records of catches made in U.S. waters of Lake Huron after 1963. Lake Michigan attained its peak sturgeon harvest in the very first year of production records (3,840,000 pounds). One million pounds was exceeded only once more in 1885 after which production declined rapidly to under 20,000 pounds after 1910. Separate production levels are provided for the waters of Michigan, Wisconsin, Illinois and Indiana. Commercial lake sturgeon fishing was banned in Michigan waters from 1929-1950 and in other waters since 1929. Since 1953, the sturgeon harvest did not exceed 3000 pounds. The statistics for Lake Superior show similar high initial production (224,000 pounds in 1884) followed by a decline to under 30,000 pounds after 1900. Commercial sturgeon fishing from Michigan's share of the waters was banned from 1928-1950 and in the two other states, Minnesota and Wisconsin, since 1928. The last harvest record was for 1976 when 1000 pounds were taken, all of it in Canadian (Ontario) waters.

BALLARD, W.W., and A.S. GINSBURG. 1980. Morphogenetic movements in acipenserid embryos. J. Exp. Zool. 213(1): 69-103.

Morphogenetic movements, a timetable for involution and a fate map for the blastulae of four species of Eurasian sturgeon are presented for the first time and are found comparable to unpublished studies carried out on lake sturgeon from Wisconsin in 1979. The close resemblance of holoblastic sturgeon embryos to frog embryos and their differences with meroblastic teleost embryos are discussed. The earliest movements at the surface involves the massive migration of inner cells of the blastocoel roof to an inner marginal zone. This is followed by the first drift of cells at the surface. A band of cells encircling 360° of the surface of the blastula from the equator up to the 20° latitude mark gives rise to the definitive endoderm lining the archenteron and their movement across the lip of the blastopore to the interior is termed involution and is not invagination. A complete band of both surface and inner marginal cells from 20° to 30° latitude produces notochord and somite mesoderm, also by involution. Mesoderm of the tail reaches the interior before the closure of the blastopore and head mesoderm and intermediate and lateral plate mesoderm are not found in the surface region of the blastula.

BARDACH, J.E., J.H. RYTHER, and W.O. McLARNEY. 1972. Culture of sturgeon, p. 520-528. In Aquaculture, the farming and husbandry of freshwater and marine organisms. John Wiley and Sons, Inc., New York, NY.

This account reviews the early destructive practices of sturgeon fisheries with reference to North American sturgeon and in particular lake sturgeon exploitation that led to its collapse. The early attempts at artificial propagation are also recounted and an overview (historical and recent) is provided on sturgeon culture in Russia, including a discussion on species used for fishery, culture and a section on the prospectus of the world sturgeon fishery at present.

BARNEY, R.L. 1924. An extended reproductive cycle in Acipenser rubicundus. MS. Rep. p. 1-15.

This article was referred to in Harkness and Dymond (1961) but could not be located.

BARNICKOL, P.B., and W.C. STARRETT. 1951. Commercial and sport fishes of the Mississippi River between Caruthersville, Missouri and Dubuque, Iowa. Bull. Ill. Nat. Hist. Surv. 25(5): 288-290.

Lake sturgeon biology, commercial exploitation and present distribution in the Mississippi River is discussed. From old accounts, the lake sturgeon was a common fish of the system but its numbers declined during the early 1900's and no sturgeon were caught while test-netting in 1944 and 1946, although one was caught in a hoop net by a commercial fisherman in 1946. It is now considered uncommon and is occasionally taken by commercial fishermen.

BARTLEY, D., G.A.E. GALL, and B. BENTLEY. 1983. A description of the genetic structure of lake sturgeon from the Menominee River, Wisconsin. Wis. Dept Nat. Res. MS. Rep. 10p.

The genetic characteristics of two sub-populations of lake sturgeon from the Menominee River, isolated from each other by the Grand Rapids dam, is described using starch gel electrophoresis and 12 enzyme systems from muscle tissue of fish. Of the 24 loci surveyed, nine were found to be polymorphic and the average heterozygosities were 0.12, 0.10 and 0.11 for White Rapid, Grand Rapid and total areas, respectively. G_{ST} was estimated to be 0.026, indicating that the two populations have not diverged very far and that the greatest source of genetic variation is due to differences among individuals within each subpopulation.

*BASSETT, C. 1982. Management plan for lake sturgeon (Acipenser fulvescens) in the Indian River and Indian Lake, Alger and Schoolcraft counties, Michigan. United States Forest Service, Manistique Ranger District, Hiawatha National Forest in cooperation with Michigan Department of Natural Resources, Manistique,

Michigan, USA.

BEAN, T.H. 1903. Catalogue of the fishes of New York. N.Y. State Mus. Bull. 60 (Zool. 9): 63-69.

The lake sturgeon appears under the name Acipenser rubicundus Le Sueur, with A. maculosus Gunther as the sole synonym. The review by Kirsch and Fordice (1889, see in this bibliography) on the North American acipenserids is not referred to. The description is followed by brief notes on size and habits. Several species of snails, and occasionally fish eggs, serve as food items. The parasitic lamprey eel (Petromyzon concolor) is stated to cause ulcerous sores.

BEAULIEU, G., and E. CORBEIL. 1964. Etude preliminaire de l'esturgeon de lac, Acipenser fulvescens, dans la region de l'Abitibi. Nat. Can. (Que.) 91: 175-181.

This is a study of lake sturgeon in the Abitibi region, including Lake Waswanipi during 1961. Two hundred and fourteen sturgeon were captured and tagged and of these 29 were recaptured. Based on captures it seems that sturgeon catches were related to water temperatures, with younger sturgeon tolerating higher temperatures than older sturgeon. The greatest distance moved was 48 km over a period of three days.

BERG, L.S. 1948. Acipenseriformes. p. 57-110. In Freshwater fishes of the USSR and adjacent countries. Volume 1. Izdatel'stvo Akademii Nauk SSSR. Moscow-Leningrad.

This book contains information on some acipenserids not covered in any other work (Huso dauricus and the three species of Pseudoscpahirhynchus.

BERKES, F., and M. MACKENZIE. 1978. Cree fish names from Eastern James Bay Quebec Canada. Arctic 31(4): 489-495.

This paper provides names of fishes in the language of the Cree communities of the eastern James Bay area. The lake sturgeon is known as "nimaw" in the dialect of the Fort George and Wemindji communities, and "namew" by the Eastmain, Rupert House, Waswanipi, Nemaska and Mistassini communities.

BIŃKOWSKI, F.P. 1987. Feeding behaviour of young lake sturgeon as a function of olfactory response. In Program and Abstracts, 11th. Annual Larval Fish Conference. Gr. Lakes Fish. Comm., Mich. Dept Nat. Res. (No pagination).

This presentation was made at the annual larval fish conference held at Michigan Technological University, Houghton, Michigan, in 1987 as part of the special session "North American Sturgeon Larvae". The published conference proceedings did not contain this article. Interested readers are directed to the Department of Natural Resources, Michigan, for a copy.

BINKOWSKI, F.P., and D.G. CZESKLEBA. 1980. Methods and techniques for collecting and culturing lake sturgeon eggs and larvae. Wisconsin Department of Natural Resources, Madison. MS. Rep. 2p.

This brief note describes the methods used in the collection of the sperm and eggs from ripe lake sturgeon. Eggs were collected by conventional stripping and by caesarian sectioning. Sperm was collected with the help of a syringe and no difference in fertilisation was observed between using freshly collected sperm and sperm stored on ice for two hours. Water temperatures ranged from 14-16^{o}C and bentonite clay was used in suspension after fertilisation and during water hardening of eggs. Eggs were incubated in quart hatching jars and 84% of the eggs hatched in 7 days. Approximately 300,000 two day old sac-fry were stocked in the Red Cedar River, 24,000 were held at the Wild Rose State hatchery, and the remaining at the Centre for Great Lakes Studies at the University of Wisconsin-Milwaukee. At this last facility, larvae were fed a diet consisting of W-13 formulate dry food, tetramin, and fresh frozen zooplankton. At the hatchery, the diet consisted of W-7 and W-13 formulated dry foods, supplemented by beef liver and live brine shrimp nauplii. Increased water temperatures of 19^{o}C during the sac fry stage and 22^{o}C during the exogenous feeding stage (at the hatchery), resulted in faster growing fish. At 5 months, the University reared sturgeon were 50-150 mm whereas the hatchery reared sturgeon reached 80-230 mm.

BISHOP, F.G. 1981. The 1980 harvest of lake sturgeon (Acipenser fulvescens) from the South Saskatchewan River, Alberta. Alberta Energ. Nat. Res. Fish Wildl. Div. MS. Rep. 18p.

Two hundred and sixty seven anglers purchased a lake sturgeon fishing license (1980/81) and of these 82% returned the questionnaires mailed to them. Seventy-six percent fished for sturgeon and 34% of the respondents caught a sturgeon. The estimated catch was 74 sturgeon for 1980 and was the highest harvest since 1968. The largest sturgeon caught was 62 pounds and the average weight was 15 pounds (6.8 kg); close to the historical average of 15.2. Recommendations include no changes in current legislation, an annual assessment of the population, no increase in the size limit, steps should be taken to reduce the nutrient loads in the South Saskatchewan river, and an effort should be made to obtain information on catch per unit effort by the sport fishermen.

BISHOP, F.G. 1982. The harvest of lake sturgeon (Acipenser fulvescens) from the South Saskatchewan River, Alberta. Alberta Energ. Nat. Res. Fish Wildl. Div. MS. Rep. 18p.

A total of 408 anglers (72% of total) who purchased a sturgeon angling license returned questionnaires. Seventy-seven % fished for sturgeon and 43% caught at least one sturgeon. The extrapolated total catch was 150 sturgeon and the estimated exploitation rate was 5.2%. The largest sturgeon caught weighed 105 pounds and was a new record for Alberta but the average weight was 14 pounds, close to the historical average of 15.2 pounds. Most of the sturgeon caught were from the Grand Forks area. Recommendations included, current legislation to remain the same, more information is needed on sturgeon biology, a sub-sample of anglers should be done to save time and costs, and the questionnaire should be modified to include catch/unit effort.

BISHOP, F. G. 1983. The 1982 harvest of lake sturgeon (Acipenser fulvescens) from the South Saskatchewan River, Alberta. Alberta Energy - Nat. Res. Fish Wildl. Div. MS. Rep. 26p.

This is a continuation of the annual reports on lake sturgeon in Alberta based on questionnaires. Five hundred and fifty two anglers purchased licenses and 79% returned the questionnaires. A total of 611 sturgeon were caught, of which 486 were released and the harvest estimate was 181. Some respondents suggested increased enforcement patrols. Average weight of sturgeon caught was 13 pounds or 6.3 kg. Rattlesnake Hole of the South Saskatchewan was the best area to catch a sturgeon (0.124 fish/hr). The best bait was a combination of fish and meat. More small sturgeon were caught in 1982 (20% of the catch less than 5 pounds). The population is considered healthy and no changes in the regulations were considered necessary.

BISHOP, F.G. 1984. The 1983 harvest of lake sturgeon from the South Saskatchewan River in Alberta. Alberta Energ. Nat. Res. Fish Wildl. Div. MS. Rep. 20p.

An annual report and estimate of harvest based on questionnaires. Questionnaires were mailed to the 536 license holders and 79% of the questionnaires were returned. Thirty eight % of respondents caught at least one sturgeon. The total catch was 555 of which 83% were released and the estimated harvest was 120 sturgeon. The largest sturgeon caught was 101 pounds and the average weight was 15 pounds (6.8 kg). Catch/effort showed that Rattlesnake Hole was the best place to catch sturgeon (0.16 fish/hr). A combination of native minnows, meat and worms were considered to be the best bait. The average time spent fishing was 5.2 days.

BISHOP, F.G. 1985. The 1984 Harvest of lake sturgeon from the South Saskatchewan River, Alberta. Alberta Energ. Nat. Res. Fish Wildl. Div. MS. Rep. 27p.

A total of 392 licenses were issued (a marked decline from previous years) and 79% returned the questionnaire. Forty one % of the respondents caught a sturgeon. The total catch was 431 of which 88% were released and the estimated harvest was 67 fish. The average size of fish was 12 pounds (5.4 kg).

BISHOP, F. G. 1986. The 1985 harvest of lake sturgeon from the South Saskatchewan River, Alberta. Alberta Energ. Nat. Res. Fish Wildl. Div. MS. Rep. 19p.

Three hundred and twelve licenses were purchased and 72% of the questionnaires were returned. Thirty-five % of the respondents caught at least one sturgeon and the total catch reported was 80 fish of which 72% were released. Harvest was estimated at 25 fish with an average weight of 15.8 pounds (7.2 kg). Catch effort was down from previous years i.e., 0.021 fish/hr.

BISHOP, F.G. 1987. The 1986 harvest of lake sturgeon form the various rivers in Alberta. Alberta Energ. Nat. Res. Fish Wildl. Div. MS. Rep. 21p.

Three hundred and forty nine licenses were purchased and 81% of the questionnaires were returned. Forty one % of respondents caught at least one sturgeon. A total of 455 sturgeon were caught of which 82% were released and the estimated harvest was 102 sturgeon. Most of the sturgeon caught came from the South Saskatchewan River but 36 were caught in the Old Man River, six in the Red Deer, and 12 in the North Saskatchewan Rivers. The average weight of fish caught was 15.2 pounds (6.9 kg). Eight tagged sturgeon were caught and catch/unit effort (0.11 fish/hr) was up over the previous year.

BISHOP, F.G. 1988. The 1987 harvest of lake sturgeon in various rivers in Alberta. Alberta Energ. Nat. Res. Fish Wildl. Div. MS. Rep. 17p.

Three hundred and ninety seven licenses were purchased and 81% of the questionnaires were returned. Seventy three % of the respondents fished, 41 % caught at least one fish; of a total of 731 fish caught 91% were returned. The estimated harvest was 82 Fish. Most sturgeon were caught in the South Saskatchewan River, but 14 were caught in the Red Deer and three in the North Saskatchewan. The average reported weight was six pounds (2.7 kg), a substantial decrease from the historical average of 14.6 pounds (6.6 kg). Three tagged fish were caught by anglers, from a total of 31 tagged by RL & L Environmental Services Limited with long-life

radio tags, and 162 tagged with Floy spaghetti tags.

BISHOP, F.G. 1990. The 1989 harvest of lake sturgeon. Alberta Energ. Nat. Res. Fish Wildl. Div. MS. Rep. 18p.

A total of 305 anglers purchased an angling license in the 1989-1990 season. Of 239 questionnaire respondents, 68% caught a total of 519 sturgeon. The majority (473 or 91%) was released. The mean weight of the sturgeon caught (14.1 lbs) equalled the long term average. Most of the angling occurred on the South Saskatchewan River (87%) followed by the North Saskatchewan River (8%), Red Deer River (3%) and Oldman River (2%), with Rattlesnake hole on the South Saskatchewan River proving to be as productive as in the past.

*BOURGUIGNON, G. 1989. Les marches mondiaux de l'esturgeon chair et caviar. Publ. Dept Halieut. Ecole Natn Super. Agron. Rennes (France). 76p.

BRICE, J.J. 1898. A manual of fish culture based on the methods of the United States Commission of Fish and Fisheries. Rep. U.S. Comm. Fish Fisheries 23: 189-191.

A brief discussion of the sturgeon fishery in the United States is given. The six species of sturgeon were the common, short-nose, Atlantic, white, green and the lake or rock with the most valuable being the common and lake sturgeons. Sturgeon are caught with gill and pound nets, seines, and set lines. The principle fisheries were the Great Lakes, Delaware and Sacramento rivers with a value of $300,000. Secondary products included caviar, isinglass and oil. The author discusses the rapid decline (60-80%) in the sturgeon fishery in a single decade. The weight of common sturgeon can be 500 pounds, for the lake sturgeon 200 pounds, for the Pacific sturgeon 848 pounds but current catches have much lower weights. The collection and incubation of fertilized eggs is discussed with the glutinous nature of the eggs causing clumping. Treating the eggs with starch particles or swamp muck was the best way to prevent sticking. Under hatchery conditions eggs were attached by fungi. The incubation period was 7 days in water at 62 to 66 ^{o}F and brackish water may be better than freshwater for incubation.

BROUSSEAU, C.S. 1987. The lake sturgeon (Acipenser fulvescens) in Ontario. Ont. Fish. Tech. Rep. Ser. 23: 2-9.

Overfishing and habitat decline are considered the major causes for the decline of lake sturgeon populations in Ontario. The commercial yield dropped from over 816,000 kg in 1885 to less than 10,000 kg in recent years. It is also pointed out that their slow rate of growth and late maturing age make them vulnerable to exploitation. There are only a few places in Ontario that sustain sturgeon abundant enough for sport fishing. Unexploited populations in favourable habitats may be expected to yield only 0.2 kg/hectare. The future of lake sturgeon in Ontario is considered bleak since current regulations are inadequate to protect this species from stock depletion and immediate and significant changes are urged.

BROUSSEAU, C.S., and G.A. GOODCHILD. 1989. Fisheries and yields in the Moose River Basin Ontario Canada, p.145-158. In D.P. Douglas (ed.) International Large River Symposium (LARS), Honey Harbour, Ontario, Sept. 14-21, 1986. Can. Spec. Publ. Fish. Aquat. Sci. 106.

The fisheries of the important tributaries of the Moose River basin in Ontario and their physicogeographic features are reviewed. Lake sturgeon is reported from all six river systems. Water fluctuations between dams have caused a decline in lake sturgeon populations and low water conditions immediately after spawning produce variable water temperatures and low oxygen. Fry become trapped in shallow pools and are subjected to mortality due to predation and environmental stress. It is concluded that sauger and lake sturgeon are the most vulnerable fish species to hydroelectric effects. Rapid flushing of systems effects sturgeon; at Adams creek sturgeon are washed over the spillway during high flow rates and during spawning and when the discharge is stopped sturgeon are left stranded. While the polluting effects of pulp and paper mills were discussed there were no specific examples relating to sturgeon. Estimates of lake sturgeon in a 14 km region of the Frederick House River were <3.3 fish/ha and lake sturgeon were estimated to comprise 37% of the biomass. Standing stock estimates of lake sturgeon from Frederick House, Abitibi, Groundhog and two sites on the Mattagami River ranged from 0.17 to 7.2 fish.ha-1 with corresponding standing stocks of 1.0-84.7 kg.ha-1. The Mattagami population is low and appears to be effected by water level fluctuations during spawning and commercial over-harvesting. It is suggested that lake sturgeon in the Moose river can sustain a harvest of only 1.8% of the population per annum. Eighty per cent of the lake sturgeon recaptured in the Moose River were taken within 1 km of the tagging location and most moved less than 5 km over a 3 year period; this makes them especially vulnerable to exploitation.

BUDDINGTON, R.K. 1985. Digestive secretions of the lake sturgeon, Acipenser fulvescens, during early development. J. Fish Biol. 26(6): 715-723.

Lake sturgeon exhibit embryonic and larval development similar to white sturgeon and because of that the author speculated that

digestion should be similar. Larval fish were fed starting day 12 post hatch with tubificid worms until 60 days post hatch. Fish were sampled on days 18, 22, 26, 30, 36, and 60 post hatch by removing the entire alimentary canal and separating into anatomically distinct sections. Samples were pooled and protein concentration determined and enzyme assays were conducted at 23 C. Enzymes assayed for were trypsin, chymotrypsin, pepsin, alpha amylase, and lipolytic enzymes. During the yolk stage (day 1-16) yolk proteins are preferentially assimilated into tissues and lipids are conserved. This is evident by the accumulation of oil droplets in the gut. The larval feeding phase (day 16-24) is characterized by high amylolytic and lipolytic activities. Tryptic proteolysis was supplemented by gastric secretion of acid and pepsin and increased chymotrypsin. It appears that the gastric region of lake sturgeon is functional at the onset of feeding. There is an enzymatic shift at metamorphosis specifically lipase and amylase, and chymotrypsin concentrations decrease while pepsin and trypsin continue to increase. Digestive capabilities of sturgeon appear to be higher than for other teleosts prior to metamorphosis and the availability of carbohydrates and lipids to larval sturgeon may also be higher relative to juvenile and adults. Most digestion takes place in the spiral valve. Natural foods are high in lipids (up to 56%) and elevated lipolytic activity during larval feeding may enhance utilization of the high dietary lipid levels. Following metamorphosis lipid and protein requirements decline and there is a increased dependence on protein catabolism.

CAMPBELL, R.R. 1990. Rare and endangered fishes and marine mammals of Canada: COSEWIC fish and marine mammal subcommittee status reports: VI. Can. Field Nat. 104(1): 1-6.

The lake sturgeon is listed as a NIAC (not in any category of COSEWIC designations) species. This status was assigned in 1986 and was valid up to April 1989. The lake sturgeon is also listed as a species for which status reports are in preparation or under review as of August 1989 and a question mark (?) appears under "Proposed Status".

CANADA-UNITED STATES INTERNATIONAL JOINT COMMISSION, INTERNATIONAL GARRISON DIVERSION STUDY BOARD. 1976. J. Loch and D. Henegar (ed.) Report to the International Joint Commission-1976, Appendix C, Biology Committee final report - environmental impact assessment, alternatives and recommendations, attachments. p.128-135.

The impact of the introduction of fish species and potential pathogens into the Hudson Bay drainage from the Upper Missouri basin rivers via the proposed McClusky Canal is discussed. It is felt that shovelnose and pallid sturgeon, once established in Canadian waters would compete with lake sturgeon populations for food and habitat, although this impact cannot be quantified and both these potential colonizers are rare and non-migratory (p. 115). The potential impact of the parasite Polypodium is also mentioned.

CARLANDER, K.D. 1969. Lake sturgeon, p. 33-45, In Handbook of freshwater fishery biology. Iowa State University Press, Ames, Iowa.

This is a set of data which includes weight, length, number, range of values and regressions of growth) on selected fish species. Data on lake a sturgeon from across North America is given with the largest female being a 125 kg fish caught in Lake Winnipeg and the largest male at 100 kg, caught in Lake Erie. Age was determined by sectioning fin rays. A tagged lake sturgeon of length 533 mm and weight 907 g grew to 610 mm and 2268 g in three years and five months; another sturgeon tagged at 6,350 g increased to 34,019 g in 28 years. Sturgeon from Lake Winnebago, Wisconsin appear to grow above the average for North America. Sturgeon appear to spawn every 4-7 years, and slower growth 2-3 years prior to spawning results in "belts" of good and poor growth. There is a definite periodicity in females but some males spawn in consecutive years. The period between spawning for females was four years in Minnesota, 4-5 years in the St. Lawrence, six years Lake Nipigon. Spawning occurs from April 15 to May 15 in Minnesota at temperatures of 12-15^{o}C. Spawning in Ontario occurs from early May to the end of June at temperatures of 12-19^{o} C and in Quebec from early May to the end of June at water temperatures of 18.4^{o} C. The main food items are insect larvae, leeches, molluscs, isopods, and crustaceans.

*CARLSON, D.M. 1983. A description and comparison of larval sturgeon (Scaphirhynchus spp. and Acipenser fulvescens) from the central United States. Trans. Mont. Acad. Sci. 17: 19-26.

CHERR, G.N., and W.H. CLARK. 1985. An egg envelope component induces the acrosome reaction in sturgeon Acipenser transmontanus sperm. J. Exp. Zool. 234(1): 75-86.

The sperm of Acipenser transmontanus has an acrosome and an acrosomal process. Homologous egg water causes exocytosis and process formation in A. transmontanus sperm. Lake sturgeon were also tested and the egg water appears to be species specific in its ability to induce the acrosomal reaction. The egg water can be fractionated on Cl 4B sepharose to obtain a specific reactive fraction. The component of egg water that induces the acrosomal reaction is characterized as a 66,000 dalton glycoprotein present in layer 3 of the egg envelope. The authors conclude that the soluble inducer may be a smaller product of a 70,000

dalton molecule that is cleaved by a proteolytic enzyme. Evidence for this interpretation comes from the absence of the 66,000 dalton molecule when inhibitors of trypsin are used in the egg water.

CHERR, G.N., and W.H. CLARK. 1985. Gamete interaction in the white sturgeon Acipenser transmontanus: morphological and physiological review. Environ. Biol. Fish. 14(1): 11-22.

This paper concentrates on gamete morphology, fertilisation, acrosome reactions and other sperm-egg interactions of the white sturgeon with a brief discussion of cross-fertilisation experiments with lake sturgeon. Lake and white sturgeon sperm were incubated with an isolated 70 KD glycoprotein component (precursor of the sperm inducer) of egg water, released by the egg envelope, to determine the specificity of this protein in activating sperm of the two species. Only white sturgeon sperm were activated and this species specificity was true for egg water as well. No lake sturgeon sperm adhered to white sturgeon eggs; at low sperm concentration (10^3 sperm/egg) no fertilisation occurred but a high concentration (10^6 sperm/egg) resulted in a 5% cross fertilisation. This is attributed to the fact that a low proportion of the eggs undergo the acrosomal reaction when diluted in freshwater and may be the successful sperm.

CLASSEN, T.E.A. 1949. Age and rate of growth of the sturgeon. Age at sexual maturity. Wisconsin Conservation Department, Madison, Wisconsin, 20p.

A review of the methods used to age sturgeon from Europe is discussed. The relationship between the annual growth of scales or bones and the total length of the fish are presented in relation to ageing fish. The author collected the marginalia of the pectoral fin for ageing sturgeon. Sections about 0.5 mm in thickness were made with a hack saw, polished with a very fine file, and then mounted in Canadian balsam. Ageing structures were collected from spawning fish and very few young fish were examined. Amur fish were compared with fish of Southern Europe and it was found that the Amur fish grew more slowly. There was little correlation between age i.e., 11- 19 years and length (130 - 140 cm). The use of photography to record the sections appeared to work and illustrations were used to show clearly how annuli were determined. It was determined that males reach sexual maturity at a size of about 120 cm and an age of 10 - 11 years. Females generally reach sexual maturity at 15 and occasionally at 13 years. There was considerable variation in size relative to age. It was concluded that female sturgeon in the year of spawning grow less than the year they remain at sea. The author believes that the sturgeon spawn in alternate years.

CLEMENS, W.A., J.R. DYMOND, N.K. BIGELOW, F.B. ADAMSTONE, and W.J. HARKNESS. 1923. The food of Lake Nipigon fishes. Univ. Toronto Stud. Biol. Ser. Publ. Ont. Fish. Res. Lab. 16: 173-188.

A total of 12 lake sturgeon captured on June 23, 24, July 9, 12, and August 26 were examined for intestinal contents. Contents included emphemerid nymphs which made up 98% of the food for sturgeon captured in August, chironomid larvae which constituted 65% of the gut contents of one sturgeon of June 24, molluscs which comprised 50-100% of five samples, and fish remains which made up 20-98% of the diet of four fish. Miscellaneous finds included trichopterans, gammarids, odonate nymphs, algae and vascular plant tissues, cyclopoid copepods, diatoms and cladocerans.

COLLINS, J.J. 1988. Changes in the North Channel Canada fish community with emphasis on pink salmon Onchorhynchus gorbuscha Walbaum. Hydrobiologia 163: 195-214.

This paper focuses on the community dynamics of the North Channel, a discrete basin differing qualitatively from other basins of Lake Huron. Although the account emphasizes pink salmon, information on lake sturgeon can be gained from a graphic description of the history of various fisheries. The lake sturgeon fishery was established after 1880 with productions rising to over 100 tonnes in 1885 and declining thereafter quite rapidly to negligible quantities at the turn of the century. Insignificant quantities continued to be harvested until the fishery was closed around 1910. The principle fishing gear used was gill-nets.

COOK, F.A. 1959. Freshwater fishes in Mississippi. Mississippi Game Fish Commission, Jackson. 239p.

Four species of acipenserids, including the lake sturgeon, are included in a fairly detailed key. This is followed by brief notes for individual species. The lake sturgeon population rapidly declined after 1895. Historical weights of lake sturgeon were 100 pounds or more although 40 pound fish are more likely now. Included is a report of a 35 pound ripe female sturgeon in the Upper Mississippi in 1950.

COOK, W.J. 1987. Enforcement implications for management of lake sturgeon (Acipenser fulvescens) in Ontario. Ont. Fish. Tech. Rep. Ser. 23: 95-96.

The problems in enforcing regulations for sturgeon fishing are discussed. These include a lack of knowledge about fishing regulations, licensing, fishing gear, and audit procedures. Recommendations to improve current enforcement practices include a communications plan between managers and the public, the development of a

data base for sturgeon fisheries and enforcement plans developed on a regional basis.

COOPER, E.L. 1957. What kind of sturgeon is it? Wis. Conserv. Bull. 22: 31.

This is a short note on distinguishing between two of Wisconsin common sturgeon, the lake sturgeon and the shovelnose sturgeon. The distinguishing features include the presence of a filament from the upper lobe of the caudal fin and a tail completely covered by scutes in the shovelnose sturgeon. The shovelnose also occurs only in the Mississippi drainage in Wisconsin but not in the great lakes or their tributaries. Lake sturgeon are abundant in Lake Winnebago, their traditional location in Wisconsin.

COPELAND, J. 1970. Experimental sturgeon rearing, 1970. Michigan Department of Natural Resources. Wolf Lake State Fish Hatchery, Kalamazoo, Michigan. 3p.

This is a report on sturgeon culture at the Wolf Lake Fish Hatchery. Fertilized eggs were transported on ice to the hatchery. Fifty thousand eggs were collected but only 638 hatched. Fungal infections on eggs seemed to be the main cause of mortality and treatment of eggs against fungi was suggested. Fry were place in 55 gallon aquarium with fine gravel on the bottom and it was suggested that fish be reared in troughs without gravel in the future. Initially, they were fed brine shrimp and as the fish became bigger were fed chironomids, tubificids, and finally annelids. Three inch fry were placed in ponds but no fish were recovered after 135 days.

CROSS, F.B. 1967. Lake sturgeon, p.33-34, In E.R. Hall (ed.) Handbook of fishes of Kansas. Univ. Kans. Nat. Hist. Misc. Publ. 45. 357 p.

The author regards the record of Snow (1875) of lake sturgeon in Kansas as valid although there may be reason to doubt it. Since 1952, the author has seen photographs of two lake sturgeon caught in the state.

CROSSMAN, E.J. 1976. Quetico Fishes. Roy. Ont. Mus. Publ. 86p.

This species is considered among the largest in the park and known only from four lakes or 2.1% of the locations. This species ranks 28th with the fathead minnow.

CROSSMAN, E.J., and H.D. VAN METER. 1979. Annotated list of the fishes of the Lake Ontario Watershed. Gr. Lakes Fish. Comm. Tech. Rep.36: 1-8.

The lake sturgeon is listed and the annotation on it states that it was once abundant in the lake but stock depletion occurred by 1900 and it is doubtful whether the lake supports a spawning population at present.

CUERRIER, J.-P. 1947. Quelques indications sur la taille de maturite, la frequence des pontes et la saison de ponte de l'Esturgeon de lac. Ann. ACFAS, Montreal 13: p. 100. [Abstract].

Observations were made on 527 commercially captured lake sturgeon in Lake Saint-Pierre between June and September, 1945. The size of sampled fish reportedly ranged from 60-180 mm (?, this is probably a misprint and should be 'cm') and weighed between 3-101 pounds. The author describes the gonads and stages of female gonad development and discusses size at maturity, frequency and season of spawning. The author applies this data to legislation related to sturgeon fishing.

*CUERRIER, J.P. 1949a. Observations sur l'esturgeon de lac (Acipenser fulvescens Raf.) dans la region du lac Saint-Pierre au cours de la periode du frai. These Manuscrit. Universite de Montreal, Montreal. (Pagination unknown).

*CUERRIER, J.P. 1949b. Observations sur l'esturgeon de lac (Acipenser fulvescens) dans la region du lac St. Pierre au cours de la periode du frai. MS. Rep. (Pagination unknown).

CUERRIER, J-P. 1949c. L'esturgeon de lac,-age-croissance-maturite. Chasse et Peche 1(6): 26.

Age was determined by sectioning a pectoral fin, placing in glycerine, and counting the growth rings. Fish were grouped by age i.e., 0-10 and up to 40-50 of age. The male age at maturity was determined to be 14 years and the female was 25 years old at maturity.

CUERRIER, J-P. 1951. The use of pectoral fin rays for determining age of sturgeon and other species of fish. Can. Fish Cult. 11: 10-18.

A summary of bibliographical material on sturgeon aging is presented and the technique for aging sturgeon by sectioning the marginal pectoral fin ray is described along with figures. The first ray or first few rays are removed from the pectoral fin at the articulation with the basal cartilaginous piece and dried. Thin 0.3-0.5 mm sections are made about 1/4 inch from the base of the fin-ray with a jewellers saw. The sections are mounted temporarily in a drop of glycerine which renders the annuli visible. Wide opaque zones alternate with narrow clear zones, the former corresponding to summer growth and the latter to winter growth. The summer bands are thick and opaque indicating abundant deposition of connective tissue subsequently converted into bone during active metabolic activity and feeding phase.

The winter growth ring signifies the period of metabolic inactivity when only a small amount of connective tissue deposition and conversion to bone occurs.

CUERRIER, J-P. 1962. Inventaire biologique des poissons et des pecheries de la region du Lac Saint-Pierre. Nat. Can. (Que.) 89: 193-213.

This report discusses the survey of fish from the Lac Saint-Pierre region from 1944 to 1946. A detailed map of the Saint-Pierre region is included in the text. Fish were divided into six groups; the most important commercial species (lake sturgeon were in this group), the second most important commercial species, the most important sport fish species, sport fish of secondary importance, and species which are predaceous or parasitic. The total catch for the years 1945 and 1946 were 266,190 and 324-,610 pounds, respectively. Data collected for lake sturgeon is reported and includes the location of populations, numbers, and their movements. A table is included which gives data on the commercial catch of lake sturgeon by month for the years 1944 to 1946. The catch ranged from 32,612 pounds in 1944 to 44,300 pounds (value $15,000) in 1946. Sturgeon were caught with lines and seines and were separated into those less than 12 pounds and those greater than 12 pounds. During the winter fishery sturgeon are caught in the whitefish nets and there was likely some illegal fishing of sturgeon in May of 1944-46. Figures are included illustrating the proportion of the catch which was under 12 pounds and the June catch had the highest proportion of small fish. From 690 specimens sampled the length ranged from 22 to 67 inches and 3 to 101 pounds and of 534 examined for sex ratios 51% were male and 49% female. First maturation of males occurred at 15-20 pounds and for females maturation occurred about 30 pounds. Stomachs were examined from 200 specimens and food items included amphipods, larval of diptera, trichoptera, and the small gastropod Bullimus tentaculatus (present in most of the stomachs examined).

*CUERRIER, J-P. 1966. The lake sturgeon Acipenser fulvescens Raf. of the Lake St. Pierre region during the spawning period. Nat. Can. (Que.) 93(4): 279-334.

CUERRIER, J-P., and G. ROUSSOW. 1951. Age and growth of lake sturgeon from Lake St. Francis, St. Lawrence River. Report on material collected in 1947. Can. Fish Cult. 10: 17-29.

This report summarizes the data collected in Lake St. Francis during 1947. A total of 342 sturgeon were examined, of which 138 were killed and sold on the local market. Two hundred and four were tagged and released. Long term statistics revealed that the Lake St. Francis sturgeon fishery has been quite prosperous with catches of 14,000 to 35,400 (average of 27,040 pounds) between 1923 and 1933. From 1933 to 1943 the average catch was 13,800 pounds. The decline of the fishery was discussed and while popular opinion considered dam construction to be the major cause, the authors suggest that fishing methods may have contributed to the decline. Interesting information is included, such as the legal size of 28 inches for sturgeon, as specified in the fishing regulations of the Province of Quebec. By contrast, the Ontario administered portion of Lake St. Francis had a size limit of 36 inches while elsewhere in Ontario the size limit was 42 inches. The Quebec fishery also used mesh sizes that offered no protection against small sturgeon as indicated by size frequency plots of length and weights. Lake St. Francis sturgeon were found to grow faster than Lake Nipigon sturgeon in both length and weight. The coefficient of condition for Lake St. Francis sturgeon was 2.67 while that of Lake St. Peter was 3.15. Only three mature fish were caught, two males 15 and 21 years and a female 23 years old but none were in spawn condition.

*CUSSON. M.P. (Date unavailable). The sturgeon. King of fishes, Fish of Kings. Ontario Dept Lands and Forests, Kapuskasing District, MS. Rep. 5p.

CZESKLEBA, D.G. 1979. Activities in dry feeding of cool water species. 1979. Wisconsin Department of Natural Resources, Wildrose Hatchery, Wildrose, Wisconsin, U.S.A.

The University of Manitoba "Interlibrary Loans Section" informs us that they have exhausted all possible locations for this item. Furthermore, The Department of Natural Resources Technical Library informs us that they have received many requests for this publication in the past and believe the citation to be incorrect.

CZESKLEBA, D.G., S. AVELALLEMANT, and T.F. THUEMLER. 1985. Artificial spawning and rearing of lake sturgeon, Acipenser fulvescens, in Wild Rose State Fish Hatchery, Wisconsin, 1982-1983. Environ. Biol. Fish. 14(1): 79-85.

This paper documents the efforts of the Department of Natural Resources, Wisconsin, under the supervision of the authors, to obtain and culture lake sturgeon eggs at the Wild Rose State Fish Hatchery. Lake sturgeon eggs and milt were collected from the Wolf River sturgeon population in the spring of 1982 and '83, fertilised and hatched, and the larvae reared in the state hatchery. The overall hatching success was 59.2% with mortalities caused by fungal infection. A temperature of 13°C resulted in greater hatching success and fewer fungus problems, compared to incubation at 16°C. Formalin treatment reduced but did not eliminate fungal problems. Growth of larvae during the first 30 days post hatching (the

first 10 days were devoted to endogenous yolk feeding) was comparable to wild fish from the Wolf River. Growth of hatchery larvae was further stimulated by the addition of live food (Daphnia) up to day 50. Thereafter, hatchery reared larvae grew at a lower rate, reaching 101.4 mm by day 123 (2.5 g at day 110), compared to approximately 200 mm (from graph) for wild juveniles. Lake sturgeon larvae did not accept Oregon Moist Pellet as an artificial diet and died by day 29 under that regime. In all cases live food was preferred over commercial diets. Frozen food (Daphnia and brine shrimp) was a marginal diet and it is recommended that lake sturgeon larvae be fed a variety of live food initially and gradually weaned to other artificial diets to prevent imprinting on a particular diet. Sturgeon larvae did not contract any diseases during weekly treatments with chloramine-T-hydrate. The numbers of larvae stocked into various waterways as part of the program are also provided.

DALY, R. 1967. Fishing the big one. Wis. Conserv. Bull. 32: 12-13.

This is a popular article which discusses the sport-fishing on Lake Winnebago. Sturgeon fishing is increasing in popularity with 4,292 spearing licenses issued in 1967. This sport is unique to only a few lakes in North America. The main fishing items are spears which come in all shapes and sizes and decoys (old bowling pins, cobs of corn, carved fish, or old weighted rubbers and rag dolls). Over the past 12 years 650 sturgeon were speared. The record was a 168 pounder in 1957.

DEACON, J.E., G. KOBETICH, J.D. WILLIAMS, and S. CONTRERAS. 1979. Fishes of North America; endangered, threatened or of special concern. Fisheries (Bethesda) 4: 29-45.

This is a composite list of all the fish species in North America that are in a special conservation category for the year 1979. The lake sturgeon is listed as being threatened in the following states: Alabama, Arkansas, Georgia, Iowa, Illinois, Indiana, Kansas, Kentucky, Louisiana, Michigan, Minnesota, Montana, Missouri, Nebraska, New York, Ohio, Pennsylvania, South Dakota, Tennessee, Vermont, Wisconsin, and West Virginia. The threatened status is caused by present or imminent destruction of habitat.

DEANS, N.L. 1987. Looking at the life of a great lakes relict. Aquaticus: J. Shedd Aquar. 19(2): 13-20.

This is a popular article dealing with lake sturgeon and gives an account of one brought to the aquarium in 1931 which lived for 44 years, dying in 1975. There is a discussion of Fred Binkowski's work on lake sturgeon and his identification of four major problems with sturgeon culture; locating spawners, recovery of eggs and sperm, prevention of fungal infections of incubating eggs and feeding of young sturgeon. Lake Winnebago is considered the best lake sturgeon population in the world with numbers estimated at between 25,000 to 40,000. Use of riprap along the Wolf and Fox Rivers has increased sturgeon spawning sites. There is an active spearing and hook and line fishery but poaching is a problem. Licensing for sturgeon fishing is strict and fishermen must register each fish caught with the state. The annual harvest of fish over forty-five inches is about 700 and 6-12 sturgeon each year weigh over 100 pounds. A state record was set in 1979 when a 195 pound sturgeon was speared. There is a discussion on ways to fish sturgeon. Research continues on sturgeon but the state is not interested in culturing sturgeon. F. Binkowski and coworkers are continuing to culture sturgeon and are particularly interested in feeding behaviour and feeding response time. They compare live feeds such as brine shrimp, Tubifex, white worms and red worms with commercial preparations. They have also released fingerlings and found that fingerlings held overnight adjusted better to the new environment. This is a list of books and magazine articles dealing with lake sturgeon.

DELISLE, C.E. 1978. Mercury in aquatic ecosystems of Quebec, Canada. Int. Ver. theor. angew. Limnol. Verh. 20(3): 1947-1955.

This is a report on the mercury levels in aquatic ecosystems in Quebec. Of the water bodies examined 81 were over 1,000 m3 (2,589 km2). There is a map indicating all the drainage systems in Quebec. The average mercury levels in lake sturgeon was 0.24 ppm with a maximum of 2.38 ppm. This level seems to be in the intermediate range with the predacious pike having an average value of 0.92 ppm.

DIECKMAN, M. 1963. Sturgeon on the rocks. Wis. Conserv. Bull. 28: 14-15.

The author, a conservation warden, describes fishing for sturgeon in shallow to moderately deep rock pools formed by draining water when the gates of the Jim Falls dam on the Chippewa river swing shut for the last time in the year heralding the onset of the September open fishing season. Occasionally, the gates have to be closed during the summer and sturgeon find themselves trapped in rock pools. The warden narrates several cases of illegal fishing witnessed by him and how the culprits were encountered and arrested. The sturgeon are reported to be quite plentiful and the average weight of sturgeon in this part is stated to range from 25 - 45 pounds with the occasional 60 - 70 pounder and a rare 100 pound fish being taken. The importance of legislation and enforcement is emphasized in deterring illegal fishing and protection of this potentially vulnerable species.

DICKSON, T. 1991. Minnesota's gentle giant. Minn. Volun. May-June, 1991: 27-31.

This article describes what the author considers should be Minnesota's state fish, the lake sturgeon. The high regard for sturgeon flesh and roe by the royalty and aristocracy of Europe is described with anecdotes of past decrees reserving the sturgeon for royalty. The important role of sturgeon in aboriginal cultures is also noted. The familiar tale of wanton destruction of sturgeon during the early days of commercial fishing is recounted. The effects of dams, erosion and pollution on sturgeon populations is discussed. The article also described more recent research being carried out by the Department of Natural Resources; these include tagging fish and restocking with hatchery raised fingerlings (36,000 fingerlings have been stocked over the past 7 years). Registering angled fish as Wisconsin is considered a worthwhile conservation measure.

DOROSHOV, S.I. 1985. Biology and culture of sturgeon Acipenseriformes, p. 251-274. In J.F. Muir and R.J. Roberts (ed.) Recent Advances in Aquaculture. Croom Helm, London, West View Press, Boulder, Colorado.

This review highlights methods, important problems and issues in world sturgeon aquaculture. There is reportedly an absence of knowledge on genetics, nutritional requirements and pathology, and no F_2 generation of any sturgeon species has yet been established in hatcheries. Aquaculture programs and methods in the Soviet Union are reviewed in considerable detail. He also mentions that in the U.S. jar incubators were successfully used for the eggs of lake sturgeon (among other sturgeon and paddlefish).

DOWNS, W. 1975. Fish of Lake Michigan. Univ. Wisconsin Sea Grant College Program WIS-SG-74-121. p. 14.

In this book, a brief one page account with a drawing of lake sturgeon is provided. The fish is characterised as reaching 3-5 feet in length and 80-100 pounds in weight.

*DUBREUIL, R., and J.P. CUERRIER. 1950. Rapport sur l'etude du cycle de maturation des glandes genitales chez l'esturgeon de lac (A. fulvescens Raf.) de la riviere Ottawa, 1949. Ministere de l'Industrie et du Commerce du Quebec, MS. Rep. 63p.

DUMERIL, A. 1870. Histoire naturelle des poissons ou ichthyologie generale, Tom II. Ganoides, Dipnes, Lophobranches. Paris. 624p.

In this second volume of the natural history of world fishes, the author covers the sturgeon under the Ganoides. The following species are mentioned from various freshwater locations in North America: Acipenser maculosus (p. 113); A. serotinus (p. 158, Ohio R.); A ohiensis (p. 156, Wabash R.); A. rhynchaeus (p. 111, Lake Superior); A. copei (p. 108, maybe Upper Missouri); A. rauchii (p. 118, Osage R.); A. richardsonii (p. 120, Missouri R.) A. anasimos (p. 122, Missouri R.); A. paranasomos (p. 124, Huntsville Alabama); A. anthracinus (p. 126, Lake Erie); A. lamarii (p. 139, Mississippi R.); A. atelaspis (p. 141, Saskatchewan R.); A. rafinesquii (p. 143, Ohio R.); A. rosarium (p. 152, Lake Erie); A. platyrhinus (p. 154, Upper Mississippi or Lake Erie); A. kirtlandii (p. 161, Lake Erie); A. nertinianus (p. 162, Michigan); A. honneymani (p. 177); A. cincinnati (p. 229, Ohio R.) and A. buffalo (p. 231, Lake Erie). Of these, all but the first four species and A. rhynchaeus appeared as new species. In a review of the North American acipenserids, Kirsch and Fordice (1889) (see annotation in this bibliography) listed all these species as synonyms of the lake/rock sturgeon: "Acipenser rubicundus".

*DUMOUNT, P., F. AXELSEN, and P. FOURNIER. 1981. L'esturgeon jaune, Acipenser fulvescens, biologie et exploitation dans les eaux du Fleuve Saint-Laurent et de L'Archipel de Montreal. Que. Minist. Loisir Chasse Peche. Rapp. Tech. 06-41. (Pagination unavailable).

The Center de Documentation, Ministere du Loisir, de la Chasse et de la Peche, Montreal, Quebec, informs us that this item is in preparation and not yet published.

*DUMONT, P., and N. FOURNIER. 1987. Choix d'un engin de peche pour la capture commerciale de l'Esturgeon jaune dans le couloir fluvial. Que. Minist. Loisir Chasse Peche. Serv. L'ameng. L'expl. Faun. Mont. 5p.

Quoted in Dumont et al. (1989) as unpublished.

DUMOUNT, P., F. AXELSON, H. FOURNIER, P. LAMOUREUX, Y. MAILHOT, C. POMERLEAU, and B. PORTELANCE. 1987. Avis scientifique sur le statut de la population d'esturgeon jaune dans le systeme du fleuve Saint-Laurent. Plan de gestion de la peche comite scientifique conjoint. Minist. Loisir Chasse Peche. Minist. Agric. Peche. Aliment. 21p.

This report summarizes the available data on the biology and commercial harvest of lake sturgeon in the Saint-Laurent and the Montreal archipelago. The species is localized but there appears to be a single population from Lake Saint-Louis to Lake Saint-Pierre. Commercial yields varied from 102.5 t in 1983 to 138.8 t in 1986 and were highest in the lakes Saint-Louis and Saint-Pierre. The Lake Saint-Francois lake sturgeon population is decimated while the population in Lake des Deux Montagnes is being

restored. Data is presented for annual catch records from 1963 to 1986 and there were substantial increases in the catch from Lake Saint-Pierre and from the Saint-Laurent River downstream of Montreal. Recommendations include the protection of spawning females and a decrease in fishing mortality of fish between 14 and 28 years of age.

DUMONT, P., R. FORTIN, G. DESJARDINS, and M. BERNARD. 1987. Biology and exploitation of lake sturgeon (Acipenser fulvescens) in the Quebec waters of the Saint-Laurent River. Ont. Fish. Tech. Rep. Ser. 23: 57-76.

Data collected between 1981 and 1984 on the biology and commercial exploitation of lake sturgeon in the Saint-Laurent River from Lake St. Francois to Lake Saint-Pierre. The mark recapture experiment indicates that movements are restricted, except for rather extensive spawning migrations. From Lake Saint-Louis to Lake Saint-Pierre, sturgeon probably form a single population and local differences in the length-weight relation and harvest structure which are probably related to variations in environmental and exploitation factors. Natural and fishing mortalities are high in all commercial fishing sectors and the annual legal harvest was over 100 t. Yields vary from 1.4 - 3.4 kg/hectare. The Lake Saint-Francois fishery, which is isolated from the downstream fisheries is depleted. The sustained high yields are for a long period of time are related to the moderate biological activity of these waters, to the fact that the large sectors are lightly exploited, and to the fact that commercial fishermen are selective in the use of gill-nets.

DUMONT, P., P. LAMOUREUX, G. LAFORCE, M.L. HAYE, and N. FOURNIER. 1989. Influence de la dimension de l'hamecon sur la selectivite et le rendement de la ligne dormante pour la capture de l'esturgeon jaune (Acipenser fulvescens). Avis Scientifique 89/1, Minist. Loisir, Chasse. Peche. Minist. Agric. Peche. Aliment. 35p.

A long line fishing study was undertaken during 1987-88 to assess different hook sizes. The objective was to determine a hook size that would selectively catch about a 15 kg fish (the size of females at first sexual maturity) but still allow some commercial harvest. There are diagrams of hooks ranging from 6/0 (largest) to 2/0 (smallest), an illustration of a set and a map of the study area. Hook sizes of 6/0 and 3/0 were most used and most efficient in catching fish but when more large fish were present 6/0 caught more. The 3/0 hook was less likely to catch a sexually mature female than a 6/0 and is similar to gill nets of mesh size 19-20.3 cm. Illegal sized fish (3.1 kg) are more frequently caught with the 3/0 hook versus the 6/0 and much higher when compared to commercial gill nets. Length and weight frequency distributions of the catch for each of the hook sizes is presented. The authors suggest that stronger hooks and more frequent lifts would increase the catch of larger fish but feel more work is needed to prove this conclusively.

DYMOND, J.R. 1926. The fishes of L. Nipigon. Univ. Toronto Stud. Biol. Ser. Publ. Ont. Fish. Res. Lab. 27: 108p.

The physical nature of Lake Nipigon and its various bays is characterised and this is followed by an account of the fish species present in the lake. The external morphology of the lake sturgeon is described in taxonomic format and this is followed by a paragraph on its general biology. The sturgeon is said to be fairly common in Lake Nipigon and is found in the shallower bays such as Humboldt, Ombabika, Windigo and Gull bays. The sturgeon diet in this lake consists mainly of chironomid larvae, ephemerid nymphs and molluscs.

DYMOND, J.R. 1947. A list of the freshwater fishes of Canada east of the Rocky mountains. Royal Ont. Mus. Zool. Misc. Publ. 1:4.

The geographical range of lake sturgeon in Canada is briefly mentioned, ranging East-West from Lake Champlain, St Lawrence river to the Saskatchewan river (Alberta) and North-South from the Hudson bay drainage to the Great Lakes.

EDDY, S. 1945. Paddlefish and sturgeon. Geological relicts among Minnesota fishes. Conserv. Volunt. 8: 29-32.

In this article, the author discusses the lake sturgeon in the context of the evolutionarily ancient fishes found in the world and the acipenseriforms in Minnesota. The lake sturgeon is one of the two acipenserids found in the state's waters, shovelnose sturgeon being the other. The differences between the two sturgeon, their food habits, and spawning behaviour at the foot of Taylor Falls is described. Smoked flesh of both sturgeon are considered to be the best smoked fish available. Despite protective laws, sturgeon populations are on the decline and artificial propagation is viewed as having been largely unsuccessful.

EDDY, S., and T. SURBER. 1947. p. 75-79. In Northern Fishes, with special reference to the Upper Mississippi Valley. Charles T. Branford Co. Mass.

The sturgeon is regarded as the largest fish of the native fishes of Minnesota and neighbouring states. Protective laws caused an increase in lake sturgeon populations from low levels prior to 1939, in the Snake, Cross and Kettle rivers, and in Lake Pokegama. Favourite spawning grounds include the Soo rapids on Rainy River and the Cross Lake dam upstream of the Snake

River. Spawning migrations have been noted as early as April 5 when the ice begins to break and lasts to the middle of June. Additional observations on the condition of ovaries of 40 fish sampled at the mouth of the Rainy River indicated that sturgeon spawned over a period of several months and deposited few eggs at a time at various locations.

EDDY, S., and J.C. UNDERHILL. 1976. Sturgeon. p. 125-131. In Northern Fishes with special reference to the Upper Mississippi Valley. University of Minnesota Press, Minneapolis, Minnesota. p. 125-131.

In this account on lake sturgeon, the life history is briefly described and the decline in populations following early exploitation of the species is also recounted.

EIGENMANN, C.H. 1895. Results of explorations in western Canada and the northwest United States. Bull. U.S. Fish Comm. (1894) 14: 101-132.

On page 107, the author reports Acipenser sturio. This record appears as a synonym of the lake sturgeon, Acipenser fulvescens.

ENVIRONMENTAL APPLICATIONS GROUP LIMITED. 1988. Lake sturgeon culture techniques manual. Prepared for Ontario Ministry of Natural Resources, Northern Region. 108p.

This manual contains all information pertinent to the aquaculture of lake sturgeon. A variety of areas are covered and the manual proceeds systematically through 11 chapters, from methods of sperm and egg collection and fertilisation procedures to the actual rearing and feeding of hatched sturgeon. Various feeds and their efficacy are described. Eight sites are appraised of their potential egg and milt collection (spawning sites). Information on the dates or duration of the spawning act is not available for most of the sites nor is their substantial information on the spawning population in those areas. The potential problems associated with bacterial and fungal pathogens are mentioned. Various designs and costs for a hatchery are discussed. The three appendices in the reference section list the names and addresses of principal sturgeon culturists, food supply contacts and hatchery equipment. The manual draws extensively from progress made on white sturgeon culture in California.

ENVIRONMENTAL APPLICATIONS GROUP LIMITED. 1988. Lake sturgeon stocking plan. Prepared for Ontario Ministry of Natural Resources, Northern Region. 36p.

Lake sturgeon are considered a threatened species in North America and the basis of stocking programs is to establish a self-sustaining populations. Due to their slow growth and low yield an analogy is made between the management of forests and stocking of lake sturgeon, with a time frame of 25-40 years. Interestingly, the authors quote unpublished information suggesting that the presence of a strong walleye population is an indication that habitats are suited for lake sturgeon. Ideal water quality and habitat is difficult to assess since current populations may be in less than ideal conditions. The Groundhog River was used for comparison. Stocking assessment is difficult since so few programs have been undertaken. It is generally believed that sturgeon fry have high mortality. It is suggested that stocking be done with fish (2.5-7.5 cm) with a density that is about 20 fish / hectare. Feed costs were estimated to be $9 (Can.) per 454 g for tubifex worms with a feeding rate of 1.4 kg/2500 fish/day. Diet conversion to artificial feeds is difficult and mortalities are high. Estimated costs to raise sturgeon fingerlings in Minnesota is approximately $2.60 (Can.) while cost of fry is 1-2 cents/fish (capital cost of hatchery not included). Problems associated with levels of mercury in sturgeon flesh need to be considered in a stocking programs. Stocking of adults and subadults, from unexploited systems only, was suggested as a management strategy. Assessment should involve the marking and recapturing of marked fish to determine the success of stocking. Binary coded microtags injected into the cartilaginous cranium were considered to be a good tag. A mandatory head return program would be needed if a sport or commercial fishery were involved in the area of release. Computer models were used to predict outcomes for a sturgeon stocking program. Predictions suggest that a combination of natural recruitment, adult transfers and natural recruitment would give the best returns and a "buy back" time of four years.

FEDORUK, A.N. 1969. Checklist and key to the freshwater fishes of Manitoba (preliminary). Man. Dept Mines Nat. Res., Land Inventory Project. MS. Rep. 98p.

The lake sturgeon appears in the key on p. 26 and is characterised as having a heterocercal tail fin, no scales but bony scutes and a mouth posterior to front of eye.

FINNLEY, D. (ed.) 1978. Missouri's "Design for Conservation" plan is broadening E.S. protection: more habitats being acquired. Endangered Spec. Tech. Bull. 3(4): 4-6.

The report highlights certain endangered and vulnerable species of Missouri and studies being initiated or carried out with these species under Missouri's endangered species program. The brief account on lake sturgeon attributes the collapse of the state's sturgeon population to overfishing and poor management. The status of the pallid sturgeon is also discussed.

FOGLE, N.E. 1975. Michigan's oldest fish. Mich. Nat. Res. 44(1): 32-33.

This popular article, accompanied by one of the few colour photographs of a live sturgeon, describes the general life history of the lake sturgeon. The standing Michigan record is 193 pounds, 87 inches long with a girth of 40 inches, speared from Mullet Lake in February, 1974 by Joe Maka.

FOLZ, J.L., D.G. CZESKLEBA, and T.F. THUEMLER. 1983. Artificial spawning of the lake sturgeon in Wisconsin. Prog. Fish Cult. 45(4): 231-233.

The paper discusses efforts to spawn, fertilize and rear lake sturgeon without sacrificing the adults. The first attempt to obtain ripe adults was made in the spring of 1978. Sperm, extracted by palpation and drawn into a syringe, was stored in glass vials on ice. It was not possible to obtain eggs manually by stripping and caesarian sections to obtain free eggs which flowed from the body cavity. Eggs were placed in a wet plastic pan and sperm added after which water was added and the mixture stirred and allowed to stand for 2-3 minutes. A bentonite clay suspension was introduced to the pan to counteract the adhesiveness of eggs. Sperm from some males were viable after 22 hours storage on ice. Hatching percentage ranged from 34 - 92. The paper lists 14 separate occasions of artificial fertilisation and all studies were carried out on the Wolf River. The paper also briefly mentions a radio-tracking study done on an individual female sturgeon implanted with a transmitter. The individual was followed for two years and appeared healthy when eventually captured.

FOLZ, D.J. and L.S. MEYERS. 1985. Management of the lake sturgeon Acipenser fulvescens; population in the Lake Winnebago system, Wisconsin. Dev. Environ. Biol. Fish. 6: 135-146.

Current management objectives are to limit harvest to maintain a sustained yield. The history of the system includes a moratorium on fishing from 1915 to 1931, with a spear fishing season started in 1932. An extensive research/management program was conducted on the lake sturgeon from 1955 to 1967 on the biology, recruitment and harvest of the population. A winter spear fishery is the only legal means to harvest lake sturgeon in the Winnebago system. From 1975 to 1983, 3,380 lake sturgeon were marked at spawning sites and netting of lake sturgeon in Lake Winnebago resulted in an additional 2,826 being marked. Spawning sites were created by placing riprap on the outside bends of tributary rivers. Each fish caught by spear fishing is registered and total length, weight, location, date and tag number is recorded. Trap nets and otter trawls are used in lake Winnebago to remove freshwater drum and sturgeon caught during this program, and above 114 cm, are tagged (monel self-piercing cattle ear tag size 681 and 62, applied at the base of dorsal fin) and released. Density estimates are based on marking and recovery through registration of all sturgeon caught and use of the Peterson mark-recapture formula as modified by Bailey. Spawning sites were divided into major (more than 20 fish captured each year) minor (less than 20 fish captured and not utilized each year) sites. A total of 18,075 sturgeon were legally harvested in Lake Winnebago from 1955 to 1983. In 1974 the minimum length was increased from 102 to 114 cm in order to reduce the harvest by 11% and bring in line with the estimated recruitment of 540 fish. Lake sturgeon are fully recruited to the harvest by age 16 and few remain above age 36. Lake sturgeon spawn in the Fox and Wolf rivers from mid April to early May. From 1975 to 1983 spawning activity occurred over 4 to 10 days with peak activity usually over 2-3 days. Spawning is initiated at 11.7 C but spawning has been noted at 14 to 16 C. The mean length of spawning females was 160.3 cm (range 129.5 to 200.7 cm) and mean length of males was 133.4 cm (range 82.6 to 175.3 cm). It was suggested that a shorter season for spear fishing may be more effective than increasing the length limit. Netting operations from 1975 to 1983 noted a decline in the mean size but this was not due to a decline in the catch but rather an increase in numbers of smaller sized sturgeon. The population is estimated at 24,600 and recruitment is estimated at 6.3% with a harvest of 2.5%. Fresh riprap spawning sites may be preferred as older sites become covered by silt, debris and algal growth. The final suggestion is to manage the spear fishery as a trophy fishery.

FRASER, E.A. 1927. Observations on the development of the pronephros of the sturgeon, Acipenser rubicundus. Q. J. Microsc. Sci. 71: 75-112.

Sturgeon embryos from 76 hours to 30 days after fertilisation were examined for the development of the pronephros. The origin of the duct and canal could not be observed as these arise 51 hours after fertilization. The following stages post-fertilization are described; 76 hrs, 88 hrs, 100 hrs, 112 hrs, 6-7 days, 9 days, 12 days, 14 days, 20 days and 28 days. Embryos at 76 hrs possess 6 short pronephric canals opposite somites 4-9. These canals empty laterally into the pronephric duct. This is followed by the appearance of a tubule opposite somite 10. Thereafter the nephrotomes IV, V and VI open into the splanchnocoele, nephrotome IV disappears, and the first tubule opens dorsally into the second. The posterior nephrotomes become completely enclosed by the formation of a new ventral wall giving rise to a series of pronephric chambers. This is followed by development of the glomeruli with an accompanying disintegration of the walls separating the pronephric chambers. This results in the formation of a single elongated chamber containing a glomus. The pronephros reaches its full development a few days after the embryo hatches 9 days post-fertilisation. It consists of a

single external nephrostome with 5-6 internal nephrostomes connecting the duct with an elongated pronephric chamber containing the glomus. The mesonephros begins development at somite XVI and by 20 days post-fertilisation, the anterior nephrostome begins to disappear and definite degeneration of the pronephros begins. The pronephros of sturgeon is considered more primitive and better developed than in other ganoids and Polypterus and the chambers are more completely fused than in any other vertebrate.

GARDINER, B.G. 1984. Sturgeon as living fossils. p. 148-152. In N. Eldridge and S.M. Stanley (ed.) Sturgeons as living fossils. New York, Springer Verlag.

The fossil history of extinct and present day sturgeon are briefly reviewed. It is felt that the characters separating the genera Scaphirhynchus and Pseudoscaphirhynchus are weak and that the fundamental similarities are sufficient to group the 5 species of the two genera under a common genus. This work is referred to in the key to the acipenseriformes.

GIBBONS, D.W., P.J. ANDERSON, and R.N. PERHAM. 1970. Amino acid sequence homology in the active site of rabbit and sturgeon muscle aldolases. FEBS Lett. 10: 49-53.

The sturgeon muscle used in this study came from the Ottawa River and is presumed to be lake sturgeon, but the species was not given in this paper. There was strong homology around the lysine residue in the aldolases from rabbit muscle, sturgeon muscle and rabbit liver. All the enzymes were tetrameric with a subunit molecular weight of approximately 40,000. Work in progress on muscle aldolases from other sturgeon suggests there are sequence differences, perhaps species specific differences.

GIBBONS, I, R.N. PERHAM, and P.J. ANDERSON. 1972. Amino-acid sequence homology in the muscle aldolases from sturgeons of different species. Nature (Lond.) 238(84): 173-174.

This study is based on a comparison of the sequence homology around the active-site-lysine residue of aldolases from Acipenser fulvescens, A. sturio, A. oxyrhynchus, and A. transmontanus. The peptide containing the active-site-lysine residue and an eighteen-residue peptide adjoining it in the primary structure were isolated from aldolases. In all four species the peptides SXb1T3 were shown to have identical primary structure. Residues 29 and 31 were variable i.e., in aldolases from A. fulvescens and A. transmontanus position 29 is occupied by tyrosine. In the aldolases of A. sturio and A. oxyrhynchus the tyrosine is occupied by aspargine. Serine occurs in position 31 of the aldolase from A. fulvescens but alanine occupies this position in the other three species. The primary structure of muscle aldolase is identical from A. sturio and A. oxyrhynchus. Two replacements occur between the aldolases of these species and A. fulvescens. A. transmontanus has an intermediate structure for its aldolase, at position 31 but at position 29 it is identical to both A. sturio and A. oxyrhynchus. The authors acknowledge that their sturgeon sample size is small (one individual in most cases) but comment on the fact that this enzyme is highly conserved in such diverse animals as pigs, ox, and rabbit. The authors also suggest that the European species of sturgeon are likely allopatric.

GLOVER, C.R. 1961. The sturgeon in Pennsylvania. Penn. Angler, Jan. 1961: 3.

This popular article introduces the reader to the acipenserids of North America and recounts the history of commercial exploitation of lake sturgeon. This is accompanied by a description of the life history and a comparison with other sturgeon. Photographs accompany the text.

GODDARD, J. 1963. The lake sturgeon (Acipenser fulvescens) of Chipman Lake in the Geraldton Forest District of Ontario. Ontario Department of Lands and Forests, MS. Rep. 23p.

A commercial license was issued to fish for lake sturgeon, for the first time, on Lake Chipman in 1962. A total of 250 fish were caught, 16 of which were tagged and released, and 234 were killed for the market giving a total harvest of 5400 pounds. In order to gain base line data for future management strategies, the harvested fish were aged, measured for lengths and weights, sexed, and the gonads examined for maturity. The mean coefficient of condition [K(FL)] was calculated to be 2.73 (from 204 individuals). Lake sturgeon of lake Chipman were less fat and robust than those of Lake St. Francis. The sturgeon ranged in age from 25-92 years with the majority between 35 and 50 years. The mean annual increment is 0.5 pounds between 25-35 years, 0.6 pounds between 35-45 years, and 1.5 pounds between 45-64. Sturgeon reached legal commercial size at a length of approximately 43.5 inches and a total weight of 17 pounds. Of a total of 226 sturgeon sexed, 147 were female and 72 male. From analysis of annuli from pectoral fin ray sections, the spawning pattern showed notable variation. All sturgeon that were marketed had spawned atleast once. The mean depth of capture was 14.8 feet. An average of 37.5% of the total weight of the sturgeon was lost in dressing. During fall and winter, 16.3% of the body weight of females may consist of near mature roe. It was calculated that approximately 2/3 of the lake bottom was suitable substrate for sturgeon. Assuming an optimistic annual quota of 2150 pounds of whole sturgeon, it is deduced that little if any profit would come out of a long term commercial venture.

GOUGH, J. 1991. Fisheries Management in Canada 1880-1910. Can. Manuscr. Rep. Fish. Aquat. Sci. 2105: 47-52.

There is a discussion of how easy fishermen and society in general can damage a fishery. The fisheries reviewed include river systems, the Great Lakes, and the prairie provinces. The harvest of sturgeon in Manitoba is used as an example of rapid destruction: 1895, 104,240 pounds; 1900, 981,500 pounds; 1905, 600,000 pounds; 1909, 94,300 pounds. The author discusses the implementation of quotas for whitefish and states that "...prairie regulations were in some ways well in advance of the sea fisheries."

GOYETTE, D., S. GUNETTE, N. FOURNIER, J. LECLERC, G. ROY, R. FORTIN, and P. DUMONT. 1988. Maturite sexuelle et periodicite de la reproduction chez la femelle de l'Esturgeon jaune (Acipenser fulvescens) du fleuve Saint-Laurent. Que. Minist. Loisir Chasse Peche. Serv. Amenagement Exploit. Faune Dir. Reg. Montr. Rapp. Trav. 6(2): 1-84.

A sample of 800 lake sturgeon was examined from commercial operations. The Lake Saint-Louis females reached sexual maturity at an average age of 27 years and length of 133 cm respectively. It was estimated that the Lake Saint-Pierre female sturgeon spawn every 9.4-9.7 years. Both, age at maturity and spawning intervals are higher than reported before for this species. The oogenesis was estimated to last 5 years culminating in spawning and followed by a four year recovery phase. The manner in which maturation cycles influence the growth pattern of females was tested by the contigency periodogram applied to annual increment series drawn from Roussow's (1957) examples and supported this author's qualitative estimate that dominant periods of growth cycles had a 8-9 year periodicity. Dominant growth periods for the two populations examined in the present study lasted 6, 8 or 11 years. No significant differences were found between male and female growth patterns during adolescence (4-15 years) although ages for sexual maturity differ. Automatic classification based on correlation analysis and discriminant analysis did not reveal a significant relationship between growth pattern during the last years of life and the state of sexual maturity at capture.

GRAHAM, K. 1984a. Missouri's lake sturgeon reintroduction plan. Missouri Dept Conserv., Columbia, Missouri. Fish and Wildlife Research Centre. 11p.

This is a review of lake sturgeon history in North America and includes information on population declines and some general information on its biology. Reasons are given for the projected success of fingerling stocking in the Mississippi versus the Missouri Rivers i.e., larger amount of littoral areas and benthic production. It was suggested that the best place to release the sturgeon fingerlings was into sloughs and that rock dikes on either side of the river would serve as spawning sites. Several reservoirs were suggested as possible sites for sturgeon stocking.

GRAHAM, K. 1984b. Reintroduction of lake sturgeon in Missouri. Missouri Department of Conservation, Columbia, Missouri. Manuscript Report. 11p.

Historical information on the lake sturgeon is discussed, including the decline of populations due to overfishing, sturgeon habitats and habits, and reproduction. Spawning is closely tied to water temperature and even a drop of only a few degrees can cause a temporary halt in spawning. The potential for the Missouri River is discussed but lake sturgeon are rare in the Missouri and Mississippi rivers. Only the rare adult is reported and a stocking hatchery-produced fish would be the fastest way to increase numbers. Based on the success of stocking 8-10 inch hatchery produced paddlefish the author believes stocking of sturgeon would be equally successful. Lake sturgeon should be stocked into large reservoirs or rivers.Initially, to test stocking schemes fingerlings would be stocked into small bodies of water (2 to 10 acres) which could be sampled in 2-3 years. The Mississippi River is probably better for stocking due to its diverse benthic community and rock dikes which are similar to riprap on the Wolf River, known to be a suitable spawning substrate. Recommendations were to stock in a productive reservoir with rivers in the vicinity containing gravel and boulders suitable for spawning.

*GRAHAM K. 1984c. Reintroduction of lake sturgeon in Missouri, Performance Report: Dingell-Johnson Project, F-1-R-34, Missouri Department of Conservation, Study S-35. Columbia, 7p.

Please see final report on this project below.

GRAHAM, K. 1986. Reintroduction of lake sturgeon into Missouri. Final Rep., Dingell-Johnson Project F-1-R-35, Missouri Dept Conserv. Study S-35, Columbia, 11p.

This is a preliminary study to evaluate culturing and the reintroduction of fingerling lake sturgeon into Missouri. Eyed sturgeon eggs were obtained from Wisconsin and hatched at the Blind Pony Hatchery. After swimup the fry were fed Daphnia and live young brine shrimp. They were either stocked into fertilized ponds (0.5 and 1.5 acres) or reared in fibreglass troughs and fed artificial diets, live and frozen tubifex worms, live aquatic black worms and frozen adult brine shrimp. Ponds were filled and fertilized 10-14 days prior to stocking. Afterwards they were fertilized weekly with 150 lb/acre each of dehydrated alfalfa meal and

dehydrated cow manure, 50 lb/acre of Brewer's yeast, and 25 lb/acre of fresh chicken manure throughout the growing season. This method of culture was largely unsuccessful as few sturgeon were recovered. Best results were obtained by culturing sturgeon in tanks and troughs, starting on Daphnia and live brine shrimp, and after 1 inch in length they were switched to live aquatic worms, frozen bloodworms or frozen brine shrimp. Frozen adult brine shrimp were cheapest at $3.00/ lb. Survival in troughs was excellent with fish reaching 4.0 inches after 45-50 days at 60-65 C and disease was generally not a problem. Elevated ammonia levels of 0.275 ppm apparently killed young sturgeon.

GUDERLEY, H., L. HAMEL, and J. LAFOND. 1983. Close resemblance between muscle pyruvate kinase from a primitive vertebrate, the river sturgeon Acipenser fulvescens, and the ancestral type K isozyme. J. Comp. Physiol. 153(2): 247-256.

Pyruvate kinase (PK) is present in lake sturgeon in the form of two tissue specific isozymes, distinguished by electrophoresis, one present in muscle, heart and spleen and another five membered one in eyes, liver, gills and intestine, suggesting that it is also synthesised in non-muscle tissues, in eyes, liver, gills and intestine, suggesting that it is also synthesised in non-muscle tissues, in contrast to other vertebrates. Sturgeon muscle PK showed partial immunological cross-reactivity to dog and frog muscle PK. Phosphophenolpyruvate saturation curves for sturgeon muscle pyruvate were expressed by the equation $S_{0.5}$ = 0.33 mM and the Hill coefficient, n_H, was 1.24. The enzyme was strongly inhibited by phenylalanine, alanine and MgATP but inhibition was reversed by fructose 1,6 biphosphate. The kinetic properties of sturgeon PK closely resemble those of vertebrate type K PK but not the type M isozymes of higher vertebrates. It is extrapolated that the sturgeon muscle PK would be a slightly modified transcript of the basic type K gene while the higher type M isozyme represents highly modified transcripts.

GUILDAY, J.E. 1971. Biological and archaeological analysis of bones from a 17th. century Indian village (46 PU 31), Putnam County, West Virginia. W. VA. Geol. Econ. Surv. Rep. Archeol. Invest. 4: 1-64.

The report discusses archaeological finds at the site of Buffalo Village (AD 1650) on the flood plain of the Ohio River (Putnam County, West Virginia), occupied by aboriginal farming and hunting people until contact with European settlers ended organized Indian settlement at this site. A faunal list (p.7) contains the genera/species names of the mammals, birds, reptiles and amphibians identified from analysis of bones (including fragments thereof). Lake sturgeon remains did not figure prominently; only one item was found and it corresponded to an estimated 50 pounds of meat. Remains of drum-fish, Aplodinotus grunniens were found to the most common.

GUNTHER, A. 1870. Catalogue of Fishes in the British Museum, VIII. London. 549p.

This concluding volume of the catalogue series lists Acipenser liopeltis as a new species (p. 34). A. maculosus and A. rubicundus are also mentioned. Kirsch and Fordice (1889) (see in this bibliography) synonymized them with the lake sturgeon, A. rubicundus.

HANSEN, M.J. (ed.). 1990. Lake Superior: the state of the lake in 1989. Gr. Lakes Fish. Comm. Spec. Publ. 90-3: 43-45

The report describes the existing fish community of Lake Superior and discusses the fishery objectives, one of which is to re-establish depleted stocks of native species such as lake sturgeon. In reviewing the progress towards fulfilling this objective it was concluded that lake sturgeon stocks remained as suppressed localised populations under the control of local management agencies. Historically, over--harvest and habitat degradation have led to the depletion of stocks. Spawning populations of lake sturgeon occur in the Bad, Sturgeon, Kaministikwia, Michipicoten, and Black Sturgeon rivers, all tributaries of Lake Superior, and spawning sturgeon are also reported off the harbour breakwall off Ashland, Wisconsin. Six agencies manage commercial and sport fishing regulations for lake sturgeon. The departments of Natural Resources of Michigan, Wisconsin and Minnesota prohibit possession by commercial fishermen. Strategies outlined to restore sturgeon populations include stocking of rivers with sturgeon juveniles reared in hatcheries, preventing habitat loss and enforcing stringent water pollution laws.

HARKNESS, W.J.K. 1923. The rate of growth and the food of the lake sturgeon (Acipenser rubicundus, Le Sueur). Univ. Toronto Stud. Biol. Ser. 24. Publ. Ont. Fish. Res. Lab. 18: 15-42.

This is a report on the growth and food habits of lake sturgeon from Lake Nipigon, Ontario. Otoliths were used to age sturgeon and were found to be adequate. The average age was 50 years and the increase in length was rapid in the first 20 years while increases in growth were slow. Sexual maturity was reached by 22 years of age. It was suggested that no sturgeon be harvested under 35 years i.e., 50 inches in length and 27 pounds. Chironomidae larvae, Mollusca, and Ephemerida nymphs are the main food items of sturgeon. Trichoptera larvae are numerous in the diet when Ephemerida are scarce or lacking. Sturgeon will feed almost exclusively on these items such that the other food items that are considered staple items in the diet are practically negligible. Examples are Decapoda, Anisoptera, Amphipoda and fish

remains. It appears that sturgeon will take anything of food value, as long as it is abundant and easily acquired. Sturgeon did not appear to feed on eggs and fry of fishes. A survey of Lake Nipigon indicated that most of the food items are available, including beds of Decapoda and Anisoptera nymphs. Although whitefish and lake sturgeon feed on similar organisms the author does not think there is much competition since whitefish are found in deep water while sturgeon frequent shallow water and the mouth of rivers.

HARKNESS, W.J.K. 1980. Report on the sturgeon situation in Manitoba. Manit. Dept Nat. Res. Fish. Branch, MS. Rep. 80-3: 18p.

This report discusses the trends in the sturgeon fishery in Manitoba from 1876 to 1935. The harvest in meat ranged from a low of 600 pounds with a value of $3,000 in 1876 to a high of 981,000 lbs with a value of $58,890 in 1900. Caviar reached a peak harvest of 37,000 lbs in 1906 with a value of $37,000. In 1901 there was evidence that the fishery was in trouble and production in Manitoba started to decline. Lac du Bonnet was opened in 1910 and 173,000 lbs taken. This fishery was closed, reopened in 1916 and again in 1922-28 as prices rose. There is a brief discussion of lake sturgeon habits including spawning locations, temperature of 56°C at spawning time below rapids. Some sturgeon apparently do not spawn in rapids but prefer shallow water near the shore and some stay in rivers at all times and some leave the rivers in the summer. Sturgeon are rarely found in water deeper than 20 ft and tend to concentrate in the shallower areas of the lake. It was suggested that if there had been a more structured fishery with a continuous but reduced catch/year over the same period more sturgeon could have been harvested with less damage to the fishery. It was recommended that any sturgeon fishery started in Manitoba should be no more than 10,000 lbs. It was also recommended that sturgeon should not be taken between May 1 and July 1 in Manitoba and perhaps as late as July 10 in the north. There was also concerns about protecting spawning and feeding grounds, the potential impact of dams, and protection of sturgeon during spawning.

HARKNESS, W.J.K., and J.R. DYMOND. 1961. The lake sturgeon, the history of its fishery and problems of conservation. Ont. Dept Land. For. Fish Wildl. Br. 121p.

This is perhaps the most widely cited reference in the literature on lake sturgeon and is a valuable compendium of information on the early knowledge of this fish. It also serves as a literature review to that date and draws on 116 references for information. Every aspect of the sturgeon studied prior to 1961 is covered beginning with a description of juvenile and adult morphologies. On pages eight and nine are records of lake sturgeon weighing 129 pounds and more with a 310 pound, 7'11'' sturgeon being the largest recorded. The two 'morphs' of lake sturgeon as reported by Roussow and Greeley are discussed. A map outlines the geographic range of the lake sturgeon and 43 locations in Ontario alone, named after the sturgeon discloses the keen interest in this species. The food habits are discussed at some length and mayfly and chironomid larvae, molluscs (sphaerid clams) and crustaceans such as crayfish are said to be common. Their reputation as a voracious feeder on fish eggs is regarded as prejudiced. The efforts to feed young sturgeon (with no success) are described and the food of young sturgeon is considered a mystery. lake sturgeon growth and reproduction are also discussed. Importantly, the authors point out that the age at maturity (12-22 years, depending on geographical location) as reported in past literature sometimes do not specify whether the ages represent true first time spawning or the age at which milt was collected by the observers. The dates of spawning at various locations are listed (early May to as late as mid-June). Spawning temperature, sites and behaviour are also discussed. Photographs of early development remain the earliest of their kind and early efforts at artificial propagation are described. The importance of the sturgeon to the native cultures is vividly portrayed as is the exploitation that decimated the sturgeon populations. This sad account is replete with anecdotal information, unpublished eye-witness reports, excerpts from old reports (some as old as 1703) and quotes from past literature. Slow growth to commercial size, infrequent spawning, habitat degradation including physical changes and pollution are said to be the main cause of the decline of sturgeon. Conservation measures are discussed. The history of fishery regulations affecting sturgeon is critically analyzed and the account ends with an account of the taxonomy and early developmental events of the sturgeon.

HARNED, C.N., and P.A. HACKNEY. 1981. Occurrence of lake sturgeon, Acipenser fulvescens, in the Cumberland River of Tennessee. J. Tenn. Acad. Sci. 56(2): 59-60.

Reports of lake sturgeon once abundant in the Tennessee and Cumberland river systems, are rare, with the previous report being in 1968. The authors report the capture of two specimens below the Cordell Hull dam on the Old Hickory reservoir in Tennessee. One apparently healthy individual taken on 24 May, 1977, immediately below the dam, was 145 cm long and approximately 23 kg in weight but its sex was not determined. The second was captured in April, 1978, with an estimated total length of 2 m and 50 kg in weight. The origin of these sturgeon remains unknown and it is possible that the fish were present in the impounded reservoir when the dam was constructed.

HARRIS, R. 1952. The sturgeon harvest. Wis. Cons-

erv. Bull. 17: 3-6.

In this article, caution is urged in the commercial harvest of lake sturgeon in view of its slow growth and late maturity. The lake sturgeon, its life history and distribution are briefly described. The discussion focuses on the rationale for a spear fishing season in winter on lakes Butte des Morts, Winneconne, and Poygan in addition to the existing spear fishery on Lake Winnebago. In view of a suspected surplus, a special 15 day season was opened on the three aforementioned lakes during February 1952. The novelty drew considerable popular response. Spear fishermen cooperated by providing fisheries biologists with samples of gonad and fin rays. A total of 200 sturgeon were removed and the validity of this fishery is strongly advocated by the argument that 200 fish from 156,000 acres of water could hardly harm the fishery. The sport is promoted and specifications are provided at the end of the article on pre-requisites for this kind of adventure.

HART, M.L. 1987. Considerations for the management of lake sturgeon (Acipenser fulvescens) commercial fisheries in Ontario. Ont. Fish. Tech. Rep. Ser. 23: 85-90.

The is a review of the problems and concerns of fishery managers as they relate to lake sturgeon with some recommendations on ways to improve management. The decline of lake sturgeon populations are thought to be due to overfishing, increased market demands for the fish, habitat destruction, toxic effluents, increased angling pressure and overfishing by native peoples of some subsistence fisheries. Management strategies should include sustaining annual yields, protection of broodstock, restoration of depleted stocks, protection and enhancing spawning and nursery habitat, and partitioning the harvest between commercial and sport fishery, if appropriate. Smaller fish should comprise a substantial component of the quota and a slot limit should be considered. While information on age to maturity and length-at-age is important this data is rarely available. There are concerns about sport-fishing as fish, taken by angling, can be sold. It was recommended that management of lake sturgeon be done on a watershed basis since biological data differs substantially among regions. The proposed revision to the Ontario Fishery Regulations would allow the manager through a condition of licensing to specify species and size to be taken; also included are the period of time for fishing, type of gear, mesh size, quantity and manner in which it may be used and location of the set. This would allow control of the harvest based on location and stock.

HAUGEN, G.N. 1969. Life history, habitat and distribution of lake sturgeon Acipenser fulvescens, in the South Saskatchewan River, Alberta. Alberta Fish Wildl. Div. Res. Rep. 4: 22p.

This study reports the life history characteristics of the lake sturgeon in the Alberta portion of the South Saskatchewan River from the confluence of the Bow and Oldman rivers to the Saskatchewan border. Age was determined for a total of 223 lake sturgeon. Age classes ranged from two years (208 mm long) to 51 years (1705 mm long). (LII and LIX). Female sturgeon were older than males in older age groups but the sample sizes were small. The mean growth increment varied from 263 mm for age groups 2-3 years to 13 mm for age groups 21-51 years. The male : female sex ratio was 1.1 : 1. The youngest male in the study was 29 years and the youngest female 25 years. Only 3 of the 97 females had mature eggs in their ovaries. The length - weight relationship was given by the equation LogW = -9.067 + 3.286 LogL. Of the food contents in the stomachs (prevalence in brackets), chironomids and tipulids (85.5%), ephemeropteran nymphs (75.4%), plecopteran nymphs (42.3%), odonate nymphs (33%) and trichopteran larvae (73.2%) were important constituents. Fish occurred in 25% of the stomachs. An attempt was made to correlate fishing success to physical parameters. Depth and velocity of waterflow were most important. All lake sturgeon were captured in waters over two m deep with a flowrate less than 80 cm/sec.

HAUGEN, G.N. 1970a. Life history, habitat and distribution of the lake sturgeon, Acipenser fulvescens, in the South Saskatchewan River, Alberta. Proceedings of the 18th Annual Workshop of the Great Plains Fisheries Workers Association. 1 p.

This is an abstract of a conference presentation and contains basically the same information as in the previous reference.

HAUGEN, G.N. 1970b. The preference of river minnows (Cyprinidae) and smelt (Osmeridae) in the diet of lake sturgeon (Acipenser fulvescens). Alberta Energ. Nat. Res. Fish Wildl. Div. M.S. Rep. 10p.

In this report, the efficacy of river minnows and smelt as sturgeon bait was tested by baiting set lines with equal numbers of minnows and smelt in six sections of the South Saskatchewan River for a total of 504 hours. A total of 45 sturgeon were taken of which 93% were by minnow baits. Catch per unit effort for minnows was 0.083 compared to 0.0059 for smelt. Of the captured fish, 82% came from Area 1 characterised by a 20-40% sand-silt bottom, lower water velocity and greater mean depth. All sturgeon were captured where water depths exceeded two m. It is concluded that the angling success for lake sturgeon in the South Saskatchewan River is less than standard for a sport fishery.

HAY-CHMIELEWSKI, E.M. 1987. Habitat preferences and movement patterns of the lake sturgeon (Acipenser fulvescens) in Black lake Michigan. Mich. Dept Nat. Res. Fish. Div. Fish. Res. Rep. 1949: 39p.

Daily tracking of lake sturgeon was carried out using biotelemetry in Black Lake, Michigan, during the summers of 1985 and 1986 and for two weeks in October 1986 and January 1987. Preferred depths were 10.3 ± 2.14 m in summer and 7.1 ± 0.76 m in winter. Preferred food matter included crayfish and mayfly larvae and was correlated with preferred substrates such as muck. Lake sturgeon neither schooled nor aggregated and diel activity rhythms were absent. Sturgeon did not have a home range and moved 18-6877 m/day, the linear movement being positively correlated with water temperature and was independent of the sex of the fish.

HEACOX, C.E. 1952. King of fishes. Conservationist, April-May. p.18-19.

This is a popular article on sturgeon (A. sturio oxyrhynchus, A. brevirostris and A. fulvescens) and much of what is written has been presented elsewhere in this bibliography. An interesting comment about the sturgeon leaping out of water accounting for the frequent sea serpent stories is worth noting. Lake sturgeon, referred to as mud sturgeon, is the most common species in New York. The author refers to juvenile sturgeon as rock sturgeon. The catch in 1950 was 19,522 pounds with a value of $16,868. Hyde park was an important sturgeon centre, including the preparation of caviar, and fishermen kept their 18-foot flat-bottomed river skiffs not far from the spot where Hedrick Hudson anchored in 1609. The author also make an interesting comment on the difference between the appearance of juvenile and adult "A. sturio oxyrhynchus" (the Atlantic sturgeon). Apparently, the juvenile sturgeon are so unlike their parents that many commercial fishermen consider then another species and give them a special name of "pelican" (pronounced pee-li-can).

HOLZKAMM, T.E. 1987. Sturgeon utilization by the Rainy River Ojibwa Bands, p. 155-163. In W. Cowan (ed.) Papers of the Eighteenth Algonquin Conference, Carlton University, Ottawa.

The history of sturgeon utilization for the production of isinglass as a tradeable item as well as sturgeon flesh for food is reviewed. Sturgeon harvest occurred mostly during summer spawning runs. The occasion also had significant religious and social significance and formed an integral part of Ojibway cultural traditions. Isinglass production provided 7.66% of the total district (Lac la Pluie) return valuation for the period between 1835 and 1869. The average annual production of edible flesh by Ojibway fishermen from the Rainy River from 1823-1885 has been calculated to be 275,415 pounds. Sturgeon oil was considered desirable and was extracted from the head, viscera and gonads. The roe or eggs were also consumed. Sturgeon accounted for over half the caloric values obtained from food sources during 1825-1881, which was later superseded by fur bearing animals.

*HOLZKAMM, T.E., and M. McCARTHY 1987. Lake sturgeon (Acipenser fulvescens) in the returns of the Hudsons Bay Company Lac LaPluie District. Resource Report prepared for TARR Grand Council Treaty No. 3. Kenora, Ontario.

HOLZKAMM, T.E., and M. McCARTHY. 1988. Potential fishery for lake sturgeon (Acipenser fulvescens) as indicated by the returns of the Hudson's Bay Company Lac la Pluie District. Can. J. Fish. Aquat. Sci. 45: 921-923.

Quantitative district returns of isinglass from the Hudson Bay records for 1823 was converted into the equivalent dressed weight of sturgeon. The weight ratio of isinglass to dressed sturgeon was calculated to be 1:25. The average annual Ojibway native harvest of sturgeon was 141,210 kg for the period 1823-1885 with a maximum annual yield of about 200,000 kg. For a subsequent period from 1888 to 1925, the average non-Ojibway commercial annual harvest was 100,890 kg which, although less than preceding native yields, was achieved in a dramatically different manner. Commercial exploitation by non-native fishermen reached a peak in 1899 with a maximum yield of almost 500,000 kg and then crashed to negligible harvests by 1915. The data presented is used to support the contention that the potential for a long term sustainable sturgeon fishery existed before non-native over-exploitation decimated stocks.

HOLZKAMM, T.E., and WILSON, CHIEF W. 1988. The sturgeon fishery of the Rainy River Ojibway Bands, p. 1-10. In Smithsonian Institution (ed.) Smithsonian Columbus Quincentenary Program "Seeds of the past" ("Raices del Pasado"). Smithsonian Institution, Washington.

The sturgeon fishery played a significant role in the economy of the Rainy River Ojibway bands in the 19th century. Pemmican was made from pounded sturgeon flesh and sturgeon oil was considered valuable. A giant sturgeon was associated with spirits controlling the fisheries. Sturgeon were fished by harpooning and spearing and were often tethered through the mouth and gills and kept alive for several weeks.The Ojibway were formidable traders during the fur trade and independent of the Hudson Bay Company due to the abundance of sturgeon and wild rice which they relied upon when they did not trade. The Ojibway valued isinglass from the sturgeon's air-bladder as an effective binding agent of paint as well as a sought-after product for fining beers and wine in Europe. Following several unsuccessful

attempts, a trade was set up between the Ojibway Indians and the Hudson Bay Company for isinglass. Between 1839-1860, the isinglass production was significant and from 1823-1885, the sturgeon harvest averaged 311,000 pounds/year of which the greater portion was reserved for the Indians themselves. In 1873, Treaty #3 was signed between the Canadian Ojibway and the Canadian Government, by which they reserved their native rights to the fisheries in the Rainy River. Despite this, Canadian and American non-native fishermen began expanding their operations at the mouth of the Rainy River in the Lake of the Woods, leading to a depletion of spawning sturgeon in the Rainy River. Under pressure from non-native fishermen, a portion of the Lake of the Woods was opened to gill and pound nets in 1892, adversely affecting native subsistence. Repeated petitions and appeals by the Ojibway were to no avail and the fishery soon produced over 1 million pounds dressed weight/year during 1895-1899, but by 1920 the harvest dropped to negligible levels. Pollution by the pulp and paper mill at Fort Frances set up in 1907 degraded the spawning grounds in the Rainy River. The sturgeon population has not recovered to date despite low harvest quotas for the Ojibway (2100 pounds for 1987). Ojibway fisheries were calculated to be 30% more productive than subsequent non-Ojibway fisheries for a similar length of time, without the mis-management that accompanied this latter fishery. There are plans by the Government to rebuild the sturgeon stocks in the Lake of the Woods.

HOLZKAMM, T.E., V.P. LYTWYN, and L.G. WAISBERG. 1988. Rainy River Sturgeon: An Ojibway Resource in the Fur Trade Economy. Can. Geogr. 32(3): 194-205.

The history of the sturgeon fishery on the Rainy River during the period of the fur trade and its effect on the Ojibway Indians is recounted. The depletion of this fishery by the end of the 19th century had a lasting impact on the welfare of the local peoples. Sturgeon were captured most easily during the spawning concentrations and traditional Ojibway methods such as spears, weirs and nets were effective. Spearing, weir construction and net fishing is discussed in some detail supplemented with excerpts from old literature sources. Nearly every part of the sturgeon was utilized by the Ojibway; the flesh and eggs (caviar) were consumed and the inner membrane of the swim bladder was processed and used as a source of isinglass in glues, paints and for fining alcohols. The isinglass trade was the most important byproduct of the sturgeon fishery and was developed as a profitable trade by the Hudson Bay Company, and reached a high of 3500 pounds during 1865-1869. The competition among American companies for sturgeon is documented and sometimes the native people were also able to control the terms of agreements. Treaty 3, signed between native Ojibway people and the Canadian government protecting the fisheries from outside exploitation is discussed and the gradual destruction of these fisheries, over the two following decades, by a changing government policy influenced by settlers, is described. As American and then Canadian commercial fishermen began exploiting Lake of the Woods sturgeon, harvest levels rose to over one million lbs of dressed fish. This overfishing contributed to the near extinction of sturgeon spawning runs in the Rainy river and the Ojibway sturgeon fishery now yields a very small harvest. The Euro-Canadian settlement is regarded as the single cause for the severe economic loss to the native Ojibway people.

HOPKINS, G.S. 1895. The enteron of American Ganoids. J. Morphol. xi: 411-439.

The author describes gut morphology of lake sturgeon (material from Knoxville, Tennessee), along with other ganoid fishes. The account begins with a brief description of the general organization and anatomical position of the total enteron. The alimentary canal is made up of two ascending and three descending portions, in the following order from the mouth to anus: oesophagus, stomach (pyloric portion muscular and thick walled), three pyloric caeca fused into an apparent single organ, intestine and spiral valve of the terminal portion. The oesophagus is characterised by the presence of fleshy papillar elevations and stratified epithelium which disappear shortly before the opening of the pneumatic duct. This is succeeded by a region of columnar epithelium extending uninterrupted to the pylorus. Contrary to previous reports on acipenserids, the columnar epithelium is described as overlapping the stratified epithelium, supporting the authors contention that the posterior portion of that segment of gut that most other authors have called oesophagus is in fact part of the stoma. The greater part of the gastric epithelium is ciliated with numerous, distally opening beaker cells interspersed amongst them; these are described in some detail. Gastric glands are of the cardiac and pyloric type.

*HOUSTON, J.J. 1984. Status of the lake sturgeon (Acipenser fulvescens) in Canada. Prepared for the Committee on the Status of Endangered Wildlife in Canada. 44p.

HOUSTON, J.J. 1987. Status of the lake sturgeon, Acipenser fulvescens, in Canada. Can. Field Nat. 101(2): 171-185.

Various aspects of the biology and population dynamics of lake sturgeon are reviewed. The species had been listed as endangered by CITES but was delisted in 1983. The decline of sturgeon fisheries is reviewed and various existing populations are compared. The author relies on personal communications for some important information. Manitoba is singled out for having (with the exception of Lake Winnipeg) a rela-

tively healthy lake sturgeon population, particularly in the Winnipeg river. The South Saskatchewan river has historically produced 75% of landings in Saskatchewan but overfishing and high mercury levels forced the closure of the fishery in 1969. It was reopened in 1973 in Cumberland Lake and Churchill River. The average weight of sturgeon caught in Alberta is said to be 14-22 kg, prior to 1940 when the fishery closed. It reopened in 1969 under stringent regulations and the present population is considered possibly healthy and similar to historical levels. Other information is from well known and accessible literature.

HUBBS, C.L. 1917. Acipenser fulvescens Rafinesque, the great lake sturgeon. Copeia 44: 48.

In this one page report, the author brings to notice that the first species designation of lake sturgeon as Acipenser fulvescens by Rafinesque (1817) had been overlooked in favour of the then more popular designation of A. rubicundus by Le Sueur (1818). The original 1817 description by Rafinesque is reprinted in whole.

JOLICOEUR, P. 1985. A flexible 3-parameter curve for limited or unlimited somatic growth. Growth 49(2): 271-281.

This paper describes the derivation of a simple 3-parameter asymptotic growth curve, $X = A/(1 + D/t^C)$ from the logistic curve, $X = A/[1 + D/\exp(Ct)]$, by replacing time (t) with its natural logarithm. This curve is more flexible than other curves of its kind (Gompertz, logistic) since it passes through the origin. This derived curve also shows better numerical convergence and has a variable inflection point. When growth appears unlimited, within the range of the data, the curve becomes similar to allometry with respect to time. Two sets of data, one from elephant seals and the other from lake sturgeon from Lac des Deux Montagnes of the Ottawa River, were used to illustrate the curve. Growth was found to be only marginally asymptotic for female lake sturgeon. The author considers it surprising that although the asymptotes are higher than the maximum length and weight observed in the present sample, they do not reach the maximum dimensions of the species. The present sample of lake sturgeon were from a population which did not include specimens older than 25 years.

JOLLIE, M. 1980. Development of head and pectoral girdle skeleton and scales in Acipenser. Copeia 1980: 226-249.

The author describes the development of the head and pectoral bones of Acipenser fulvescens and Acipenser ruthenus, based on cleared and stained specimens and serial sections. The stages are designated 0 (14 mm lake sturgeon) through to 9 (120 sterlet)and 10 (full grown sturgeon or sterlet). The description begins with the lateral line system. In the smallest (14 mm) specimens studied, the nasal capsule is undivided and the first line of the lateral line system is the temporal. This is followed by the formation of a closed ethmoid canal in stage 2 (14-15 mm) opening anteriorly and bilaterally on the snout. The various sensory structures, canals, and lines undergo modification as development proceeds. The large number of sensory organs, later appearance of the preopercular canal indicating a suppression of it, and the separate appearances of the two different sections (frontal and nasal) of the supraorbital canal are also noteworthy. Of the development of the cartilaginous elements of the head, five separate elements are chondrified in the hyoid arch in stage 0 sturgeon specimens. The development of the occipital region is unique and that of the neurocranium and palatoquadrates indicates great modification compared to other fish and any comparison to sharks is superficial. The formation of the snout bones is described and it is concluded that the characteristic ventral keel has no homology with the vomer of other fishes as could be supposed. The canal bones of the infraorbital line and the bones behind the eye are discussed, the latter arranged as in Amia or gars. Of the other head bones described, the dermosphenotic is reminiscent of the palaeoniscoids. Of the bones of the supraorbital line and the cranial roof, the bones of the intertemporo-supratemporal complex, parietal and nasal appear early, followed by the frontal and supraorbital. The bones of the occipital line, preopercular canal and those of the cheek are described and the status of "branchiostegal rays" is discussed. The bones of the mouth are uniqely developed. A premaxilla is lacking and the margins of the maxilla are closely related to the margins of the palatoquadrate. The maxilla along with its 8 teeth (4 on each side) form early (stage 0) and the teeth are gradually lost. The palatopterygoid possesses 4 teeth at stage 0 increasing to 15 by stage 4 (23 mm). The dentary is also present in stage 0 and its teeth increase in number to six initially and subsequently drop off as development proceeds. The prearticular is well developed in fully grown lake sturgeon but its absence in developing sterlet larvae is considered inexplicable. The endocranium is massive and entirely without ossification even in the oldest lake sturgeon studied. The elements of the pectoral girdle are described individually and differences are noted between the postcleithrum of the lake sturgeon and the sterlet, this bone being less exposed in the former. Some differences are noted in scute development between the lake sturgeon and sterlet. Variation in pattern of the roof bones in the head was noted among specimens of lake sturgeon, considered to be in accordance with such phenomena reported in Atlantic sturgeon. An abnormality due to confluence of anterior nasal openings in one specimen of lake sturgeon is discussed in relation to the development of associated bones.

JOLLIF, T.M., and T.H. ECKERT. 1971. Evaluation of present and potential sturgeon fisheries of the St. Lawrence River and Adjacent waters. New York Department Environment Conservation, Cape Vincent Fisheries Station. 113p.

This report describes the two year study begun in 1969 to determine the present and potential value of the St. Lawrence River sturgeon resources. The report is divided into three sections under Jobs I, II and III. Job I reviews the past and present sturgeon fisheries of the St. Lawrence River. Numbers of trap and bait lines were highest between 1923-1926, and steadily declined thereafter as did harvests (maximum of 23,500 lbs in 1923). Licenses increased to a maximum of 178 in 1949 and then decreased to 35 in 1963. Canadian harvest data for 1964-1969 indicates a decline over these years. Attempts to evaluate present sturgeon populations proved statistically difficult because of sampling problems which are discussed. It is suggested that the sturgeon population in the upper areas is much lower than in the area below Robert Moses dam. Sturgeon captured below the dam (N=139) ranged in age from 7-38 years and 80% of the fish were between 9 and 13 years old. Relationships between age (A), length (L) and weight (W) are given by the equations logW= -0.433 + 1.433-logA; logL= 1.070 + 0.422logA; and logW= 4.122 + 3.405logL. The youngest mature and ripe male was 9 years old. Stomach contents of three fish examined consisted of snails (Nitocris) in one case and packed full with alewives (Alosa pseudoharengus). A total of seven dams located on the St. Lawrence river and its five tributaries are believed to be the main causes of the decline in sturgeon populations and it is believed that lake sturgeon populations in the St. Lawrence river exist at a low level of abundance with a continuous decline. Some regulations are recommended to manage sturgeon stocks more adequately and include, among other measures, a closed season from 1 April-30 June, closure of sturgeon fisheries above and below Robert Moses dam for 15 and 25 years respectively, and increasing the legal harvest size to 54.4 inches (fork length). As an appendix (I), a summary of the Russian sturgeon culture program is presented.

KEMPINGER, J.J. 1988a. Spawning and early life history of lake sturgeon in the Lake Winnebago system, Wisconsin. Am. Fish. Soc. Symp. 5: 110-112.

Spawning behaviour and the early life history of the self-sustaining lake sturgeon population in lake Winnebago was studied. The spawning site at the Shawano dam on the Wolf river was chosen as the study area and the study spanned four years from 1981-1984. Fish spawned over boulders in rapid currents at the foot of the dam and preferred a shoreline with relatively strong current and shallow water. Six to eight males accompany one female and eggs run for 7-10 seconds, while the males vibrate simultaneously alongside the female. A spawning foray can consist of several such acts of egg release, following which the group dispersed into deeper waters. Spawning was observed to occur in two phases. Depending upon the year, the initial/peak spawning took place at water temperatures ranging from 8.3 to 16.1 C, and secondary spawning at water temperatures of 13.0 -23.3 C. Spawning may be interrupted by a drop in temperature, producing cold water fronts which caused the sturgeon to disperse. Females are said to spawn every 4-6 years while males spawn every other year. Eggs were randomly scattered during spawning, adhered to rocks and other available substrates, and were most abundant in fast flowing water. Eggs were eaten by crayfish, Necturus, Moxostoma, common carp and sturgeon. Other causes of mortality included fungus over-growth, sediment deposition and water level fluctuation. The data also indicates that the egg survival (to hatching) is better at shorter incubation times and a gradual warming of water during pre-spawning, spawning and post-spawning. Yolk-sac larvae were nocturnal drifters and nightly catch rates were nine times higher than daytime catches. A total of 1232 larval (8-898) sturgeon were netted over 4 years, 150 m downstream of the dam, ranging in length from 8-22 mm. Figures of various larval stages are provided. Larval stomach contents included baetid and chironomid larvae. Growth (in length) of the larvae was approximately linear up to 20 mm. The regression line slopes for the relationship between total length of larvae and their age varied significantly among years and indicated a direct proportionality with water temperature.

*KEMPINGER, J.J. 1988b. Early life history of lake sturgeon. Prog. Rep. Wis. Dept Nat. Res. Stud. 227: 79-112.

KILAMBI, R.V. 1968. Analysis of the growth of the Pacific herring (Clupea pallasii), lake sturgeon (Acipenser fulvescens) and white sturgeon (Acipenser transmontanus). Proceedings of the 21st Annual Conference S.E. Assoc. Game Fish Comm, New Orleans, Louisiana. 1967: 297-314.

The author discusses methods of assessing fish growth and outlines the equations developed by Von Bertalanffy and Parker-Larkin. Data for lake sturgeon were from Manitoba fish and the oldest fish was 55 years but length measurements were for the first 21 years only. Observed and predicted lengths agree well by the Parker-Larkin method but were underestimated by the Bertalanffy method. There are large annual size increments in the first six years and relatively constant increments thereafter.

KIRSCH, P.H., and M.W. FORDICE. 1889. A review of North American Acipenserids. Proc. Acad. Nat.

The taxonomy of sturgeon found in American waters is reviewed and six species are distinguished. A list of synonyms with their corresponding references is provided for each species. The lake sturgeon appears as Acipenser rubicundus Le Sueur, 1818. Twenty-six synonyms are listed for A. rubicundus, of which only one synonym, Dinectus truncatus Rafinesque, appears under a generic name other than Acipenser. Sixteen of the synonyms are after Dumeril (all from the same reference: Hist. Poiss. II, 1870), three after Agassiz (Lake Superior, 1850), one each after Richardson (Fauna Bor. Amer. 1836), Gunther (Cat. Fish. Brit. Mus. VIII, 1870) and Le Sueur (Trans. Am. Phil. Soc. 1818) while the remaining are after Rafinesque (Ichthyol. Ohiensis, 1820). A brief note follows on its habits. This is a valuable source for the early taxonomical literature on lake sturgeon and the interested reader is directed to it for minor references not annotated in this bibliography.

KOOYMAN, B. 1955. An analysis of dat collected in 1953 and 1954 from the sturgeon fisheries on the Nelson River and Churchill River. Manit. Dept Mines Nat. Res. Game Fish. Br. MS. Rep. 8p.

This is an interesting report with some historical data and good insights into the problems of over exploitation of lake sturgeon populations. For example, since 1920, 803,200 pounds of sturgeon were taken from the Nelson River and if each sturgeon had an average weight of 30 pounds this represents 27,000 fish caught. The author estimates that 20% were immature and the remaining 21,600 were adults. The author continues to extrapolate as follows; assuming there were 25,000 fish and there was a complete turnover of the population in 25 years that would mean a harvest of only 1000 fish/yr. These mature fish would average about 35 pounds which would mean about 22,500 pounds harvested anually. He goes on to suggest that a sustained harvest of 25,000 pounds was likely possible. The adult sturgeon population, as of 1955, is estimated to be 25% of its former strength and it is suggested that the current population could not sustain a annual harvest of 10,000 pounds. The Churchill River has a much younger population and this fishery could not sustain 10,000 pounds annually over the next 10 years. The general recommendations were that present production figures be reduced substantially, the individual size limit be increased to protect the immature fish and the season be set to allow spawning of females OR continue the harvest until the fishery becomes uneconomical and/or collapses. The final conclusion was to have the fishery continue until its collapse and collect population data on the lake sturgeon so that better management strategies could be developed for the future.

KORNELY, G.W. 1988. Lake sturgeon Creel Survey of the Menominee River Wisconsin-Michigan Boundary Water, 1981-1984. Bur. Fish. Manage. Wis. Dept Nat. Res., Madison. Fish Manage. Rep. 134: 20p.

This is a report of a creel survey of lake sturgeon along the Menominee River. A map outlines the main areas where hook and line fishing is allowed in the watershed and details of the Menominee River (including location of dams) are given. Lake sturgeon used to migrate from Green Bay up to Sturgeon Falls but dams now prevent any migration. A creel survey in 1969-70 between White Rapids and Grand Rapids concluded that exploitation was too high and the size limit of lake sturgeon was increased from 42 to 50 inches in 1974. A creel survey was done in 1981-82 and mandatory registration was begun in 1983. Fishing pressure was calculated for each category of day (weekday, weekend, opening day) as number of days x 12 hours x average angler count. Harvest rates were determined by the number of harvested lake sturgeon reported on the postcards divided by the total fishing hours and use of direct interviews. It was concluded that fishing pressure on lake sturgeon was substantially less than 10 years earlier. The study found that an angler who caught a legal sized sturgeon was more likely to return postcards than anglers who did not catch a sturgeon. The current harvest is about 20 sturgeon per year. It was felt that mandatory registration and law enforcement to ensure this would be a more accurate method of determining harvest.

KORNELY, G., and T. THUEMLER. 1989. Hook and line lake sturgeon fishery Menominee river Wisconsin, Michigan. Wis. Dept Nat. Res. MS Rep. 12p.

This study reports the results of the first seven years of a registration system instituted in 1983 on the Menominee River for lake-sturgeon fished there. The minimum size limit for lake sturgeon is 50 inches and a bag limit of two fish for one season which covers the period from the first Saturday of September to November 1. Approximately 66% of the harvest comprised of fish 50-54 inches in length and 10% of above 60 inches. The length-weight relationship was given by the formula LogW = -4.32 + 3.38 LogL. Fish reached 50 inches by 15 years although 67% of the fish were between 20-26 years and ranged 50-58.5 inches. The season fishing pressure has been steadily increasing. Wisconsin anglers account for 86% of the harvest of which 91% occurs in September.

KROON, E.L. 1984. Identification of bone projectile points fashioned by alteration of the caudal fulcra of sturgeon (Acipenser fulvescens). Mich. Acad. 17(1): 97-102.

This article addresses itself to the discovery of two specimens of modified lake sturgeon caudal fulcra projectile points recorded from the midden deposits from the Weiser Site (Adho 1) Kent County, Ontario, two similar ones from

the Reeve Village site in southern Ontario, and one from the Steward site in Dundas County, Ontario. In view of the scepticism with which the discovery was received by archaeologists, the article discusses the osteology of the sturgeon tail and the plausibility of the artifact reportedly fashioned from its bones. The V-shaped fulcra from the dorsal margin of the caudal fin of sturgeon are described in detail with an accompanying X-ray photograph and drawings of the fulcra. Of the 23 fulcra from the specimen (a 65 pound sturgeon) used by the author, 6 conformed to the shape of the recovered artifacts. Modifications to these fulcra involved shortening the basal prongs and sharpening the dorsal apex to remove a bulbous node. Both slender and thicker fulcra were used to fashion projectile points. An experiment was conducted to measure the efficacy of these fulcra as arrow heads by mounting them on short hardwood foreshafts and a longer hollow hindshaft made of dry cane reed, all of which were available locally, and firing the arrow with fibreglass (35 pound) and compound (85 pounds) bows. Results showed that at draw weights up to 85 pounds, this indigenously designed arrow equals the effectiveness of a modern hunting arrow. Lengths of the excavated fulcra indicated that they came from a lake sturgeon weighing approximately 85 pounds.

*LAMB, N. 1984. Lake sturgeon- on the way back. MO Conserv. 45(11): 4-7.

LARSON, T. 1988. The lake sturgeon fishery of Lake Wisconsin, 1978-1985. Bur. Fish. Manage. Wis. Dept Nat. Res. Fish. Manage. Rep. 136: 34p.

This study was aimed at determining the angler fishing pressure on Lake Wisconsin sturgeon and estimating the population and harvest yields. Angling characteristics for 1979 include a predominance of male anglers (94%) and 92.8% of the anglers were between 16-65. Estimates of the total population ranged from 8,000-23,000 depending on the methods used. The Peterson and multiple-recapture methods are compared and discussed with respect to sampling bias. The average rate of recruitment for 1979-81 was 23%. During the period 1983-85 the annual harvest between the Prairie du Sac and Wisconsin Dells dams was 73 sturgeon and the exploitation rate was estimated at 7.3%. The length-weight relationship was given by $\log L = -4.319 + 3.398 \log W$. The age-length equation was $l^t = 64.31(1-e^{-.0887(t+1.652)})$ and the condition factor increased with length. Analysis of movement showed that lake sturgeon moved randomly throughout the lake area. Sturgeon spawned in 50-51 F water and recaptures indicated a 30-40 mile spawning migration to and from the Wisconsin Dells dam. The method of weighing sturgeon by hanging from a rope by the caudal peduncle did not significantly increase mortality and neither did the practice of removing the leading pectoral fin-ray. Five fish >50 inches showed metal and pesticide levels well below detection levels but for PCB's, three of the fish were at or above the 2.0 ppm FDA tolerance level. Management recommendations include continued voluntary angler surveys and mandatory registration to assess catch and harvest, a reduced annual harvest limit of 50 fish, promoting trophy sturgeon fishing, monitoring for PCB levels, enhancing spawning sites and conducting a life history study to determine habitat characteristics for fingerling and yearling sturgeon.

LAUER, C. 1988. Identification of critical life history periods of lake sturgeon and factors that may affect population survival. Correspondence/Memo to District Manager Kapuskasing. 9p.

In this correspondence, the author hypothesises on the potential effects of hydroelectric installations (dams, etc) on lake sturgeon populations. In view of the paucity of information pertaining specifically to lake sturgeon, inferences are made from comparable studies carried out on Eurasian sturgeon. Direct impacts include fluctuating levels caused by controlled discharge by dams and blocking migratory routes. Critical periods such as overwintering, pre-spawning, spawning, and egg hatching are adversely affected by fluctuating water levels and water flow rates and consequently fluctuating temperatures. The importance of water current on spawning migration, spawning acts and downstream larval drift is discussed. Other environmental factors considered include low oxygen tensions coupled with increased temperature, nature of the substrate and prey community structure, water depths and turbidity.

LAWRIE, A.H., and D.J.F. RAHRER. 1972. Lake Superior: Effects of exploitation and introduction on the salmonid community. J. Fish. Res. Board Can. 29(6): 765-775.

The paper identifies the effects of industrial pollution, exploitation and introduction of exotic fish species on native fish populations of Lake Superior. While the focus is on the coregonids and salmonids, there are references to lake sturgeon that are of some interest. There is a reference to accounts of maintenance fisheries by native Indians during the early days of exploration of the region and the Jesuit Relation of 1669 is quoted as stating that a single fisherman would catch 20 large sturgeon in a net in one night. This is probably one of the first non-native records of lake sturgeon fishing on the North American continent. The lake sturgeon is one of few fish species that have yielded harvests as large as 250,000 pounds. The maximum harvest occurred during the first recorded season, in 1885 when 224,000 pounds were taken. Production declined at an average rate of 9% per annum until 1920 after which harvests exceeded 10,000 pounds only three times. The inability of lake sturgeon to withstand high fishing pressures is

attributed to its low biotic potential. Habitat destruction by discharges from the lumbering industry is also stated to have caused the collapse of this fishery. A graph illustrates this decline.

*LAWSON, K. 1983. Biology, age, growth and angler harvest of lake sturgeon (Acipenser fulvescens) of the Groundhog and Mattagami rivers, 1982. Ontario Ministry of Natural Resources, Kapuskasing District MS Rep. 49p.

LEACH, J.H. and S.J. NEPSZY. 1976. The fish community in Lake Erie USA Canada. J. Fish. Res. Board Can. 33(3): 622-638.

The fish community of Lake Erie is discussed in view of historical changes in the environment of the lake and the effect of commercial fishing. Although this lake is considered as having the largest number of fish species of the Laurentian Great lakes, there have been drastic changes in the structure of the native fish communities. A number of fishes including the lake sturgeon have virtually disappeared due to over-fishing and pollution. The draining and filling of bordering marshland is stated to have reduced spawning areas of species such as lake sturgeon. The environmental changes including changes in fishing methods are reviewed and historical accounts are provided of the more important fishery species including the lake sturgeon. This species, considered abundant during the late 1800's was first fished out and dumped and later commercially exploited to near extinction. The alteration of habitat is also seen to have contributed to the decline in native sturgeon populations.

LEE, D.S., C.R. GILBERT, C.H. HOCUTT, R.E. JENKINS, D.E. McALLISTER, and J.R. STAUFFER JR. 1980. Atlas of North American Freshwater Fishes. N. C. Biol. Surv. Fish. Publ. 1980-12. p. 39.

A one page account of the lake sturgeon is provided with short sections on type locality, systematics, distribution and biology. A map of its distribution is included.

LELEK, A. 1989. Threatened fishes of Europe. AULA-Verlag, Wiesbaden. 322 p.

Data on the status of acipenserids in Europe used in Table 1 of this bibliography was obtained from this volume of the series edited by the European Committee for the conservation of nature and natural resources-Council of Europe.

LENZ, C.B. 1970. Sturgeon challenges Wisconsin spearmen. Then and now. State Hist. Soc. Wis. Publ. 16: 2-3.

Spearing sturgeon in Wisconsin waters has not changed much from the days of the Menominee and Chippewa (Ojibway) Indians. In the early days sturgeon were speared during spawning in the rivers but were also speared from canoes at night using torchlight. Sturgeon were also speared through the ice by using a weighted wooden decoy fish. Today one needs a spearing license as well as a valid hook and line fishing license. Tags are furnished with each license and must be locked to the tail of the sturgeon and the sturgeon must be transported "openly visible". Type of equipment for fishing and costs are outlined. There is also a brief discussion on the biology of the lake sturgeon.

LESUEUR, C.A. 1818. Description of several species of chondropterygious fishes. Trans. Am. Philos. Soc. 1: 388-394.

The lake sturgeon is described in considerable detail as a new species Acipenser rubicundus. The type specimen was four feet long with Lake Erie and Lake Ontario as the type localities. Two other varieties are described, one from the lakes mentioned above and the other from the Ohio River. The author mentions that it is eaten by the Indians but not widely sought after for the table. The paper also contains descriptions of A. brevirostrum and A. maculosus. A. maculosus was subsequently synonymized with A. rubicundus by Kirsch and Fordice (1889, see in this bibliography). LeSueur does not mention Rafinesque's brief description of lake sturgeon nor its naming as Accipenser fulvescens only a year before (Rafinesque, 1817).

LINDBERG, G.V. 1967. Order Acipenseriformes, p. 30-34. In Fishes of the Sea of Japan and the adjacent areas of the Sea of Okhotsk and the Yellow Sea. Academy of Sciences, Moscow, USSR.

Three species of Acipenser are discussed and a key is provided for them. The description of A. multiscutatus is incomplete and could not be used in the key to the world species of acipenseriforms that precedes the bibliography.

LORD, J. 1984. The kids ate caviar. The story of Manitoba's mighty sturgeon.....then and now. Nat. Can. (Ott.) 13: 19-22.

This informal account tells the history of sturgeon in Manitoba, relying on interviews with old-timers like Art Wold who recounts the prewar days when sturgeon were relatively common and so was poaching. Apparently conservation officers were not strict. Art Wold also recounts the making of caviar from lake sturgeon roe and the rich taste of sturgeon flesh, considered tastier than even the famed goldeye. The familiar story of overfishing leading to extirpation in parts is also narrated with some statistics. The author interviews resource biologist Jo Sidgurson who is surprised to find a healthy sturgeon population in the Winnipeg

river. Some anecdotal information about the strength of lake sturgeon and its larger relatives is also provided.

LOVE, G.F. 1972. The lake sturgeon (Acipenser fulvescens) of Lake Nipissing - 1971 study. Ontario Ministry of Natural Resources. MS Rep. 16p.

This report succeeds the preliminary report on lake sturgeon of Lake Nipissing. A total of 133 sturgeon were sampled during the 1971 season of which 132 were legal size (25 inches commercial length). The average length was 53.7 inches and the average weight (from 116 fish) was 37.1 pounds. Females (92) had an average age of 23.3 years (12-51) and males (34) 21.3 years (11-51 years). A dressed sturgeon lost approximately 33.4% of its whole weight. The male-female ratio was 1:3 and 41 (31.1%) of the legal sized fish had never spawned. It was statistically shown that the last narrow annulus in each belt of narrow annuli denotes a spawning year. Males first spawned between 10 and 20 years (average 14.8) and females between 12 and 22 years (average 16.5 years). Female sturgeon are said to spawn every 6 years. Spawning sturgeon were reportedly seen from May 27 - June 15, 1972 below the Sturgeon Falls dam. It is hypothesized that strong year classes result in fish of that particular year class maturing and entering the fishery together so as to produce a sizeable spawning population and a good harvest year. Of the 22 stomachs examined for food items, 10 had only crayfish, 7 had aquatic vegetation and 5 had a variety of items including mayfly larvae and numerous small perch and unidentified worms. It is pointed out that under current size existing regulations, nearly 1/3 of the sturgeon harvested have not spawned for the first time. There is evidence of spawning below the Abitibi dam and possibly elsewhere. It is possible that spawning migration occurs early, sometime in April, when the ice is off the river. It is recommended that the legal size limit be raised from 25 inches to 30 inches to enable females to spawn once before harvesting. This may result in a 15% profit cut for fishermen but is considered to be of long term benefit to fisheries.

MACKAY, H.H. 1963. p. 31-38. In Fishes of Ontario. Ontario Department of Lands and Forests, Toronto. 300p.

The lake sturgeon is the largest of the native fishes in Ontario. A general account is provided of the natural history of this fish with information gleaned from referenced sources. There is a relatively rare drawing of a sturgeon otolith. Graphical representations of commercial sturgeon harvests from Lakes Superior, Ontario, Erie and Huron show similar trends; a near perpendicular increase in yields to a peak over a very short period (5-10 years) since fishing began followed by a steep decline to negligible levels within the next 20 years. It is suggested that the Eurasian freshwater sturgeon Acipenser ruthenus could be introduced into selected Ontario rivers as a future target for fisheries.

*MACRITCHIE, I. 1983a. Rationale and recommended sturgeon quotas for large rivers in the Cochrane District. Ontario Ministry of Natural Resources. MS Rep. 12p.

*MACRITCHIE, I. 1983b. Towards a river fish productivity estimator. The Frederick House River Experience. Ontario Ministry of Natural Resources. Cochrane District. MS Rep. 14p.

The University of Manitoba "Interlibrary Loans Section" informs us that they have exhausted all possible locations for this item.

MAGNIN, E. 1962. Reserches sur la systematique et la biologie des Acipenserides, Acipenser sturio L., Acipenser oxyrhynchus Mitchill et Acipenser fulvescens Raf. Ann. Stn Cent. Hydrobiol. Appl. 9: 7-242.

This is a review on the systematics and biology of three species of sturgeon, A. sturio, A. oxyrhynchus, A. fulvescens. A. fulvescens is a well defined species but although the former two are less well defined the author concludes that they are two separate species. The growth of the three species of sturgeon are similar and a cross section of the fin ray is a good method of determining age. Growth of all acipenserids continues throughout their life but growth decreases after reaching sexual maturity. There is considerable variation in growth of sturgeon among individuals and geographical regions but freshwater sturgeon grow slower. Young A. oxyrhynchus migrate to salt water (estuarine water) whereas A. fulvescens are much more sedentary. Acipenserids feed primarily on benthic invertebrates but the proportions of the major food items will vary depending on the location and sturgeon that feed in the ocean utilize polychaetes as food. Fish are also eaten by sturgeon. A review of the literature was done to determine the properties of acipenserid plasma concerning minerals and how these values related to other species of fish, especially salmonids. Age to maturation for A. sturio is 18 to 20 years for other species of fish, especially salmonids. Age to maturation for A. sturio is 18 to 20 years for females and 14 to 15 for male at Gironde; 27 to 28 for females and 22 to 24 for males of A. oxyrhynchus in the St. Lawrence River and 21 to 22 for females and 17 to 18 for males of A. fulvescens in the St. Lawrence River. Using histological methods the author established five stages of maturation of the gonads for females and males.

MAGNIN, E. 1964a. Croissance en longeur de trois esturgeons d'Amerique du Nord: Acipenser oxyrhynchus Mitchill, Acipenser fulvescens Rafin-

esque et Acipenser brevirostris Le Sueur. Int. Ver. theor. angew. Limnol. Verh. 27: 968-974.

This study deals with the growth in length of the lake- and Atlantic- sturgeon for the first time from the St. Lawrence waterway and short-nose sturgeon from New Brunswick in Canada. The outstanding feature of the results obtained from age-length relationships is the slow growth of all these sturgeons. The lake sturgeon is considered the longest lived of the three species. The annuli in the pectoral fin ray sections of lake sturgeon are clear and regularly spaced unlike the Atlantic sturgeon where the annuli are often interrupted by secondary growth areas. This difference is attributed to the anadromous migration of the Atlantic sturgeon. There is a brief discussion of the participants at the presentation following the article.

MAGNIN, E. 1964b. Premier inventaire ichthyologique du lac et de la riviere Waswanipi. Nat. Can. (Que.) 91 (11): 273-280.

This report deals with the first inventory of fish in Waswanipi Lake and River and was done during May 23 to June 28 1963. The One hundred and fifty six lake sturgeon collected made up 7.36 % of the total catch and had an average length of 72.7 cm and an average weight of 28.75 kg. A length weight relationship and a length frequency distribution is given for lake sturgeon. A map of the watershed and sample areas is included.

MAGNIN, E. 1966. Reserches sur les cycles de reproduction des esturgeons, Acipenser fulvescens, Raf. de la riviere Nottaway tributaire de la baie James. Trav. Biol. Univ. Montreal 14: 1018-1024.

The reproductive cycle of the lake sturgeon in the Nottaway River is presented. Data was collected from two groups for a total of 119 sturgeon, captured during and after spawning. Histological examination of the gonads determined the stage of development. Various stages of oocyte development are described. Immediately after spawning the gonads are very thin (2 cm diameter) with prominent transverse lamina. The ovary displays numerous large resorbing unovulated eggs and many smaller oocytes (300 - 500 um diameter). The early (second stage ?) oocytes are un-pigmented yellowish, 1-1.8 mm in diameter and the cytoplasm is made of 5 distinct strata with the nucleus interior-most in position. These oocytes contain very small amounts of yolk granules. Stage III eggs are larger 2-2.7 mm in diameter, pigmented greyish-black in colour, and contain three layers of yolk. The author feels that the transition from Stage II to III takes more than a year and a further year to reach stage IV. The eggs of stage IV are slightly larger (2.5-2.7 mm) but not noticeably different from stage III eggs in terms of appearance. The change is considered to be rather one of internal reorganisation. The nucleus shifts to the animal pole. The author interprets the data to indicate spawning every six years for lake sturgeon of the Nottaway basin. The morphology and gross histology of the testes of active males are described. It is concluded that males spawn every two years. The authors also indicate that spawning frequency in females decreases with more northern latitudes but remains constant in males.

MAGNIN, E. 1966. Croissance de l'esturgeon Acipenser fulvescens Raf. vivant dans le bassin hydrographique de la riviere Nottaway, tributaire de la baie James. Trav. Peche. Que. 11: 193-204.

This is a report of a study on lake sturgeon from the Nottaway river and basin in Quebec. A total of 316 sturgeon from eight lakes and the confluence of two rivers were collected from 1961 to 1963. Over 50% were recovered from Lake Waswanipi. The average length of sturgeon ranged from 34.0 to 142 cm and weight ranged from 0.195 to 21.25 kg over a range of age from 3 to 85. Sturgeon from Waswanipi and the St. Lawrence region were compared and the sturgeon from the St. Lawrence were larger and longer over ages from 3 to 50. Differences between the two populations of fish was most pronounced for weight.

MAGNIN, E. 1966. Quelques donnees biologiques sur la reproduction des esturgeons, Acipenser fulvescens Rafinesque de la riviere Nottaway, tributaire de la baie James. Trav. Peche. Que. 13: 257-263. [and in Trav. Biol. Univ. Montreal, 7: 257-263.]

Two hundred and sixty three sturgeon were examined from the Nottaway River system during June 1963. A map is given of the region indicating the sampling sites and the location of numerous rapids which were thought to be possible spawning sites. The sturgeon were separated based on length and age class. Immature females ranged from 60-100 cm in length and 13-23 in age whereas mature females ranged from 80-130 cm in length and 17-28 in age. Immature males ranged from 60-95 cm in length and 13-21 in age whereas mature males ranged from 70-130 in length and from 15-30 in age. The oldest female collected was 80 years and the oldest male was 55 years of age. Sturgeon could not be sexed until age nine. Spawning began in early June and lasted until the end of June.

MAGNIN, E. 1967. Reserches sue les cycles de reproduction des esturgeons Acipenser fulvescens Raf. de la riviere Nottaway, tributaire de la baie James. Trav. Peche. Que. 16: 1018-1024.

This study deals with the reproductive cycle (gonad histology) of sturgeon collected from the Nottaway River during the months of June and August 1962. One hundred and nineteen

sturgeon, 62 males and 57 females were examined. The age of these fish were 20 to 23 for the females and 18 to 22 for the males. Gonadal tissue was collected and fixed with Bouins for histological examination to determine the stages of development. Female sturgeon from the Nottaway system were thought to spawn every six years which was the same as for sturgeon from Lake Nipigon. By comparison females spawn every four years in Minnesota and every 4 to 5 years in the St. Lawrence. Males were reported to spawn every 2-3 years.

MAGNIN, E. 1977. Croissance, regime alimentaire et fecondite de esturgeons Acipenser fulvescens Rafinesque du bassin hydrographique de la Grande Riviere (Quebec). Nat. Can. (Que.) 104(5): 419-427.

This a report on lake sturgeon from the Grande River Basin of Quebec. One hundred and twenty-seven sturgeon were collected and their age determined using pectoral fin ray sections. Ages ranged from 20 to 38, length varied from 721 mm to 1,080 mm, and weight ranged from 621 g (age 13) to 7,220 g at 38 years of age. The main food items were Pelecypoda (29%), Ephemeroptera (23%), Mollusca (15%), larval Trichoptera (12%), and larval Diptera (11%). Growth in length and weight of lake sturgeon from the St. Lawrence River, Lake Waswanipi were compared and growth of sturgeon from the Grande River basin was the slowest with growth of sturgeon from Waswanipi being intermediate.

MAGNIN, E., and G. BEAULIEU. 1960. Deplacements des esturgeons (Acipenser fulvescens et Acipenser oxyrhynchus) du fleuve Saint-Laurent d'apres les donnees du marquage. Nat. Can. (Que.) 87: 237-252.

This paper deals with a mark-recapture study on the St. Lawrence river from Three Rivers to Montmagny. Two thousand seven hundred and eighty fish were marked. Most of the yellow sturgeon tagged and recaptured were in the size range from 40 to 89 cm. The largest was in the size class 140-149 cm. Young sturgeon moved distances that did not exceed 48 km and usually moved less than 16 km.

MAGNIN, E., and P.P. HARPER. 1970. La nourriture des esturgeons Acipenser fulvescens de la Riviere Nottaway, tributaire de la Baie James. Nat. Can. (Que.) 97: 73-85.

The stomach contents of 55 lake sturgeon were collected from the Waswanipi River and Lake during the period May 23 to June 28, 1963. The main food items were benthic invertebrates of larval insects belonging to the Trichoptera, Ephemeroptera, Diptera, Plecoptera, and Odonata. The Ephemeroptera were less frequent in young (3-5 years) and older (20-46 years) sturgeon. Mollusca were found in only seven of the stomachs examined but were the main food item in these individuals. The frequency of molluscs in the diet was much higher in older fish 20-46 years of age. Differences in diet between young and older sturgeon appeared to be primarily due to the type of habitat utilized.

MASUDA, H., K. AMAOKA, C. ARAGA, T. UYENO, and T. YOSHINO. Fishes of the Japanese archipelago. Tokai Univ. Press. Tokyo.

Photographs (in plates) are accompanied by brief descriptions of the species of sturgeon. Five species are recognized from the Japanese archipelago.

McALLISTER, D.E., and B.W. COAD. 1974. Fishes of Canada's National Capital Region. Can. Nat. Mus. Nat. Sci. Misc. Spec. Publ. 24: 36-37.

This brief account contains an original description based on eight specimens. The authors suggest that the lake sturgeon invaded the Ottawa river basin from a Mississippian refugium via the lower Great Lakes and St. Lawrence River.

McALLISTER, D.E., and E.J. CROSSMAN. 1973. A guide to the freshwater sport fishes of Canada. Can. Nat. Mus. Nat. Sci. Nat. Hist. Ser. 1: 20p.

A brief (one paragraph) account of the size, distribution and comments of its general biology is offered. A diagram of the sturgeon and a map showing its distribution is provided.

MECOZZI, M. 1988. Lake sturgeon (Acipenser fulvescens) Wis. Dept Nat. Res. Bur. Fish. Manage. PUBL-FM-704 88. 6p.

The distribution, habits and habitat, life cycle, identification, fishing methods and environmental concerns relating to lake sturgeon are discussed with special reference to Wisconsin waters. Spawning is stated to be dependent upon water temperature and flow and does not begin until water temperatures reach 58-59^{o} F if the flow is low or 53^{o} F if the flow is high. Males reach maturity at 15 years and usually spawn alternate years, while females mature at 24-26 and spawn at 4-6 year intervals. Diagrams point out the difference between it and Wisconsin's other acipenserid, the shovel nosed sturgeon. It is illegal to sell the flesh and roe of lake sturgeon in Wisconsin. PCB's in sediment, where sturgeon feed, are of greatest concern as these fat soluble chemicals are easily absorbed and concentrated in the fat rich flesh of this fish. The state's Department of Natural Resources issues warnings to anglers against PCB-contaminated sturgeon.

MEEHAN, W.E. 1909. Experiments in sturgeon culture. Trans. Am. Fish. Soc. 39: 85-91.

The failure of early attempts to obtain ripe male and female sturgeon and hatching eggs is mentioned. The report deals with efforts at hatching shortnosed sturgeon from the Delaware river, but in the discussion that follows the relevance to lake sturgeon culture is discussed. The eggs of lake sturgeon, it is pointed out, are lighter in colour than those of shortnosed sturgeon. Efforts are underway to gather large lake sturgeon into ponds as had been done with the shortnosed species.

MEYERS, L.S. 1982. Lake sturgeon population--upriver lakes (Poygan, Winneconne, Butte des Morts), 1979-1981. Wisconsin Department of Natural Resources Intra-departmental memo. 7p.

The lake sturgeon population of the lakes mentioned in the title were sampled during the fall seasons of 1979, '80 and '81, using gill nets. The objectives were to assess the population size of sturgeon $\geq$ 45 inches (legal size) and those under this size, movement of the fish and tag retention. The catches for 1979, '80 and '81 were 152, 595 and 131 sturgeon respectively. In all three years, the average size of the fish was 38 inches. The population estimates based on the 7.5-8 inch mesh gill nets was 9,059 for 1980 and 10,824 for 1981. However, since this mesh size did not adequately sample legal sized fish or fish under 30 inches, the population estimate is highly conservative. Management recommendations include the use of a variety of mesh sizes to sample the entire population and establishing a quota system on the upriver lakes.

MEYERS, L.S. 1983. Lake sturgeon population-Upriver Lakes (Poygan, Winneconne and Butte des Morts), Winnebago County, 1982-1983. Correspondence from L.S. Meyers to District Director, Green Bay. 3p.

The lake sturgeon population of the lakes mentioned in the title was sampled by 8-, 10-, 12- and 14- inch mesh gill-nets during October, 1982 and 1983, and 136 lake sturgeon were captured. The lengths ranged from 23-67 inches with a binomial distribution. Nine of these were recaptures from tagging in 1979-1981. Based on the 8-inch gill net catch, the population size was estimated at 12,600. The lake sturgeon population appears to be increasing.

MICHIGAN STATE BOARD OF FISH COMMISSIONERS. 1890. In 9th Biennial Report, Lansing, MI. p. 44.

This report introduces the lake sturgeon as once despised but having become one of the most valuable fishes of the rivers and great lakes of the state. Sturgeon are reported as being taken principally by pound nets and set lines. The report recounts the first efforts of the board to artificially propagate this species, starting with experiments in the summer of 1889, at Algonac on the St. Claire river which was already the site of a caviar factory (Neilson & Co.). Milt from one male sturgeon was squeezed from the ripe gonads into a shallow (4 inch deep) tub and eggs allowed to run from females that were slit open and held over the tub. Half of the estimated 40,000 eggs were considered fertilized. Two days later a fungus appeared and spread rapidly over the incubating eggs. Hatching commenced from "good" eggs from day 9 onwards and on day 12, 8,000-12,000 hatched sturgeon were released into the river. The report also mentions, possibly the first successful artificial sturgeon hatching experiments in this country in 1876, at New Hamburg on the Hudson river. Approximately 20,000 eggs were used and "140,000" sturgeon hatched. The latter number is obviously an error and is probably 14,000.

MICHIGAN STATE BOARD OF COMMISSIONERS. 1895. Sturgeon. In 11th Biennial Report, Lansing, MI. p. 28.

Sturgeon hatching experiments of 1893 and 1894 are reported. During the 1893 season, 450,000 young sturgeon were hatched and released into the Detroit river. Hatching stations were set up at Michigan Central railway bridge and at Clarke's Point on the Detroit River. Set lines were used to capture sturgeon at the first station and no running females were obtained. At Clarke's Point, where seine nets were used to capture sturgeon, running females were obtained, eggs of which were used in artificial propagation experiments resulting in the hatching and release of 130,000 fry that year. It is concluded that methods of capture such as grappling result in ripe and running females expelling most of their eggs during the struggle for freedom. The subsequent relaxation allegedly allows water to enter the vent rendering the remaining eggs infertile. It is recommended that seining be used in future to secure running females for all artificial propagation experiments.

MICHIGAN STATE BOARD OF COMMISSIONERS. 1899. Report of Statistical Agent, C.H. Moore. In 13th Biennial Report, Lansing MI. p. 22-26.

This is a report on the commercial fisheries of Michigan during the 1896 and 1897 seasons. The decline in lake sturgeon catches in Michigan waters from 831,606 pounds in 1891 to 184,881 pounds in 1897 (commercial value of $9,640.19) is noted. It is also observed that during this period the sturgeon became, from a fish of lowest market value to "one of the most profitable fish" in Michigan. This is attributed to the value of their cured and smoked flesh and the caviar made from their roe. The common practice of capturing these fish by bottom set-lines and hooks is considered "barbarous", resulting in fatal and long-lasting injuries. The capture of sturgeon as small as two pounds in weight is, by personal experience of the author, common in the state and according to

him "should not be tolerated". The tables following the text of the report gives details of the lake sturgeon yields by district. The total lake sturgeon yield for 1896 is 224,920 pounds worth $ 9,965.56 c. The total caviar yield for 1896 was 38,399 pounds worth $ 7,518.06 c and 44,119 pounds worth $9,663.35 c. The report ends in a warning about the inevitable doom of commercial fisheries if immature fish are wantonly captured.

MIDGALSKI, E.C. 1962. Angler's guide to the freshwater sport fishes of North America. Ronald Press Company, New York. p. 92-96.

A general account is provided of the biology and life history characteristics of the lake sturgeon. Anecdotal information from old-time sturgeon fishermen is recounted.

*MILLER, M.D., and R.R. ANDREWS. 1972. An investigation into the sport fishery of Nutimik Lake, summer 1968. Manit. Dept Mines Res. Env. Manage. Res. Br. MS Rep. 72-17. (Pagination unknown).

MONGEAU, J.-R., J. LECLERC, and J. BRISEBOIS. 1982. La dynamique de la reconstitution des populations de l'esturgeon jaune Acipenser fulvescens du Lac des Deux Montagnes, Province de Quebec, de 1964 a 1979. Rapp. Tech. Queb. Minist. Loisir Chasse Peche. 6-33: 1-194.

MOREAU, G, and L. LEGENDRE. 1979. Relation between habitat and fish populations attempt at defining a numerical method for Northern Rivers. Hydrobiologia 67(1): 81-87.

This paper describes the relationships between various species of fish in the downstream sections of the Nottaway, Broadback and Rupert rivers of Northern Quebec. A total number of 18 species of fish are identified of which 11 are not abundant. Six types of habitat are identified by linkage clustering based on physical characterisation of 163 sampling locations using characters such as depth, current, water transparency, bottom substrate type and aquatic vegetation. This was followed by a multiple discriminant analysis between the six groups of stations using abundances of the different species. Three species, lake sturgeon, pike and walleye (pickerel), were characteristic of the second discriminant function (second axis) and these discriminated stations showed differences in the interaction between vegetation and current velocity.

MOSINDY, T.S. 1987. The lake sturgeon (Acipenser fulvescens) fishery, of the Lake of the Woods, Ontario. Ont. Fish. Tech. Rep. Ser. 23: 48-56.

The collapse of the lake sturgeon fishery in the Lake of the Woods is reviewed. There were no gear restrictions by the U.S. fishery, other than prohibiting gill nets, until 1895. Thereafter regulations restricted the licensee to initially a maximum of 50 pound nets which decreased to six per licensee in 1925. The Canadian fishery was restricted from the start to one pound net and 914 m gill net per license holder. Within one decade (1893-1903), the sturgeon catch declined by 95% and the fishery became virtually non-existent by 1930. Overfishing thus was the major reason for the collapse. Mismanagement was evident on both sides of the border. During the peak of the catch in the beginning of this century, a recommendation by the International Fisheries Commission to curtail all sturgeon fishing for four years too allow stocks to rebuild was not implemented. The lack of minimum size regulations left immature sturgeon unprotected and the decline in caviar production reflects the loss of mature fish from the population. The pulp and paper industry and the construction of a hydroelectric dam at the outlet of Rainy lake (Rainy river) that were set up following the period of maximum exploitation proved disastrous to any chances the remaining sturgeon population might have had to rebuild their stocks. Waste effluent from the mills contributed to the documented decline of at least two other fish species in the region (walleye and longnose sucker) and the loss of prime spawning ground of sturgeon is blamed on this industrialization. Problems were compounded by agricultural development which increased runoffs into natural waterways. A sturgeon fishery still exists in one part of the lake and the majority of the catch comes from fishing lots 47 and 57 and from a native fishery at Manitou rapids. Only gill nets are now in use and licensed sturgeon fishermen are restricted to a maximum of 1,850 m of net and a minimum dressed length of 58 cm. Since 1984 the total annual sturgeon quota for the Ontario part of the lake is 4,545 kg and the Rainy river fishery has an annual quota of 1,275 kg. The reduction of effluent from the paper industry has reportedly had an impact on reproductive success as evidenced by an increase in the number of younger fish caught. Compared to other populations in northern Ontario, the Lake of the Woods population seems to be faster growing. The age of sexual maturity for this population remains unknown.

NASH, C.W. 1908. Vertebrates of Ontario. Department of Education, Toronto. 107p.

The lake sturgeon is briefly described with a short note on its distribution and biology. The commonly held view by fishermen that two forms of the freshwater sturgeon exist is attributed to age related morphological differences among individuals and it is affirmed that only one species, the lake sturgeon, occurs in Ontario waters. The species is said to spawn from the end of May to the beginning of July.

NIEUWENHUYS, R. 1974. Topological analysis of the brain stem; a general introduction. J. Comp. Neurol. 156(3): 255-276.

This paper discusses the protocol for a project to analyze the brain stems of 12 representative vertebrates using the topological method. The lake sturgeon is chosen as a representative of the chondrosteans. The article starts with a review of the literature of brain stem anatomy. Due to the arrangement of the stem into longitudinal columns, the actual number, cellular content and organization and delimitation of these zones are difficult to follow in cross-section. Consequently the author introduces the procedure of topological analysis (expounded in an earlier paper) to resolve problems in three dimensional interpretation of the anatomy. It is proposed that the brain stems of each of these species will be subjected to the analysis and the results compared for similarities and phylogenetic affinities.

*NOWAK, A.M. 1984. Status of the lake sturgeon fishery lower Groundhog River, Kapuskasing District. Ontario Ministry of Natural Resources, Kapuskasing Dist. MS Rep. 67p.

NOWAK, A.M., and C.S. JESSOP. 1987. Biology and management of the lake sturgeon (Acipenser fulvescens) in the Groundhog and Mattagami rivers, Ontario. Ont. Fish. Tech. Rep. Ser. 23: 20-32.

The population was estimated at 8,492 fish with a corresponding annual production of 4,648 kg/-hectare/year. The growth rate was fastest in the Groundhog river population. Earliest observed ages of maturity for males was 19 years and for females 22 years; ages ranged from 9 to 49 years and the sex ratio was 1:1. Mean concentrations of mercury in fish from the Groundhog and Mattagami populations were 0.11 ppm and 0.17 ppm respectively. Fish movements of upto 22 km upstream and 24 km downstream were recorded. Sport fishing catch equals or exceeds production at the present exploitation rate of 5%. Alternatives suggested to improve stock conditions include creating a fish sanctuary, placing constraints on sport fishing and imposing a slot limit on all sturgeon.

*NOWAK, A.M. and I. MACRITCHIE. 1984. A study of the Frederick House River, Cochrane District, 1981-1983. MS. Rep. Ontario Ministry Natural Resources, Cochrane. (Pagination unknown).

OLVER, C.H. 1987. Introduction to the proceedings of a workshop on the lake sturgeon (Acipenser fulvescens). Ont. Fish. Tech. Rep. Ser. 23: p. 1.

This short editorial note introduces the proceedings of the lake sturgeon workshop which was held on February 27 and 28, 1986. It is mentioned that most of the presentations focused on the biology and management of sturgeon in Ontario. The editor also reports that following the presentations, three working groups were formed to discuss management pertaining to sport- and commercial fishing and enforcement.

ONO, R.D., J.D. WILLIAMS, and A. WAGNER. 1983. p. 29-33 & 232-233. In Vanishing fishes of North America. Stone Wall Press Inc.

The general biology and habits of the lake sturgeon and the history of it's exploitation is described without specific references to sources of information. The lake sturgeon is described as a threatened species.

*ONTARIO MINISTRY OF NATURAL RESOURCES. 1985. A lake sturgeon yield study on the Kenogami River. Geraldton District. Prepared by Ecologists Ltd. 47p.

*ONTARIO MINISTRY OF NATURAL RESOURCES. 1986. A sturgeon Bibliography. 2nd. Edition, Geraldton District, Prepared by Ecologists Ltd. 52p.

*ONTARIO MINISTRY OF NATURAL RESOURCES. 1986.A lake sturgeon yield study on the Kenogami River. Year 2. Geraldton District. Prepared by Ecologists Ltd. 77p.

*ONTARIO MINISTRY OF NATURAL RESOURCES. 1986. Incidental fish species caught in the Kenogami River, 1985. Geraldton District. Prepared by Ecologists Ltd. 70p.

*ONTARIO MINISTRY OF NATURAL RESOURCES. 1987. A lake sturgeon yield study on the Kenogami River Year 3- Phase I Report. Geraldton District, Prepared by Ecologists Ltd. 58p.

A three year study was carried out to determine a yield model for lake sturgeon in the Kenogami River. Three separate study areas, Kapeesawatan, Ogahalla and Mammamatawa were examined. The first two sites yielded very small numbers of sturgeon. The Mammamatawa sample yielded 509 fish, 477 of which could be aged. Fish were 2 - 58 years old (mean 14.6 years). Total annual mortality was estimated at 2.8%. The length-age relationship is expressed by the equation TL (Total length) = 2.291(Age) + 29.26 (after age 2) and the age-weight relationship is given by $WT = 23.16(Age)^{1.473}$; the weight-length relationship was $WT = 0.0015(TL)^{3.26}$. Of the 85 sturgeon checked for sex, the male:female ratio was 1:0.47. The overall sex ratio for the Kenogami River sturgeon was 2 males : 1 female. Of the food items analyzed from stomach contents, crayfish accounted for 60.37%, clams for 6.64%, dragonflies for 5.18% and caddisflies for 7.34% of the volume of the contents. How-

ever, dragonflies and crayfish occurred with the highest frequency (53.33% for both), followed by caddisflies (46.67%), stoneflies (35.56%), mayflies (33.33%), dipterans (-22.22%), snails (15.56%) and clams (13.33%). When sturgeon reach 80 cm, they actively select crayfish as food. The shorthead redhorse (Moxostoma macrolepidotum) was identified as the only fish with a diet similar enough to lake sturgeon to be a potential competitor. Males were found to mature 20-25 years and females at 25-31 years. The mouths of the Little Ash River, the Pagwachuan River and the Kabinakagami River were identified as spawning areas. Sturgeon moved downstream in the fall to inhabit deeper areas over winter and upstream during summer. The population was estimated at 640 - 3,432, depending upon sampling period with a total biomass of 1,327 - 4,908 kg. Based on the biophysical characteristics of the river, a qualitative estimate shows highest yields to be in regions where; river width is > 300 m, depth is variable (0.5 - 1.5 m) with deeper pools, substrate is predominantly gravel, sand or rubble, vegetation is uncommon or absent, flow rate is high with numerous ruffles and rapids and where catostomids and whitefish are rare.

ONTARIO MINISTRY OF NATURAL RESOURCES. 1987. Proceedings of a workshop on lake sturgeon (Acipenser fulvescens). Ont. Fish. Tech. Rep. 23: 99p.

This is an effort to determine the current state of knowledge on lake sturgeon in Canada, primarily Ontario. There is a short introduction (see Olver, 1987), nine papers on various aspects of lake sturgeon and three papers dealing with management considerations. Most of the work has been presented in other formats i.e., technical reports etc. Comments on management include the lack of biological information on lake sturgeon and a proposed amendment to the Ontario Fishery Regulation which would allow managers to control the harvest on an area and stock specific basis. The management for a sport fishery was outlined and included habitat protection and rehabilitation, harvest control and population rehabilitation (this would require intensive culture). There appears to be a lack of what is referred to as socio-economic data, presumably the value and desirability of lake sturgeon sport fishing. The final management paper dealt with enforcement. It seems that the fishing regulations as they apply to lake sturgeon are not well understood and staff are not experienced with harvesting methods. If one can make a general conclusion it appears there is a lack of basic biological information, lack of a comprehensive data set for both commercial and sport fishing, and inadequate procedures for handling local (watershed) problems on all aspects of lake sturgeon management.

*ONTARIO MINISTRY OF NATURAL RESOURCES. 1988. Management plan for the lake sturgeon in the Kenogami River. Hearst District. Prepared by Ecologists Ltd. 58p.

This is a report of a three year field study of an area which included the Geraldton district portion of the Kenogami river and an area downstream to Mammamattawa. Biological data collected included; fish age (2-28 years), age of maturity for females was 25-31 and for males was 20-25 years. The sex ratio females:males was 1:2 and on larger fish was determined surgically. Five hundred and twenty-six fish were sampled during the period June 1985 to June 1986. Annual mortality was estimated to be 2.8%. There appeared to be a downstream movement of fish in the fall and upstream movement in the spring. Recommendations included the maintenance of a viable brood stock, possibility of a protected slot size of 105 to 130 cm fork length, and a maximum annual harvest of 175 kg. The commerical fishery was not considered to be viable and a sport fishery should be considered as the economic benefits to the community was much higher.

ONTARIO MINISTRY OF NATURAL RESOURCES. 1988. Lake sturgeon stocking plan. Prepared by The Environmental Applications Group Ltd. 36p.

The contents of this report include various aspects of a stocking programme; rationale, schedules, economic considerations, assessment and consequences. The following waterbodies were covered in the report; Mattagami and Peterlong lakes and the Black, Blanche, Grass, Mattagami and Upper Kapuskasing rivers. Reasons for stocking vary from stock enhancement, introduction to establish a naturally reproducing population, reduction of fishing pressure and trophy fishing. It is recommended that lake sturgeon should be stocked as three month old fish but alternatives are also discussed. The stocking densities for the various waterbodies are also discussed. A table describing the guidelines for human consumption of sturgeon indicate that the Mattagami River sturgeon may be consumed without any restrictions (mercury contamination standards). The annual cost of stocking sturgeon into all the suggested waterbodies is estimated at $ 400,000. The report also presents computer models to predict the status of the stocked sturgeon fishery 45 years from the introduction. The stocking programme seems promising economically and it is believed that eventually stocking will become redundant as natural recruitment will maintain the population at the carrying capacity of the system.

OWEN, J.B., D.S. ELSEN, and G.W. RUSSEL. 1981. Distribution of fishes in North and South Dakota Basins affected by the Garrison Diversion Unit. Fisheries Research Unit, University of North Dakota. p. 137-138.

Lake sturgeon is listed (Table 2, p. 69) as one of the fishes to be potentially affected by the

Garrison Diversion Unit. The species was reported from the Red River by Surber in 1920 and by Keheler and Kooyman from the Assiniboine river in 1957, but not in North Dakota.

PAETZ, M.J., and J.S. NELSON. 1970. p. 50-53. In The fishes of Alberta. Queens Printer, Edmonton.

A short account of the natural history of lake sturgeon is provided. Most of the annual catch is taken from the South Saskatchewan River between the junction of the Bow and Oldman rivers and the Eastern boundary of Alberta. Angling for sturgeon in Alberta was opened after a long closure following a population decline. This fish was first recorded from Alberta by Whitehouse in 1919 from the Bow River at Bassano as Acipenser transmontanus (white sturgeon).

PATALAS, J.W. 1988. The effects of commercial fishing on lake sturgeon (Acipenser fulvescens) populations in the Sipiwesk Lake area of the Nelson River, Manitoba, 1987-1988. Manit. Nat. Res. MS. Rep. 88-14: 38p.

This report summarises the data collected from annual sampling of the commercial lake sturgeon catch from Sipiwesk lake, Nelson River, to evaluate the effects of present management regulations on lake sturgeon populations of that area. Totals of 80 and 110 sturgeon were sampled in 1987 and 1988 respectively. The overall age range of the sturgeon was 12-87 years. Both years showed little difference in age, length or weight distributions of the sample. The condition factor for sexes combined was 0.84 in 1987 and 0.82 in 1988, and analysis of the length-weight relationship showed that sturgeon grow isometrically. Calculated mean fork lengths for each age interval indicate that after 20 years of age, growth is linear at the rate of 10 mm/year. A low proportion of fish under 25 years and a high mean catch age indicates that the population is relatively well balanced at present. The data obtained from the present study is compared to other studies carried out on this population (Sunde, 1953-1959; Sopuck, 1977-1978). An explanation is advanced for the possible misinterpretation of data by Sopuck (1987) for the sample of 1977-'78. Analysis of sturgeon sizes for fish between 19 and 45 years of age showed a higher growth rate compared to samples of 1953-1956, indicating that a drastic population decline during the 1950's reduced intra-specific competition and increased food availability. However, the mean length-weight relationships and condition factor did not change much over the years compared. The mean annual harvest between 1970 and 1987 was 2,688 kg, less than the estimated sustained yield or the catch quota. Recommendations for management include closure of the commercial sturgeon fishing to protect remaining stocks, annual sampling of the commercial catch to monitor population parameters and studying the Nelson river population to allow for long-term management of the species and prevent its extirpation.

PAYNE, D.A. 1987. Biology and population dynamics of lake sturgeon (Acipenser fulvescens) from the Frederick House, Abitibi and Mattagami rivers, Ontario. Ont. Fish. Tech. Rep. Ser. 23: 10-19.

Sturgeon populations from the three river systems are compared. Populations from the Frederick House and Abitibi rivers appear robust while those from the Mattagami river are a young population with few remaining large adults. This is supported by mean length, age, and relative biomass data which are greater in the first two river populations. Moreover, the Mattagami had a faster growth rate. Commercial over-harvest and water level fluctuations may have resulted in these differences. Recommendations are made to stop commercial fishing on the Mattagami river, allocate the Frederick House population to sport fishing and adjust quotas and conditions for commercial licenses on the Abitibi river.

PEARCE, W.A. 1986. Methuselah of freshwater fishes-the lake sturgeon. Conservationist 41(3): 10-13.

The lake sturgeon has been called the stone, rock, Ohio, red or rubbernose sturgeon. There is a general discussion on sturgeon of the world with 25 known species, eight of which are found in North America and two of these the lake sturgeon and shovelnose are strictly freshwater. There is a discussion on the decline of sturgeon populations throughout much of its range. Differences between the resources allocated for sturgeon culture in North America and the Soviet Union are outlined and it appears that the major reason for the success of culture in the Soviet Union versus North America was government support. The projections are that a decline in the concentrations of lethal chemical (PCBs, Mirex, mercury), protection from exploitation and continued environmental rehabilitation should allow populations to recover. The time frame may be 100 years and exploitation rates would have to be about 5% per year to maintain stable populations.

PEARSON, W.D. and B.J. PEARSON. 1989. Fishes of the Ohio River USA. Ohio J. Sci. 89(5): 181-187.

This report discusses the historical fish fauna of the Ohio river and the disappearance and reappearance of certain species over time. The lake sturgeon which was reported as a native of the Ohio river in 1818 by Rafinesque and in 1870 by Dumeril was not reported after 1969 and have apparently been eliminated from these waters. It is the only species known earlier that has not been reported from the Ohio river for the previous 20 years. Lake sturgeon popu-

lations that may have been extirpated by the installation of dams which interfered with the spawning migration. It is hoped that the recovery of several fish populations would serve as an incentive to try and revive lake sturgeon once more in the Ohio river.

PERRON, D. 1983. Lake sturgeon, p. 147-158. In G. Watson et al. (ed.) Beyond the rainbow; alternate species for commercial aquaculture in Ontario. Aquaculture Development Program, Owen Sound, Ontario.

There is a description of lake sturgeon, its' distribution, biology (including spawning), fecundity; most of the information coming from published literature. The author relies heavily on what is known on white sturgeon and gives some interesting information on water quality parameters. Natural nutrition in the form of a condensed list of food items and formulated diets are discussed. The author concludes that "..for the time being, feeding a semi-dry, high protein diet produces adequate results." Culture methods include the use of raceways and ponds by the Russians and the use of circular tanks in California. Incubation has been successful (average 90%) with McDonald (Bell) jars, Williams troughs, and upwelling boxes. Work in Wisconsin utilizes nylon net cages in the summer with transfer indoors during the ice period. Predictions are that a 4.5-6.0 kg lake sturgeon can be produced in 3-6 years. The environmental impact of sturgeon introductions are unclear but the suggestion was made, based on the literature, that they may consume large numbers of eggs of other species or introduce parasites such as Polypodium. A table outlining the total production of sturgeon by Canada from 1975 to 1980 (133 metric tonnes for 1980) and other world producers is taken from an FAO report of 1981. Lake sturgeon markets are discussed and values as high as $22.00/kg are quoted for smoked meat versus unsmoked sturgeon at $3.90 to $4.40/kg. Values given for white sturgeon larvae were 0.40 /1000 or 0.15/100,00, fry 0.75/1000 or 0.30/100,000, and for fingerlings $2.50/100 or $1.50/1000-5000 (it was not clear from the report if values are Canadian or US dollars). The final recommendations were not very optimistic on the establishment of lake sturgeon culture in Ontario, due to markets, international competition, especially for the European market, and lack of warm water.

PHILLIPS, G.L., W.D. SCHMID, and J.C. UNDERHILL. 1982. p. 29-31 & 61-63. In Fishes of the Minnesota Region. University of Minnesota Press, Minneapolis.

In this book, there is a brief account of the lake sturgeon and its life history characteristics. The Minnesota record for this species stands at 162.8 lbs, caught at Rainy River Koochiching County on May 15, 1968.

PRIEGEL, G.R. 1964. The sturgeon spearer. Wis. Conserv. Bull. 29: 18-19.

This is a popular article on sturgeon from Lake Winnebago dealing with the spear fishery from the second week in February through March 1. Spearers often scatter mussel shells, shelled corn, egg shells over the bottom to increase visibility. Decoys include ears of corn, wooden toy airplanes and carved replicates of fish. There were 3,352 licenses sold in 1961, 3,242 in 1962 and 4,522 in 1963. Spearing success increases the sale of licenses in the following year and an average 15% of sturgeon spearers are successful. There is information on who buys a sturgeon spearing license, the time of day when sturgeon are caught, the average age of the successful spearer, and the type and cost of equipment (total value usually in the order of $150.00).

PRIEGEL, G.R. 1973. Lake sturgeon management on the Menominee River. Wis. Dept Nat. Res., Wis. Tech. Bull. 67: 20p.

A 26 mile long section between Grand Rapids dam and White Rapids dam was studied in 1969 and 1970 to estimate the lake sturgeon population and determine the exploitation rate. A.C. boom shockers were used to sample fish and the population estimates for fish $\geq$ 42 (legal fish size) were 234 and 185 for 1969 and 1970 respectively and the age of the fish sampled ranged from 1-45 years. The fishing pressure was calculated to be 14,300 hours in 1969 and 11,400 hours in 1970 and opening weekends accounted for 20-30% of the annual fishing pressure and only 20-30% of the annual fishing pressure occurred during October. The estimated exploitation rate for 1969 was 13% and 17% for 1970. This was based on angler harvest data and exceeded the desirable exploitation rate of 5%. The majority (78%) of the fishermen were from Wisconsin and the minimum legal sized fish (42 inches) belonged to the age group of atleast 12 years and all fish of 17 years of age were 42 inches or more. The fish sampled ranged from 1-45 years and there was a lack of sturgeon under 15 inches below the area of intensive study. Growth of the Menominee river sturgeon is slower than the Lake Winnebago stock and Lake Winnebago sturgeon weigh more than Menominee sturgeon at a given age. Management recommendations include increasing the size limit to 50 inches, introducing special licenses or registration for lake sturgeon fishing, reduction of the bag limit to one fish from the current two, and closing the season during October.

PRIEGEL, G.R., and T.L. WIRTH. 1971. The lake sturgeon - its life history, ecology, and management. Wis. Dept Nat. Res. Publ. 240.

(See below for annotation).

PRIEGEL, G.R., and T.L. WIRTH. 1974. The lake stur-

geon. Its life history, ecology and management. Wis. Dept Nat. Res. Publ. 4-3600(74): 20p.

Life history characteristics of the lake sturgeon are reviewed with special reference to Wisconsin water-bodies. Food and feeding habits are described. Various food items such as insect larvae, leeches, snails, small clams and miscellaneous invertebrates are sensed with barbels, strained and washed through their gills, and sucked in by a protrusible mouth. lake Winnebago sturgeon have a strong homing tendency after travelling upstream for as much as 125 river miles to spawn. Spawning occurs during late April and early May in central Wisconsin. Sturgeon spawn in areas where there is upwelling or "slowly boiling" water, with rocks, boulders and broken concrete slabs forming steep angles into the water such as shallow, rocky river banks. When water flow is high and water temperatures rise slowly, spawning begins at water temperatures of 53 F. In seasons of low water flow and rapid temperature rise, spawning begins only when water temperatures reach 58-59 F. Males are observed at spawning sites ahead of females and cruise the site in groups of eight or more. Spawning commences when females join the group and one or more males vibrate simultaneously beside a female during one act of oviposition which lasts for 5 seconds after which the group moves to deeper waters until the next act of oviposition. A female spends 5-8 hours in spawning activity and 50,000-700,000 eggs may be released by a female. Egg and milt release is accompanied by vigorous tail thrashing Females reach maturity in 24-26 years and spawn every 4-6 years while males reach maturity in 11-14 years and spawn every year or in alternate years. Eggs hatch in 5 days at 60 F or above and small sturgeon display schooling behaviour in late summer and early fall. No serious attempt at artificial propagation has been made in the U.S. Growth in length is more rapid than weight until sexual maturity after which weight increase is proportionately more rapid. Factors contributing to the mortality of sturgeon and a decline in populations include human over-exploitation, alteration of spawning habitat, predation on eggs by fish, and predation on young by aquatic mammals (otters). The history of the fishery is reviewed and spearing remains the dominant method of harvesting.

PRIEGEL, G.R., and T.L. WIRTH. 1975. Lake sturgeon harvest, growth and recruitment in Lake Winnebago. Wis. Dept Nat. Res. Tech. Bull. 83: 25p.

A system of registration from 1955 to 1969 was used to determine the characteristics of the spearer, harvest, age-weight-length relationships, population size and recruitment of lake sturgeon from Lake Winnebago. Average spearing success from 1962-1967 was 15.9%, with residents of the four counties surrounding Lake Winnebago accounting for 78.2-83.8% of the fish speared. The total harvest for the period 1955-1969, was 8,981 fish, ranging from 8-1,505 (312 - 64,715 lbs.) with an average annual harvest of 599 fish. The number of fish harvested depended upon good weather conditions and water clarity. The average annual length of total lake sturgeon harvested was 54.5" and the registered lake sturgeon ranged in age from 7-68 years. Year classes were represented by 1907-1960 year classes (in all but 3 fish). None of the year classes showed trends of decline over this period of time and no individual age group was consistently speared with greater frequency. The length-weight relationship, calculated from 40-70 inch fish, resulted in the equation LogW = -4.0371 + 3.2530 LogL. The population of lake sturgeon over 40 inches long was estimated at a maximum of 11,500. It is recommended that the annual harvest not exceed 4.7% in order to maintain 1969 population levels.

PRIEGEL, G.R., and T.L. WIRTH. 1978. Lake sturgeon populations, growth, and exploitation in Lakes Poygan, Winneconne and Lake Butte des Morts. Wis. Dept Nat. Res. Tech. Bull. 107: 23p.

Studies were carried out over the period 1952-1976 to assess harvest, growth and population structure of lake sturgeon in the above lakes with the intention of determining whether over-exploitation had occurred. The total harvest over this period totalled 124,904 lbs (4.5 lb/acre), with an average of 10,408 lb/year (1 lb/2.6 acres). From 1954-1976, Lake Poygan accounted for 77.1% of the fishing pressure. Harvested fish represented 1916-1955 year classes. Individual year classes peaked when they entered the fishery at age 15-16. There was a general decline of larger fish (50-55", 55-59" and >60" groups), especially after 1957 and the proportion of fish under 50" increased from 61.6-63.8% in 1952-54 to 84.5% in 1971. The length-weight relationship was expressed by LogW = -3.900 + 3.135 LogL, based on 2,278 40-70" fish. Registered lake sturgeon were from 8-43 years old and 45.2% of the total harvest. Average length and weight increased with increasing age of fish (42" and 12 lbs at 10 years to 66" and 69 lbs at 39 years). The population is estimated at 3,700 - 5,200 fish of 40 inches and longer. Different growth rates shown by the Lake Winnebago and Poygan-Winneconne Basin populations are interpreted to indicate distinct populations with little mixing between them, although they utilize the same spawning grounds. The possibility of a homing behaviour for young sturgeon to return to their parents basins is suggested and further research into the biology urged. Management recommendations include maintaining the present fishing season, limiting fishing pressure and regulating through minimum size limit.

PRINCE, E.E. 1905. The Canadian sturgeon and caviare industries. Can. Sess. Pap. 22. Spec. Append. Rep., liii-lxx.

This is an excellent report of the status of sturgeon in Canada. The value of the sturgeon fishery to Canada and information on the potential extent of the sturgeon in Canada is discussed. The author comments on the fact that sturgeon was the main source of food of Indians, for a considerable portion of the year, but at this time (late 1800s) there was practically no demand for it as a white man's food. Within the past 10 years of the date of this report the fishery began to have considerable value in the great lakes i.e., Lake Huron but even more important was the rapid development in the Lake the Woods (claimed to be the most valuable in the world). By 1895 the sturgeon fishery was important in Lake Winnipeg and other Manitoba waters. The sturgeon taken from Lake Winnipeg were considered the best in the world due to their ".. rich edible qualities.." Applicants wanting to fish sturgeon throughout Canada rated them the top fish, along with salmon. It was the value of sturgeon products that increased fishing pressure. These products included (1) caviar, (2) isinglass, (3) the flesh salted, smoked, (4) oil for the leather industry, (5) fertilizer, made from entrails and scrap, (6) the soft grisly backbone with its sheath which prepared is called wesinga and all over Russia is an esteemed article of diet, (7) the brain and nerve cord removed from the gristle when smoked and dried is considered a great delicacy in China, (8) the back portion of the sturgeon or dorsal region is made into a food product called balyki, (9) the ventral part or belly of the fish is made into a food called pupki, (10) a valuable fish glue, differing from isinglass of the swim-bladder is made from the nose, fins, tail, and (11) the skin produced leather for mill belts and boot laces. Interestingly Canadian fishermen did not appreciate the value of the roe as contracts would state that the meat was worth 10 cents a pound but the waste (the roe, swim-bladder) was to be carefully kept and handed over for nothing. St. Clair fishermen received 4-5 cents/pound for the meat, 10 cents/pound for caviar, and 5 cents/pound for swim-bladders.Lake Erie sturgeon were found to yield up to 12 gallons of eggs per fish. Sturgeon were usually fished while migrating and an example is given from the Volga river in Russia where large numbers were killed. Methods of capture varied but included large 12 inch mesh nets, baited hooks, bare grapnels, fish traps or pound nets. The author gives numerous examples of the decline of the sturgeon fishery. The Lake of the Woods is used as an example. Canadian regulations enforced over the greater part of the lake and on the Rainy river would have permanently preserved the fishery but a very small part of the lake fell within the United States border where most of the sturgeon were taken. So much so that the value of the fishery declined from 1,059,267 pounds in 1894 to 197,-033 pounds in 1899. So important was the fishery at this time that the New York Fishing Gazette (June 1986), quoted by the Winnipeg Colonist, wrote that the Lake of the Woods fishery produced 75% of the world caviar and practically controlled the world caviar industry. In 1986 190,000 pounds of caviar were produced from Lake of Woods. At the peak of the Lake of the Woods sturgeon fishery there were 14 steamboats, fifteen barges, a large number of so-called pound-boats, employment for 500 men and the money brought to Rat Portage from sturgeon sales was $200,000, annually. Remarkably, even with this destructive fishing there were people at this time with enough insight to report on the importance of lake sturgeon, as a food source to Indian populations in the western regions of Canada. A well-informed Dominion officer urged the formation of reserves for sturgeon on Lake Winnipeg and other waters of the west "...as these waters have the last available supply in the known world untouched." The economics to the Indians were clear; source of meat, the oil was like butter, and the caviar could be exported. A female sturgeon with roe was worth more than a beaver. There is a discussion of the best roe for caviar i.e., sturgeon in the third or fourth year. Lake sturgeon produce larger eggs than anadromous sturgeon. A description is given for the handling of sturgeon roe and the preparation of caviar. There are two types of caviar, the fresh or grain caviare (zernistaia ikra) and hard or pressed caviare (paiousnaia ikra). Sturgeon flesh was greatly prized by some while others would not eat it. It has been stated "...that a good cook can obtain beef or mutton, pork or poultry out of one sturgeon, in other words, fish, flesh and fowl,..." and the peculiarly streaked colours in sturgeon steaks bear out this statement. Isinglass was considered the finest quality of glue and is almost pure gelatine. The swim-bladder was removed, cleaned and dried in sheets. The best isinglass is a flexible white semi-transparent flaky material, devoid of taste and smell. Even in Roman times isinglass was highly valued and by 1905 it retailed for $3.00 a pound. It was used as a food for the sick due to its nutritious, pure and unirritating qualities, for cooking and confectionery, and for refining wines and beer. There is a brief discussion of food items consumed by sturgeon with a reference to fish in the diet.

PRINCE, E. 1899. The food of the sturgeon. Can. Sess. Pap., Spec. Rep. Append. 31st Ann. Rep. Dept Mar. Fish. 1898: lvi - lx.

In view of frequent allegations of the sturgeon being a voracious consumer of the spawn and fry of commercially important fish, the author reports on investigations into the food items of sturgeon as found in their gut. Specific mention is made of examinations of white sturgeon and specimens from St John River. The lake sturgeon is not specifically mentioned and it is implied that the North American sturgeon have similar food habits.

PROBST, R.T. 1954. Why study sturgeon? Wis. Conserv. Bull. 19: 3-5.

Attention is drawn, in this article, to the lack of knowledge about sturgeon populations in Wisconsin, preventing the formulation of wise management strategies. Recommendations include tagging studies with a large sample size and obtaining pectoral fin rays and gonads from spear fishermen. The technique of using sections of the pectoral fin ray for aging is discussed. The size regulations governing sturgeon fishing are seriously questioned in view of the advanced age of maturity and spawning of lake sturgeon and the possible need for modifying existing regulations.

PROBST, R., and E.L. COOPER. 1955. Age, growth and production of lake sturgeon (Acipenser fulvescens) in the lake Winnebago region, Wisconsin. Trans. Am. Fish. Soc. 84: 207-227, 1954.

The age and growth of lake sturgeon in the Lake Winnebago area (including Lakes Butte des Morts, Poygan and Winneconne) were assessed from 966 fish caught between 1951-1954. Fish ranged between 30-79 inches in length. Lake Winnebago yielded a greater proportion of bigger fish (>60 inches) than the other lakes. The method of age determination used the marginal pectoral fin ray and the validity of the method is discussed. Age ranged between one and 82 years. The length-weight relationship of lake sturgeon from Lake Winnebago was logW = -4.01939 + 3.24070 logL in comparison to logW = -4.12298 + 3.26625 logL for Lakes Poygan, Winneconne and Butte des Morts. The length-weight relationship for the combined data was given by logW = -4.17096 + 3.30367 logL. Length-weight relationships were "practically identical" for males and females. The male:female sex ratio for Lakes Poygan, Butte des Morts and Winneconne were nearly 1:1 whereas in lake Winnebago, females were 72.4% of the sample. Tendipedid larvae (86.6% occurrence) were the most important food item taken of sturgeon in Lake Winnebago, with sturgeon from the other smaller lakes feeding frequently on ephemeropteran larvae.

*RADFORD, D.S. 1972. The harvest of lake sturgeon (Acipenser fulvescens) in the South Saskatchewan River from 1968 to 1972. Alberta Lands and Forests, Fish. Manage. Rep. 13. 19p.

RADFORD, D.S. 1976. The 1974 harvest of lake sturgeon (Acipenser fulvescens) from the South Saskatchewan River. Alberta Dept Rec. Pks Wildl. Fish. Manage. Rep. 21: 27p.

Based on returned questionnaires from licensed anglers, a total of 42 sturgeon were caught of which 25 were released and the estimated harvest was 21 sturgeon. The average weight of the catch was 17.3 pounds. There was one recapture of a sturgeon tagged in 1969. The largest sturgeon caught weighed 60 pounds and 65% of the reported catch was taken at or near the Grand Forks area. The sturgeon population of the South Saskatchewan River is discussed and the harvest is compared to previous years. It is recommended that regulations checking the harvest of juveniles and adult be considered, enforcement of legislation against illegal fishing be improved and the sturgeon harvest be monitored annually.

*RADFORD, D.S. 1977a. The 1975 harvest of lake sturgeon (Acipenser fulvescens) from the South Saskatchewan River, Alberta. Alberta Recreation, Parks and Wildlife, Fish Manage. Rep. 25: 16p.

RADFORD, D.S. 1977b. The 1976 harvest of lake sturgeon (Acipenser fulvescens) from the South Saskatchewan River. Alberta Dept Rec. Pks Wildl. MS. Rep. 17p.

One hundred and thirty one questionnaires were mailed to purchasers of sturgeon angling licenses (1976/77); 72% were returned and 87% of the respondents fished for sturgeon. Eighty two sturgeon were caught and 48 released. The size distribution of the catch was similar to previous years but the average weight of sturgeon released was 12 pounds while the average weight of sturgeon kept was 33 pounds. A sturgeon tagged in 1969 was reported in the catch from Estuary, Saskatchewan. A map of the sport fishing area is included.

RADFORD, D.S. 1978. The 1977 harvest of lake sturgeon (Acipenser fulvescens) from the South Saskatchewan River, Alberta. Alberta Parks and Recreation, MS. Rep. 16p.

One hundred and twenty seven questionnaires were mailed to purchasers of sturgeon angling licenses (1977/78); 82% were returned and 89% of the respondents fished for sturgeon. Seventy sturgeon were caught and 46 released. The size distribution of the catch was similar to previous years and the average weight of fish kept was 32 pounds (14.5 kg) and average weight of those released was 11 pounds (5 kg). There was an overall decline in the catch compared to previous years. Blooms of Cladophora in the South Saskatchewan river were extensive due to drought conditions. Tables include historical records from 1968 on the number of licenses issued, summaries of the catch from respondents to a questionnaire, size distribution of sturgeon caught, and approximate average weight of sturgeon.

RADFORD, D.S. 1979. The 1978 harvest of lake sturgeon (Acipenser fulvescens) from the South Saskatchewan River. Alberta Dept Rec. Pks Wildl. MS. Rep. 18p.

One hundred and forty nine questionnaires were mailed to purchasers of sturgeon angling licenses (1978/79); 84% were returned and 76 % of the respondents fished for sturgeon. Eighty

sturgeon were caught and 50 released. The size distribution was similar to previous years but the trend to a higher proportion of large fish in the catch stopped in 1978. The average weights of fish kept was 26 pounds (11.8 kg) and those released was 10 pounds(4.5 kg). a conclusion was the possible over-exploitation of the fishery due to a general decline in angler success and the poor representation of sturgeon greater than 35 pounds in weight in 1978. Tables are included giving cumulative data since 1968.

RADFORD, D.S. 1980. The harvest of lake sturgeon (Acipenser fulvescens) from the south Saskatchewan River, Alberta between 1968 and 1978. Alberta Energ. Nat. Res. Fish Wildl. Div. MS. Rep. 35p.

The sturgeon season was closed from 1940 and then reopened in 1968. From that time an annual questionnaire evaluated the harvest and a special 5 dollar license was required to fish sturgeon. Only two fish can be in possession and each must be tagged. There is also a minimum size limit of 36 inches (from tip of tail to tip of snout) and weighing about 10 pounds. A total of 886 licenses were sold for the period 1968-1978, an average of 82% of questionnaires were returned, 84% of respondents fished for sturgeon, and 36% of respondents caught sturgeon. Forty four percent of 625 sturgeon were kept and of these about 10% were larger than 35 pounds. The official angling record for Alberta is 72 pounds caught in 1978; the unofficial record is 90 pounds caught in 1975. The estimated population of Alberta sturgeon is 2,890. Based on tagging results there appear to be two movements above and below Medicine Hat. A map illustrates the location and general movements which appears to relate to spawning. Recommendation were current legislation should remain in effect, the ratio of fish over 10 pounds and the proportion of the catch (10%) over 35 pounds should continue. Nutrient loads should be reduced in the system.

RAFINESQUE, C.S. 1817. Addition to the observations on the sturgeons of North America. Amer. Mo. Mag. 1: 288.

The reference appears in a report on the sitting of the Literary and Philosophical society of New York on July 10, 1817 and reports that the authors paper in question was read before the society. In this so-called "memoir" Rafinesque indicates that the lake sturgeon is a distinct species and proposes the name "Acipenser fulvescens" due to its "dark fulvus colour". The brief description states that it reaches 6 feet in length, possesses a short obtuse snout, falcated dorsal fin, smooth skin, with the lateral of the five rows of shields composed of more than 40 small shields. This is the first description of lake sturgeon and the first binomial nomenclature attributed to it. The type locality is the Great Lakes. [In the following year, Le Sueur (1818, see in this bibliography) described the lake sturgeon and gave it the name A. rubicundus. This seems to have been the more widely circulated name and A. fulvescens does not appear even in Kirsch and Fordice's review of North American acipenserids of 1889].

RAFINESQUE, C.S. 1820. Ichthyologica Ohiensis or natural history of the fishes inhabiting the Ohio river and its tributary streams, preceded by a physical description of the Ohio and its branches. W.G. Hunt, Lexington, Kentucky. 90p.

Under the title "Atelosian Fishes", the author provides an account of several species of sturgeon - "Accipenser". In his introduction preceding the individual species accounts, Rafinesque states the names of seven North American species in which he includes A. rubicundus (LeSeuer's 1818 designation for the lake sturgeon) but does not mention his own 1817 designation of A. fulvescens. This is followed by descriptions of six new species of which Acipenser maculosus, A. serotinus, A. ohiensis, A. macrostomus and Dinectus truncatus are considered synonyms of the lake sturgeon by Kirsch and Fordice (1889) (see in this bibliography).

RICHARDSON, J. 1836. Fauna Boreali-Americana; or the zoology of the northern parts of British America, part third: The Fish. Richard Bentley, London. 327p.

In this account of North American fauna the lake sturgeon is mentioned as Acipenser rubicundus(p. 284) and a new species A. rupertianus is reported (p. 311) from the Mississippi river. This latter species was subsequently synonymized with A. rubicundus by Kirsch and Fordice (1889) (see in this bibliography).

ROBISON, H.W. 1974. New distributional records of some Arkansas fishes with addition of three species to the state ichthyofauna. Southwest. Nat. 19(2): 220-223.

The lake sturgeon is reported in Arkansas for the first time. One 135 pound sturgeon was captured by hook and line by Mr Kenneth Walsh. The fish was taken in July from the Little Missouri River near Chidester, Ouachita County.

ROCHARD, E., G. CASTELNAUD, and M. LEPAGE. 1990. Sturgeon (Pisces: Acipenseridae); threats and prospects. J. Fish Biol. 37(Suppl. A): 123-132.

The biology and conservation status of the world sturgeon species are reviewed and various measures to compensate for negative impacts on sturgeon are discussed. Sport fishing for lake sturgeon is described as being popular in Canada and its commercial fishery as "intense". Fishing regulations in Canada are cited and

these regulations are reported as being apparently effective (the authors quote Dumont et al. 1987, see in this bibliography).

ROUSSOW, G. 1955. Les esturgeons du fleuve Saint Laurent en comparison avec les autres especes d'acipenserides. Peche, Biometrie, Croissance, Age, Migration, Pisciculture. Office de Biologie, Ministere Chasse et Pecherie, Province de Quebec, 124p.

This is a Ph.D. thesis which reviews the literature of sturgeon worldwide (especially Rumania and the USSR, including Siberia) and compares with the sturgeon of the St. Lawrence River. There is a description of the key morphological measurements that are usually done on sturgeon and a description of ageing methods, including a photograph and a diagram of a section through the pectoral fin ray. Chapter 2 is an interesting description of fishing for sturgeon on the St. Lawrence River but it also details fishing methods on the Danube River in Europe, including how to set up baited hook lines. There are photographs illustrating barriers which were set up to stop the migration of sturgeon in Russia and methods for fishing through the ice using long handled curved hook harpoons. There is a discussion on the preparation of industrial products i.e., caviar, smoked fillets, and glue as well as the treatment of swimbladders and salted heads. This thesis study collected seven hundred and fifty sturgeon and two hundred and thirty seven individuals were marked and recaptured. The average age of females was 11.59 and for males was 11.63. a frequency distribution of age is shown graphically with ages ranging from 2 to 30 years. Graphical comparisons of growth variables were made for A. fulvescens Lake St. Francois, Lake St. Pierre, and Lake Nipigon and with A. baeri from the Irtych River, A. gueldenstadti from the Volga and A. baeri from the Enissei. A detailed map is given of the St. Lawrence River showing sites of capture and marking and recapture sites. There is an extensive discussion of the artificial culture of sturgeon, diagrams illustrating collection and incubation of fertilized eggs, and early stages of embryonic development.

*ROUSSOW, G. 1955. Quelques observations sur les variations de forme et de couleur chez les esturgeons de la province de Quebec. Ann. ACFAS 21: 79-85.

ROUSSOW, G. 1957. Some considerations concerning sturgeon spawning periodicity. J. Fish. Res. Board Can. 14: 553-572.

The paper describes spawning periodicity of lake sturgeon through the use of cross-sections of the leading marginal pectoral fin ray. The length, weight, age and state of gonads of 175 females and 164 males examined by the author as well as other field observations indicated the following; sturgeon move upstream to spawn in groups made up of individuals in different stages of maturity, ages and sizes, the male-female ratio is about equal, spawning takes place between the end of May and first three weeks of June, temperatures varied from 9-18°C, two morphs (A. fulvescens acutirostris and A. f. obtusirostris) were found in the catch but did not differ in age and maturity. Cross-sections of the leading pectoral fin ray revealed age, growth during favourable and unfavourable periods in terms of particular years, age of first reproduction (maturity), sex and intervals between spawning periods. The logic and methods behind these interpretations is discussed. Periods of slow growth are manifested in closely spaced annuli. This could indicate a post-spawning recuperation period or antithetically, a period of slow growth preceding spawning. From detailed examination of the state of the gonads and corresponding fin-ray sections of 17 sturgeon, the latter was found to be true. Fish without such belts of annuli are considered immature and the nature of these belts reportedly gives information on the stage of the gonads and whether a female is a first time spawner. From the observations made, it was concluded that the females matured and spawned at 14-23 years of age (average 18 years) with a 7-9 year spawning periodicity and that males matured at age 9-13 and spawned at 15-19 years, spawning periodicity being 7 years interval and spawned every 7 years (average). In a sample of sturgeon from spawning sites, 4% of the females and 20% of the males were in a ripe and running condition indicating the females have a considerably shorter period of oviposition. The age-length graph of female and male sturgeon from the Ottawa River indicates the alternate slow and fast growth periods in the life history. The Russian sterlet ovary/oocyte maturation scale of Nedoshivin and, Lukin and Mochanova are described and should be of value when applied to lake sturgeon maturation. Drawings show the various stages of oocyte maturation in sturgeon.

ROUSSOW, G. 1960. Quelques anomalies de gonads chez l'esturgeon de lac (Acipenser fulvescens Rafinesque) du Nord de la province de Quebec. J. Bord Off. Biol. Min. Chas. Pech. 2: 319-323.

One form of egg degeneration was called cement and consisted of a grayish liquid in which the remainder of the decomposing eggs were floating. The second anomaly consisted of ovarian cysts which were grape-like in appearance. Cysts on the testes were also noted on two sturgeon. Photographs illustrate the anomalies.

ROY, D. 1989. Physical and biological factors affecting the distribution and abundance of fishes in rivers flowing into James Bay and Hudson Bay. Can. Spec. Publ. Fish. Aquat. Sci. 106: 159-171.

The main rivers of northern Quebec are outlined

and it was noted that lake sturgeon are not generally found North of the La Grande River. Data on number of lake sturgeon caught per year per fisherman for the period 1976-77 by the communities was 0.6 for Rupert, 1.7 for Eastman, 0.7 for Wemindji, and 0.8 for Chisasibi.

ROYER, L.M., F.M. ATTON, and J-P. CUERRIER. 1968. Age and growth of lake sturgeon in the Saskatchewan River delta. J. Fish. Res. Board Can. 25: 1511-1516.

The age composition of 127 sturgeon collected over 4 years from the commercial operation at Cumberland House, Saskatchewan is described. Ages ranged from 1-65 years (one 70 lb sturgeon was recorded from the Saskatchewan delta during the study). The data suggests that males grow more slowly than females at least beyond age 35. The Saskatchewan River population is considerably faster growing than the Nelson River or the Waswanipi lake and river populations but grow slower than the Winnebago (Wisconsin) population. Average annual increment in growth until age 20 was 2.1 inches fork length and 0.9 lb round weight. From age 20-40 growth rate was 0.5 inches and 1.3 lb per year and beyond 40 years the growth rate decreased to 0.3 inches with a concomitant increase in weight to 1.4 lb. The length-weight relationship was expressed by log W = -4.02743 + 3.26445 log L. The largest sturgeon ever taken from the Saskatchewan river was a female fish caught on hook and line at Saskatoon, measuring a little over 6 feet and weighing 270 pounds.

SANDILANDS, A.P. 1987. Biology of the lake sturgeon (Acipenser fulvescens) in the Kenogami River, Ontario. Ont. Fish. Tech. Rep. Ser. 23: 33-46.

A mark recapture study of lake sturgeon carried out on the Kenogami River, Ontario, showed that estimates of biomass and density varied among three stretches of the river, biomass being least for the Kapeesawatan lake stretch (6.0 kg/hectare). Differences have been attributed to habitat preferences and interspecific competition, and of the four other bottom feeding fish examined, only the shorthead redhorse appeared to be a significant competitor. The age of fish caught ranged from 2 to 60 years and sex determination was not possible until 6-15 years of age. The youngest female close to maturity was 31 years old while the youngest maturing male was 20 years old. The maximum movement exhibited by a sturgeon in this study was downstream almost 150 km in 113 days. Mortality of sturgeon increased after age 45. The annual mortality rate of the total population was estimated at 4.6%. The diet of sturgeon was almost entirely invertebrates, of which crayfish was the predominant food item by volume (71.8%). Molluscs comprised only 10.5% of the food eaten and the remaining food items were aquatic insects (dragonflies, caddisflies etc.). There are no commercial licenses on this river and only subsistence fishing by natives is practised.

SATHYANESAN, A.G., and W. CHAVIN. 1967. Hypothalamo hypophyseal neurosecretory system in the primitive actinopterygian fishes (Holostei and Chondrostei). Acta Anat. 68: 284-299.

In the lake sturgeon, one of the species studied, the infundibular canal penetrated the neurohypophysis and reached the lumen of saccus vacsulosus indicating the close proximity of the pituitary to the saccus vasculosus. Two types of neurosecretory nuclei were present, in contrast to other acipenserids studied. The preoptico-hypophyseal axonal tract was divisible into two parts and the various regions are described by histochemistry. The nucleus lateralis tuberis (NLT) is distinct in the lake sturgeon in contrast to other acipenserids studied and the morphology of this nucleus suggests that its products may have directly enter the hypothalmic blood vessels, the third ventricle or may be directed toward the pituitary.

SATO, C.S., and F. GYORKEY. 1976. Zinc binding by glycosamino glycans. J. Biochem. 80(4): 883-886.

Seven glycosaminoglycans (GAG) were used in the experiments of which one standard was chondroitin 4-sulphate (C4S) from "rock sturgeon" (lake sturgeon) notochord tissue. Gel filtration of the solution containing 65Zn and the GAGs gave similar results for all GAGs; only the first of the two peaks contained the GAG. C4S bound more zinc at pH 4.0 than at pH 7.0.

SAUNDERS, D.A. 1981. Recommendations on the Mattagami River sturgeon fishery. Ontario Ministry of Natural Resources, Cochrane District, MS. Rep. 46p.

Recommendations for the management of lake sturgeon in the Mattagami River are outlined and factors affecting the fishery such as dams, manipulation of water flows and pollution are discussed. Estimates of lengths and ages of sturgeon, at first spawn, from the Mattagami River were made from data collected from the Onakanwana study. Males were 76-96.5 cm and 14-22 years of age and females were 84-96.5 cm. and 17-22 years of age. The physical characteristics of the river (size, depth, presence of rapids, shoals and riffles), available food for sturgeon and commercial catches suggest there is a somewhat stable population. A tag and release programme was recommended to determine populations and it was suggested that the commercial fishermen should record data on length, weight, collect fin rays for ageing and preserve gonads in formalin. It was also recommended that a commercial trap net be considered as undesirable or undersized fish could be returned to the system.

SCHOLL, D.K. 1986. Lake sturgeon of the Upper North Fork Flambeau River. Wisconsin Department of Natural Resources, MS. Rep. 8p.

The sturgeon population of an 18 mile stretch of the upper north fork of the Flambeau River was studied to collect baseline data on various biological characteristics. Of the 115 sturgeon caught, 78 were electrofished and the rest netted. Sturgeon were first sighted in the rapids of the Upper Park Falls dam when the water temperature reached 48° F and highest catches were during May 14-16 with water temperatures of 52-54° F and may indicate spawning peak. The six inch gill-nets were the most efficient in capturing legal sized fish (45" and above). The weight-length relationship was expressed by the equation Log W = -4.18 + 3.29 LogL. Sturgeon ranged in age from 8-40 years. The Flambeau River population is the slowest growing compared to Lake Winnebago, Yellow Lake and Menominee River populations (45 " in 23-24 years compared to 10 years in Lake Winnebago). A creel survey revealed that most of the fishing pressure (86%) occurred in September. The projected total sturgeon catch for the 1986 season was 343 fish (all sizes) and a harvest of eight fish. The average sturgeon harvest from 1983-1985 was 17.3 fish. Caution is recommended in fishing this population due to its slow growth characteristics, but there is no evidence, based on present data, that overharvesting is occurring.

SCHULTZ, P.T. 1958. King of Fishes. Wisconsin Conserv. Bull. p. 26-28.

This popular article describes the life history of lake sturgeon in the Lakes Winnebago, Butte des Morts, Winneconne and Poygan. Males are thought to spawn every year after reaching 14 years (average 18-22 years) and females mature at 25 years and spawn every 5 years. The population in Lake Winnebago is estimated at 12,500 - 12,700, of which 11,300 are estimated to be $\geq$ 40 inches and a 6% annual addition to the catchable population. In lakes Butte des Morts and Winneconne, the legal size population is estimated at 3,366-3,782 with a 8% annual addition to the legal class. The fear is expressed that the smaller lakes may already have been overharvested. Tagging studies and growth rate analysis have shown that sturgeon populations of Lake Winnebago and Lake Poygan-Winneconne systems are different and hence managed separately. The author expresses the opinion that sturgeon harvest quotas need to be lowered to sustain the present population.

SCHUPP, D.H., and V. MACINS. 1977. Trends in percid yields from Lake of the Woods 1888-1973. J. Fish. Res. Board Can. 34(10): 1784-1791.

This study shows, among other things, that the commercial yields in walleye increased with declining yields of lake sturgeon and lake whitefish. This correlation is considered to be due to the change in fishing gear from impoundment gear (pound nets) to entangling gear (gill nets) as sturgeon and whitefish yields became unprofitable for the fishermen to pursue. From 1952-1973, the few sturgeon caught, were all from Ontario waters of the lake.

SCHNEBERGER, E., and L.A. WOODBURY. 1944. The lake sturgeon, Acipenser fulvescens Rafinesque in Lake Winnebago, Wisconsin. Trans. Wis. Acad. Sci. Arts Lett. 36: 131-140.

The study reports on a creel census for sturgeon fishing on Lake Winnebago over the seasons of 1941, '42 and '43. Fishermen were issued cards for length, weight and other data. Despite limitations and the possible reluctance of fishermen to share the knowledge of their success, 49 heads and 11 alimentary tracts were collected. A total of 788, 467, and 238 fish were caught in 1941, '42 and '43 respectively. The number of people reporting catches increased from 19.5% in 1941 to 66.3% in 1943, although the number of people purchasing such tags almost halved and the average number of sturgeon per fisherman also decreased from 0.95 to 0.53. The number of fish per person reported caught varied from 0-5. Fish ranged from 14-40 years, sizes from 47-62" and weights from 28-81 pounds. The sturgeon were found to feed mostly on chironomid larvae during February and were relatively free of parasites.

SCOTT, W.B., and E.J. CROSSMAN. 1979. Freshwater fishes of Canada. Fish. Res. Board Can. Bull. 184: 966p.

This authoritative compendium of freshwater Canadian fishes contains an account on lake sturgeon. The morphology and biology of the species is reviewed and concisely presented.

SHIVLEY, J.D., and N. KMIECIK. 1989. Inland fisheries enhancement activities within the ceded territory of Wisconsin during 1988. Great Lakes Indian Fish and Wildlife Commission. Odanah, WI, Admin. Rep. 89-1: 16p.

Results of three fisheries enhancement programmes, one of which was the culture of lake sturgeon are discussed. The lake sturgeon programme was conducted in association with the Bad River and Lac du Flambeau native Indian tribes. Four female and two male sturgeons were snared (one was dip-netted) from the Bad River falls area. A total of 221,192 eggs were collected by caesarian section and milt by stripping. Following fertilization in the field, eggs were incubated at the Lac du Flambeau hatchery at 4-6°C. Hatching commenced on day 12 and a total of 6,000 larvae hatched (7% of eggs incubated). Of these, 3,000 fry (< 1 inch) were stocked into a rearing pond and left to overwinter. The remaining 3,000 were transferred to the Bad River Natural Resources hatchery and

reared on brine shrimp, annelids, zooplankton nauplii and Pacific krill. Of these, 830 survived to 4-6 inches in length. These fish were micro-tagged and fin-clipped and stocked in the St. Louis river (290 fish) and in the Bad River (540 fish). The study met its objectives and it was recommended that a weir be constructed at the Falls dam to capture more spawners and that higher temperatures be used for incubating fertilized eggs.

SHOUDER, M.P. 1975. A progress report on the lake sturgeon in the Black Lake system. Chebogyan and Presque Isle counties. Mich. Dept. Nat. Res. Fish. Div. Tech. Rep. 75-8: 6p.

Lake sturgeon in Black Lake were surveyed with gill nets (8 or 10 inch mesh) for four years (1970-73), collected during May and early June. The efficiency of gill nets can be increased by reefing (take a 14 foot deep net and reef down to 8 feet). Fish were tagged with two dart tags, placed at the base of the anterior end of the dorsal fin and the leading fin bone from the pectoral fin was removed for aging. A total of 136 lake sturgeon were tagged and released. Most fish caught had full stomachs, suggesting they were feeding rather than spawning. Attempts were made to collect small sturgeon using boom and stream shockers and a back pack shocker were unsuccessful. Artificial spawning reefs were constructed by using rock riprapp on the outside of a river bend and constructing a rock deflector on the inside of the bend to speed water flow into the rock riprapp. A sturgeon histogram of year class strengths was constructed and no decline in year class strength was apparent.

SINGER, T.D., V.G. MAHADEVAPPA, and J.S. BALLANTYNE. 1990. Aspects of the energy metabolism of the lake sturgeon, Acipenser fulvescens, with special emphasis on lipid and ketone metabolism. Can. J. Fish. Aquat. Sci. 47(5): 873-881.

Levels of nonesterified fatty acids were measured in the plasma of lake sturgeon as an indicator of fatty acid turnover. Also measured were the long chain fatty acids, specifically arachidonic, eicosapentaenoic and docosahexaenoic acids. The enzymes assayed for included, carnitine palmitoyltransferase, carnitine octanolytransferase, carnitine acetyltransferase and citrate synthetase, 3-hydroxyacyl CoA dehydrogenase, malic enzyme, B-hydroxybutyrate dehydrogenase, succincyl coenzyme-A ketotransferase acetyl-CoA thiolase, hexokinase, phosphofructokinase, lactate dehydrogenase, glutamate dehydrogenase, alanine aminotransferase, aspartate aminotransferase. Based on their assays lipid oxidation occurs in the liver as well as all extrahepatic tissues (brain, red muscle, heart and kidney). Lipid oxidation appears to be intermediate between elasmobranchs and teleost fishes. The low level of lipid oxidation in sturgeon tissues appears to be supported by low levels of lipases in adult sturgeon. Oleic acid levels were high in the plasma of sturgeon. The presence of a beta-hydroxybutyrate dehydrogenase activity in the tissues of lake sturgeon is similar to elasmobranchs.

SILFER, G.E. 1969. You can tell. Wis. Conserv. Bull. 34(3): 5

This short note draws attention to the main differences between lake and shovelnose sturgeon in view of the difficulty that many anglers have in differentiating the two species. Shovelnose sturgeon have four papillose lobes on its lower lip while the lake sturgeon has two. There is an accompanying photograph of the ventral view of the heads of the two species and a diagram of the two sturgeon with some other external distinguishing features labelled.

SKAPTASON, J.B. 1926. The fish resources of Manitoba. Manit. Industrial Development Board. Wpg. 43 p.

This is a detailed description of the fisheries resources of Manitoba, replete with photographs depicting harvests and contemporary commercial operations. Lake Winnipeg and its tributary rivers (vicinity of Berens, Pigeon, Bloodvein and Winnipeg rivers) are considered prime sturgeon fishing areas and Manitoba waters are recognized as the last important resort for sturgeon on the continent. Lake sturgeon from these waters command the highest price of any North American fish and its superior quality flesh, even at a higher price, have easily overcome competition from imported Russian sturgeon. The sturgeon fishing season is from June 15th to October 15th, the 12 inch mesh being the legal size. For example, 88,600 pounds of sturgeon worth $ 44,340, were fished from Lake Winnipeg in 1924, and 800 pounds of caviar, worth $ 1000 were also taken. Winter fishing on Lake Winnipeg took place between 15th November and the end of February. Among the less important lakes, the Sturgeon and Cumberland lakes are traditionally fished for sturgeon in the summer. Beaver and Moose lakes also provide some sturgeon catches. Serious depletion of sturgeon stocks of The Big Saskatchewan River (sturgeon limit increased from 50,000 pounds to 65,000 pounds in 1923), by heavy poundnet fishing, was prevented by timely intervention from the Fisheries Administration. The Nelson River (sturgeon limit increased in 1924 from 100,000 to 140,000 pounds) has yielded sturgeon for 10-12 years although Playgreen Lake was fished for sturgeon for 30 years. The catch was brought to Selkirk via Lake Winnipeg but later construction of the Hudson Bay Railways allowed access to other lakes, like Split Lake. The Bladder rapids north of Playgreen and Cross lakes are considered a natural barrier for sturgeon. Of the total catch, 40,000 pounds are obtained South

of this point, the remaining 100,000 pounds being taken from the more downstream waters where sturgeon are said to be very plentiful. The Churchill River (sturgeon limit, 100,000 pounds) was fished for sturgeon for the first time in 1924-1925 between Duck and Pukkatawagan Lakes. In the downstream waters of Granville and Indian lakes, the sturgeon are considered larger and more plentiful but not yet commercially exploited. Freight hauling drawbacks have prevented earlier and more extensive commercial exploitation. The Hayes River is potentially the "most valueable unexploited sturgeon fishery resource". The completion of the Hudson's Bay Railway, it is noted, will aleviate the difficulties now encountered in transporting commercial harvests. In 1924, a total of 146,800 pounds of sturgeon worth a market value of $ 75,400 were taken from Manitoba's northern waters. Additionally 3,180 pounds of caviar yielded $ 3,223. Comparative statistics for 1924, show 235,000 pounds worth $ 118,028 of lake sturgeon fished from Manitoba, of a total Canadian catch of 685,900 pounds worth $ 228,300. The period of 1920-1924 also saw a steady increase in lake sturgeon production, from 397 Cwt. in 1920 to 2,359 Cwt. in 1924, with a concommitant increase in caviar harvest from 200 pounds in 1920 to 3980 pounds in 1924. The author also describes the lake sturgeon as being rare in the estuaries but plentiful in the upper reaches of the Nelson and Hayes rivers. Efforts at culturing sturgeon are discussed and one early successful attempt by C.P. Paulson (Superintendent, Gull Harbour hatchery) in 1924 is described. Eggs were hatched yielding 8000 fry but no ripe females could be obtained the following year. The author cautions that, with increasing fishing pressure, attention should be given to proper management of the province's sturgeon fishery including replenishing stocks with culture efforts.

SMITH, H.M. 1914. Passing of the sturgeon. Rep. U.S. Comm. Fish. 1913: 66-67.

There is a discussion on the decline of the sturgeon due to its destruction when it was considered a nuisance fish and then exploited for caviar and meat. A decline in the catch of Atlantic sturgeon from 7,000,000 pounds to less than 1,000,000 in 15 years. A similar decline in the Pacific sturgeon from 3,000,000 to a few hundred thousand pounds in a decade. The sturgeon fishery reached its peak of 12-15,000,000 pounds about 1890 and by 1914 declined to about 1,000,000 pounds. Attempts at artificial propagation failed. The prediction was that everywhere in America the sturgeon was doomed to commercial extinction. It was recommended that in every state in which sturgeon occur there should be a ban on capture and sale for not less than 10 years and that transplanting of sturgeon be considered.

SMITH, T.I.J., and E.K. DINGLEY. 1984. Review of biology and culture of Atlantic (Acipenser oxyrhynchus) and shortnose sturgeon (A. brevirostrum). J. World Maricult. Soc. 15: 210-218.

This review deals mainly with the two species in the title but mention is made of the fact that a paucity of simultaneously ripe male and females coupled with fungal infection of incubating eggs were the principal causes of the early failures of lake sturgeon (as well as other sturgeon) culture efforts.

SOKOLOV, L.I., and I. BERDICHEVSKII. 1989. Acipenseridae Bonaparte 1831, p. 150-455. In J. Holcik (ed.) The freshwater fishes of Europe. Volume 1(II). Wiesbaden, AULA-Verlag.

SOPUCK, R.D. 1987. A study of the lake sturgeon (Acipenser fulvescens) in the Sipiwesk Lake Area of the Nelson River, Manitoba, 1976-1978. Manit. Dept Nat. Res. Fish. Br. MS. Rep. 87-2: 59p.

The Nelson River supports one of the remaining commercial sturgeon fisheries in North America. Catches have declined over the years,since exploitation began in 1907. The study was restricted to the confluence of the Landing and Nelson rivers and encompasses management areas 2 and 3. Exploitation of this resource and changes in the Upper Nelson River population since 1961 are assessed and sturgeon migration is studied. The length-weight relationship was expressed by LogW = -11.85 + 3.03 LogL (r=0.95) for 142 fish collected in 1977 and by LogW = -12.93 + 3.26 LogL (r=0.96) for 142 fish collected in 1978. The Nelson River sturgeon grow isometrically. Mean lengths of fish collected in 1977 (112.9 cm) and in 1978 (108.9 cm) were not significantly different. However, mean weights for 1977 (12.6 kg) and 1978 (10.5 kg) were significantly different. Sturgeon caught ranged in age from 16-70 years. The population size was estimated to be 3,236 by mark recapture (tagging) studies with an exploitation rate of 0.104. The conditional and instantaneous fishing mortality rates were 17.4 and 18.4 times that of conditional and instantaneous natural mortality rates. Only 3 of the 47 recaptured sturgeon were collected downstream. The majority (56%) were captured within 30 days of release and 57% were captured within 10 km of the tagging site. Problems associated with sexing fish are discussed. A late spring in 1978 resulted in a delayed spawning migration; ripe males were taken from May 12-23 in 1977 but not until May 31 in 1978. The age structure of sampled fish shows a shift towards younger fish. It is recommended that low catch quotas be implemented to manage the Nelson River sturgeon.

STONE, L. 1900. The spawning habits of the lake sturgeon (Acipenser rubicundus). Trans. Am. Fish. Soc. 29: 118-128.

The time of spawning was difficult to ascertain as were their spawning beds. Fishermen almost never catch a ripe and running female in their nets and eggs are found in every stage of development except running ripe eggs. The author reports that the first instance of any sturgeon eggs being taken and hatched is that of the Atlantic sturgeon by Seth Green and A. Marks on the Hudson on 7th June, 1875. In cooperation with commercial fishermen, the author examined over a hundred sturgeon during their spawning run in May-June, 1899. Females that were captured and held in pens in anticipation of maturing their eggs failed to become ripe and runny. The gonads were either in pre- or post-spawning stages and presented a complex mix of various stages of oocyte development. Penning continued until the end of June, and although females very close to spawning were captured, no running females or eggs were obtained. Efforts during the spring of 1900 proved that sturgeon go up the Missisquoi river to spawn on the rapids below Swanton dam, the spawning season is short (1 week long), eggs are not laid all at once, sturgeon rush downstream after spawning, a ripe female is recognised by a sagging abdomen and spawning eggs run freely. The mystery surrounding the rarity of ripe and running females is solved by the fact that such females when caught in the nets expel most of the eggs and become spent. Lake sturgeon eggs were also successfully hatched for the first time under the auspices of the U.S. Fish Commission. The key to successfully obtaining eggs is the careful handling and confinement of the fish. A lively discussion follows the presentation. The secretary of the association suggested that sturgeon may spawn in alternate years and points out that males and female sturgeon do not run together. Mr. Ravenel and Mr. Clark debated the verity of the hypothesis that penning maturing females stops them from further maturation.

STONE, L. 1901. Sturgeon hatching in the Lake Champlain basin. Trans. Am. Fish. Soc. 30: 137-143.

Various techniques to overcome the difficulty of capturing ripe and running females, before they release their spawn in the struggle following their netting, are discussed. Trap nets were avoided by sturgeon and poachers proved detrimental to the field-work. The few sturgeon that were captured still holding ripe eggs proved elusive, either spawning at odd times or struggling so violently during stripping that very few eggs could be obtained. Specific instances are vividly described and ultimately eggs were successfully hatched. A make-shift hatchery constructed on the banks of the Lamoille consisted of 22 jars with water supplied from a brook. Developing embryos proved that 90% of the eggs were fertilised, but two days of frost during development lowered water temperature to 45° F and all the embryos died. The eggs fertilized at the Swanton hatchery hatched in 7 days at 65° F water temperature. It is inferred from observations that sturgeon do not spawn until water temperatures reach 60° F. It is also pointed out that sturgeon do not mature their spawn when confined in pens unless very ripe. Stuffing a handkerchief instantly into the female's vent proved the most effective way of preventing egg loss caused by the struggle that ensued when running females were lifted out of the water. The main difficulty is said to be finding males and females simultaneously and eggs are stated to be easy to fertilize and hatch. A stream of water run with sufficient pressure to keep the eggs in motion is considered important for a high proportion of hatching.

SUNDE, L.A. 1959. The sturgeon fishery in Manitoba with recommendations for management (analysis of Nelson River data: 1953-1956). Manit. Fish. Br. Dept Mines Res. MS. Rep. 23p.

An introduction deals with the effects of commercial exploitation on lake sturgeon populations along with short notes on the experimental fishery and biology of the species. The bulk of the report discusses the management of the Nelson river sturgeon fishery and the fishery is reviewed since its beginning in 1907. A peak and subsequent sharp fall characterised production curves during each of the intermittent periods of fishing between periods of closure, all this despite the fact that harvest limits were never achieved in any year. The harvest data is interpreted to indicate that sturgeon may not be over-exploited although annual production shows a downward trend since there is an increase in the proportion of large fish from year to year. However it is felt that the production of 1953-1956 could not be sustained unless the annual quota is kept at 20,000-25,000 pounds. Objections, biological and economic, are raised against the fishing season (June 10/22 to August 8) on the grounds that late spawning sturgeon are susceptible to capture before they have a chance to spawn and nets are fouled up by trapped slime algae. It is recommended that the open season on sturgeon should be changed to the fall beginning mid-August/early September and the minimum legal size should be raised to the equivalent of 20 pounds round weight but the weight criteria should be replaced by length (25 inches).

SUNDE, L. 1959. The royal fish. Fishing, A bulletin for commercial fishermen (Winnipeg). 1: 20-23.

This popular article discusses the biology of lake sturgeon in Manitoba waters and recounts the history of exploitation that led to the general population decline in North America. Commercial sturgeon fishing began in Lake Winnipeg a little after 1887 and by 1900 the annual production reached 981,500 pounds. By 1910, the annual harvest had declined to 30,200 pounds. Consequently, the fishery was closed. The fishery was closed and reopened a number of

times thereafter but each time the fishery failed. Sturgeon from Manitoba waters are slow growing and slow maturing. The majority of females are said to spawn for the first time at age 25 and males at 15-20. There is a graph showing the relationships between age and fork-length and round weight.

SUNDE, L.A. 1961. Growth and reproduction of the lake sturgeon (Acipenser fulvescens Rafinesque) of the Nelson River in Manitoba. M.Sc. Thesis. University of British Columbia. 93p.

A total of 791 lake sturgeon were sampled from the Sipiwesk Lake (Nelson river) commercial catch during the periods 1953-1956 and 1959. Preliminary studies on methods of age determination showed that most reliable aging is from pectoral spine sections made ideally within 1/2 inch of the basal articulation, although annuli are closely packed and difficult to read, and sometimes impossible, especially in the case of older fish. Sections between 1-2 inches away from the spine articulation are easiest to read but usually lack one annulus.

SWANSON, G. 1986. An interim report on the fisheries of the lower Nelson River and the impacts of hydroelectric development, 1985 data. Manit. Dept Nat. Res. Fish. Br. MS. Rep. 86-19: 228p.

The sturgeon part of this report deals with a description of the study area and the net set locations for collection. A total of 26 sturgeon were collected in gill nets and some data analyses were done. Thirteen fish were radio tagged by sewing the transmitter to the dorsal fin (diagrams are given showing the location). Movements were variable with some fish moving short distances and others moving greater distances. There was no definite pattern of movement and there was insufficient data to establish population dynamics of the species. Recommendations were that the lower Nelson River should not be completely closed to sport fishing.

SWANSON, G. and K.R. KANSAS. 1987. A report on the fisheries resources of the lower Nelson River and the impacts of hydro-electric development, 1986 data. Manit. Dept Nat. Res. Fish. Br. MS. Rep. 87-30: 240p.

A total of 18 sturgeon were collected during June 19-26, 1987. Sixteen were tagged and released and two were transferred to Long Spruce Reservoir. Catch per unit effort varied from 0.33 to 9.00 (number/ 24 hr) and 0.75-16.90 kg/24 hr). Twenty-three sturgeon were sampled in Angling Lake and ranged in size from 2.3 to 20.0 kg with a mean age of 36.3. Nine sturgeon were radio tagged and total movement of individual fish ranged from 45 to 275 km. Most movement occurred in August and early September. Sturgeon utilize the Nelson River during the summer months and overwintering occurs in three distinct areas. The authors conclude that sturgeon may remain in the Angling River Watershed-Gillam Island Forebay system. Recommendations, in addition to more field work, was the permanent closure of the commercial fishery.

SWANSON, G., and K.R. KANSAS. 1990. A report on the fisheries resources of the lower Nelson River and the impacts of hydro-electric development, 1988 data. Manit. Dept Nat. Res. Fish. Br. MS. Rep. 90-18: 158-221.

This report deals with the radio telemetry study started in 1988 on lake sturgeon movements in the Angling Lake/Angling river system, in an attempt to assess the importance of the lake to the sturgeon populations of the lower Nelson river. Ten fish were radio tagged and tracked in 11 flights over a period of almost 7 months. Lengths and weights ranged from 1009 - 1346 mm and 7 - 17.1 kg respectively. Ages are given for four fish and ranged from 37 to 59 years. Only one sturgeon was captured in the south-basin area; the remaining were captured in the narrows. All but one sturgeon moved upstream. After the initial movement, most sturgeon were located in the deeper regions of the lake and remained in that general area. Three fish remained in shallower portions of the lake. The longest migration between tracking flights was 12 km upstream by one sturgeon. Two other radio-tagged sturgeon that entered Angling Lake in 1987 were tracked by 17 flights for 11 months from May 12, 1988 and remained in the lake and one individual showed extensive movements, traversing the entire distance between inflow and outflow basins in 3 1/2 months of tracking and remaining in the outflow basin thereafter. The results are interpreted to support the hypothesis that Angling Lake is a refuge of sorts for Nelson River sturgeon in terms of an overwintering and year-round habitat. The movements observed within the lake, mainly during late summer and early fall are thought to be in accordance with the behaviour of sturgeon searching for a suitable overwintering location in the lake. Extrapolations of the data must take into account the fact that radio-tracking commenced post-spawning and ended well before potential spawning migrations the following year. It is hypothesised that sturgeon may use the Angling River and Lake as spawning areas. In the second part of the study, gill nets were set in the lower Nelson River from below the Limestone coffer dam to the B-axis of the proposed Conawapa Generating station. Three different habitat types were sampled during spring, summer and fall. Three sturgeon were caught, all from the rapids. Sturgeon made up 0.6% of the species composition in the lower Nelson river but did not figure in the composition of Long Spruce Reservoir (forebay, 1985/86 data). Sturgeon apparently undergoing the rolling and surface breaking ritual of spawning were sighted at the Lower Limestone Rapids on June 22, 1988 during high water discharge from the dam. It is

believed that dislodging and desiccation of the eggs result from water level fluctuations caused by the dam. No sturgeon eggs or fry were found during the sampling of the rapids. It is recommended that a minimum flow of water from the dams should be maintained to prevent desiccation and displacement of the eggs. Conclusions were that limited spawning probably occurred below the Long Spruce generating station and at the mouth of Angling River

SWANSON, G.M., K.R. KANSAS, S.M. MATKOWSKI, and P. GRAVELINE. 1991. A report on the fisheries resource of the lower Nelson river and the impacts of hydroelectric development, 1989 data. Manit. Dept Nat. Res. Fish. Br. MS. Rep. 91-03: 248p.

This is the usual data report from a multiyear study of sturgeon form the Nelson River and Angling Lake. A small sample of 14 sturgeon was collected and tagged. A little more data was collected from some of the fish as some samples were collected for mitochondrial DNA analyses (not reported on) and parasites determined (Tables in the appendix). Limited daily catch data and recaptures was also included. Recommendations include monitoring of existing radio tags until expiry, investigation of Angling Lake and Angling River for juvenile sturgeon, increase radio telemetry flights during the spring to follow spawning migration, and determine if it is feasible to improve spawning substrate below hydroelectric dams.

THREADER, R.W. 1981. Age, growth and proposed management of lake sturgeon (Acipenser fulvescens) in the Hudson Bay Lowland. Ontario Ministry Natural Resources, Moosonee District. MS. Rep. 106p.

The lake sturgeon population of the lower Moose River system in the Hudson Bay lowland was investigated to determine population age structure and growth patterns, evaluate tissue mercury levels and assess the effects of current fishing methods. The population size was estimated at 7,088 (range 5,774-8,919). A Walford plot showed that there was no deleterious effect of the tagging operation on growth of fish. Tagged fish were randomly distributed throughout the population and tag loss was believed to be minimal. Evidence obtained in the study indicates a localised population. The relationships between total length (TL), forked length (FL) and dressed length (DL) are given by the equations; $TL = 2.94\ DL^{0.882}$, n = 70, r^2 = 0.779, and $FL = 2.41\ DL^{0.902}$, n = 72, r^2 = 0.958. The length-weight relationship of a representative sample of 375 sturgeon (males + females) was $W = 0.002665\ FL^{3.22623}$ (this figure appears to be characteristic of lake sturgeon when compared to other studies). Age-length (FL) and age-weight (W) relationships were expressed by the equations: log FL = 1.738 + 0.00973 (Age, males), log FL = 1.653 + 0.0144 (age, females) and, log W = 3.003 + 0.0324 (age, males), log W = 2.722 + 0.0475 (age, females). This data indicated that growth could be treated independent of sex. The von Bertalanffy growth curve was expressed by the equation $l_t = 212.176\ (1 - e^{-0.0193(t + 6.852)})$, for the age groups 2 - 28 years. The sex ratio was found to be 1:1. Increase of fish length was rapid (3 cm/year) for the first 7 years but weight gain (100 g/year) was slow (long thin fish). Between 11 and 28 years fish gained 388 g/year with a length increase of 2.41 cm/year. Between 16 and 23 years, instantaneous weight gain was maximum (579 g/year) with an increase in FL of 3 cm/year. Beyond 28 years, growth decreased (147 g/year, 1.7 cm/year). Lake sturgeon found in the lower Moose River are smaller for a particular age class than found anywhere else. Males begin gonadal maturation at 14 years and females at 18 years and fish become vulnerable to fishing pressure at 7 years. It is suggested in the alternate management plan that smaller sized fish be taken commercially to spare the larger spawners and that 376 kg of fish be taken annually from the recommended range of harvestable fish. A gillnet mesh size of 7 inches would be most effective in capturing the recommended size range (40 - 90 cm, median of 2.5 kg). Light consumption is advised for fish >90 cm and no consumption for fish above 115 cm due to mercury levels of 0.50 ppm in these larger sized fish. The tail walking behaviour (breaking water surface) is attributed to air gulping and utilization by the physotomous air bladder fishes.

THREADER, R.W., and C.S. BROUSSEAU. 1986. Biology and management of the lake sturgeon in the Moose River, Ontario. N. Am. J. Fish. Manage. 6(3): 383-390.

A three year study was initiated in 1980 on the Moose River to determine growth-rates and age at sexual maturity of lake sturgeon, estimate population size and examine mercury contamination in tissue. The 549 sturgeon sampled in 1980 and '81 ranged from 2-38 years. The length-weight relationship of a sample of 375 sturgeon of all sexes and maturity stages was $W = 0.002665FL^{3.22623}$ and showed allometric growth. The age-length relationship was as follows; for males $\log_{10}FL = 1.738 + 0.00973$(age), r= 0.72 and for females $\log_{10}FL = 1.653 + 0.0144$(age), r= 0.88. Growth of the Moose river population closely approximated Northern populations such as Lake Nipigon sturgeon but was considerably less than southern populations of Wisconsin and Lake Nipissing. The population was estimated at 7,088 and the sex ratio was 1:1. The age at maturity for females was calculated to be 20 years. Tissue mercury levels increase with increasing length of fish and exceed the allowable 0.5 ppm limit in fish over 102 cm. It is predicted from the Beverton-Holt yield model that increases in fishing pressure will result in over-exploitation. It is recommended that the minimum limits of 63 cm for harvestable fish be removed and in its place, a maximum limit of 100 cm be imposed. An annual

yield of 400 kg could be taken from this recommended range of harvestable fish, resulting in an increase in the exploitation rate for this size range but an overall decrease in exploitation rate from the current 2.5% to 1.8%. This would protect existing spawners and, over time, increase the number of spawners in the population thereby bringing more harvestable fish into the population.

THREADER, R.W., and C.S. BROUSSEAU. 1987. Biology and management of the lake sturgeon in the Moose River, Ontario. Ont. Fish. Tech. Rep. Ser. 23: 47.

The abstract of the paper is reprinted with permission of the North American Journal of Fisheries Management in which it originally appeared. See the above reference for full summary.

THUEMLER, T.F. 1985. The lake sturgeon, Acipenser fulvescens, in the Menominee River, Wisconsin-Michigan. Environ. Biol. Fish. 14(1): 73-78.

A survey of lake sturgeon was carried out on the Menominee river, particularly on the 42 km middle section between White Rapids dam and Grand Rapids dam. Fish were sampled by electroshocking Estimated numbers were 2,543 for sturgeon between 25-107 cm and 206 for fish longer than 107 cm. This data and length frequencies for sturgeon caught compare well with previous studies which were discussed in some detail. Creel data from 1969 and 1970 estimated sturgeon harvests of 59 and 48 fish, respectively. Some aspects of management are also discussed and a 5% exploitation rate is aimed for.

THUEMLER, T.F. 1988. Movements of young lake sturgeons stocked in the Menominee river, Wisconsin. Am. Fish. Soc. Symp. 5: 104-109.

Radio telemetry with surgically implanted radio transmitters were used to monitor the movement of 24 hatchery reared yearling sturgeon of lake Winnebago stock and 10 young sturgeon (2-3 year olds based on size but not aged) of native Menominee river stock after introduction into a section of the Menominee river. A full year separated the two studies. Typically, the yearlings from the Lake Winnebago stock moved quickly downstream, and the fastest recorded downstream travel was 39 km/day and the fastest upstream was 3.2 km/day. The native Menominee River stock dispersed much slower after their release and the fastest downstream and upstream movements were 14.5 km/day and 5 km/day, respectively. It is believed that genetic differences between the Lake Winnebago and the Menominee River stocks of lake sturgeon caused different behaviour patterns.

TODY, W.H. 1974. Whitefish, sturgeon and the early Michigan commercial fishery. In Mich. Fish. Michigan-DNR Fish Div. Manage. Cent. Rep. 1873-1973., Mich. Dept Nat. Res. MS. Rep. 6: 45-60.

In this historical account of the whitefish and lake sturgeon fisheries on the Great Lakes, the author describes the bountiful catches of both species in the early days of the fishing industry. The unchecked commercial exploitation of lake sturgeon began after its value was discovered by an entrepreneur in Sandusky, Ohio who started smoking sturgeon in 1860. It is important to note that lake sturgeon were destroyed in great undocumented numbers as a trash fish, since 1830 when commercial fishing first began on the Great Lakes, and the actual population size in the Great Lakes will never be known for certain. Prior to 1860, sturgeon could be obtained free from the fishing docks. The use of the roe for caviar was unknown in the early days and the flesh was fit only for "servants and slaves". Biennial reports of the State Fish Commission are extensively quoted to describe the rise and fall of the sturgeon fishing industry. It is the authors contention that no single animal was ever subjected to such wanton destruction as the lake sturgeon.

TOWER, W.S. 1909. The passing of the sturgeon: A case of unparalleled extermination of a species. Pop. Sci. Mo. 73: 361-371.

This paper reviews the early experiences of human contact with sturgeon on the North American continent. Sources of reference dating back to 1626 tell of the existence of a sturgeon fishery in Virginia which was later abandoned for some unknown reason. This represents the first attempt at an organised sturgeon fishery on this continent. The abundance of sturgeon is evident from records as antiquated as William Penn's 1683 letter to the Free Society of Traders identifying sturgeon as the most abundant fish of his state. In view of the fact that references are made to the Bay and the Delaware River, they may have been referring to anadromous Atlantic sturgeon. The distinction between the different species can only be tentatively made from early statistics showing the distribution of the catch (east, west coast and Great Lakes). Historians even tell of sturgeon leaping into the canoes and boats of the aboriginal Indians and white settlers. The strong prejudice against sturgeon flesh prevented its emergence as a major industry until after 1850. The history of the early fisheries is reviewed with the Hudson, Delaware and James rivers as important sturgeon fishing areas. In 1880, sturgeon from Lakes Erie and Michigan (undoubtedly lake sturgeon) constituted 3/5 ths of the total US catch. Catch statistics tabulated for the Great lakes region for 1880, 1890, 1897 and 1904 were also probably for lake sturgeon. Statistics for inland sturgeon fisheries were collected for the first time in 1895 and totalled 2,250,000 pounds. Two-thirds of this came from the Minnesota region of the Lake of the Woods. Large catches were also reported

from Washington and Oregon but the first signs of impending collapse were already evident in the returns from the Great Lakes which, in 1897, decreased to one-fourth of the yield in 1880. The decline continued and in 1904, the great lakes region produced 10% of what it did 20 years earlier. The situation is best described by Lake Saint Clair which produced 1,000,000 pounds in 1880, but not more than 10,000 pounds at the time of writing while that of lakes Michigan and Erie had fallen to one-sixtieth of the yield in 1880. This unprecedented collapse of the lake sturgeon fishery is considered a result of poor fishing methods; small mesh size gill nets, grappling hooks dragged over spawning grounds and the pursuit of fish during the spawning season. Georgia was the earliest state to ban all sturgeon fishing for 5 years from 1901 and Minnesota was one of the earliest states to establish close seasons for sturgeon. The author concludes by stating that it is without parallel that a fish that was most abundant all over the continent was virtually fished to near extinction in less than thirty years. The account is valuable for some old references listed as footnotes.

TRAUTMAN, M.B. 1954. A 152-year-old lake sturgeon caught in Ontario. Comm. Fish. Rev. 16: 28.

This short note reports that a lake sturgeon was caught in July by a fisherman. It measured 81 inches in length and weighed 215 pounds.

VAN OOSTEN, J. 1956. The lake sturgeon, p. 9-10. In Our endangered wildlife. National Wildlife Federation, Washington. DC.

This popular article narrates the general life history of lake sturgeon, the process of its extirpation and its present status as a depleted species. The future of the sturgeon and hopes for its restoration are said to appear bleak if earnest research efforts are not initiated to overcome existing problems in their culture techniques.

VLADYKOV, V.D. 1955. Fishes of Quebec - Sturgeons. Departement des Pecheries, Province de Quebec. Album 5: 11p.

This is a general review of sturgeon in Quebec where the French speaking fishermen give it several names; Esturgeon jaune or Camus for adults, Escargot, Maille or Charbonnier for the young. Young sturgeon have large black spots on their snouts, back and sides. The black spots disappear in the adults which become a uniform brownish colour. These lake sturgeon are normally freshwater but during the rainy season they can descend to brackish water. Published records for the largest male is 220 pounds and 275 pounds for the largest female with current catches ranging in size from 50 to 125 pounds. There is a general review of the biology of sturgeon covering the lack of external features for sexing male and females, spawning (between May and July), food habits and growth. Young sturgeon grow from 2.3 to 4.5 inches from August to November. After the rapid early growth it takes about five years for a sturgeon to double its weight. Commercial fishing in Quebec occurs in the James Bay drainage, especially the Ottawa River and its tributaries in Abitibi, Temiscamingue and Pontiac counties. Other areas include the St. Lawrence River from Lake Ontario to the brackish St Roch des Aulnaies. Intensive fishing occurs near Lake of Two Mountains, lakes St. Francis, St. Louis, and St. Peter and the St. Lawrence east to Montmagny. The rivers most frequented by sturgeon are those on the south shore of the St. Lawrence; Bichelieu, St. Francis, and Nicolet and on the north shore are the Batiscan and St. Anne. They are not encountered in Lake St. John, the Saguenay or the tributaries of the Gulf of St. Lawrence. Lake sturgeon are captured in the estuary of the St. Lawrence from Lotbiniere to Montmagny. Old fishermen claim there are five types of meat on sturgeon. Fish are caught with gill nets, baited lines and in weirs or fascines. The average yield is about 200,000 pounds.

VLADYKOV, V.D. 1956. Fish tags and tagging in Quebec waters. Trans. Am. Fish. Soc. 86: 345-349.

The paper discusses tag returns obtained from eight commercial fishes tagged with different types of tags during 1945-1956. Experiments were carried out with cattle ear tags, ring-shaped strap tag and split ring and plate tag. A total of 1,005 lake sturgeon were strap tagged over 1945-1954 and 68 tags were recovered (6.7% return). The maximum time between tagging and recovery is 10 years and the maximum mileage between tagging and recovery stations was 130. This is in contrast to a maximum of 892 miles travelled by the Atlantic sturgeon. Most of the tagging studies were conducted on the St. Lawrence River.

VLADYKOV, V.D., and G. BEAULIEU. 1946. Etudes sur l'esturgeon (Acipenser) de la province de Quebec. I Distinction entre deux especes d'esturgeon par le nombre de boucliers osseux et de branchiospines. Nat. Can. (Que.) 73(6-8): 143-204.

The two species of sturgeon (Acipenser oxyrhynchus and A. fulvescens) in Quebec are described as part of a two year study to evaluate the commercial fishery in the St. Lawrence. Over 2,500 individuals were studied. The mean length of A. fulvescens was 303 cm and for A. oxyrhynchus was 354 cm. Major differences between the two species was based on the bony scutes (plates) and the number of branchiospines (gill rakers). The arrangement of the bony scutes between the anus and the annal fin for A. fulvescens are no more than three rows with two only in the first or second row. There was some

overlap in the arrangement of these scutes (i.e., number of rows) among individuals of A. fulvescens and A. oxyrhynchus but usually there were more scutes per row. The arrangement of scutes post anally in terms in the ventral view differed substantially between the two species. Similarly the scute pattern (post dorsal fin) showed very differ patterns in scute arrangement between the two species. The gill raker counts for the first gill arch of A. oxyrhynchus was a minimum of 16, a maximum of 27 and a mean of 21.6. The gill raker counts for the first gill arch of A. fulvescens was a minimum of 27 a maximum of 39 and a mean of 33.1. The text is well supported by numerous photographs and drawings.

VLADYKOV, V.D., and G. BEAULIEU. 1951. Etudes sur l'esturgeon (Acipenser) de la Province de Quebec. II. Variation du nombre de branchiospines sur le premier arc brachiae. Nat. Can. (Que.) 78: 129-154.

The number of gill rakers on the first branchial arch were used to differentiate between Acipenser fulvescens and A. oxyrhynchus). Less than 4% of the specimens of A.oxyrhynchus can be confused with A. fulvescens in terms of total gill rakers. Less than 2 % of A. fulvescens have the same number as A. oxyrhynchus.

VLADYKOV, V.D., and J.R. GREELEY. 1963. Order Acipenseroidei. Reprinted from Fishes of the Western North Atlantic, Memoir Sears Found. Mar. Res. p. 24-60 In Contributions du Departement des Pecheries, Quebec, No. 53.

In this account the authors describe (original descriptions from preserved specimens) the five types of sturgeon (species and subspecies) found along the East coast of North America. They also discuss life histories and geographical distributions and list synonyms and references. A general account on world sturgeon species precedes a more detailed consideration of the East American species. A key to all North American sturgeon is provided. Acipenser fulvescens (lake sturgeon) is described from 800 specimens caught mainly along various sections of the St. Lawrence River. Its viscera differs from that of the Atlantic sturgeon in being black. Among the East coast species studied, the lake sturgeon is second in size to the Atlantic sturgeon. In 29 stomach samples analyzed for food contents, mayfly (Hexagenia) larvae had the highest prevalence (76%), followed by amphipods (73%), gastropods (48%), bivalves (35%) and fish (24%). Considering it's range, this species is considered to be of greatest commercial value for its smoked flesh. In 1951, 2000 pounds of caviar were produced from roe of this species. Lake sturgeon have been occasionally taken from brackish water but there is no evidence for a marine resident population. It is considered an exclusively freshwater species.

VONDETT, H.J. 1957. A questionnaire census of sturgeon spearing, January-February, 1956, on Black, Burt, and Mullet lakes, Chebogyan County. Mich. Dept Nat. Res. Inst. Fish. Res. Rep. 1529: 12p.

A questionnaire census was conducted for the first time to determine lake sturgeon winter fishing (spearing) on Black, Burt and Mullet lakes during the 1956 spearing season to determine the number and size of sturgeon harvested and fishing pressure. There were a total of 156 shanties on sturgeon fishing grounds (of a total of 473 shanties), 106 questionnaires were sent out of which 74 were returned. The total number of sturgeon spearers for the season was estimated at 103, 64% of whom were covered by this census. A total of 1,316 fishermen days (6,582 hours) with at an average of 5 hrs/day spent spearing 52 fish (127 hrs/fish), was calculated from the questionnaires. The estimate was higher; 9,630 hours for a total of 70 fish. The census showed that Black Lake had the heaviest fishing pressure (3,519 hours) and yielded the most fish (42). The average length was 54.5 inches and 31% of the total consisted of fish over the minimum legal limit of 42 inches. Of 51 fishermen, 53% considered the fishing to be the same as previous years, while the remaining fishermen were divided as to the spearing having been better or worse.

VONDETT, H.J., and J.E. WILLIAMS. 1961. The sturgeon fishery of Black, Burt and Mullett lakes. Chebogyan County, 1957-1958. Mich. Dept Nat. Res. Inst. Fish. Res. Rep. 1616: 29p.

A questionnaire census of the winter sturgeon fishery on Black, Burt and Mullet lakes was conducted in 1957-1958. The census results obtained for the three years is compared and the age and growth data is summarized. The total number of sturgeon spearing shanties increased marginally on Black lake and decreased on the two other lakes. The total number of spearers declined over the two seasons (129 to 108), as did the number of hours (4,751 to 3,720). The number of fish speared increased from 8 to 14 and the hours/fish decreased from 594 to 266. Burt lake produced only two fish in 1957 and none in 1958. Black lake was the most productive, with the highest number of fish and the least number of fishing hours per fish. Data from the 1957-1958 census is compared to the 1956 data and the trends appear similar, with the 1956 season and Black Lake being the most productive. Data on length-weight and age parameters indicate that a large proportion of the sturgeon speared in Black Lake are removed before they reach 60 inches in length and the limited data suggests that Michigan lake sturgeon attain legal size (42 inches) when they weigh 12 - 15 pounds and 15 years of age and about 150 pounds at 80 inches. The populations of these three lakes have been reportedly isolated from the Great lakes population since 1868 by a dam on the Cheboygan River and the Alverno dam on the lower Black

River separated the Black Lake population from the other two since 1903. Two other dams, Tower and Kleber dams, built since then restricted spawning migrations and sturgeon presently spawn at the foot of the dams. It is suggested that imposing season limits on sturgeon and spacing of the spearing season every 4-5 years would help in conserving this species. Tagging studies are urged on the Upper Black River to investigate migration and spawning habits.

WALKER, C.R. 1952. The sturgeon. MO Conserv. 13: 16.

This article describes the sturgeon of Missouri's freshwaters. Three acipenserids are present of which the lake sturgeon is the largest. Individuals 200 pounds in weight were reported in 1911. Commercial sturgeon harvest (mostly shovelnose) ranged from 6,000 -13,000 pounds a year over seven years prior to 1952. The 1946 harvest was only 6% of the 1899 catch. The alteration of habitat by impounding waters for navigation pools is thought to have contributed to the near elimination of the sturgeon. The failure of artificial propagation of sturgeon is attributed to the difficulty in obtaining ripe and running females.

*WALLACE, R.J. 1913. A retrospective examination of lake sturgeon abundance and growth in the Saskatchewan River, Saskatchewan. University of Manitoba. M.Sc. Essay. 32p.

There is no record of this article in the holdings of the University of Manitoba libraries.

WALLACE, R.G. 1991. Species recovery plan for lake sturgeon in the Lower Saskatchewan River (Cumberland Lake area). Saskatchewan Parks and Renewable Resources Fisheries Branch, Fish. Tech. Rep. 91-3. 51p.

The status of the lake sturgeon population in the Cumberland Lake area is discussed. The report outlines the historical causes for the decline in populations; the loss of half the mature sturgeon population in 1960 during the construction of the squaw rapids hydro-electric dam, elimination of large spawning grounds through re-routing of waterways, water-level fluctuations by hydro dams during spawning, and continued commercial exploitation at the same level despite the above changes to the population. A comparison between commercial catches of 1958 and 1975-1980 showed a disappearance of sturgeon above 40 years of age. The commercial fishery was monitored in 1990 and showed that introduction of young individuals into the population was occurring at only 8-15% of the former level. Growth of Saskatchewan River sturgeon (as expressed by fork-length over age) compares favourably with other populations (Winnebago, Upriver, St. Lawrence, Menominee, Nipigon, Nelson etc., see Fig. 5 on p.10). The recovery plan includes public awareness, habitat enhancement and protection, reduction of fishing quotas and protection of spawners, inter-provincial cooperation and applying for funding.

WALTON, D.G. 1976. Sturgeon fishery, Cumberland House area, 1975. Department of Northern Saskatchewan. MS. Rep. 16p.

The report outlines the history of the fishery and discusses the management aspects such as annual limit, minimum size restrictions and the use of hooks and nets. The annual quota of the time (6000 lbs.) is considered acceptable but a more in-depth study on population size is urged, Males are said to mature at 16 years of age (39 in.) and females at 20-23 years (42-45 in.). It is recommended that the minimum size should be atleast 42 in. (lengths are fork lengths). It is also strongly recommended that the 10 lb. minimum dressed weight be immediately stopped. In view of the difficulty in comparing whole sturgeon (delivered when caught by hook) with dressed sturgeon (net fishery), the use of the standard length is considered more practical. The use of hooks should be discontinued or used subject to certain conditions to avoid indiscriminate hooking of undersized sturgeon. Also, more data is required on age of fish at maturity.

WANG, Y.L., F.P. BINKOWSKI, and S.I. DOROSHOV. 1985. Effect of temperature on early development of white and lake sturgeon, Acipenser transmontanus and A. fulvescens. Environ. Biol. Fish. 14(1): 43-50.

This paper investigates the effect of temperature on the timing of early development and survival of white- and lake- sturgeon. The different stages of development, pre-hatch (cleavage, gastrulation, neurulation, organogenesis) and post-hatch (yolk-sac stage and yolk depleted) are described with a plate of figures for each species. Development is accelerated by 100% as early as gastrulation between 10 and 20°C. More advanced stages are accelerated even further in lake sturgeon but the overall development of lake sturgeon is slower than in white sturgeon. Lake sturgeon eggs hatched in 380-430 hours at 10°C and 90-105 hours at 20°C and the yolk-depletion stage was reached 1,316 hours post fertilisation at 10°C. All embryonic mortalities occurred between early gastrula and late neurula. Temperatures of 20-22°C during cleavage and 18-20°C during organogenesis lowered embryonic survival.

WARREN, M.L.Jr., B.M. BURR, and B.R. KUHAJDA. 1986. Mississippi river sturgeons: New Kentucky records and comments on status. Trans. Ky. Acad. Sci. 47(1-2): 52-53.

This is the first confirmed report of lake sturgeon in the Mississippi river of Kentucky.

Records of lake sturgeon from this river in Kentucky, in the 20th century, have been anecdotal and the authors consider the population in the state as endangered. The occurrence of two other acipenserids in the state (pallid and shovelnose) is also discussed.

WEBB, P.W. 1986. Kinematics of lake sturgeon Acipenser fulvescens at cruising speeds. Can. J. Zool. 64: 2137-2141.

The authors observations on sturgeon were designed to test the hypothesis that the locomotor kinematic pattern of teleosts is a general one for actinopterygians and that the differences in patterns with selachians are to maintain appropriate phase differences between median fins, to increase efficiency. The 2-minute critical swimming speed of sturgeon was calculated at 38.6 ± 4.2 cm/sec or 2.45 ± 0.23 total body length/sec at 15°C. The equations f(frequency, Hz) = 1.67 + 0.07 x U(speed, cm/sec); a(amplitude, cm) = 3.2 + 0.020U and propulsive wavelength (cm) = 11.0 + 0.039U. Swimming kinematics were similar to those of teleosts and anuran larvae indicating that fin propulsive movements are conserved in evolution. Drag per unit area is 3.5 times higher than other actinopterygians owing to the scutes and the thrust generated by a swimming sturgeon was an average of 82% that of the same sized trout.

WELLS, LaR., and A.L. McLAIN. 1973. Lake Michigan. Mans effects on native fish stocks and other biota. Gr. Lakes Fish. Comm. Tech. Rep. 20: 1-55.

This report opens with description of Lake Michigan, followed by a discussion of the factors that have changed the native fish populations over time. The lake sturgeon is one of 15 species of fish discussed as case studies. The original population of this species was reportedly more drastically depleted over the shortest span of time compared to any other fish species. The catch plummeted from 3.8 million pounds in 1879 (the year of first production records) to 96,000 pounds in 1899. The trend continued and a harvest of only 2000 pounds in 1928 marked the introduction of a ban the following year, on any lake sturgeon fishing on the Lake. Sturgeon fishing in the state was legalised in 1951 but production has never exceeded 5000 pounds. This decline is attributed to overfishing and stream degradation, coupled by late maturity ages. Prior to the first harvest record of 1879, fishermen had already depleted stocks in an effort to exterminate what was perceived at the time to be a nuisance fish damaging nets.

WILLIAMS, J.E. 1951. The lake sturgeon. Mich. Conserv. 20(6): 15-18. (Also, Mich. Dept Conserv. Ann Arbor, MI. Rep. 1297: 4p).

This article covers general information on lake sturgeon such as its body shape, biology, feeding, life history statistics (age to maturity, large size). It became commercially important in the 1870s in Michigan for caviar, isinglass, and its skin. By 1885 there was a harvest of 1.5 million pounds but declined to "...practically nothing by 1926"... Sturgeon spearing has occurred since 1948, concentrated in the Cheboyan and Indian River chain of lakes (Black, Burt, and Mullet). A brief description of winter spear fishing of sturgeon is given and fish were sold ($1.00/pound for meat and $3.00-/pound for eggs). The record sturgeon from Mullet lake was 152.5 pounds, 78 inches long with 47 pounds of eggs. Michigan planted 580,-000 young sturgeon in the Detroit River in 1893 to 1894 as this was the only successful rearing of sturgeon at the time of this report. Spawning occurs at temperatures between 60-70 F and rolling, splashing, and jumping are often observed. Several males are associated with each spawning female and it is thought that females do not spawn each year. Young sturgeon feed on small crustacea and adults fed on larval midges, caddisflies, dragonflies, mayflies, clams, snails, and crayfish. Small fish are eaten and large suckers have been found in sturgeon stomachs. The author reports a sturgeon caught in Lake Michigan weighed 375 pounds and was eight feet in length. It was suggested that it takes 15-20 years for a sturgeon to reach the legal size of 36 inches. There is a discussion on the wanton destruction of sturgeon including the commercial fisheries and work being done in Michigan. The author concludes that very little is known about the life history of sturgeon in Michigan.

WILLIAMS, J.E., and H.J. VONDETT. 1962. The lake sturgeon, Michigan's largest fish. Mich. Dept Conserv. Fish Div. Pamph. 35: 6p.

The general life history of lake sturgeon is described with reference to Michigan waters. The presentation is for popular reading without specific references in text. Information includes a brief history of sturgeon fishing in the state, the spawning behaviour and the questionnaire census of 1956-1958 determining the winter fishing status of lake sturgeon in Burt, Mullet and Black lakes. Some of the comparative census data is repeated from other publications and graphs depict the length - weight and age-length relationship of lake sturgeon of these lakes.

WILLOT, P. (Ed.) 1989. Acipenser, Actes du Colloque. Premier Colloque International sur l'esturgeon. Centre National Machinisme Agricole du Genie Rural des Eaux et des Forets. (CEMAGREF). Bordeaux. 519p.

This book covers the proceedings of the First International symposium on sturgeon held at Bordeaux in 1989. A total of 43 articles were published, four of which deal specifically with

lake sturgeon. Three of the four articles describe the population biology of lake sturgeon stocks in the St. Lawrence River and two other waterbodies in Quebec. Fortin et al. (p.295-314) discuss distinctions between lake sturgeon stocks in the Saint Lawrence river and the Lac des deux Montagnes, Gunette and Fortin (p.327-328) compare the morphology of the sturgeon from the above mentioned waterbodies, and Lamourex and Laforce (p. 315-326) present analysis of the lake sturgeon caught in the Saint Lawrence River between 1985 and 1989 with a discussion of their biological characteristics. There is one article on subsistence lake sturgeon fishery of the village of the Muskrat Dam in Ontario (Michalenko et al. p.447-458).

WILSON, N.C. 1987. Age determination of lake sturgeon (Acipenser fulvescens) by use of the marginal pectoral fin ray. Ont. Fish. Tech. Rep. Ser. 23: 77-83.

Various aspects and problems associated with age determination of sturgeon using sections of the marginal pectoral fin ray are discussed. It is suggested that cuts to remove this fin ray be made 3-5 mm from the basal cartilage articulation to minimize blood loss and increase accuracy of readings. Sections between 250-400 um thickness and taken close to the proximal cut end of the ray are considered best for reading annuli. Annular patterns are discussed and the posterio-lateral regions of the section are considered to give the clearest readings. Sturgeon under 20 years are most easily aged and although clumping of annuli into multiple narrow bands was characteristic for older fish, it was impossible to accurately count the number of annuli making up each such narrow band. Followup studies are recommended to determine the effect of fin ray removal on survival of sturgeon ages by this method.

WIRTH, T. 1959. Winnebago: the big lake. Wis. Conserv. Bull. 24: 15-19.

The physical parameters such as drainage rivers and bottom substrate and the biota, particularly the fish are discussed with a view to supplying pertinent information to sport-fishermen. Spearing for lake sturgeon is recommended in the winter since there is no angling season for lake sturgeon since it is unproductive.

*WIRTH, T., and C. CLINE. 1955. The harvest of lake sturgeon (Acipenser fulvescens) by spears in Lake Winnebago and connecting waters, Wisconsin. Wisconsin Conservation Department. Mimeo.

WOODS, L.P. 1956. Problems of conservation in the great lakes. Bull. Chicago Nat. Hist. Mus. 27(4): 3-5.

The problems associated with lake sturgeon, whitefish and lake trout fisheries of the Great lakes is considered. The decline of these three fisheries is regarded not only as a case of overfishing but selective fishing and the introduction of pound nets in the 1850's resulting in a great number of immature fish being captured. Of the three depleted species, the sturgeon was reportedly the first to go. The fishery for sturgeon began around 1870 with initial catches of 10,000 - 20,000, reaching a high of 8 million pounds in 1885 and declining rapidly thereafter to a level of commercial insignificance during the 20th century. The general effects of climatic changes, fishing gear, pollution and the introduction of exotic species, as factors, are discussed in context of declining fish populations. The necessity of an overall survey is discussed and the need to support various institutes and commissions set up to monitor Great Lakes productivity is discussed.

YAMADA, K., and M. HOSHINO. 1972. Effects of added electrolytes upon ruthenium red reactions of model poly anions on filter paper and in tissue. Acta Histochem. Cytochem. 5(1): 18-25.

Chondroitin sulfate A was recovered from the notochord of lake (rock) sturgeon and used as a reference standard for acid mucopolysaccharides. Tissue was recovered, minced, fixed with Carnoy's, dehydrated with ethanol, cleared in benzene and embedded in paraffin, and sections cut at 8 u. These sections for sulfation were immersed for 10 minutes at 4 C in 40% (V/V) sulfuric acid in glacial acid. Ruthenium red was the dye being tested for use in light microscopy. Results indicate that the three anionic groups i.e., sulfates, phosphates and carboxyls can be responsible for the ruthenium red reactions of polyanions.

YOUNG, J.K., and G.F. LOVE. 1970. The lake sturgeon (Acipenser fulvescens) of lake Nipissing. Ontario Department of Lands and Forests, North Bay District. MS. Rep. 24p.

The Interlibrary Loans Section of the University of Manitoba informs us that they have exhausted all possible locations for this item.

YOUSON, J.H., and D.G. BUTLER. 1976. The adrenocortical homolog in the lake sturgeon, Acipenser fulvescens. Am. J. Anat. 145(2): 207-224.

The adrenocortical homolog of the lake sturgeon was examined by histochemistry and electron microscopy to understand it's phylogeny among vertebrates. The tissue was located in spherical or oblong yellow corpuscular bodies approximately 81 in number (in one specimen) along the dorsal band of connective tissue supporting the cardinal veins running between the kidneys. The bodies are more concentrated anteriorly and rarely deep within the kidney. Histochemistry revealed that they contained d^5-3b-hydroxy-

steroid dehydrogenase, common to adrenocortical cells and their homologues in other vertebrates. The corpuscles were made of anastomosing cords of epithelial cells with blood vessels separating them and completely surrounded by hoemopoeitic tissue. The fine structure of the cells is described with the Golgi apparatus as the most conspicuous component along with lipid droplets in large cytoplasmic vacuoles, numerous mitochondria and replete with smooth endoplasmic reticulum. The concentration of corpuscles anteriorly indicates a more advanced state in comparison to anadromous Atlantic sturgeon and follows an evolutionary trend among vertebrates towards the concentration of adrenocortical tissue into larger bodies or in specific areas. Morphological evidence suggests that the corpuscular epithelial cells are actively involved in corticosteroid synthesis.