THE LAKE STURGEON

LAKE STURGEON (*Acipenser fulvescens*)

ONTARIO

DEPARTMENT OF LANDS AND FORESTS

HON. J.W. SPOONER
Minister

F.A. MacDOUGALL
Deputy Minister

R.W. Threader
1981

THE

LAKE STURGEON

THE HISTORY OF ITS FISHERY
AND PROBLEMS OF CONSERVATION

By

W.J.K. HARKNESS and J.R. DYMOND

Fish & Wildlife Branch

ONTARIO DEPARTMENT OF LANDS AND FORESTS

Hon. J.W. Spooner, Minister — F.A. MacDougall, Deputy Minister

ONTARIO

1961

Foreword

The accumulation of information for this account of the Lake Sturgeon began in 1922 when Dr. W.J.K. Harkness, then a recent graduate in biology of the University of Toronto, undertook a study of the sturgeon in Lake Nipigon. At that time, Lake Nipigon had an almost virgin population of sturgeon since commercial fishing had only begun on the lake in 1917.

Field studies on Lake Nipigon continued during the summers of 1922 to 1926, with some observations on Lake Nipissing in 1926 and 1929 to 1935, and on Lake Erie during the summers of 1941 and 1942.

While Dr. Harkness was a member of the staff of the Department of Zoology, University of Toronto, 1924 to 1946, and Chief of the Fish and Wildlife Branch, Department of Lands and Forests, 1946 to 1960, he continued to compile information on the sturgeon, but never found time to organize it for publication.

Dr. J.R. Dymond's contribution has been in extracting additional information from published accounts of the sturgeon and in organizing it in the present form. The work of organization and editing had been almost completed in co-operation with Dr. Harkness before his death on July 5th, 1960.

J.W. Spooner,
Minister, Lands and Forests

TABLE OF CONTENTS

I THE LAKE STRUGEON

The early history of European settlement in North America has been marked by the profligate use, amounting in many cases to deplorable waste, of natural resources. Classic examples of reckless destruction are afforded by the history of the bison and of the passenger pigeon. Not as well known, but equally inconsiderate, was the early treatment of the sturgeon once found in abundance in our more productive waters.

Common to most of these examples of the destruction of living resources was the wish to eliminate them in the interest of others considered at the time to be of more importance. The sturgeon was not only a nuisance but a detriment in efforts to catch the kinds of fish sought when the fisheries of the Great Lakes began to be exploited.

Patrick Campbell, (13) in an account of his travels in the interior inhabited parts of North America in 1791 and 1792, records that on the north side of the Niagara River where it empties into Lake Ontario he "saw 1008 (fish) caught at one hawl of the seine net, mostly what is called here whitefish and a few herrings . . . . . I saw several other kinds caught here, particularly the sturgeon which is a bad, useless sort of fish."

Sturgeon, being bottom feeders like whitefish, were commonly taken in seines used to capture this species. It can be imagined how a fisherman felt at finding that the difficulty in hauling his net ashore was due to the weight of worthless fish, some weighing up to 150 pounds. Although sturgeon today sell for more per pound than any other freshwater fish, they could at that time seldom be sold at all. Not only were they worthless, but the weight of the big ones and the bony, serrated plates of smaller ones injured the nets so that it sometimes required days to repair them after a catch of several sturgeon.

Some fishermen were considerate enough to lower the corner of their seine nets and allow the sturgeon to escape, but one gets the impression from reading the accounts of these early fishing efforts that the sturgeon were more commonly drawn out of the net with a gaff-hook and let go wounded or taken ashore and thrown on the refuse heap with the remark that there would be so many less to cause trouble in future.

Another picture of sturgeon destruction before their value became appreciated is afforded by an account (98) of the practice of spearing them from a bridge over the Missiquoi River flowing into Lake Champlain. When speared, they were hauled over the bridge by means of a cord attached to the spear, "the eggs coming from the sturgeon so freely that they covered the bridge". This practice was stopped, not because of the waste of eggs and fish, but "because the bridge was smeared with sturgeon eggs . . . . . they actually stopped the sturgeon fishing because they wanted to avoid the stench from the eggs." Even after their value began to be appreciated, the immature and unmarketable young incidentally caught, were too frequently destroyed as nuisances.

Many picturesque accounts are given of early efforts to dispose of sturgeon. In places, they were piled on the beach like cordwood and, after they had been

lying in the sun long enough for the fat to run, they were set afire and burned. Mr. A.F. Langlois, father of Dr. T.H. Langlois, told Harkness that in the days of wood-burning steamboats on the Great Lakes, sturgeon were piled on the wood-dock at Amherstburg, taken aboard the boats and burned under the boilers. Another use was to dig them into the ground as fertilizer.

In 1942, Bert Millen, hatchery superintendent at Put-in-Bay, Ohio, told Harkness that his grandmother, who was born about 1850, used to live at Point Pelee. She remembered when sturgeon came to the bar off the Point in May and June in such numbers that her father, standing in a flat-bottomed boat, killed numbers of them by hitting them on the head with an axe. Only the largest were taken. These they boiled in a big pot using driftwood along the shore. When it cooled, the oil was skimmed off and sold in Detroit at 75 cents a gallon. It was probably used as a paint oil. The flesh was fed to pigs or ploughed into the the ground. This would be between 1860 and 1879. Small quantities were smoked and eaten, or sold to people who came for it from Detroit. Other ways of preparing it was by drying or putting it in brine like corned beef.

French-Canadian people are said to have prepared sturgeon in the form of soups (bouillon). "With a good, hearty out-door appetite, this is very palatable food, but too rich in the flavour of the oil of the fish for ordinary use. The flavour of sturgeon meat has very little of the taste of fish, and the bouillon, when carefully prepared by skimming off the oil, is very much like chicken soup. A very good pickled meat is made of it by boiling it and preserving it in vinegar." (67) Small, writing in 1865, (83) said its flesh, if properly cooked, was very good, resembling veal more than fish; it was, he said, generally cut into steaks and fried.

Until long after the colonial period in the United States, sturgeon roe was regarded as worthless except as feed for hogs or as bait for other fish.

Prejudice against eating sturgeon seems to have had two bases; one was not knowing how to prepare it, and the other was that it was the food of inferior people, such as servants, slaves and Indians.

The low opinion of sturgeon was based not only on its destructiveness to nets and its worthlessness as a commercial fish but to the belief that it was destructive to more valuable food fishes. E.E. Prince, Dominion Commissioner of Fisheries, writing in 1899, (73), refers to "the charges almost universally made against the sturgeon that it is the most voracious of all fish-eating species, that it scours the spawning grounds of the great lake trout, the whitefish, and every other kind of valuable market fish, sucking up the eggs with its tube-like mouth and scooping in whole schools of defenseless fry". The food habits of sturgeon, discussed in detail below, give no support to this exaggerated and ill-founded statement.

The slight demand and the abundant supply resulted in a very low price. Before 1860, if it was possible to sell them at all, they did not bring over 10 cents apiece. When they began to be smoked in Sandusky in 1860, the price rose to 25 cents apiece, but they had to be at least four feet long to command this price. A little later, Indians are said to have taken them to Detroit, piled

on wagons like cordwood, and sold them at 50 cents apiece (98).

It was the practice of smoking sturgeon and the use of their roe in the making of caviar that led to an active demand. The supply was so abundant at that time on Lake Erie that, during 1872, 13,880 sturgeon averaging 50 pounds each were smoked. By 1880, the sturgeon fishery had become an important branch of the fishing industry.

Another product in demand at the time sturgeon began to be fished commercially (which contributed to the development of an appreciation of the fish) was isinglass. This was a form of gelatin obtained from the swim-bladders of certain kinds of fish. The most valuable source was the various kinds of sturgeon. Other uses of sturgeon at this time included the making of leather from its skin and oil from its flesh.

II. STURGEON – LIVING FOSSILS

Sturgeon are fascinating fish for reasons other than the economic. They belong to a small group of fish living to-day which have retained to the present many of the features possessed by their ancestors.

The sturgeons, as a group, have the appearance of relics of a past era. They are living fossils in that they are so like their remote ancestors, impressions of which, essentially sturgeon-like in appearance, are found in rocks laid down during the upper Cretaceous period nearly one hundred million years ago. At that time, sturgeon-like fishes were much more numerous than they are today.

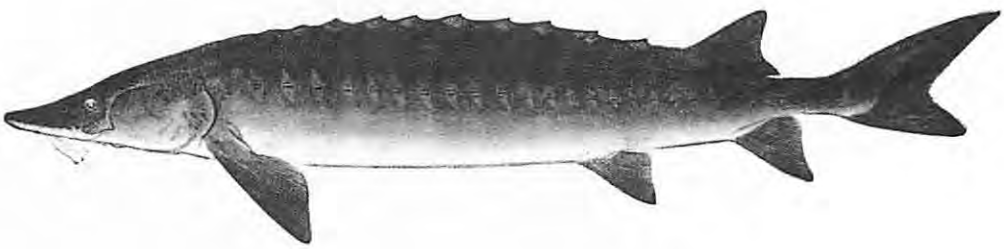
These ancestral sturgeons lived in what may be called the middle ages of fish life. Like the knights in the middle ages of human history, most of the fish at that time were armoured. This armour they still wear in the form of large, bony shields. Just as the cumbersome armour of our middle ages has been abandoned in favour of freer movement, so modern fish wear smaller, thinner, overlapping scales which also favour freer movement.

The sturgeons have many other primitive characters which have been lost or radically modified through the slow evolutionary changes by which the kinds of fish which dominate our waters today have been derived from their ancient ancestors.

One of these primitive characters is their large, cellular swim-bladder which contributes to the economic worth of the sturgeon through its value in the manufacture of isinglass. The swim-bladder which, in modern fish, is a thin-walled hydrostatic organ, has been derived from an air-sac used as a lung in ancient times. In the sturgeon, it still retains some of its lung-like characters.

Still another primitive feature of sturgeons is the shape of their tail fin whose upper lobe is longer than the lower, as in the shark.

The lake sturgeon is only one of twenty-five kinds of sturgeon found in Europe, Asia and North America. They are most numerous in Europe and least so in Asia. Most of them live in the sea except when they come into rivers to spawn; however, several kinds spend all their lives in fresh water, and our lake sturgeon is one of these. A complete list of the sturgeons of the world may be found in Appendix I.



LAKE STURGEON ***(Acipenser fulvescens)***

III. SIZE

Sturgeon are famous for the size to which they grow. The largest lake sturgeon of which we have authentic record weighed 310 pounds. It was caught in Batchewana Bay, Lake Superior, on June 29th, 1922, and a more recent fish of the same weight was taken in Lake Michigan in 1943. Each was nearly eight feet long. Larger ones are reported to have been taken in earlier times, but the weight of none of these can be authenticated.

Our lake sturgeon, however, has much larger relatives. The largest North American sturgeon for which we have a reasonably authentic record (41), was a white Orgeon sturgeon (Acipenser transmontanus) 12.5 feet long, weighing 1,285 pounds. It was taken in 1912 in the Columbia River about 125 miles from the mouth.

Larger American sturgeon have been reported, but the reports lack the authenticity of the Columbia River specimen. It is reported that a 2,000-pound fish caught in 1892 near Astoria was mounted and exhibited at the World's Fair at Chicago. However, it is impossible now to obtain confirmation of the legendary weight of this fish.

The world's record sturgeon appears to be Huso huso, often called beluga, although this name is also applied to a whale. The record Huso was taken at the mouth of the Volga River in 1912. Its length was 14 feet, 2 inches, and its weight 2,250 pounds. (41)

Reports of larger specimens, up to 3,200 pounds, are doubted by Gudger (41) who carefully sifted all the reports of giant fishes he could find.

1. The King of Fishes and the Fish of Kings

On the white sand of the bottom
Lay the monster, Mishe-Nahma,
Lay the sturgeon, king of fishes.

Longfellow, Hiawatha.

Sturgeon are called the King of Fishes because of their great size and the Fish of Kings because in Great Britain the sturgeon is a Royal Fish. By an Act of King Edward II, still unrepealed, "the King shall have the wreck of the sea throughout the realm, whales and great sturgeons . . . . . except in certain places privileged by kind". The Lord Mayor of London can claim all sturgeons caught in the Thames above London Bridge.

There is something about fish which stimulates tall tales, and sturgeon, being the largest of all fish except for a few of the largest sharks, are responsible for their share of "fish stories" An interesting one concerns an event which allegedly occurred during Revolutionary days in the United States. According to this story, Silas Cattell, a colonial militia commander, hooked into a mighty sturgeon in the Shrewsbury River, and was taken for a "Nantucket sleigh-ride" which continued until the fish ran into shoal water. Silas jumped overboard and wrestled the sturgeon into the boat.

But, the fish was so long that its tail hung over the stern, and it soon

found that by wiggling its tail it could propel the boat. So, off they went again at a furious pace until the boat upset and the sturgeon got away. Silas felt badly about losing the fish, but the next time he went out in his boat he found the sturgeon hanging around. He baited the big fish, the bait was accepted, and off they went again on their joy-ride.

This happened frequently, until one day the sturgeon varied procedure by veering into a small side creek. Silas looked up just in time to note that they were approaching at break-neck speed a log bridge on which some cattle were passing. Silas didn't think he could clear the bridge, so cut the line. But the sturgeon ran into the piling of the bridge and knocked it into the stream, including the cattle. Silas had been using beef for bait and the sturgeon had become quite fond of it. The fish grabbed a calf for himself and disappeared.

Sturgeon stories less fantastic but more credible, illustrating its strength, have been told. In March, 1951, it was reported from Haileybury that a Lake Timiskaming sturgeon burned down an ice-fisherman's shack. The fisherman hooked a five-foot sturgeon and landed it after a terrific battle. Dragging the fish into his hut, he dashed out to tell his friends about his luck. Thrashing around the floor, the sturgeon upset the fisherman's stove. By the time he returned with his friends, a pile of glowing embers was all that was left of his hut, fish and equipment.

Another story concerns a sturgeon that broke the leg of one of two fishermen who were trying to spawn her. She dealt the leg such a terrific blow with her tail as to fracture it.

2. Some Record Lake Sturgeon

Whether larger sturgeon were to be found in our lakes before their numbers were so drastically reduced is not known. Milner, who in 1872 visited the fisheries on Lakes Michigan, Superior, Huron and Erie, heard reports of nine-foot sturgeon "in the good old days", but saw none that attained a length of even six feet, (67). One of the two largest lake sturgeon for which we have adequate data was taken as recently as 1943.

Following are details of all the sturgeon over 100 lbs. in weight of which we have record. Many of these records are taken from newspaper accounts and, therefore, cannot be given the same credence as scientific records, but the largest ones have been reasonably well authenticated:

310 lbs., 7'11", Lake Michigan, 1943. Van Oosten.

310 lbs., 7' 6", Batchewana Bay, Lake Superior, June 29, 1922. This record is well authenticated.

287 lbs., Olga Lake, P.Q., 1956. Report by Gordon Kelso, Sturgeon Falls to District Forester, North Bay.

275 lbs., Lake Winnipeg, July, 1941, (45).

242 lbs., 7' 2", Georgian Bay at Wasaga Beach, July 1951. Toronto Star, July 11, 1951.

240 lbs., Lake Erie, about 1900. Verbal report to Harkness.

236 lbs., about 8 feet long, off Long Point, Lake of the Woods, June, 1911. (29).

235 lbs., S. Lake Huron near Sarnia. Toronto Globe and Mail, May 24, 1948.

230 lbs., 6' 8", Niagara River, Oct. 28, 1946. Reported by Overseer Muma.

225 lbs., 6' 7", Georgian Bay, June, 1951. Toronto Star, June 29, 1951.

220 lbs., Lake Erie, 1948, (92).

217 lbs., Ottawa River near Montebello, Toronto Globe and Mail, March 26, 1931.

215 lbs., 7' 4", Lake Erie, June, 1934. Toronto Star, June 1, 1934.

215 lbs., 6' 9", Lake of the Woods, 1953. Dept. of Lands and Forests, Fish and Wildlife Management Report, No. 34, 1957.

212 lbs., 7' 6", Beaumont, P.Q., 1945, (105).

212 lbs., "Largest fish to be caught in Bay of Quinte waters in almost half a century." Toronto Globe and Mail, Aug. 20, 1952.

200 lbs., 7' 1", Niagara River, foot of Porter Ave., Buffalo, May 14, 1935. Dr. Emmeline Moore, N.Y. Conservation Department.

200 lbs., Alexandria Bay, Lake Ontario, April, 1937. "Largest Sturgeon caught there in the past twenty years." Toronto Globe and Mail, April 14, 1937.

197 lbs., Lake Ontario near Niagara-on-the-Lake, June, 1944. "Believed to be the largest fish ever taken from Lake Ontario." Toronto Star, June 23, 1944.

189 lbs., 6' 8", Lake Erie, Letter, Ray B. Lambert, Sept. 9, 1942.

180 lbs., near Kelley's Island, Ohio, Apr. 20, 1935.

180 lbs., near Kettle Falls, Rainy Lake, June, 1936. International Falls Journal, Aug. 19, 1952.

180 lbs., "Believed to be the largest sturgeon ever taken from Lake Ontario in the Beamsville area." Newspaper report, July 13, year?

175 lbs., 6' 2", Georgian Bay, Apr., 1932. Toronto Globe and Mail, May 17, 1932.

175 lbs., 5'6", May 15, 1927, Lake Deschenes, Ottawa River. Toronto Globe and Mail, May 17, 1927.

165 lbs., Lake Nipigon, 1923. Largest Lake Nipigon sturgeon up to that time. Harkness diary.

163 lbs., 6' 7", Lake Erie, June 8, 1942.

157 lbs., 6' 6", Port Elgin, Lake Huron, Oct. 23, 1927. Toronto Telegram, Oct. 31, 1927.

157 lbs., 6' 2", Nottawasaga Bay, Georgian Bay. Net and Twine, Sept. 1, 1959.

154 lbs., Bay of Quinte, Lake Ontario, about 1920.

153 lbs., 6' 2", Lake Erie, Apr. 26, 1944.

152½ lbs., 78", Mullet Lake, Mich., (110).

140 lbs., Red Lakes, Wisconsin, about 1942. Letter, Lloyd L. Smith, Sept. 10, 1942.

140 lbs., Georgian Bay near Waubaushene, May 21, 1958. Toronto Star, May 22, 1958.

138 lbs., Lake Erie near Wallacetown, Ont., May, 1949. Toronto Globe and Mail, May 9, 1949.

135 lbs., 6' 10", Lake Erie at Kingsville, Apr. 14, 1928. Found dead on shore by Jack Miner

129 lbs., 6' 7", Rainy Lake, Aug. 1952. International Falls Journal, Aug. 19, 1952.

IV. DESCRIPTION

Two of the external features which distinguish the lake sturgeon from all other fresh water fishes of our area are its covering of large, bony plates and its shark-like tail fin.

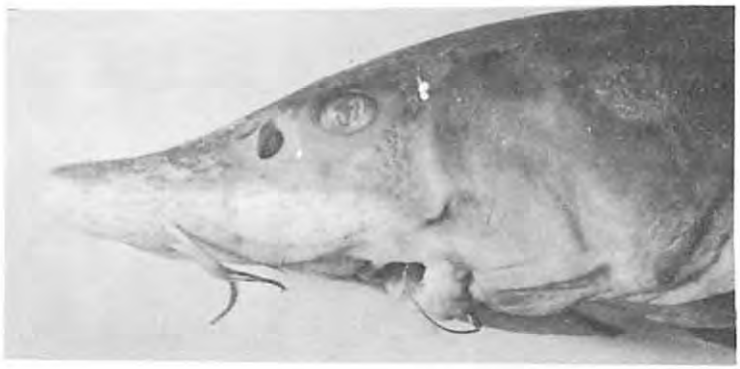
On small sturgeon, the bony shields nearly cover the back and sides, are rough and terminate in a sharp-pointed spur. Their marked difference from large sturgeon led to their being long regarded as a different kind. They were called Rock Sturgeon. The one shown here was 5.7 inches long.

In general shape, it is heavy in front and tapering behind. The snout is long and tapering, longer and sharper in the young, becoming relatively shorter and blunter with age, with a crosswise row of four sensory barbels or feelers on the lower side of its snout in front of the mouth. These help the sturgeon to explore the bottom in search of food. The mouth, in relation to its bottom-feeding habit is on the lower surface of the head; the lips can be protruded in feeding and retracted when not in use. It lacks teeth.

The stomach is gizzard-like, with thick walls, especially at its pyloric end. This is no doubt an adaptation to some items of its food. For instance, small clams and snails sometimes make up a large part of its food.

The bony plates are arranged in five longitudinal rows, two on either side and one along the back. The sides between the larger plates are roughened with much smaller plates. In young, up to a length of about two feet, the plates have well-developed keels, terminating in a sharp-pointed hook or spur. With age the plates gradually become smooth and over grown by skin so that in specimens over three feet in length the body is usually quite smooth. The spiny appearance of the young is in strong contrast to the smooth adults.

The character of the bony plates which cover so much of the sturgeon's body is indicated by the following description by Frank Buckland, (12), "the stud-like bones are most beautiful objects, being as hard or harder than ivory, with the outer surface indented and marked as though they had been carved by a Japanese artist. When set in silver, selected samples of these shackles



The sturgeon is equipped for feeding off the lake bottom by having its mouth on the underside of the head, preceded by four barbels or feelers which help in finding food. The lips can be protruded in feeding.

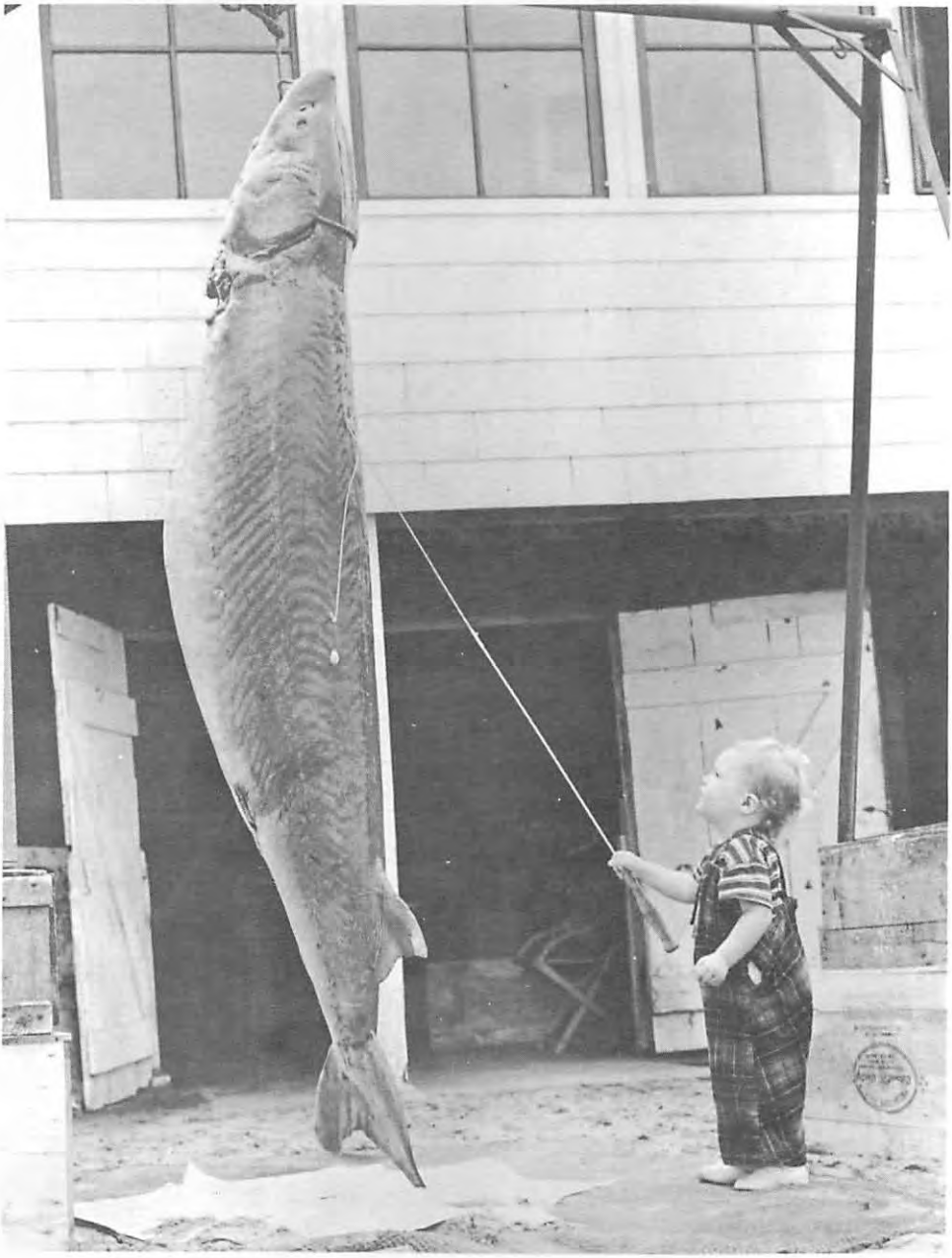
form very beautiful ornaments for ladies' dresses, and I certainly would advise my lady readers who are always looking out for something new and pretty to try the effect of sturgeon's shackles when worn as ornaments."

1 Colour

The young have dark blotches on the sides; these disappear with age. There is considerable variation in colour, the meaning of which is not clear. Some of the variation is due to age, but there also appear to be differences from one locality to another. See discussion of Kinds below.

Some shade of tan, buff, brown, olive or golden is frequently mentioned in descriptions. The scientific name fulvescens, meaning fulvous or tawny, was given to specimens taken in the Great Lakes. Others are grey or slate-coloured while some are black. Young, whether grey or some brownish shade, are usually lighter-coloured than older and larger ones.

A reddish colour is frequently mentioned in published descriptions. Le Sueur (56), described the sturgeon of the Great Lakes as yellow-red on the back and olivaceous-red on the sides. The scientific name, rubicundus, which he suggested for the lake sturgeon, means reddish. Recent accounts have described occasional specimens as red, reddish, rose-coloured, and yellowish red.



Sturgeon over three feet long are mostly smooth, owing to the wearing away of the surface roughness of the plates, which cover the young, and to their being overgrown by skin. This specimen, taken in the Niagara River about four miles north of Fort Erie in 1946, was six feet, eight inches, in total length and weighed 230 pounds.

The impossibility of making any generalized colour description of the sturgeon is indicated by a few attempts at such descriptions by various authors. A selection of these is as follows:- Young, usually dark olive above, sides paler; adults, greenish-olive or reddish. Young, tan or buff, more uniformly dark as they grow older; adults, slate gray to black. Young, drab; adults, green or red, occasionally brownish or rose-coloured; a yellowish-red colour on the back and olivaceous-red on the sides.

2 Kinds

Variations in colour, and especially differences in appearance between young and older individuals, led earlier students of fish life to believe there were several kinds of freshwater sturgeon. Nearly thirty scientific names were proposed for it before most scientific students of fish life agreed that all of the sturgeon spending their whole lives in the fresh waters of North America were of one and the same kind, the oldest scientific name for which is Acipenser fulvescens, the name given by Rafinesque in 1817. (76).

Even until comparatively recently, many still thought there were two kinds of freshwater sturgeon, one of which with longer, more pointed snout and of smaller size was known popularly as "rock sturgeon". This is now known to be the young of the species.

Even yet, suggestions are sometimes made that there is more than one "kind" of sturgeon. Roussow (83,84) has regarded the sturgeon of the Province of Quebec as belonging to two "morphae", the brown or lake sturgeon and the black or rock sturgeon. The former he calls A. fulvescens acutirostris, and the latter, A. fulvescens obtusirostris. The brown form, he says has a smaller head and more pointed snout; the black, a relatively larger and flatter head and a more rounded snout. There is no difference in age of maturity or spawning dates, but there is said to be a slight difference in growth rate, brown individuals of the same length being younger than black ones. This, Roussow suggests, may result from a better nourished condition and the colour difference to melanism which he says is often observed in poorly nourished fish.

Greeley (38) was disposed to regard specimens collected from the St. Lawrence River at the Massena power canal and at Red Mills below Ogdensburg as of two types -- gray or rock sturgeon, and black or mud sturgeon. The former which he regarded as Acipenser fulvescens, had sharp plates which, although becoming dull and obscure with age, were much sharper than those on the other species at comparable sizes. The black or mud sturgeon, which he called Acipenser sp., was characterized by greater head width and darker colour. The two types, he said, taken on the same grounds and by the same apparatus (trap lines) were about equally common, although the mud sturgeon was the more common commercially because of its larger, average size. However, he finally admitted that subsequent collections bridged over these differences and it was therefore advisable to refer all to the same species. Roussow also found intermediates between his two morphae but was disposed to regard such as hybrids.

3 Common Name

Many have been the common names applied to the freshwater sturgeon

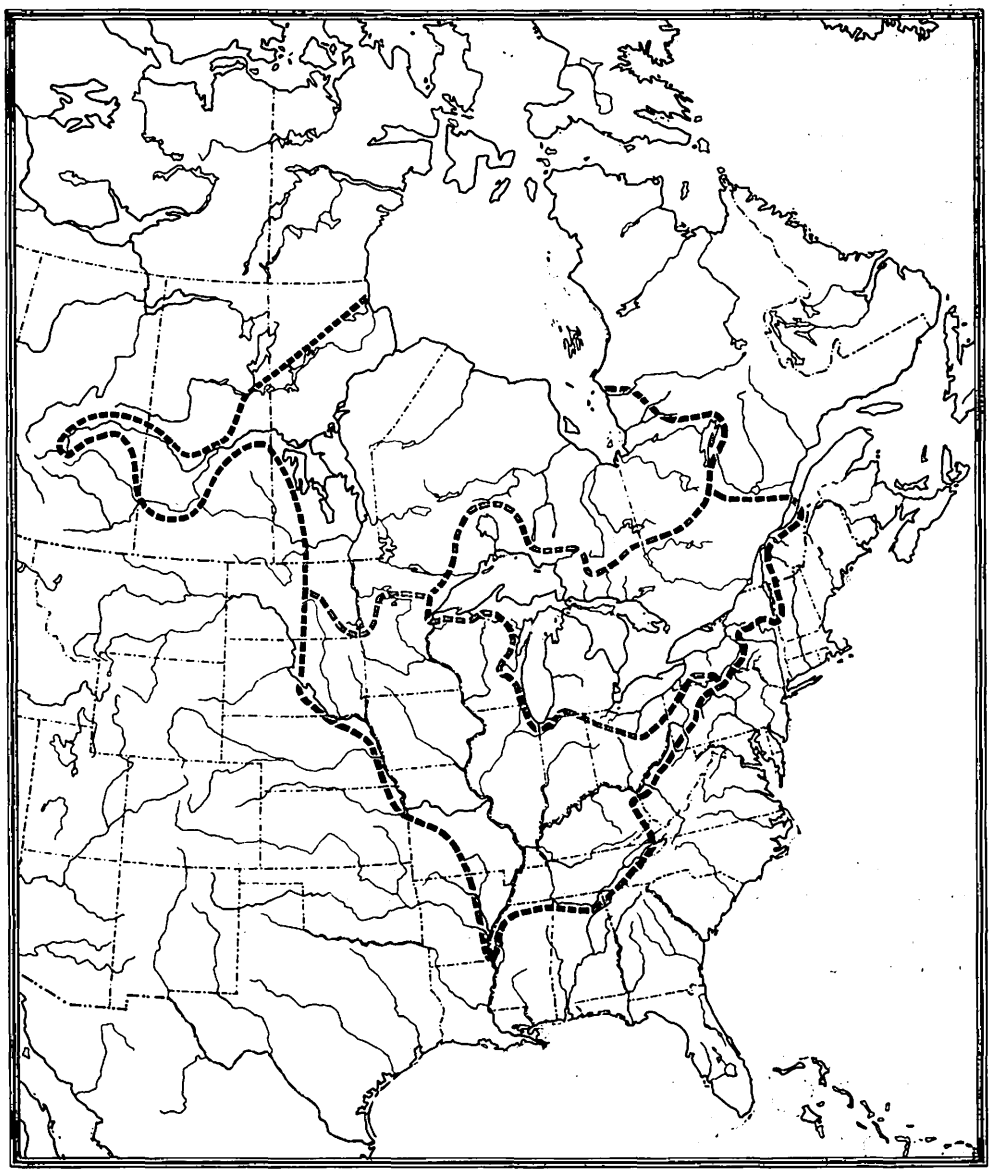
throughout its range -- lake sturgeon, rock sturgeon, common sturgeon, red sturgeon, ruddy sturgeon, Ohio sturgeon, stone sturgeon, shell-back sturgeon and bony sturgeon. Commonly, although not universally, the name rock sturgeon was applied to the smaller fish with prominent plates and a long snout.

The common name recommended by a committee of the American Fisheries Society (2), is lake sturgeon.

V. DISTRIBUTION

1. Geographic Range

The area within which the lake sturgeon occurs, or has occurred, is outlined in the accompanying map, fig. 5. Few North American freshwater fish have a wider geographic range. It comprises three drainage basins -- the Mississippi, the Great Lakes and Hudson Bay.



The area, within which lake sturgeon occur, is outlined by the outerline. The three drainage basins included in its range, Mississippi, Great Lakes - .St. Lawrence and Hudson Bay, are outlined by broken, double lines.

The Mississippi drainage basin constitutes almost all of the lake sturgeon's range in the United States. Besides being found in the Mississippi, itself, it occurred in virtually all of the larger tributaries southward, almost to the southern border of Arkansas. It appears to have occurred in varying abundance throughout the course of most of the larger tributaries until stopped by impassable falls or as the streams became too small.

The Great Lakes basin, including the St. Lawrence, is inhabited by the sturgeon in both Canada and the United States. Lake Champlain and its tributaries from the east constitute the sturgeon's northeastern limit in the United States. In the St. Lawrence, it occurs eastward to St. Roch des Aulnaies about 70 miles east of Quebec City where the salinity apparently becomes too high for it.

Northeastward, it has been reported from the Fort George (Big) River on the east side of James Bay (53°50'N). On the western side of Hudson Bay, it extends to the Seal River (59°03'N), a few miles north of Churchill. Northwestward, it extended nearly to the foothills of the Rockies at Edmonton.

2. Sturgeon As a Place Name

The prevalence of "sturgeon" as a place name attests to the wide distribution and interest in this fish. At least 43 geographic locations in Ontario have been designated by the name Sturgeon. These apply to the following kinds of places.

Rivers or creeks	11
Lakes	8
Bays	8
Falls	4
Points	4
Islands	3
Narrows	4
Beach	1
Channel	1
Cove	1

Although most of these names no doubt originated as a result of the occurrence of the lake sturgeon, at least one, namely Sturgeon Lake in Victoria County, apparently had some other origin as there is no record of sturgeon ever having been found in this lake.

3. Habitat

The sturgeon is a shallow-water fish. Most of those for which we have actual records were taken at a depth under 30 feet, and a high proportion under 15 feet. However, some are taken at 60 feet, and a few still deeper. In Lake Nipigon, large specimens have been taken at 90 feet, and we have a small one taken at 100 feet. Some have been taken at a depth of 140 feet in a deep hole in Lake Beauchene, a lake-like expansion of the Ottawa River seven miles below Lake Timiskaming.

Its ventral, suction-like mouth, without teeth, confines it to living on bottom organisms, and it is chiefly in shallow water that these are numerous enough

to support any considerable population of a fish that grows to such a great size. Adamstone(1) on the basis of extensive sampling of the bottom in Lake Nipigon, found that animals living on the bottom reached a peak of abundance both in weight and in number of different kinds at a depth of 30 feet. From there, they decreased until at 50 to 100 feet they were less than one third as abundant as in the shallower water. Sturgeon are taken over all sorts of bottoms, but mud is most common; next is gravel, with some mud. They will, of course, feed over any sort of bottom that supports the kind of animals they can use as food. In the 140-foot hole and in other parts of Lake Beauchene mentioned above, they fed on the "worms" living in decaying pulp mill waste which had settled on the bottom.

In his efforts to learn as much as he could about the habitat of the young, Harkness set nets in many situations in Lake Nipigon. Most of the small sturgeon, ranging from 7.7 to 30 inches in length, were taken in summer within the mouths of rivers or on rocky, gravelly shoals near the mouths of rivers in depths varying from 10 to 15 feet; although one, 17.5 inches long, was taken in a gillnet in 90 feet of water.

The smallest sturgeon taken by Harkness,* measuring 5.7 inches in length, was collected in a seine at a depth of four feet in a bay at the side of the Gull River, Lake Nipigon, about two miles below the rapids in which the sturgeon spawned. This one was one year old. Whether this indicates that sturgeon remain in the river throughout the first year of life is not known. It is possible that it had returned to the river after having been down to the lake. It is known that many immature sturgeon go up rivers in spring at the time mature fish are on their spawning migration.

It is only in lakes or large rivers with extensive areas of shallow water where abundant food is produced that lake sturgeon were abundant. Localities in which they are reported as having been very abundant in the early days include areas among the islands of the western end of Lake Erie, Green Bay and the southern end of Lake Michigan, the north Channel of Lake Huron, Keweenaw Bay and the vicinity of the Apostle Islands in Lake Superior, Lake of the Woods and such large rivers as the Mississippi, Ohio, St. Lawrence, Rainy, Winnipeg, Nelson, Churchill and Moose.

What influence, if any, the geological history of an area has on the sturgeon's occurrence is not known. In Manitoba, it was reported by Hinks (45), that the sturgeon occurred in all the large rivers which enter Lake Winnipeg from the east, and was very common in the Nelson and Churchill River, but was practically absent from the western portions of this lake and also from Lakes Manitoba and Winnipegosis.

The eastern shores of Lake Winnipeg are Archaean rocks whereas the western shores and Lakes Manitoba and Winnipegosis are underlain by sedimentary rocks of Ordovician, Silurian and Devonian ages. Rapids and falls where sturgeon spawn are much commoner in rivers flowing through the Archaean area than in the sedimentary area. Whether the scarcity or absence of sturgeon

* This specimen is preserved in the Royal Ontario Museum.

in the sedimentary area is due to the lack of suitable spawning sites or to some other ecological factor is not known.

The lake sturgeon does not enter full salt water but it does resort to brackish water in the lower St. Lawrence and in Hudson and James Bays. In the St. Lawrence, it occurs in brackish water near Cap St. Ignace and, occasionally, even at St. Roch des Aulnaies, about 70 miles below Quebec City. (105). Following the opening up of the rivers in spring and the clearing of the water, sturgeon go down to James Bay where they occur in brackish water.

Along the east coast of James Bay, it was reported in 1914 (66) that "as a coastwise fish, it inhabits the estuaries, and travels up the rivers early in June for spawning, ... They stay in the rivers about three weeks"; also, along the west coast, "It is never caught in the sea, but a few are taken every year in the rivers and river estuaries." (58).

VI. HABITS

1. Movement

Apart from a spawning migration in spring, usually to rapids in rivers, reports of other seasonal movements are conflicting. Many fishermen say they find sturgeon in fairly shallow water in spring, and in deeper water in summer. Some believe there is a return to shallow water in autumn, and that winter is spent in comparatively deep water where they are relatively inactive.

In Lake Winnebago, Wisconsin, where there is a winter sport fishery for sturgeon, they are active throughout that season. Since 21 feet is the maximum depth, the sturgeon cannot resort to water deeper than this, but are confined to the large mud flats (115).

In Lake Winnipeg (5), large sturgeon are reported to have been caught in shallow water, four to five feet, in June, but later in the summer in deeper places; in August, in about seven fathoms. In winter, they were said to lie in schools in the deepest holes. A concentration of sturgeon found in Lake Huron, particularly in spring, at a depth of 60 feet, 22 miles N.N.E. of Point Edward, were thought to move into shoal water (four to five feet) in summer.

A population which fed in a deep hole of the Ottawa River, south of Lake Timiskaming, congregated at the foot of rapids in May, fell back into the deep hole in June where they continued to feed throughout July and August. In the fall, they moved downstream to what was thought to be their wintering grounds. It is possible they were forced out of the deep hole as a result of oxygen depletion due to the active decomposition of the pulp mill wastes during summer.

A strong homing tendency has been shown by tagging studies in Wisconsin lakes. Lake Winnebago fish pass through lakes Winneconne and Poygan on their way to spawning grounds in the Wolf River but return to Lake Winnebago. No mixing of populations between Lake Winnebago and the upper small lakes has been found, (115). A similar conclusion was reached as a result of tagging in lakes of the St. Lawrence. Sturgeon tagged in Lake St. Francis rarely wandered to other lakes (82). Also, young lake sturgeon, tagged in the St. Lawrence between Lotbinière and Montmagny, were mostly recaptured within 30 miles of the point where they were tagged, generally less than ten miles away (61).

On the other hand, there is evidence that sturgeon sometimes wander widely. Dr. J.P. Cuerrier has reported that a specimen 31½'' - long, released in the St. Lawrence River on Aug. 23rd, 1942, was recaptured 80 miles distant on June 14th, 1944, when it was 32 2/3'' long. A sturgeon bearing a tag numbered 41 was recaptured in Lake Michigan. When tagged in Lake St. Clair twenty-eight years before, it weighed 41 lbs. When recaptured, it weighed 75 lbs. (3).

Another specimen to which a tag was attached when it was above the dam at Valleyfield, P.Q., on July 2nd, 1946, was caught nine miles west of Brockville on July 15th, 1958. When tagged it was 29 inches long and weighed seven pounds; when caught it weighed 21½ pounds.

2. Jumping

A spectacular habit of the sturgeon is jumping. Most reports of this behaviour are of sturgeon in rivers at or near spawning time. Harkness observed fish in the Gull River (at spawning time) leap vertically out of the water until they were completely out and appeared to be standing on their tail. They then assumed a horizontal position and fell back into the water with a resounding splash.

This habit is well attested by the observations of many others. Milner (67), one of the earliest to report on the habits of the sturgeon in the Great Lakes, wrote "They may be seen in this (Kalamazoo) river (at spawning time) leaping from the surface, throwing their bulky forms entirely out of the water". Surber's (102) description was as follows. "Though, in general, the sturgeon feeds at the bottom, in fine weather it often rises to the surface and frequently jumps sometimes to a height of seven feet above the water. This action was observed on the Winnipeg and other rivers." Another account says that in the old days in the Sturgeon River, Ontario sturgeon jumped night and day below the falls. "One could leave the bedroom window open at night and hear the sturgeon as they jumped and splashed in the pool below the falls".

A Thomas Williams is quoted (97) as saying that "a peculiar habit of the sturgeon is observed after spawning. They are noticed rolling over and over on the bottom, faster than one can count; then suddenly spouting to the surface, they leap completely out of the water, falling back with a loud splash."

Goldsmith in his Animated Nature, describing the same behaviour in the sea sturgeon, says that in May, June and July "they are seen sporting in the water and leaping from its surface several yards in the air. When they fall again upon their sides, the concussion is so violent that the noise is heard, in still weather, at some miles' distance". This description gives point to the criticism that strict veracity was never one of Goldsmith's virtues.

More credible is the newspaper story (Aug. 8th, 1949) that a 50-lb. sturgeon, 58 inches long, leaped out of the water and landed in a rowboat manned by two girls in the Ottawa River. Ryder (87) says that the sea sturgeon has been known in leaping to jump into small boats.

3. Timidity

In describing the spawning habits of sturgeon (under Reproduction), it is said that spearing on their spawning grounds usually leads to their abandoning the area. Others (89) have found that, in spearing them through holes in the ice, quiet is an absolute essential as fast or noisy movements scare the fish away.

Goldsmith's account of the sturgeon's timidity is just as exaggerated as is his description of their jumping. He says that it flies from small fish and that "the smallest fish is alone sufficient to terrify a shoal of sturgeon"

4. Curiosity

It is a common observation that many kinds of birds and mammals are curious and will cautiously investigate unusual sights, but the curiosity of fish is

not so commonly observed. Schlumpf (89) says that the sturgeon is a very curious fish and examines objects in the water. When they come into the area beneath a hole in the ice, they will often approach the decoy and try to touch it with their snout and look it over as if curious. Sometimes, they will attempt to take it into their mouth. The success of such objects as oranges, lemons, ears of corn and tin cans in attracting sturgeon within spearing range is probably to be accounted for on the basis of curiosity.

VII. FOOD

Most fish which grow to a large size eat large food items, chiefly other fish, and when they cannot get them do not grow very big. Not so the sturgeon; in spite of its large size, most of its food is of relatively small animals which it takes from the bottom by means of its protrusible, tube-like mouth.

Harkness (43) measured the volume and counted the number of animals found in the stomachs of more than a hundred sturgeon of all sizes from Lake Nipigon, Lake Erie, Lake St. Louis (an expansion of the St. Lawrence River near Montreal), and the Moose River. The findings combined with the results of similar studies by others in Winnipeg River, Lake Winnipeg and a number of lakes in Wisconsin, are summarized in the following statements.

Almost anything living on the bottom is eaten by sturgeon. Naturally, when very small, they cannot handle crayfish and clams which are sometimes taken by large sturgeon. The food eaten appears to depend more on what is most readily available than on the size of the fish. The practice of eating whatever is most easily come by, is not peculiar to the sturgeon; the same has been found to be true of the feeding habits of many other kinds of animals. A few kinds restrict their feeding to a narrow range of food items but most appear to put forth no more effort than necessary to satisfy their hunger with whatever comes easiest, within the size range they are equipped to deal with.

Although the sturgeon's normal food consists of animals, it has been known in the vicinity of elevators where grain is spilled into the water, to fill its stomach with wheat or corn. Sturgeon, kept in confinement for long periods in the Lake of the Woods, apparently thrived on such grains as wheat and barley (29). It is said, too, that sturgeon have been kept in hatchery ponds to keep down the growth of objectionable algae and to clean up excrement of fish kept in the ponds.

The kinds and numbers of animals living on the bottom of lakes and rivers depend on the nature of the bottom, whether sand, mud, clay, gravel, etc., and on depth. In Lake Nipigon, where many of the observations on the food habits of sturgeon were made, Adamstone (1) , as reported above, found that by far the greatest concentration of such animals was from the shore out to a depth of 30 feet.

1. Insects

Insect larvae of many kinds live in and on the bottom of lakes and are eaten by several kinds of fish besides sturgeon, including whitefish and suckers. In streams, trout, especially the smaller ones, also depend to a considerable extent on insect larvae.

(a) Mayfly nymphs normally make up a greater bulk of the sturgeon's food than any other single item in most of the areas for which information is available. They usually constitute from 30 to 90 per cent by volume of the food found in stomachs.

Mayflies live for most of their lives in small burrows in the bottom; it is only when they attain the winged adult condition that they live in air. Their aerial life is very brief - the briefest known in the winged state among insects.

Often, they live for only a few hours but sometimes for a day or two. During this time, they mate; the females deposit their eggs; then, all die.

In the water, they live in a variety of bottoms, including mud, sand and clay. The only kind they do not inhabit is rock or gravel. This fact was strikingly evident in the difference between the stomach contents of sturgeon caught over a muddy bottom at the mouth of the Sturgeon River, a tributary of Lake Nipigon, and those caught over a rocky bottom near the neighbouring Blackwater River. Mayflies made up nearly 50 per cent of the stomach contents of those caught over the muddy bottom, while none was found in the stomachs of sturgeon taken over the rocky bottom.

Mayflies live mostly in shallow water under 30 feet in depth. However, there are several kinds, and each has its preferred depth.

The immature stages of mayflies are exceedingly abundant on the bottom of many lakes. It is only when they emerge from the water on approaching or reaching maturity that their abundance becomes apparent. In the vicinity of some waters they emerge in such numbers as to become a great nuisance, covering buildings and falling to the ground in such numbers as to require the attention of street cleaners in urban communities. So well known are they that they have been given popular names, including (besides mayflies) shadflies, fishflies, dayflies, and ciscoflies.

It is not only bottom-feeding fish such as sturgeon, whitefish and a few others that feed on mayflies.

When they are making their way to the surface of the lake in preparation for taking to wing, many other kinds of fish turn from their more usual diet and for a week or ten days gorge themselves on mayflies. Even lake herrings (which for much of the year are plankton feeders) take to eating mayflies at this season. Many kinds of birds and even mice turn to a mayfly diet at this time. Recognition of the fact that trout feed on mayflies when they are at or near the surface is responsible for the fashioning of artificial flies by trout fishermen. The Green Drake, Quill Gordon and a variety of nymphs are imitations of mayflies.

(b) Chironomid larvae also live in the bottom in most lakes in enormous numbers and form a most important part of the pasture on which the sturgeon feeds. However, because of their small size (most are about 1/16'' in diameter and an inch long) they usually do not make up as large a volume in the stomach contents of sturgeon as mayfly nymphs, the usual proportion by volume being from 1 to 15 per cent.

Like mayflies, they are found most abundantly in shallow water on mud, sand and clay, although most numerous on mud. Like mayflies, too, their numbers become evident when they emerge as adult midges or gnats, sometimes forming masses so large and dense as to appear in the distance like clouds of smoke. On approaching a cloud of midges, one hears a high-pitched humming sound. In the aquatic stage, they are soft-skinned and worm-like, usually yellow or yellowish-green in colour; some red ones are called blood worms.

Besides sturgeon, several other kinds of fish including whitefish, common and northern suckers and some others, feed extensively on chironomids.

(c) Caddis flies are the only other group of insects which contribute significantly to sturgeon food. These are the insects which in the aquatic phase construct cases of sticks or stones about their bodies. In the adult stage, they resemble small moths. Like mayflies, they are eaten by many other kinds of fish including trout. This occurs when they are preparing to assume the adult condition. Like mayflies, also, they are imitated in making artificial flies; the Despair, for instance, is based on a caddis pupa. Like mayflies and chironomids, caddis flies are numerous only in shallow water.

(d) Dragonfly nymphs seldom make up any appreciable amount of the sturgeon's food. Still rarer are immature stages of beetles, alderflies and other kinds of insects.

2. Molluscs

Molluscs, both of the snail and clam types, are a regular feature of the sturgeon's diet wherever they occur; because of their relatively large size, they often bulk large in the food eaten, sometimes amounting to as much as 95 per cent of stomach contents. The usual range is from 1 to 40 per cent.

Most of the clams taken are of the kind called thumb-nail clams (Sphaerium and Pisidium) which seldom exceed a half inch in length. Our only reports of larger kinds (Lampsilis and Anodonta) are for the Winnipeg River, (5).

3. Crustaceans

(a) Crayfish are often regarded as favourite items of sturgeon food. The extent to which they are eaten varies greatly, probably depending on their availability. Crayfish are usually found where there are rocky crevices in which to hide. In Lake Nipigon, where most of our studies were made, crayfish were found in only five of 78 stomachs examined, whereas, it is reported that in Lake of the Woods, they were found in 28 of 55 stomachs. They were also found in numbers in more than half the sturgeon from the Winnipeg River and Lake Winnipeg, (5). On the other hand, Cuerrier and his co-workers found no crayfish in sturgeon from Lake of Two Mountains and Lake St. Louis near Montreal.

Nor did Harkness find any in 21 specimens from Lake Erie. However, it is quite possible that they might occur and in significant amounts in special parts of any of the waters for which we have no records of occurrence. This possibility is emphasized by the fact that four of the five Lake Nipigon sturgeon that had eaten crayfish all came from one locality.

(b) Smaller crustaceans are eaten in some numbers but because of their small size seldom make up much of a bulk. Occasionally, however, they as much as 90 per cent of the food found in individual stomachs. The commonest are freshwater shrimps (Pontoporeia and Hyalella), Gammarus, Mysis (freshwater relative of a small marine crustacean), Cladocera and aquatic sowbugs(Asellus).

4. Fish and Their Eggs

Before the food of the sturgeon had been determined by actual examination of stomach contents, extravagant charges were made that it consumed

great numbers of the spawn of other fishes and decimated their young when hatched out. Prince (73), quotes a published statement to the effect that "Experience goves to prove that sturgeon feed almost exclusively on the eggs of other fish". This is the sort of wild statement too often made on the basis of misinformation or of no information. Of more than two hundred sturgeon whose stomach contents are known as a result of actual examination, less than a dozen had eaten fish eggs. The usual number was quite small. In only one did they constitute any significant proportion of the food that had been eaten. This stomach contained 5,700 eggs believed to be those of the walleye (yellow pike perch).

Small fish are sometimes caught and swallowed by sturgeon. These are usually kinds that rest on the bottom. Sculpins are perhaps the commonest, although sticklebacks and a few other small kinds have been found.

5. Miscellaneous

Almost anything small enough to be taken into the mouth is occasionally found in sturgeon stomachs including, in addition to the items already mentioned, leeches, round worms (nematodes) plant fragments including needles of coniferous trees, pieces of decaying wood, gravel and sand. Some of this is probably taken in along with the more nutritious food materials and left in the stomach when the rest is digested.

6. Food of the Young

There is little definite information on the food of the very young. Harkness, who hatched sturgeon artificially on the Gull River, Lake Nipigon, failed to find food which the young could or would eat. After the yolk sac had been absorbed, plankton and somewhat larger forms collected in ponds and in bays along the river were placed in the containers in which the fry were confined, but this material failed to keep them from dying. When they were about ¾ inches long, they were observed trying to eat small chironomid larvae. They would take them into their mouths but after a short struggle would let them go.

Ryder (87), who hatched the Atlantic sturgeon (A. oxyrhynchus) in 1888 and tried to raise the young, expressed the opinion that the food of the very young "must be microscopic in character and probably consists of rhizopods, unicellular algae, infusoria, minute larvae of insects and worms, crustacea, etc." Some subsequent accounts of the food of the young are apparently based on this statement, without, however, indicating that it is a presumption rather than an observed fact.

As a matter of fact, no one knows what food the very young lake sturgeon eat, because, so far as we know, the smallest specimen caught in natural waters was about 5¾ inches long. However, it is quite certain that the food must be very small, presumably consisting of animals found on the bottom. Thomas Wirth of the Wisconsin Conservation Department, who has hatched lake sturgeon and attempted to rear them, reported in a letter to Harkness that "Our biggest difficulty was in supplying them with live food of a small-enough size during the period of time between absorption of their yolk sac until they could feed on small chironomid larvae. We finally discovered that they would ingest new-

ly hatched brine shrimp at this critical size . . . . . They are bottom feeders (at least in an aquarium) from the moment they begin to feed and are not pelagic during the fry stage. They did not ingest any items unless they were alive or just recently killed."

Harkness found that the fry which he hatched did not eat bread soaked in milk nor soda cracker crumbs but did eat tiny pieces of pike liver.

By the time they are nine to ten inches long, Lake Nipigon sturgeon feed on mayfly nymphs and chironomid larvae. The average proportion of these two items found in the stomachs of four Lake Nipigon specimens of these lengths was 72.5 per cent mayfly nymphs and 27.5 per cent chironomid larvae. As chironomids are considerably smaller than mayflies, it is altogether likely that chironomids are eaten when the sturgeon are quite small.

7. Feeding Habits

The feeding habits of sturgeon in aquaria were observed by Harkness. So far as could be determined by observation, neither sight nor smell played a part in locating food. In searching for food, the sturgeon swims close to the bottom with the ends of the barbels or feelers, which are located on the underside of the snout in advance of the mouth, dragging lightly over the stones, gravel and sand.

As soon as the feelers touch food, there is an instantaneous reaction: the tubular mouth is rapidly protruded and the food sucked in along with silt, gravel and, sometimes, fairly large pebbles and other debris. Some of the smaller gravel and debris is washed out between the gills, while the larger stones are cast out of the mouth.

The food is worked over in the mouth in a way suggesting mastication. During this process the food is partly ejected from the mouth and then sucked in again. Although the food is not actually masticated, some pulping of it occurs in the mouth.

In fishing for sturgeon, pieces of fish, often sucker, soaked in brine, are commonly used as bait; balls of dough have also been used. The most unusual item of which we have heard as being found in a sturgeon's stomach is an iron cross. The newspaper despatch reporting on this find was as follows:-

"Harlen, Germany, April 9, 1927 -- An Iron Cross in the stomach of an 80-pound sturgeon, caught in the Rhine near Harlen in Westphalia, has solved the mysterious disappearance of a crippled war veteran who was believed to have hurled himself into the river in a fit of despondency brought on by the realization that he could never recover from the effects of shrapnel wounds.

"Two fishermen landed the huge fish from a small boat after an hour's battle. Among numberous objects in the stomach was found the Iron Cross, second class, with the name "Sergeant August Stiefthaler" engraved on the back. Police identified the medal as one worn by the veteran when last seen seven years ago. The police now are convinced Stiefthaler committed suicide.

"During the estimated 25 years of its life, the fish had feasted on two

unopened cans of sardines, a vanity case containing a powder puff and $5 in Holland coins, two packs of German cigarettes and more than a dozen fish-hooks."

VIII GROWTH

1. Age Determination

The earlier determinations of the age of sturgeon in America were made from a study of the otoliths or ear stones (43, 90). More recently, rays of the pectoral fins have been used. Both methods depend on the differential seasonal growth of the structure examined. To use fin rays, the pectoral fin of one or, preferably, both sides is cut with a knife at the articulation with the cartilaginous basal piece. Thin cross sections, 0.3 to 0.5mm. thick, of the marginal ray are made by a thin blade saw. Under a binocular microscope, wide opaque zones alternating with narrow clear zones are seen. These correspond to summer and winter growths respectively. By counting the number of narrow clear zones, the number of winters through which the fish has lived and hence its age can be determined, (22, 84).

2. General Features of Sturgeon Growth

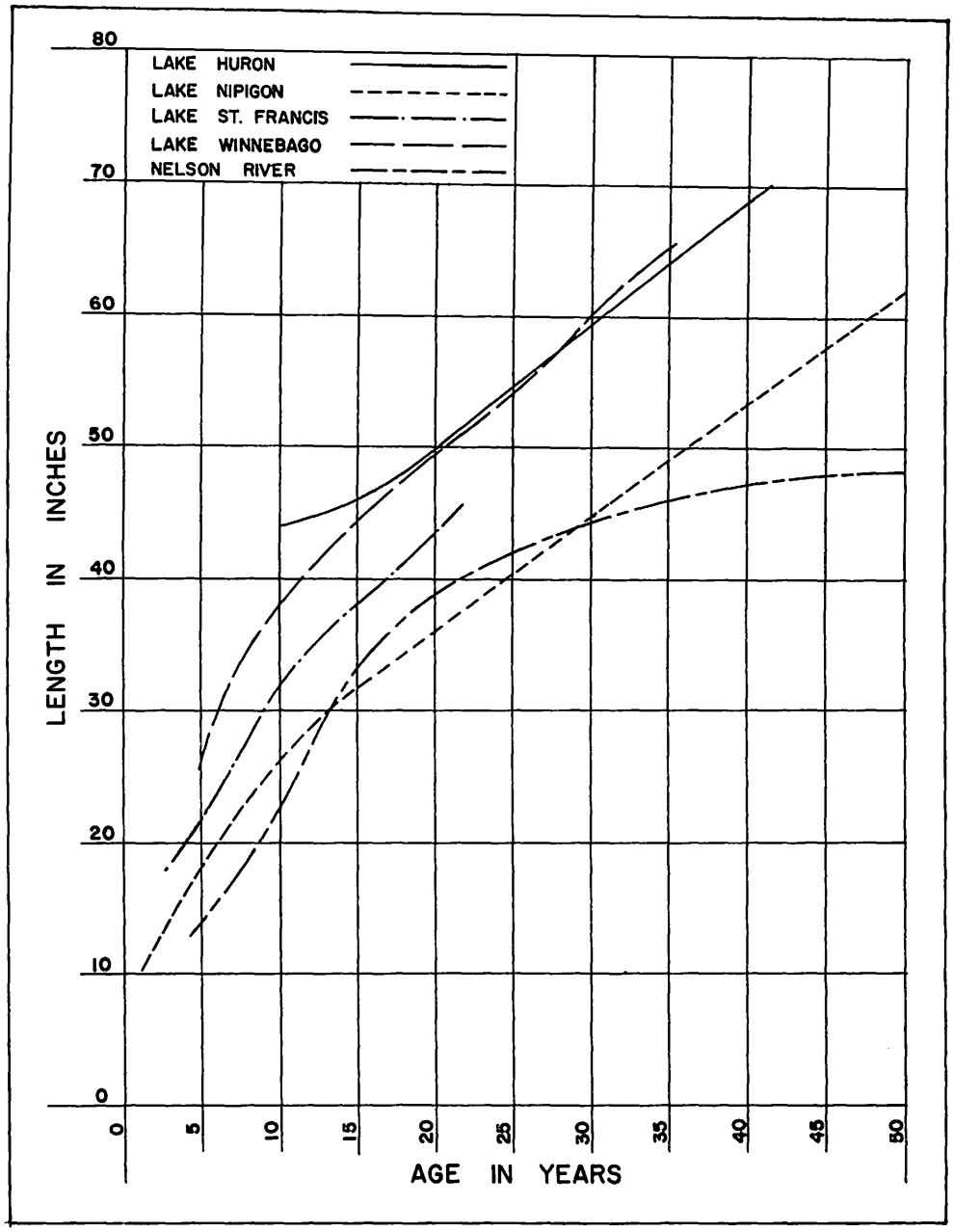
The statement is frequently made that the sturgeon is a slow-growing fish. This is not strictly true. At comparable ages, sturgeon weigh more than some other common species, but information on which to make such comparisons is available for a few lakes.

In Lake Nipigon, sturgeon weighed four ounces at three years of age, and sixteen ounces at five years, whereas the corresponding weights for whitefish were two ounces and five ounces. Thus, sturgeon grew in actual weight much faster than whitefish. These rates of growth were for specimens taken in the 1920's, shortly after the lake was opened to commercial fishing. However, growth rates are usually slower in unfished lakes in which populations are more crowded and grow more slowly than in lakes subjected to fishing. It is therefore likely that the rate of growth of both whitefish and sturgeon may subsequently have increased.

Rate of growth of the sturgeon differs from lake to lake depending on several factors including temperature and amount of food available.

Rates of growth in length in Lake Nipigon, Lake St. Francis (an expansion of the St. Lawrence River), Lake Winnebago, Wisconsin, Lake Huron and Nelson River are shown in Fig. 6. Rates of growth in weight for three of these lakes are shown in Fig. 7. These curves indicate that there is a marked difference in rate of growth, both in length and in weight, in these waters. Sturgeon are as long (50 inches) at approximately 20 years of age in Lake Huron and Lake Winnebago as they are at 36 years of age in Lake Nipigon. At 20 years of age, they weight as much (about 27½ lbs.) in Lake Winnebago as they do in Lake Nipigon at age 37 years.

Sturgeon at first grow much more rapidly in length than in weight; later, growth in length slows down and growth in weight becomes more rapid. These facts are brought out by the following table, -



Rate of growth differs from lake to lake. The above graphs indicate that, in the five areas represented, sturgeon grew fastest in Lake Huron and Lake Winnebago, and slowest in Lake Nipigon and the Nelson River. They were as long (50 inches) when approximately 20 years of age in Lake Huron and Lake Winnebago as they were at 36 years of age in Lake Nipigon.

TABLE 1.

INCREMENTS IN TOTAL LENGTH AND IN WEIGHT
DURING SUCCESSIVE FIVE YEAR INTERVALS

	Lake Nipigon Increase in		Lake St. Francis Increase in	
Period	Length	Weight	Length	Weight
0-5 yrs.	19 ins.	1 lb.	22 ins.	2 lb.
5-10 yrs.	7 ins.	2 lb.	9½ ins.	4 lb.
10-15 yrs.	5½ ins.	2 lb.	6½ ins.	6 lb.
15-20 yrs.	5 ins.	3 lb.	5½ ins.	6 lb.
20-25 yrs.	4½ ins.	4 lb.	5½ ins.	18 lb.
25-30 yrs.	4 ins.	5 lb.		
30-35 yrs.	4 ins.	7 lb.		
35-40 yrs.	3½ ins.	9 lb.		
40-45 yrs.	3 ins.	12 lb.		

Fig. 8 which represents the relationship between length and weight illustrates the same principles. Stated in other words, sturgeon, as well as fish in general, weigh much more per inch of length as they grow larger.

3. Weight-Length Relationship

The weight-length relationship of sturgeon is represented in Fig. 8. This curve must, however, be used with caution in determining the probable weight of a specimen whose length is known.

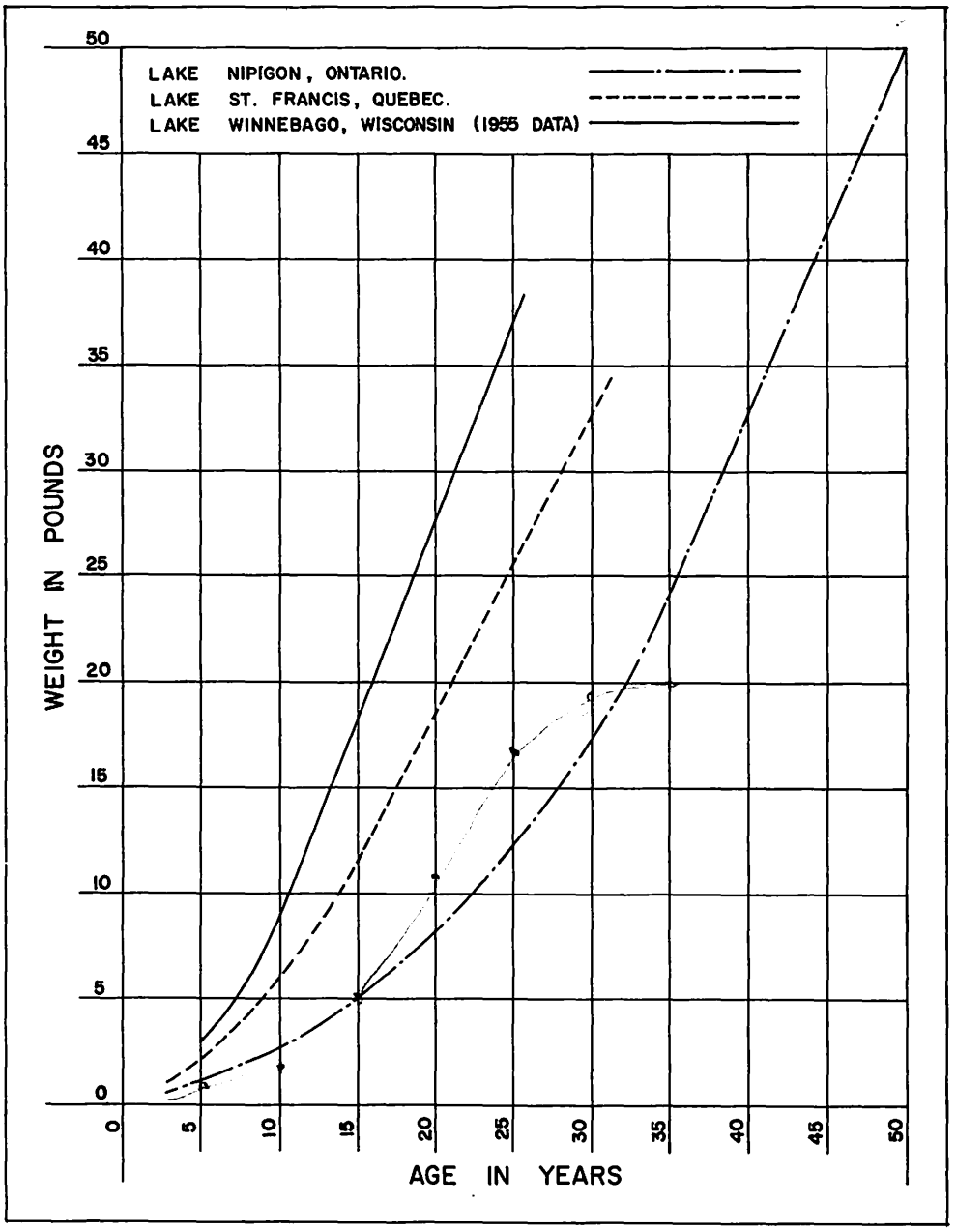
The upper part of this figure gives the length-weight relationship of the larger specimens of which we have record. (See Tabulation under SIZE). Since many of these are based on newspaper reports, their accuracy may in some cases be open to question. The lower part of the curve is based on information recorded by Harkness during the course of his studies on Lake Nipigon.

There is no fixed relationship between the weight and length of fish. It not only differs from species to species but in the same species there is often rather wide variations in the weight of individuals of the same length. These differences are due chiefly to differences in the stage of sexual maturity and to a factor known as "condition".

Female sturgeon with mature, or nearly mature, eggs weigh about 20 per cent more before spawning than after, and are heavier than ripe males of the same length. Dr. Scott of the Royal Ontario Museum is authority for the statement that the testes of a two-hundred-pound Lake Erie sturgeon weighed thirty pounds or 15 per cent of the total weight.

Immediately after spawning a sturgeon contains small eggs, but these constitute a very small percentage of total weight. As the eggs grow, the percentage of total weight which they constitute increases until after about four to seven years, depending on locality, it again amounts to 20 per cent.

Sturgeon of the same sex and stage of sexual maturity from different waters differ in weight attained at comparable lengths. Such differences are referred to as differences in "condition", and may be regarded as representing differ-



Sturgeon increase in weight, as well as in length, faster in southern than in northern lakes. The above curves indicate that a 20-year old sturgeon weighs about 27½ pounds in Lake Winnebago and eight pounds in Lake Nipigon.

ences in the suitability of the environment. Fig. 9 illustrates the average difference between weights of sturgeon of the same length from Lake Nipigon and Lake St. Francis. It shows that, at every length, Lake St. Francis sturgeon weigh more than Lake Nipigon sturgeon. Lake St. Francis being a more southern and shallower lake than Nipigon, no doubt provides more favourable living conditions.

A difference in condition has been found between sturgeon in two Wisconsin lakes in the same river system. Fish from Lake Poygan, where the growth was slower, were consistently lighter at the same length than fish from Lake Winnebago. The latter is the lower and larger lake of the system, and presumably a more favourable habitat for sturgeon.

Sturgeon also appear to vary in weight from season to season. Three fish taken by Dr. Cuerrier in Lake St. Louis during June and July, 1941, and reported to Harkness by letter, were much heavier than fish of practically the same lengths taken in the same lake the following February and March. Details of these are as follows:-

Summer Specimens		Winter Specimens	
20 inches	1 lb. 14 oz.	20.3 inches	1 lb. 6¼ oz.
		20.7 "	1 lb. 6 oz.
26.0 "	5 lb. 6 oz.	26.0 "	3 lb. 1½ oz.
28.1 "	6 lb. 12 oz.	28.1 "	3 lb. 9 oz.

4. Age and Size at Sexual Maturity

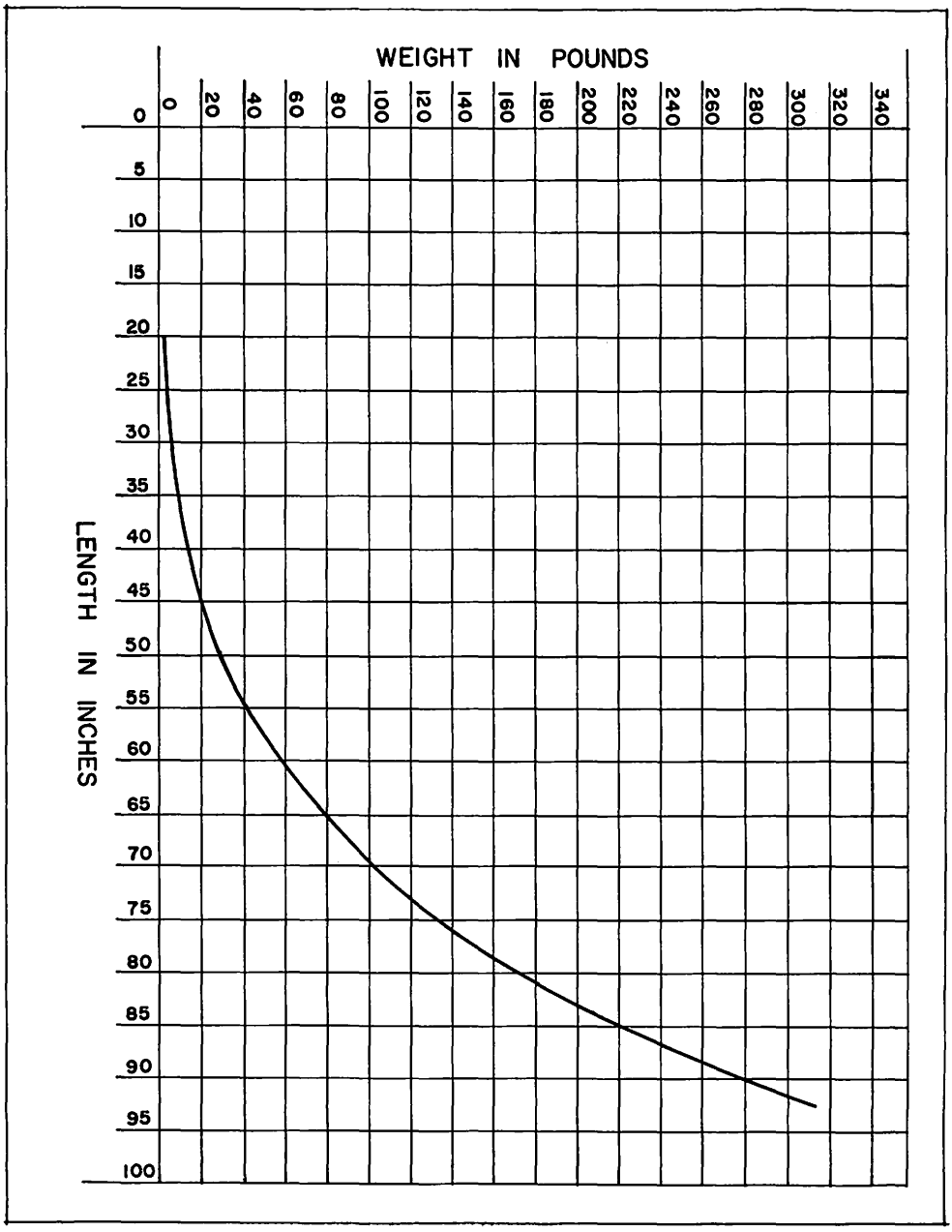
Of all our freshwater fish, the sturgeon takes by far the longest to attain sexual maturity. The age at which sturgeon first spawn is different in the two sexes, males maturing at a younger age than females. It also varies from one locality to another as indicated in Table II.

TABLE II

AGE AT WHICH STURGEON BECOME SEXUALLY MATURE IN DIFFERENT AREAS

Males	Females	Locality
22		Lake Nipigon, Ont. (43).
19-20	26	Ottawa River (25)
14	25	Lake St. Peter, P.Q. (21).
15	23	Lake St. Francis, P.Q. (23).
22	25	Lake Winnebago, Wisc. (115).
12-19	14-23	Province of Quebec (84)
14 (18-22)	25	Wisconsin (91)
15-20	25-33	Nelson River, Manitoba (100, 101).

Statements about the age at which sturgeon reach sexual maturity do not always indicate whether the age given is that at which eggs and milt are found in the fish or whether it is the age at which they first spawn. In the case of females, as discussed under Infrequency of Spawning, it requires several years for eggs, after they appear, to reach the stage at which they are actually spawned.

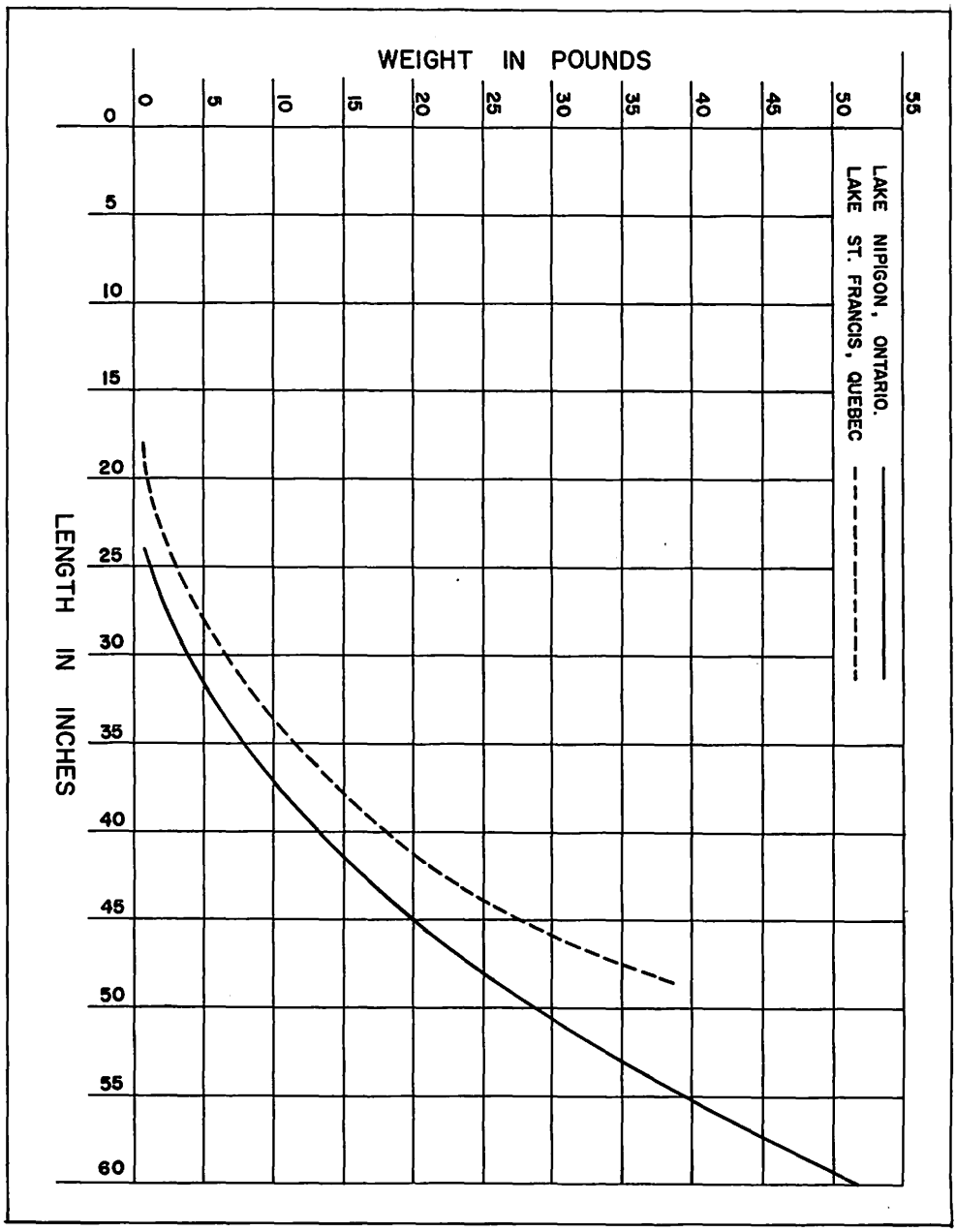


Weight-length relationship of lake sturgeon. This curve will give only an approximation to the weight of a sturgeon whose length is known, since actual weight differs with sex, stage of sexual maturity and "condition".

As is the case in most species, not all individuals spawn for the first time at the same age. Schultz (91) says that although some males (in Wisconsin) spawn at 14 years of age and a length of 42 inches, the average male is 18 to 22 years of age and 50 inches long before he spawns. The same is undoubtedly true of females.

The size at which a species first spawns is sometimes considered important in fixing the minimum size at which it may be legally caught. The sizes corresponding to the ages at which sturgeon first spawn are approximately as follows;-

Males	Females	Locality
37-38 inches		Lake Nipigon
30 inches	33 inches	Ottawa River
30 inches	46 inches	Lake St. Pierre, P.Q.
50 inches	55 inches	Lake Winnebago, Wisc.
50 inches	54 inches	Wisconsin
37-40 inches	42½-46½ inches	Nelson River, Man.



Lake St. Francis sturgeon are heavier than Lake Nipigon sturgeon of the same length. This difference is called the "condition" factor. It reflects differences in the suitability of different habitats.

IX. REPRODUCTION

1. River Spawning

Information on where and when sturgeon spawn was slow in accumulating, owing to several conditions peculiar to it. The first is that females, with ripe eggs that actually run when the fish is taken from the water, are seldom encountered. This is due to the very brief period over which the sturgeon is in spawning condition. Another factor is that only a relatively small percentage of sexually mature females spawn in any one year. This in turn is due to the circumstance that female sturgeon spawn only at four-, to seven-year intervals.

Sturgeon spawn in the spring, usually in rapid water in rivers. Most of what is known about the subject was learned when attempts were being made to develop means for artificial propagation. Since the main purpose of these studies was not to observe natural spawning, few of the observations were carefully made.

Apparently, as late as 1901, it had not been agreed that sturgeon spawned in rivers. For instance, one of those investigating the possibility of artificial propagation in that year gave it as his opinion that if reports that many of the fish caught in rivers were ripe and that they are found in rivers only a few months during the year were true, one would seem to be justified in drawing the conclusion that the fish ascended the streams to spawn.

The most thorough of the studies of the spawning of the lake sturgeon are those of Harkness as part of his investigation of every aspect of sturgeon life history and ecology. As these studies were concentrated on Lake Nipigon, the following account is based on observations made there.

On their spawning migration, sturgeon leave the lake not long after the rivers in which they spawn are free of ice and before it has disappeared from the lake. Indeed, local Indians said they had seen sturgeon going up river under the ice.

The date of the spawning migration varies with latitude and other factors affecting temperature. It is thus earlier in the south and later in the north.

Actual spawning appears to be rather precisely determined by temperature. Again, there are few precise records of temperature when sturgeon were actually spawning; most of the published statements give temperatures when ripe sturgeon were caught, and it isn't always clear whether the record is for water or air temperatures.

Following are dates for actual spawning so far as the records can be interpreted.

Missisquoi River, Lake Champlain	1900	May 20-27 (98).
" " " "	1901	May 13-20 (99).
Lamoille River " "	1901	May 23. (99).
Detroit River		May 31. (64).
Lake Pokegama, Minnesota		May 6-25 (6).
Wolf River, Wisconsin	1959	First week of May (114).
Pigeon River, Manitoba	1924	June 12-13 (80).

Gull River, Lake Nipigon	1922	June 2 and 3.
" " " "	1923	May 25-June 4.
" " " "	1924	June 2-3 and June 12 & 13.
" " " "	1926	June 4-12.
Ottawa River at Fitzroy-Quyon	1949	May 29-June 6. (25).
Northern Quebec	1954-56	First 3 weeks of June (84).

Melvill (66) reported that sturgeon travel up the east coast rivers of Hudson Bay early in June for spawning. Dr. Richardson, (79) who spend the winter of 1819-20 in northern Saskatchewan, reported that "the great rapid which forms the discharge of the Saskatchewan into Lake Winnipeg appears quite alive with these fish in the month of June."

These records indicate not only that there is a difference in the time sturgeon spawn in different areas but even in the same area (Lake Champlain) there may be a difference between different rivers in the same year (Missisquoi and Lamoille) (99) and in the same river (Gull River) from one year to another.

Sturgeon reach the vicinity of the spawning beds sometime before the temperature of the water has reached the optimum for spawning. Some observations suggest that males reach the vicinity of the actual spawning site ahead of the females. This is true in many, perhaps all, kinds of fish, and is quite likely to be the case with the sturgeon.

Whether sturgeon in different areas spawn at different temperatures, or whether the differences reported are the result of recording air temperature in one area and water temperature in others, or to estimates rather than precise records, is not known. The following statements on the temperature at which sturgeon spawn have been published.

Stone (99) said sturgeon "Will not spawn until water reaches a temperature of 60°F" but in another discussion (18) he expressed the opinion that "It must be at least 66°F."

Paulson did not record the actual spawning temperature, but the waterin which he hatched eggs was 57°to 58°F and this water was taken from the river from which he had taken the spawning fish (80).

Dubreuil and Cuerrier, (25), reported the largest concentration of spawning fish at the Fitzroy-Quyon Rapids in the Ottawa River to have occurred in 1949 at temperatures of 56°to 60°F.

In Wisconsin the minimum spawning temperature is reported as 53°F. (113).

Harkness recorded that "When the water reaches a temperature of 12.5°C (54.5°F), sturgeon appear on the spawning beds, and when it rises to 13°C (55.4°F) they ascend in numbers, and spawning is on." He recorded spawning at temperature of 13°C (55.4°F) to 18°C (64.4°F).

How sensitive sturgeon are to changes in temperature, so far as spawning is concerned, is shown by their behaviour on the spawning beds in Gull River,

Lake Nipigon. On June 4th, 1924, Harkness saw large numbers of sturgeon in the Gull River, apparently spawning when the temperature was 14°C (57.2°F). When the weather turned colder and the temperature of the river water fell to 12°C (53.6°F), the sturgeon left the spawning area and did not return until the temperature had again reached 13.5°C (56.3°F).

On the other hand, there is evidence that spawning is inhibited by a temperature of 70°F. That other conditions affect the temperature at which sturgeon spawn is indicated by the fact that sometimes they spawn at a temperature at which at other times no sturgeon are seen.

On the basis of the best available information, the optimum temperature for sturgeon spawning appears to be between 57°and 60°F.

In rivers, sturgeon spawn where the water is quite swift - in other words, in rapids. Several of the accounts of spawning speak of them congregating in a pool or "hole" after reaching the vicinity of the actual spawning site, and remaining there until certain temperature and perhaps other conditions are suitable, when they move on to the spawning grounds and spawn. This reminds one of the habit of the Atlantic Salmon of resting in pools until conditions are right for spawning, except that, in the case of salmon, the pools occur over a greater stretch of the river. There is a further similarity between the habits of sturgeon and of salmon, namely, that of jumping, already described under Habits.

All accounts agree in suggesting that sturgeon pass through minor rapids in the course of a spawning river and only spawn in rapids at the foot of falls which bar their farther progress upstream. Unlike salmon, which are able to leap over ten-foot falls, much lower ones stop sturgeon.

They are known to travel as far as 80 miles up the Wolf River, major tributary of Lake Winnebago, Wisconsin, to spawn. (115).

In Gull River, Lake Nipigon, they spawn in the swiftest water in which they can swim, among large rocks in the river bed. Indians, in describing the appearance of sturgeon on the spawning beds, placed their hands parallel, about six inches apart, and said: "The sturgeon are so thick, their tails are sticking from the water like this."

In the rapids, the fish, particularly the females, are frequently carried by the current against rocks where they remain for a time with half, or even three-quarters, of their great bodies out of the water. One gains the impression that they co-operate in permitting themselves to be washed against the rocks. They extricate themselves from such a position by a powerful stroke of the tail.

Dwight Lydell, who was in charge of the experiment in artificial propagation on the Detroit River in 1893, writing to Harkness in 1923, said: "The sturgeon, just before spawning, works up into the strong current where the bottom is rocky, and then rolls down over the rocks to bring them to the stage where spawning takes place." Sometimes, however, they become stranded on the rocks and perish there. Several of those, who have seen sturgeon spawning, have suggested that this washing against the rocks helps to loosen the eggs within the ovary.

When the female is fully ripe, her abdomen sags and when she is lifted by the tail the eggs flow easily, so that it is difficult to hold her long enough to collect them for artificial propagation. At other times, they cannot be pressed from her by the usual methods used to obtain eggs for hatchery work.

During the spawning act, they lie in groups of two or three. Where there are two, it is a male and a female; where there are three, there is a male on either side of a female. The male swims higher than the female so that his dorsal fin protrudes from the water. Although it is difficult to make accurate observations in the swift water, it is likely that the vent of the male is placed so that the milt is poured over the eggs as they are extruded. This has been observed in the Atlantic Salmon by photographing fish spawning in artificial spawning beds.

Most of the male sturgeon actually taken in the spawning act have been much smaller than the associated female. A pair caught by Mr. Geary of the Gull Harbour (Manitoba) Hatchery on June 12th, 1924, consisted of a male weighing about 15 lbs. and a female of 70 to 80 lbs., (80). Males, of course, reach sexual maturity at a smaller size and younger age than females.

There is reason to believe that all of a female's eggs are not spawned in one spawning act, and that an individual may spawn over a period of one or more days. However, this has not been definitely proved.

When actually spawning, sturgeon are very timid. The Indians, long acquainted with the habits of sturgeon during the spawning season on Gull River, Lake Nipigon, warned Harkness that as soon as they began to spear to get specimens from which to take eggs and milt for experiments in artifical propagation, the sturgeon would desert the spawning rapids. In 1923, the camp established in connection with the experimental work was pitched on the shore close to the rapids. This did not appear to alarm them but, when an attempt was made to capture some fish, most of them disappeared. The next year, when a number were speared, the rest left, and no more were seen in the rapid that season. On the other hand, they readily passed under extensive log booms on their migration from the lake to the spawning rapids.

The streams to which sturgeon resort for spawning are used by other fish, notably the walleye (yellow pikeperch), the suckers (common and northern) and two species of red-horse (Moxostoma), and the pike (Esox lucius). However, direct competition for actual spawning sites is avoided by each species being adapted to spawn at a different time or different place from the others.

The walleye is the first to spawn after the ice has left the river and the water has warmed to 38° to 40°F, whereas it must reach 57° to 60°F before sturwill spawn. Moreover, the walleye spawns in the first rapids of a stream whereas, if there is a sequence of rapids, sturgeon pass through the lower ones and spawn only when they reach a falls which they cannot surmount. They spawn in the rapids immediately below such a fall.

In the Gull River, Lake Nipigon, Harkness found that the common white sucker spawns after the walleye and before the sturgeon, although some late spawning suckers may have overlapped early spawning sturgeon. Moreover,

the sucker appeared to spawn among the rocks in any rapid. It cannot, however, maintain its position in such swift water as the sturgeon. This, in addition to time of spawning, serves to segregate the spawning suckers and sturgeon. The pike chooses the quiet backwaters of the river as its spawning place.

It is significant that the eggs of the sturgeon, walleye and sucker are adhesive and heavier than water. If they floated, they would be carried out of the stream by the current, and scattered to situations most of which would probably be unsuitable for the hatching or survival of the fry. Through their adhesiveness, the eggs become attached to rocks and other solid bodies in the water and are thus retained throughout incubation under conditions for which they are adapted. Their adhesiveness was one of the features which caused trouble when artificial propagation was first undertaken because, when the eggs were collected into vessels, they stuck together in large masses so that the inner ones were smothered through lack of contact with the air. However, when the eggs are spawned in swift water, they are dispersed, settle individually and are kept apart through attachment to solid objects in the stream.

2. Lake Spawning

Sturgeon are known to have spawned in shallow water on the wave-washed shores of lakes. Two conditions frequently described in such situations simulate the conditions under which they spawn in rapids, namely, the presence of rocks and water movement through wave action.

Lake spawning has been reported for Lake Erie (near Dunkirk, N.Y., near the mouth of the Detroit River and western end of the lake), Lake Michigan (at South Chicago, Pt. Sable, and especially at Saugatuck), Lake Champlain (south of mouth of Lamoille River), Lake Nipigon and Lake of the Woods (about rocky islands south of Kenora). Near the head of the Niagara River, spawning is said to have been "along the seams occurring in the rocky ledges so peculiar to our shores at this end of the lake" (97). Another account indicates that, in lakes, sturgeon preferred rocky ledges near shore.

Depths most commonly reported for lake spawning are three to four feet, although spawning at much greater depths has been reported. It is likely they would spawn wherever the bottom and other conditions are suitable.

Since lakes, especially large ones, warm up more slowly than streams, suitable spawning temperatures may not be reached as early as in rivers. In Lake Champlain, for instance, they were found to have collected for lake spawning in 1901 about two weeks later than in the river (99).

How important lake spawning is in maintaining sturgeon populations is not known. Where access to spawning sites in the rapids of streams has been barred by dams, the availability of suitable spawning grounds in lakes would provide the possibility for continuing reproduction.

3. Number of Eggs Produced

Lake sturgeon are known to produce hundreds of thousands of eggs, but few careful estimates of the exact numbers have been made. The most careful of these estimates are those by Cuerrier (20) and Dubreuil and Cuerrier (25). Their results are summarized in Table III.

TABLE III

NUMBER OF EGGS PRODUCED BY STURGEON OF DIFFERENT SIZES IN DIFFERENT AREAS

Weight of Fish in pounds	Number of Fish	Origin	Number of Eggs (Average for 2 or more)	No. of Eggs per lb. of Fish
11½	2	Ottawa River	49,835	4,333
13	1	Ottawa River	64,470	4,960
36	3	Lake St. Peter	184,913	5,136
43	1	Ottawa River	308,680	7,179
48	1	Lake St. Peter	277,560	5,781
57	3	Lake St. Peter	323,817	5,681
68	1	Lake St. Peter	485,500	7,140
79	1	Lake St. Peter	370,910	4,695
112	2	?	667,472	5,960

As will be seen, there is considerable variation in the number of eggs produced by fish of the same weight. For instance, one fish weighing 57 lbs. contained 273,940 eggs, while another of the same weight contained 412,420 eggs.

While the number of eggs increases with size, and there is some indication that the number per pound of fish may be greater as the fish grows, there is great variation in this respect. Some of this is probably due to the stage of maturity of the eggs. The same number of eggs at an early stage of development may constitute a smaller percentage of the total weight than eggs approaching maturity, although the matter is extremely complicated.

Harkness obtained the following information on three Lake Erie sturgeon:

Weight of Fish in Lbs.	Weight of Eggs in Lbs.
96	20
163	35
175	40 (23 pints of caviar)

The diameter of these eggs is unknown. A table giving the number of fish eggs of different diameters per quart was published in 1910 by von Bayer (8). Assuming that the eggs were 2.6 mm. in diameter, the numbers in the three Lake Erie fish (on the basis of von Bayer's figures) were respectively 369,155,643,520 and 738,309 eggs, or 3,845, 3,948, and 4,105 eggs per pound of fish.

These results are considerably lower than those obtained by Cuerrier. Since the latter's figures were obtained by weighing the ovaries and actually counting the number of eggs in sections of them of known weight, his estimates are probably more nearly accurate than those in which a number of assumptions have had to be made.

We believe it is justified to assume that 5,000 eggs per pound of fish might be a reasonable number to expect in most sturgeon of 20 lbs. or more in weight. On this assumption, a 300-lb. sturgeon would produce 1,500,000 eggs. Whether

they continue to produce eggs up to this weight and, if they do, whether their productive capacity remains as high throughout their whole lives is not known.

It will be realized, from this account of the probable fecundity of lake sturgeon, that there is still much to be learned on this important subject which, as will be discussed later, is of considerable importance in connection with their conservation.

4. Sex Ratio

Available information, although scant, suggests that in the young the sexes are approximately equally numerous but, among the largest and oldest sturgeon, there is a great preponderance of females. This means that, on the average, females live longer than males. This condition is also known to occur in other species of fish and in other animals.

It is true that males sometimes greatly exceed females on the spawning grounds, but this is a temporary situation due to the fact that males reach the areas where spawning will later occur ahead of most females.

In a group of four lakes in Wisconsin, (74) it has been found that in the three smaller lakes the sexes were approximately equal, up to a length of 59 inches or 29 years of age. Among fish over 59 inches in length, 96 per cent were females. In a larger lake (Winnebago) in the same chain, males were the more numerous up to a length of 49 inches (approx. 20 years); above 49 inches, the proportion of females gradually increased as follows,-

50-59 inches,	67.3% were females.
60-79 inches,	95.8% were females.

In Lake St. Peter and in the St. Francis River, 83 per cent of the mature sturgeon over 30 years of age (caught in the spring) were females, with no males above 39 years of age, (20).

In Lake Deschenes, an expansion of the Ottawa River, few males exceeding 45-50 years of age were caught (Cuerrier letter).

In the Nelson River, Manitoba, Sundé found males more than 50 years of age rare, (100).

In Spain, it has been found that only one male Atlantic sturgeon (A. sturio) out of 175 was older than 17 years, compared with 77 per cent of the female fish of the same age, (74).

5. Infrequency of Spawning

One of the most serious difficulties met by those who first undertook to spawn sturgeon and hatch their eggs artificially was to secure fish in spawning condition. Although sturgeon were still abundant at that time, few ripe females could be found.

One of the features of the sturgeon to which this condition is due is the fact that female sturgeon do not spawn every year. This is true also in some other kinds of fish, but the length of time between successive spawnings is

unusually long in the sturgeon, apparently varying from four to perhaps seven years in the case of different individuals, and in different areas. This condition is not peculiar to the lake sturgeon but has been reported for other kinds of sturgeon as well.

The scarcity of individuals in spawning or near spawning condition is indicated by such statements as the following:-

At a site in the St. Clair River chosen in 1889 to carry out an experiment in artificial propagation (because a caviar factory was located there), from early June until July 27, only six spent fish and two ripe females were taken among 4,000 handled.

Of the females examined on the Detroit River in 1890, only five were in spawning condition; 23 had already spawned; six had nearly-ripe eggs; and 98 were very immature.

Geo. C.B. Smith, a Fort Frances fisherman, reported that, among 275 legal-sized sturgeon taken on Rainy Lake in 1959, only one had eggs large enough for making caviar.

How it gradually became established that sturgeon spawn only at infrequent intervals illustrates the slow growth of exact knowledge, and how easy it is to misinterpret observations. Before it became accepted that sturgeon do not spawn every year, observers were puzzled by finding eggs of quite different sizes in the same female. So long as it was believed that sturgeon must spawn every year, the finding of eggs of different sizes at the same time in the same female was interpreted as meaning that spawning was spread over several months. Gradually, as more and more observations accumulated, it was realized that the eggs at different stages of maturity were to be deposited in different years, and not at different times in the same year.

The suggestion that female lake sturgeon do not spawn every year was made as early as 1900. In that year, the secretary at a meeting of the American Fisheries Society (88) said that, "A scientist from the University of Michigan . . . . . intimated to him that it was quite possible, if not probable, that the sturgeon in the Detroit River spawned about once in two years."

During his study of the sturgeon on Lake Nipigon, 1922 - 1924, Harkness concluded that they did not spawn every year, and made careful measurements of the eggs in the ovaries of many fish, on a study of which the conclusion outlined below are based.

About the same time, C.P. Paulson, superintendent of a Federal Government hatchery on Lake Winnipeg, reached the conclusion (80) that, "They do not spawn every year, ... How often, or rather, how seldom these fish spawn, I, of course, cannot say but, judging from the apparently very slow development of the ova and the small percentage that spawn yearly, I would venture to suggest that at least five years elapse between spawnings."

Working independently at the same time in Minnesota, Barney, (6), expressed the opinion that a given adult female will not spawn regularly year after year, and that the reproductive cycle is probably from four to eight years in duration.

Sunde (100) has estimated the average spawning frequency of Nelson River sturgeon as five years in the case of fish between 20 and 35 lbs., and four years for fish above 36 lbs.

Harkness' studies indicated that eggs of six different size classes were found in females taken during a single season in Lake Nipigon. Not all sizes were to be found in the same female, however. In any one ovary, there were usually eggs of three different size classes. In the case of eggs large enough to be spawned in the year in which the fish were taken, or in the subsequent year, the largest eggs were 3.0 to 3.5 mm. in diameter, while, in the next size class in the same ovary, the eggs averaged 0.42 mm. in diameter. In addition, there were a few, still-smaller eggs, 0.1 to 0.15 mm. in diameter. In other ovaries, the largest eggs were 2 to 3 mm. in diameter, with smaller eggs of two sizes averaging 0.38 and 0.125, respectively. In still other ovaries, the largest eggs were 1 to 2 mm., with smaller eggs of an average size of 0.35 and 0.125, respectively. In some females, the diameter of the largest eggs was 0.7 mm., with smaller ones averaging 0.34 mm. and 0.125 mm.

These data suggest that the smaller and presumably younger eggs in an ovary develop much more slowly than the larger ones until the latter are spawned, when eggs of the next size class begin in their turn to develop more rapidly than the still smaller and still younger eggs.

These observations suggest that female sturgeon in Lake Nipigon spawn at intervals of six years.

In Minnesota, Barney (6) found eggs of only four sizes in any one season and, on this basis, suggested that female sturgeon spawn at intervals of four years. It is not unreasonable to expect that southward, spawning may occur at shorter intervals than northward.

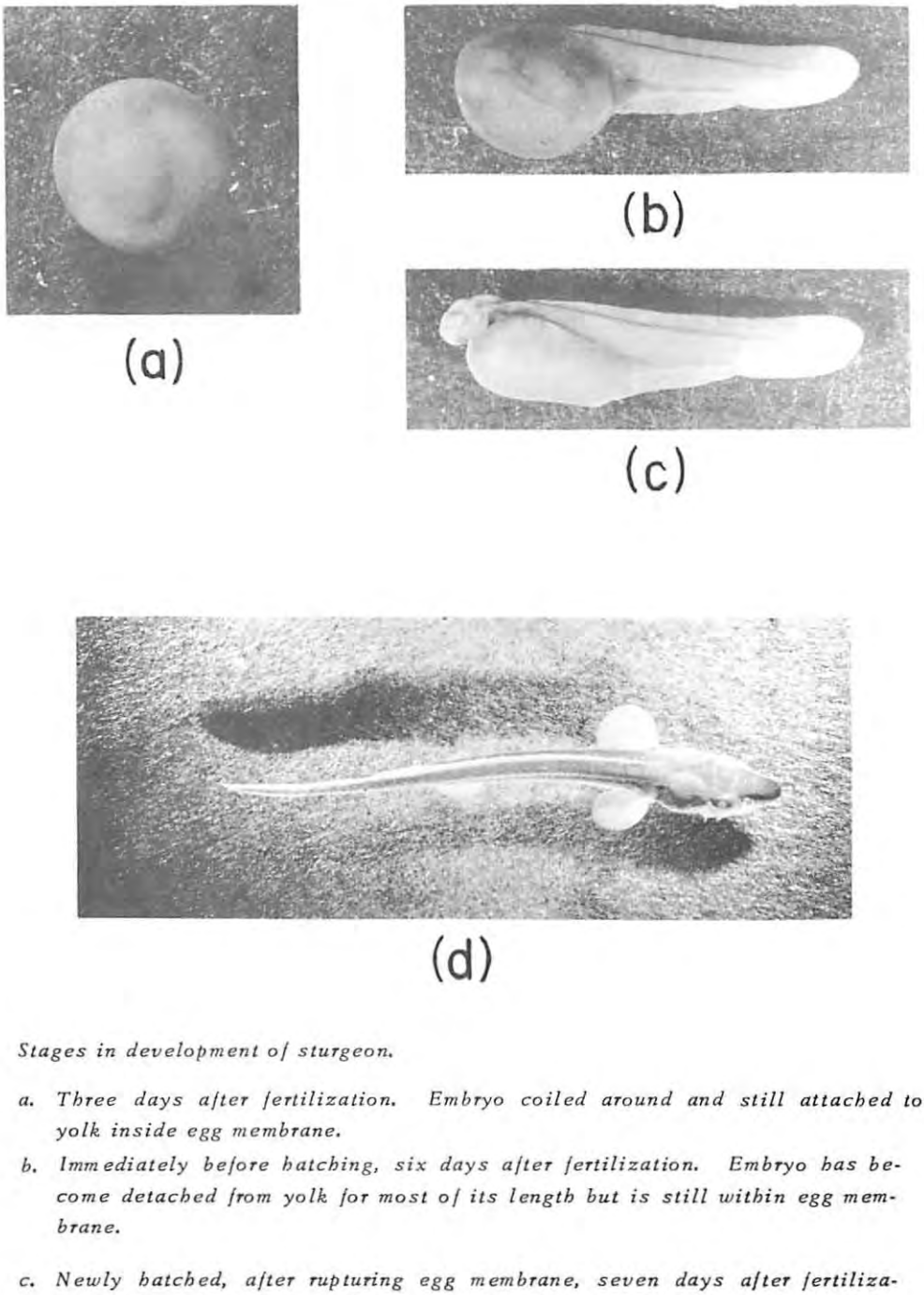
In the Province of Quebec, Roussow (84) suggested an interval of from four to seven years or more between spawnings. This estimate was based on a study of the annual growth patterns shown by cross sections of the first ray of the pectoral fin. Just as retardations of growth as a result of spawning is shown by the scales of fish in which age and growth can be determined by the scales, so retardation of growth of sturgeon is reflected by the annual growth record shown by cross sections of the first pectoral fin ray.

In the case of males, Cuerrier, (21), has expressed the opinion that they spawn every other year in Quebec. On the other hand, Wirth and Cline (115) report that, on two successive years, two tagged male sturgeon were captured on the same spawning grounds in a ripe condition. They concluded that male sturgeon occasionally spawn after the lapse of one year, but most spawn only every other year.

6. Development of Eggs and Young

In his work on hatching sturgeon on Gull River, Lake Nipigon, Harkness determined that, at the temperature of 60 to 64 F., some eggs hatched after five days, and all had hatched at the end of eight days. For sometime after hatching, the young are nourished by the yolk stored in the egg and contained in a yolk sac beneath the young sturgeon.

Externally, the yolk sac disappeared at an average age of about nine days after hatching, but the fact that the fry continued to grow in length for another week suggests that some yolk may have remained even though there was no external evidence of it. (See Fig. 20).



Stages in development of sturgeon.

a. Three days after fertilization. Embryo coiled around and still attached to yolk inside egg membrane.

b. Immediately before hatching, six days after fertilization. Embryo has become detached from yolk for most of its length but is still within egg membrane.

c. Newly hatched, after rupturing egg membrane, seven days after fertilization. Abundant yolk in yolk sac beneath young.

d. Twenty days after hatching. Yolk has disappeared and young has become more elongate, more like shape of adult.

Length increased steadily from not much more than 1/3 inches long on hatching to nearly 7/8 inches, 16 days after hatching. At this size and age, growth ceased through lack of nourishment, owing to failure of the young to eat the food supplied. In nature, the fry would have started to feed on natural food by this time.

For sometime after hatching, while the yolk sac lasts, the young sturgeon is relatively short and deep. When the yolk disappears, the fry assumes a more elongate form more like that of a larger sturgeon. The snout becomes quickly longer, more slender and dorsoventrally flattened, and the fins become more rapidly differentiated from the fin folds within which they first appear.

On hatching, the fry huddled together in dark corners or under stones placed in the aquarium. At the end of about a week after hatching, however, they began to move about more freely as if searching for food. By this time the yolk-sac from which they had been nourished had shrunk, thus forcing them to seek more of their own food. Details of the development of the eggs and young may be found in Appendix IV.

X. EXPERIMENTS IN ARTIFICIAL PROPAGATION IN CANADA

Beginning in 1875, many attempts were made in the United States to develop means of propagating sturgeon artificially. A history of these attempts may be found in Appendix III.

Confidence in the efficacy of artificial propagation to increase fish production was, at that time, much stronger than it is now. The early success in hatching such species as salmon, trout and whitefish by the millions led to the very general belief that, through artificial fish culture, the problem of making the waters yield abundant fish harvests had been solved. In Europe, where artificial propagation was practised before it was taken up in America, it was prophesied that "In a very short period of time, the rivers and lakes and even the bays of France will be teeming with shoals of fish where they had become very scarce." Dr. Theodatus Garlich, (35), often called the father of artificial fish culture in America, wrote in 1857: "It should not be surprising that the subject (fish culture) is attracting the attention of some of the best minds in in our country; more especially, when we consider the impoverished condition of our rivers and streams, many of which are susceptible of being inhabited by innumerable salmon and trout, and since a replenishment is now no longer problematical." In a similar vein, Samuel Wilmot (111) who initiated fish culture in Canada, wrote in 1870: "A repetition of this process (planting artificially hatched salmon in streams emptying into Lake Ontario) for a few years, aided by judicious enactments for their preservation and protection, would undoubtedly soon replenish and restock the waters of Lake Ontario with salmon."

Within a comparatively few years after this prediction, the salmon was extinct in Lake Ontario. It is possible that if artificial propagation had never been discovered we would be further ahead than we are today in fish conservation, because then such complete dependence would not have been placed on hatcheries as the cure-all for the maintenance of fish populations. It would probably have been learned much sooner that, unless natural conditions favourable for a species are maintained, a body of water cannot be made to produce it in numbers.

Hatcheries have a place in fisheries management, but it is not as large as was once believed. A carefully considered opinion of the place of fish culture in fisheries management is contained in a fish policy adopted by the American Fisheries Society in 1954. This is the organization through which those engaged in research or administration meet to consider problems in fisheries management. Their pronouncement contained the following statement:- "Periodic replanting is desirable of lakes that winterkill infrequently or of waters which are occasionally depleted by pollution; otherwise, the stocking of the young of any species in waters having adequate spawning conditions is considered of doubtful value"

At the time when interest in the sturgeon was at its height, belief in the efficacy of hatcheries to maintain populations was unquestioned and explains the almost frantic efforts made to learn how to propagate sturgeon artificially. H.M. Smith, Commissioner of Fisheries for the United States, wrote in 1890: (94), "The question which presents itself is - How shall the supply of sturgeon

in Lake Ontario be preserved? It is suggested (1) that legal restrictions should be placed on the capture of immature fish, and that the adult individuals should be protected during the spawning season; and (2), that artificial propagation should be resorted to. As to the expediency of enacting more fishery laws for Lake Ontario, there may be considerable difference of opinion; but in regard to the desirability of carrying out the second suggestion there can be no doubt, for the feasibility of hatching the lake sturgeon artificially has been fully demonstrated by both the United States and the Michigan Fish Commission."

Two outstanding features of the sturgeon led to demands for development of methods for rearing the young in hatcheries. The first was the price which the sturgeon commanded. By about 1905, it brought a higher price per pound than any other freshwater fish, if the value of caviar and isinglass is added to that of the flesh. The second factor which gave urgency to efforts for the development of artificial propagation was the rapidity with which the fishery declined to very low levels. In some waters, this decline amounted to 90 per cent over a period of ten years.

In Canada, two attempts were made to develop methods for the artificial propagation of sturgeon.

In 1924, C.P. Paulson, Superintendent of a Federal Government Hatchery at Gull Harbour on Lake Winnipeg, succeeded in fertilizing and hatching eggs secured without killing the fish. About 8,000 fry were released soon after hatching, (80).

Paulson's observations confirmed the experience of those who had previously tried to secure eggs by squeezing the abdomen, namely, that the sturgeon cannot be spawned in this way even when she is ripe. The eggs which Paulson got were a portion of those expelled by the female as she was being lifted from the water. When it was found that the fish was spawning, two men attempted to hold it in position over a tub but could not do so, with the result that only a few of the eggs were caught.

The other attempt at artificial propagation was part of a much broader field study of the sturgeon undertaken by Harkness working in the Ontario Fisheries Research Laboratory, Dept. of Zoology, University of Toronto, during the years 1922 to 1926, inclusive.

This work was undertaken following a suggestion on the desirability of such a study by the Biological Board of Canada, now the Fisheries Research Board of Canada. This suggestion appears to have originated in a memorandum dated August 1st, 1919, from W.A. Found, Director of Fisheries to the Chairman of the Biological Board. In this memorandum, Found pointed out that the artificial culture of sturgeon had not been successful so far on this continent but, on account of the high value of the sturgeon and of caviar produced from their eggs, it was eminently important that their culture should be undertaken if such could be feasibly carried out. He asked if the Biological Board could take up such a study. The Board had recently undertaken a comprehensive investigation of the natural and artificial propagation of fish. As part of this effort, they sought the co-operation of the recently organized Ontario Fisheries Research Laboratory.

The difficulties met with in efforts to obtain eggs, to fertilize them, and to hatch and rear the young encountered by Harkness, were those met with in every other similar attempt, and explains the reason why efforts to develop means for artificial propagation of sturgeon were eventually abandoned.

In the Gull River, Lake Nipigon, sturgeon spawn in swift water among rocks at the foot of rapids, up which they cannot ascend.

Since most sturgeon spawn in swift water, it was usually necessary to travel some distance up rivers to secure fish ready to spawn. No success had attended efforts to secure spawn from fish caught before spawning time and retained until they were ripe.

Lake Nipigon, where the Ontario Fisheries Research Laboratory carried on limnological studies from 1921 to 1926 and where the sturgeon study was concentrated, had not been fished commercially until 1917; its sturgeon population had, therefore, not yet been seriously reduced.

After searching for a place convenient to the central research station where sturgeon could be secured in adequate numbers, it was decided that no more suitable location could be found than one 20 miles up the Gull River where good numbers spawned each year.

It was now June 2nd, 1922. The ice had moved out of Gull Bay on May 16th. The temperature of the river and bay water was 64°F but, in the open lake, spring warming had scarcely begun. Although the peak of the spawning

migration had passed up Gull River between May 18th and 22nd, some spawning was still taking place at Twenty Mile Rapids. And so, travelling by canoe with two Indian helpers and a minimum of equipment, Harkness arrived at the spawning site at 7:30 p.m.

Transporting supplies and equipment up Gull River, Lake Nipigon, for experiment in artificial propagation of sturgeon.

Picture the difficulties under which it was being attempted to solve the problem of artificial propagation when others, working in more convenient locations with more adequate equipment, had failed. Camped in the primitive bush, 80 miles from the nearest white settlement - and it a pioneer bush settlement, with none of the equipment one is used to associate with the prosecution of scientific reasearch, the work was begun. The first campsite near the rapids had soon to be abandoned because the mosquitoes were unbearable. Even on a small rocky island in a nearby lake, the mosquitoes could still scarcely be endured.

The Indians, who had speared spawning sturgeon here all their lives, warned that soon after spawning began the sturgeon would leave. At first, attempts

were made to haul sturgeon out of the water by grasping them just in front of their tails. When this proved unsuccessful, spearing the fish and taking the eggs and milt by cutting them open had to be resorted to. When a quantity of eggs estimated at 50,000 had been secured and fertilized, the trip to headquarters camp on the railroad and from there to the Provincial Government hatchery at Port Arthur was undertaken. It is perhaps not surprising that, after all the vicissitudes through which the eggs passed on their way to the hatchery, none hatched.

Because it had been found impracticable to take eggs to the hatchery, it was decided to try to hatch them in floating boxes and in hatching jars through which water would be led by diverting the required amount of the river flow. Accordingly, a second trip was made to Twenty Mile Rapids on June 10th in the hope that eggs might still be secured, fertilized and hatched on the spot. However, by this time, spawning for the year had ceased, and so ended the first year's attempt to develop means of propagating sturgeon artificially.

The rest of the 1922 season was spent in gathering information on other features of the sturgeon's life history, especially its summer habits, its food and its rate of growth.

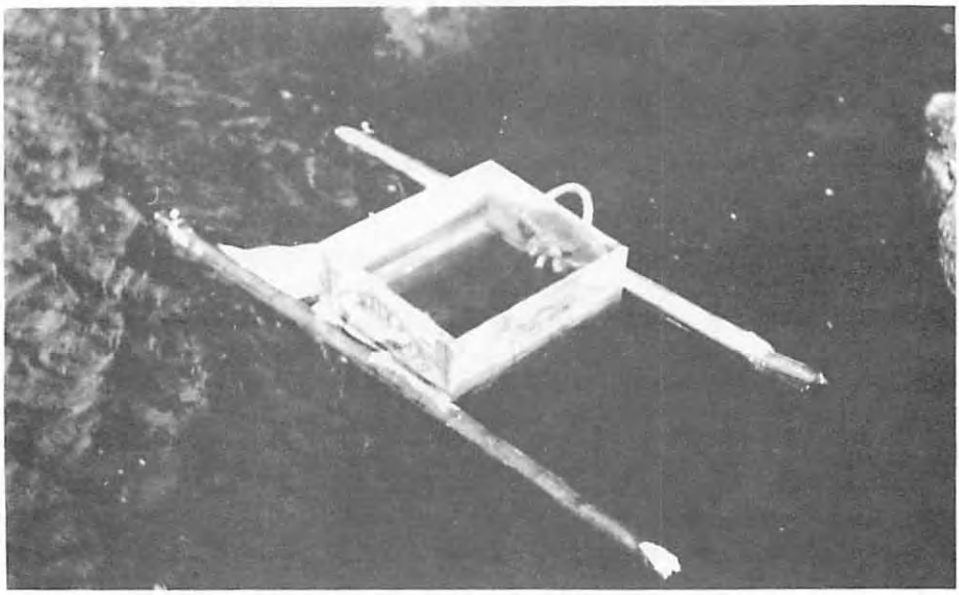
In 1923, Harkness was determined to reach the sturgeon's spawning grounds in time to secure an abundant supply of eggs. He arrived on Lake Nipigon on April 30th. The ice had not disappeared from the lake, but it was unsafe to cross. It was not until May 23rd that it was possible to cross the lake by boat. This time, the equipment necessary to instal facilities for hatching eggs on the spot, and to make a comfortable camp, required two freight canoes and the assistance of four Indians. Harkness was accompanied by a University student as assistant and companion.

Imagine their disappointment when they discovered that spawning for the year had practically ended, and that it was not possible to secure eggs and milt to test the feasibility of hatching eggs in their field hatchery.

It was not until 1924 that all conditions combined to make it possible to secure an adequate supply of eggs, to fertilize them, and to hatch and rear the young to a size of nearly one inch in length.

Having again failed to secure eggs by the method usually employed in hatchery operations, that is, by squeezing the abdomen of the female to force out the eggs, they were forced to take the eggs by opening the body cavity. The eggs were fertilized on June 12th and placed in modified Seth Green floating hatchery boxes anchored in the stream. The temperature of the water in which development began was 57.6°F. The first eggs hatched after five days and all had hatched after eight days. During this time, the temperature of the water had gradually risen to 59.5°F.

It is estimated that approximately 150,000 eggs were taken from the female and that over 95 per cent or 140,000 were fertilized and underwent segmentation. During development, about 20 per cent were attacked by Saprolegnia and died, or died first and were then attacked by Saprolegnia.



Above. Floating boxes with screen bottoms in which sturgeon eggs were hatched in Gull River, Lake Nipigon.

Below. Boxes supplied by rubber tubing with water from river, in which young sturgeon were reared after hatching.

The newly hatched fry, being of a jelly-like consistency, readily squeezed through the meshes of the screen which had successfully retained the eggs. In this way, over 90 per cent of the newly hatched fry escaped into the stream, leaving about 10,000 to be transferred to aquaria. Most of these appeared healthy and to be developing normally until some time after the yolk sac was absorbed when they began to die in numbers. Efforts to feed the fry were unsuccessful and, by 30 days after hatching, only eight remained. These were preserved for scientific study.

The chief features of the sturgeon which defeated attempts to culture it artificially are the small percentage which spawn in any one year, the failure to ripen when confined, and the inability to express the eggs from the living fish as is done in the case of most other species for which artificial propagation is practised. Means for artificially ripening fish had not at that time been devised.

Development of techniques for artificially ripening fish began with the discovery of the effect of a secretion of the pituitary gland on the ripening of the sex products. According to Atz and Pickford, (4) by far the most extensive use of pituitary extract in fish culture has been made in the Soviet Union. With the construction of more and more dams on their rivers, fewer sturgeon were able to ascend to their spawning grounds and, since they failed to ripen if retained in ponds, natural spawning was made impossible in many places. With the advent of artificially induced ripening through the injection of pituitary extract, artificial propagation could be carried on near the mouths of sturgeon rivers. Information available to Atz and Pickford was to the effect that, at that time, all sturgeon eggs for culturing in Russia were obtained from pituitary-treated fish. What contribution artificial propagation has made in maintaining the Russian sturgeon fisheries is not known.

Efforts devoted to attempts to develop artificial propagation of sturgeon were not entirely wasted. Directly and indirectly, these efforts resulted in the accumulation of a great deal of information on the life history and habitat requirements of the sturgeon which has contributed to an understanding of conditions necessary for their successful natural propagation.

XI. CAVIAR

The radical change in the value placed on the sturgeon is strikingly illustrated by the fact that its eggs, once fed to pigs, came to be used to make caviar, the food of epicures. Although there was a comparable change in the regard in which the flesh was held, as already pointed out, establishment of the lake sturgeon's reputation as a valuable fish was due as much or more to the demand for caviar than the increasing use of its flesh. The earliest caviar making on Lake Erie was at Sandusby in 1855, (97).

Some idea of the European demand for caviar at the time the sturgeon fishery was developing is indicated by Ryder's statement (88) that a single dealer, operating on the Delaware River during the season of 1888, put up about 50 tons of it for the German market, all produced from the roe of the Atlantic sturgeon.

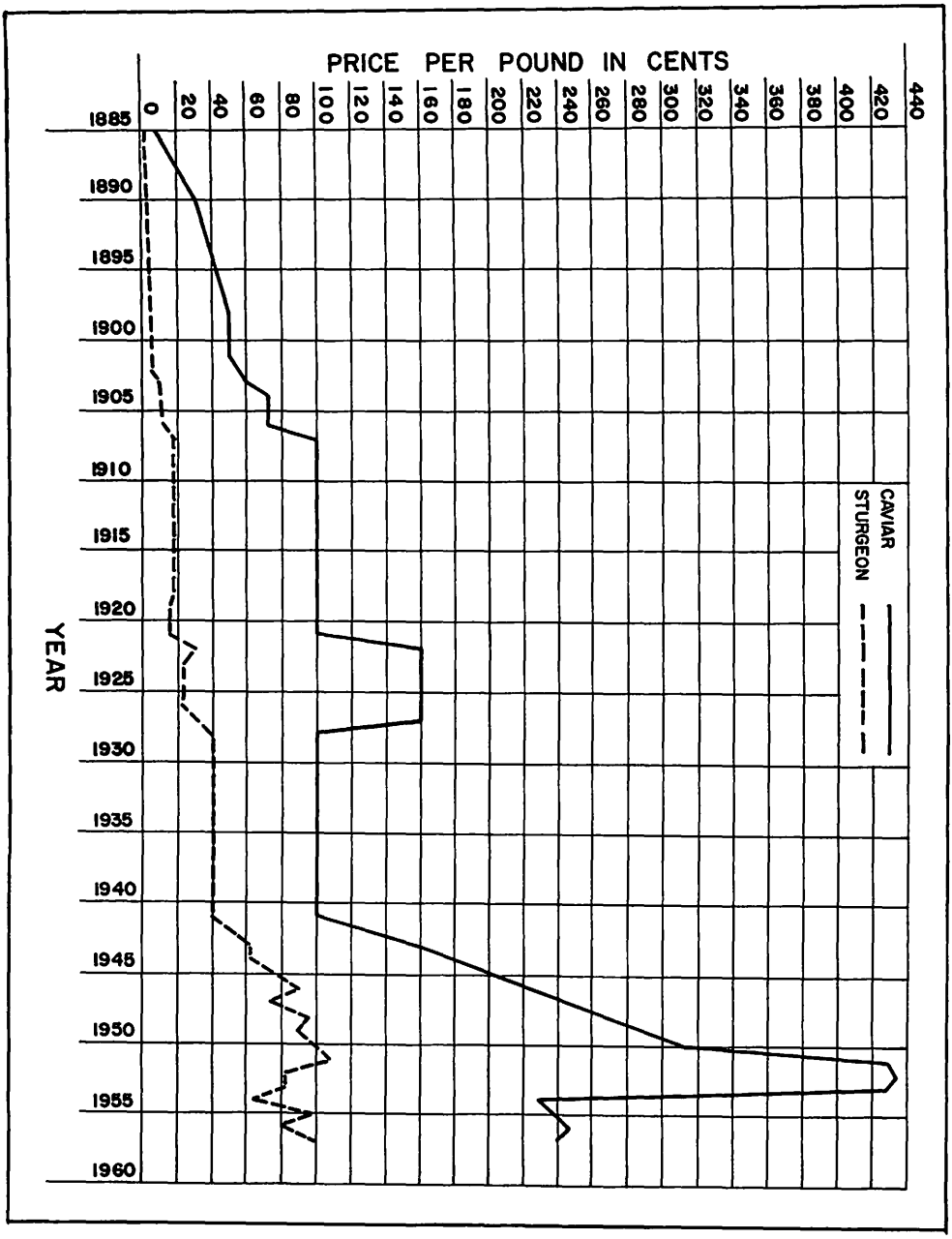
Caviar has been a highly prized delicacy in Europe, at least since the sixteenth century. Shakespeare makes Hamlet say, "His play . . . . . pleased not the million, 'twas caviare to the general' ", indicating its rating as luxury food.

Although the eggs of other kinds of fish are used for making a product sold as caviar, this name properly belongs to prepared sturgeon eggs. Among the species whose eggs are said to be used in making a kind of caviar are alewife cod, haddock, shad, whitefish, and salmon. (49).

Caviar is made by separating the eggs from the ovarian membranes by pressing them through sieves of suitable mesh, and then salting them. As a result of adding salt, a brine is formed. When this is poured off, the salted eggs that are left is the caviar of commerce.

The highest grade is made from hard roe, the nearly full-sized eggs, not yet fully mature. When ready to be spawned, the eggs are so soft that they are likely to be crushed in the screening process. It is said that caviar produced from the lake sturgeon is the best, the eggs being somewhat larger than those of the marine species.

Although there is a difference in the quality of caviar, depending on the size and stage of maturity of the eggs, the practice, at least in Ontario, is to recognize two grades. Grade I is made from the larger eggs 2.5 to 3.5 mm. or larger in diameter. Smaller eggs down to a size of approximately 1.8 mm. constitute Grade II. Within these grades, the colours are kept separate. The colour depends on the stage of maturity. The matter is complicated, however, by the fact that fully-ripe eggs are of a different size in different parts of the sturgeon's range. Thus, in Lake Nipigon, Harkness found ripe eggs to be 3.1 to 3.4 mm. in diameter, dark brown in colour, with a greenish cast. In Minnesota, Barney (6) found that eggs about to be spawned were on the average 2.72 mm. in diameter, olive brown in colour, sometimes giving a golden reflection. Eggs of the next following year were smaller and black. Cuerrier (20) has reported that in Lake St. Peter mature eggs were about three in diameter, dark gray in colour, spotted with olive-green and surrounded by dark rings. Eggs of the next smaller size, presumably requiring a year or two to mature were about two mm.. in diameter, of a dark greenish tint mixed with a little orange. These, he says, may be used to prepare caviar.



Graphs representing price of caviar and sturgeon 1885 to 1957.

The price of caviar is illustrated in figure 14. Tower (104) is authority for the statement that caviar, which had brought from $9 to $12 per keg of 135 lbs., in 1885; was worth $20; five years later; $40; in 1894 and before the end of that decade it had risen above $100 per keg.

The price continued to rise until it reached a peak of $4.33 per pound in 1952. Since then, there has been a decline to approximately $2.50 per pound. The temporary decline between 1927 and 1943 may have been due to increased export of Russian caviar. It has been reported that, about this time, large quantities of Russian sturgeon, particularly the sterlet (A. ruthenus) were imported to the New York market, resulting in a sharp decline in the price of American sturgeon and of caviar.

XII. ISINGLASS

Isinglass was another product, formerly in demand, which added to the value of the sturgeon. This was a form of gelatin obtained from the inner lining of the air-bladder of certain fish, of which sturgeon were the most important. That the sturgeon may have provided other sources of isinglass is suggested by Campbell (1793) who says that "In place of a backbone . . . . . they have only a large sinew full of gristle of which the best isinglass is made."

The principal use of isinglass was for clarifying wines, beers and other liquids. Of secondary importance was its use for culinary and confectionery purposes, as in making jellies, stiffening jams, etc. Isinglass was considered a great delicacy by the Chinese.

Dr. Neal Carter, of the Fisheries Research Board of Canada, has informed us that although, isinglass was widely used as a clarifying agent and as an adjunct in certain food products, it nevertheless had a somewhat residual taste unless it was most carefully purified. Therefore, with the increasing use of carrageenin and other materials derived from certain species of seaweeds, the demand for isinglass has virtually disappeared.

The sale of swim-bladders for making isinglass was never an important source of income from the sturgeon fishery. In contrast to the great increase in the price of caviar, the value of isinglass declined. From 1888 to 1902, the price was steady at $1.00 a pound, falling to 50 cents in 1904. Russell (86) says that, during the winter of 1892, sturgeon swim-bladders were being purchased at the Hudson's Bay Company's posts for 67 cents a pound and that it took ten fish to furnish one pound.

XIII. COMPETITORS, PREDATORS, PARASITES AND DISEASE

1. Competitors

In describing the spawning of the sturgeon, it was pointed out that, while several species spawn in or near the places where sturgeon spawn, direct competition is avoided by differences in time and site of actual spawning of different species.

At other than spawning time, the species most commonly found associated with the sturgeon in Lake Nipigon (and taken during the summer in experimental gill-nets set on known sturgeon grounds) were, in descending order of frequency - common sucker and walleye (yellow pikeperch), equal; common whitefish; northern sucker; and red-horse, pike and sauger, equal. Actual numbers of these species occurred in the following order: walleye, common sucker, northern sucker, common whitefish and pike (Esox lucius). Dr. K. H. Doan found, in an experimental net in which sturgeon were caught in Lake Erie, that other fish taken were, in order of abundance - saugers, walleye, perch, catfish, common suckers and sheepshead.

The common sucker is probably the most serious competitor of the sturgeon for food. In Lake Nipigon, its food included substantial quantities of molluscs, mayfly nymphs, chironomid larvae, caddis larvae and a freshwater shrimp (Pontoporeia hoyi), all important items in the food of the sturgeon.

The common whitefish, another bottom feeder, also eats large quantities (in order of abundance) of the freshwater shrimp, (Pontoporeia hoyi), chironomid larvae, molluscs, terrestrial insects, and mayfly nymphs. However, the whitefish ranges through a much wider range of depths than the sturgeon. In shallow water, it comes into direct competition with the sturgeon for the kinds of organisms listed but, since the sturgeon does not occur in numbers in water deeper than 30 feet, the whitefish at such depths is not a serious competitor.

While the walleye is commonly found over many of the same grounds as the sturgeon, it is not a bottom feeder and does not come into direct competition with it. At the time mayfly nymphs are rising to the surface in preparation for emerging, the walleye consumes significant numbers, but such feeding is not in direct competition with the sturgeon.

The most abundant items in the food of northern suckers are Pontoporeia hoyi, molluscs and chironomid larvae but, owing to the fact that this species is usually taken in relatively deep water, it does not appear to be serious as a competitor of the sturgeon.

2. Predators

There is no evidence that adult sturgeon are normally attacked by predators; their size makes such attacks unlikely. The young, before they reach a size which makes predation unlikely, may be preyed on by larger fish but, so far as we know, there are no records of young sturgeon having been found in the stomachs of fish or other animals.

Milner (67) has expressed the situation in this way: "It is not likely that

the young sturgeon, except in the earliest stages of their growth, suffer from the attacks of other fishes (as they are too well defended by shields to make a comfortable mouthful) and, after the spine disappears, have attained a size large enough to render them safe."

There are many reports of lampreys attacking sturgeon. Before 1921, when the sea lamprey was first reported above Lake Ontario, the silver lamprey (Ichthyomyzon unicupspis) was the parasitic lamprey common in most of the range of the lake sturgeon other than in Lake Ontario. Hubbs and Trautman (47) say, "The species best fitted for parasitism, I. unicuspis, inhabits the largest waters, where the greatest number of large host fishes, particularly the scaleless fishes of the catfish and sturgeon groups occurs, or did occur before their depletion by the white man."

Milner, (67) whose studies are the basis of much of our knowledge about sturgeon in the Great Lakes in the early days, reported that "a parasite that troubles the sturgeon is the lamprey-eel, Petromyzon argenteus Kirt, which is found very frequently attached to the skin. The circular scars and raw sores, sometimes found upon the sturgeon and attributed to this cause by the fishermen are correctly accounted for in this way . . . . . They frequently retain their hold upon a spot until they have eaten through to the flesh, and deep, ulcerous cavities occasionally result from the sore". This is the species to which the scientific name Ichthyomyzon unicuspis is now applied.

Scars made by the attacks of lampreys are still reported on sturgeon taken in the upper lakes, especially Lake Huron. It is probable that most of these are due to the sea lamprey which has become so abundant in those waters in recent years. The sea lamprey is known to attack sturgeon in salt water.

Since the sturgeon is so well protected by large bony plates over much of its body, the lamprey's wounds probably do not penetrate to the body cavity as they are capable of doing, especially in the case of fish protected by ordinary scales.

3. Parasites

Comparatively few parasites have been reported as attacking the sturgeon, and there is no indication as to how serious they may be in affecting its welfare. Lack of knowledge of the relation of parasites to the sturgeon is due, in part, at least, to the small number of sturgeon that have been examined for parasites.

Parasites reported from the sturgeon *belong to most of the groups commonly found in and on other fish - flukes, spiny-headed worms, thread worms and tape worms. The number of species of each of these groups reported from the lake sturgeon is as follows:

Trematoda (Flukes)	6 species
Acanthocephala (Spiny-headed worms)	4 species
Nematoda (Thread worms)	5 species
Cestoda (Tape worms)	1 species

In addition a crustacean fish louse, Argulus canadensis has been reported once.

The number of specimens reported from individual sturgeon has usually been small, although one fish from Wisconsin carried forty external parasites (flukes) and hundreds from its gills.

* We are indebted to Dr. Allen McIntosh of the Parasitological Laboratory of the U.S. Department of Agriculture for the list of parasites attacking the lake sturgeon.

4. Disease

The sturgeon is not free from disease and abnormal functioning which affect its welfare. Roussow (85) has recorded the following anomalies of the gonads.

Lipoid degeneration is said to be a very frequent anomaly in the sturgeon. If the female, in captivity or free, does not find the conditions necessary for shedding the eggs (current, temperature, spawning grounds, meeting with the male), in some days lipoid degeneration commences. The eggs are transformed into fat which is then resorbed. This abnormal condition is believed to postpone reproduction for one or two years.

"Cement" is the name applied by fishermen to another form of degeneration of the eggs. This condition manifests itself as a greyish liquid in which the remainder of the eggs float. Ovarian cysts appear as clusters on the ovarian tissue. Their size varies from that of small peas to that of a prune. Roussow has found these growths not only on the ovaries but also on the testes of at least one sturgeon.

XIV. FISHING METHODS

Many and ingenious have been the methods used to catch sturgeon. The first sturgeon taken in commercial fish operations in the Great Lakes were caught incidentally in seining for whitefish and other species. At that time, when sturgeon were regarded as a detriment, the effort was to avoid taking them since they added to the labour involved in fishing operations and injured the seines. When gill-nets and pound nets were introduced, sturgeon continued to be taken unintentionally and were still regarded as a liability.

According to Koelz, (53), gill-netting was begun in Lake Huron around Alpena about 1835, and at about the same time in Georgian Bay. In Lake Erie, pound nets were introduced about 1850 in the shallower water at the western end of the lake and, about the same time, gill-nets were used for fishing the deeper waters in the eastern part of the lake. The depth of water and nature of the bottom usually dictate the kind of gear used.

When only a few sturgeon were sought intentionally, especially in connection with efforts to develop methods of artificial propagation, the use of hooks and the spear was common. L.W. Crewe, an early commercial fisherman on Lake Erie, has said that, from 1890 to 1900, sturgeon caught for making oil were taken by spearing from shore and from wharves. Killing them by standing in a boat and hitting them on the head with an axe has already been mentioned.

A productive method of sturgeon fishing is by pound nets. These consist of nets running out from shore which lead the fish outward into a heart opening into a pound. Such nets have been used in all the Great Lakes and in such large inland lakes as Lake Nipissing and Lake Nipigon. They are adapted for use only in shallow water and in places where stakes to support the lead and heart can be driven into the bottom. According to Koelz, it is impossible to set pounds at greater depths than 25 to 80 feet.

In the Province of Quebec weirs made of wire mesh are used (105).

Where gill-nets are set specifically for sturgeon, only large mesh is permitted. In 1903, a Federal Order-in-Council prohibited the use of gill-nets having meshes of less than 12 inches extension measure, but in 1932 Ontario was given authority to specify the use of 10 inch gill-nets in inland waters. Smaller mesh usually take too many undersized fish. Where water is too deep for pound nets, gill-nets must be used.

Smith and Snell (97) are responsible for the statement that in 1885, at the eastern end of Lake Erie, some sturgeon were taken in gill-nets on their spawning grounds, but that at this season "they usually tear the nets into shreds and most of them escape." This is an example of the reckless and wasteful practices in taking sturgeon at the time they were so abundant.

A common method of catching sturgeon is by hooks. Many hooks are attached to a long horizontal line by shorter lines. The hooks either lie on the bottom or are anchored a few inches off bottom. Such lines are fished with both baited and unbaited hooks. There is a confusing variety of names applied to the different arrangements of hooks and lines and the way they are fished. These include set lines, bait lines, snag lines, trap lines and night lines. In Ontario,

only baited set lines have been permitted since 1903.

In New York the principal method of fishing has been by set lines. Bait or trap lines must not exceed 1200 feet in length; they must use 8-0 hooks, set not less than two feet apart, and be anchored on the bottom. Unbaited set lines, known as trap lines, have been the most effective method for taking sturgeon, but they are suited only to river conditions. Lines using number 10-0 hooks, set not less than six inches apart, are anchored not over three feet from the bottom. When bait is used, only dead bait is permitted. The use of minnows dead or alive is prohibited; worms are considered as dead bait.

Angling, using rod, hook and line, is practised in several provinces and states.

Variations of the bare-hook method of catching sturgeon (formerly in use) were known as hooking-up, twitching, jigging or snagging. Carter (18) has reported that hooking-up or twitching was the only feasible method of catching sturgeon (for artificial propagation) which were lying in a hole 40 feet deep. The equipment used consisted of a heavy handline, a two-pound sinker, six or eight extra large fish hooks, and a strong pole eight feet long and about two and one-half inches in diameter at the butt. The hooks were fastened together, back to back, anchor-shape, and then attached to the line at distances of eight inches, the lowest pair being about this same distance from the sinker. Fishing by such a device was from a boat, anchored at a suitable place in the river. The weighted line was cast into the swift water at the upper end of the hole, and as soon as it touched bottom the hooking-up began. This consisted of a succession of yanks, continued while the sinker was being carried by the current along the length of the channel with the object of forcing one of the hooks into a sturgeon's body.

Carter admitted that "hooking-up" sounded extremely barbarous but reported that of the fifteen sturgeon so taken, thirteen were hooked on the under side of the caudal penduncle, and the others in the thick portion of one of the fins. It may be that these were the most vulnerable locations owing to the absence of plates.

The practice of fastening several hooks to a weighted line and jigging or snagging sturgeon from rivers was not uncommon in earlier times.

A variation of the method of using hooks has been reported from Lake Erie where sturgeon were caught by having them rub against hooks strung on a line ruh up a pole. It was suggested that the sturgeon were caught when they came to root around or rub against the pole.

Indians apparently discovered that sturgeon could be caught on unbaited hooks attached to lines between two stakes. Various suggestions have been offered as to the reason for sturgeon becoming impaled on such hooks. It has been said for instance that the hooks pierce the skin when the sturgeon are rolling on the bottom.

Pieces of sucker are a favourite bait on set lines, but pieces of other fish and crayfish are also used. Balls of dough have also been employed.

Spearing has been practised both by holding the spear in the hand and by throwing it. Spearing through the ice in winter is a legalized method of fishing in some of the inland lakes in Wisconsin and Michigan. The method is described elsewhere in this report.

A variation of the spearing technique was grappling. Richardson (79) said the Indians at the rapid, which forms the discharge of the Saskatchewan into Lake Winnipeg, used to spear sturgeon with a harpoon or grapple them with a strong hook tied to a pole.

Grapples used at the eastern end of Lake Erie are described as "somewhat similar in shape to a small boat anchor and provided with three or four prongs which come to a sharp point and are slightly barbed. The shank of the hook is heavily leaded" (97). Grappling was carried on in this area during and immediately following spawning which here occurred along the lake shore. During June and July, farmers and others are reported as grappling from small boats, each of which frequently took 10 to 15 sturgeon in three or four hours. In 1885, about 75 men were engaged in grappling in the vicinity of Buffalo.

The use of grapples has been prohibited in Canada since 1903.

XV INDIANS AND STURGEON

Forth upon the Gitche Gumee,
On the shining Big-Sea-Water,
With his fishing line of cedar
Of the twisted bark of cedar,
Forth to catch the sturgeon Nahma,
Mishe-Nahma, King of Fishes,
In his birch-canoe exulting
All alone went Hiawatha.

Longfellow, Hiawatha.

Sturgeon appear to have been highly prized by Indians. Their large size must have made them a greatly esteemed quarry; one sturgeon would provide as much food as very many smaller fish. Then, their oily flesh meant that it would take smoke well and could thus be preserved for a long time. Another advantage the sturgeon had was its habit of congregating in rapids and their vicinity at spawning time, thus making many readily available for capture. An Indian hunter is recorded as saying, "It is to us Indians in the water what the buffalo was on land." The Jesuit Relations contain a number of references to the use made of sturgeon by Indians.

Richardson, (79) who accompanied Franklin on his first expedition in search of a northwest passage to Asia, when they spent the winter of 1814-20 on Pine Island Lake, a tributary of the Saskatchewan River, recorded that, "The great rapid which forms the discharge of the Saskatchewan into Lake Winnipeg appears quite alive with these fish in the month of June, and some families of the natives resort thither at that time to spear them with a harpoon or grapple them with a strong hook tied to a pole."

That they were not universally important to Indians is indicated by Richardson when he wrote, "The sturgeons of North America, though almost equally numerous with those of Asia, are of comparatively little benefit to the natives. A few speared in the summer time suffice for the temporary support of some Indian hordes, but none are preserved for winter use, and the roe and sounds are utterly wasted."

However there are enough references in the literature to make it certain that in some areas Indians did smoke or dry sturgeon for future use, but it is not clear to what extent they depended on such food. It probably varied from place to place.

Drying appears to have been the most widely and commonly used method of preserving fish in aboriginal North America. Smoking was probably a variant of drying through the use of fire to hasten drying.

That Indians, when they became less dependent on wild food, did not hold sturgeon flesh in such high regard is indicated by a report Harkness had that at Moose Factory in 1927 both Indians and white men used to take six or seven tons annually, smoke them and feed them to their dogs.

One of the reasons advanced by the Ontario and Manitoba Fisheries Commissions of 1909 for trying to restore the sturgeon fisheries was their importance to the northern Indians. In spite of very stringent regulations recommended for the protection of the fishery, it was suggested that they be relaxed in favour of Indians dependent on sturgeon for food. More recently, their importance as a commercial product to supplement the Indians' income from trapping, has been recognized.

The Indian mode of fishing was described by Charlevoix, (19) who came to Canada in 1720, commissioned by the French Government to seek a route to the western sea. He journeyed to Lake Superior and down the Mississippi, visiting posts of what was then the extreme western frontiers of New France. He wrote: "Two men placed themselves in each end of a canoe, the one behind steered, the other stood holding a dart in one hand to which one end of a long cord was fastened, and the other end to the canoe. When he saw a sturgeon within his reach he threw his dart and endevoured to strike where there was no scales. If the fish was wounded he darted off, drawing the canoe swiftly after him but after swimming about 150 paces the fish generally became exhausted and died, and was then drawn into the canoe by hand."

The congregation of sturgeon in or near rapids at spawning time in spring made spearing the most feasible method of capturing the fish at this time. At other times and especially in winter, gill-nets were used.

Baron La Hontan who travelled through the Indian territory, including the Mississippi, in 1688-9 reported that sturgeon were caught with nets in winter and grapples in summer. (54) Evidence of the use of gill-nets, especially in winter, is afforded by Champlain and numerous missionary reports contained in the Jesuit Relations describing conditions in the St. Lawrence and Great Lakes areas.

Rostlund, (81) quoting Zolotarev, suggests that gill-netting in winter was necessary as a means of survival of Indians in many parts of northern Canada where fish were plentiful and game scarce. All the evidence supports the belief that gill-nets and also seines were used before contact with Europeans.

Such roots as those of spruce and willow were probably used in making nets. Grooved and notched stones, which have been found in numbers in some areas, may have been used as sinkers for gill-nets, although the connection between fish nets and these stones has not been firmly established.

Hook and line fishing was probably not of great importance in aboriginal fishing on this continent. For the taking of sturgeon, it was probably much less efficient than spearing or gill-netting. However, Longfellow describes Hiawatha as using a "fishing line of cedar, of twisted bark of cedar", presumably with a baited hook. Indian fish hooks were of two types—composite hooks and those made of one piece. The former were made by lashing a point to a shank. The point, which was baited, was often made of bone. The shank was generally of wood, split for the purpose of receiving the point. Sometimes, two bones were lashed together at an acute angle. Singlepiece carved hooks were commonly

made of bone. (81)

Their rough bony scales are said (37) to have been used by Indians as rasps and graters.

XVI THE FISHERY

1. History

(a) Beginning of the Fishery. Attention has already been drawn to the fact that, before 1860, the sturgeon was not actively sought as a commercial fish. It was so little regarded as a food fish that only a few could be sold, and then at a very low price. It was not until it was found that smoked sturgeon could be sold, as a substitute for smoked halibut, that an active fishery for it began.

The smoking of sturgeon began in Sandusky in 1860 (97). Sandusky, at that time, is said to have been the largest market for freshwater fish in the world. Many fish from other Lake Erie ports, not only in the United States but in Ontario as well, were shipped to Sandusky. By 1866, two or three million pounds of sturgeon were handled annually in Sandusky. By 1885, half of the fish smoked were sturgeon. They brought a wholesale price of 12½ cents a pound, as compared with 10 cents for whitefish and trout.

Other products of the sturgeon fishery at this time were caviar, of which 1000 kegs were exported annually, 3000 lbs. of isinglass and 25 barrels of oil. When the flesh was smoked, the oil was extracted form the offal left when the fish were dressed. Previously, the flesh also had been used in making oil.

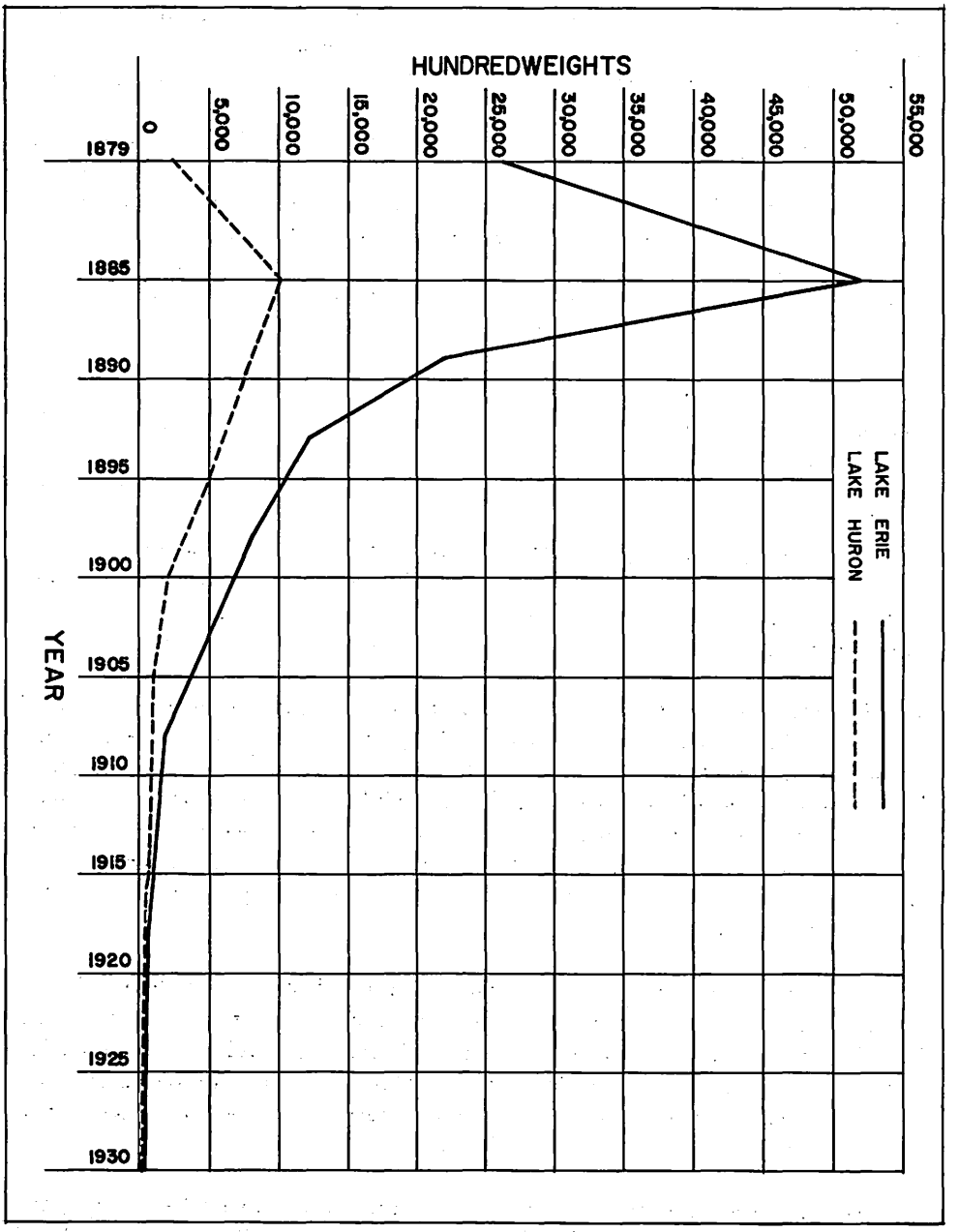
The making of caviar from sturgeon roe was begun in Sandusky in 1855. It was apparently caviar rather than smoked sturgeon that first attracted attention to the sturgeon as a valuable fish. By 1880, sturgeon had become a major fishery; by 1890, many districts were beginning to show a decline.

The early fishery for sturgeon in Ontario is not nearly as well documented as that in the United States. In the 1892 report of an Ontario Game and Fish Commission, almost the only reference to sturgeon is that of Ramsay Wright in his account of the Fishes of Ontario, (116) in which he says that the sturgeon was at that time hardly appreciated at its true value in Ontario, and that the greater proportion of the fish caught in Canadian waters were shipped to the United States. This, of course, is still true of the sturgeon and many other freshwater species.

(b) Rapidity of Decline A distressing feature of sturgeon fisheries is the rapid decline in yield which occurs when populations are fished. The result has always been the same—a relatively high, initial yield, followed by a sudden and permanent decline to very low levels. This is graphically shown in Figs. 15, 16, and 17 illustrating the history of the fisheries in Lake Erie, Lake Huron, Lake Nipissing, Lake Nipigon and Lake of the Woods.

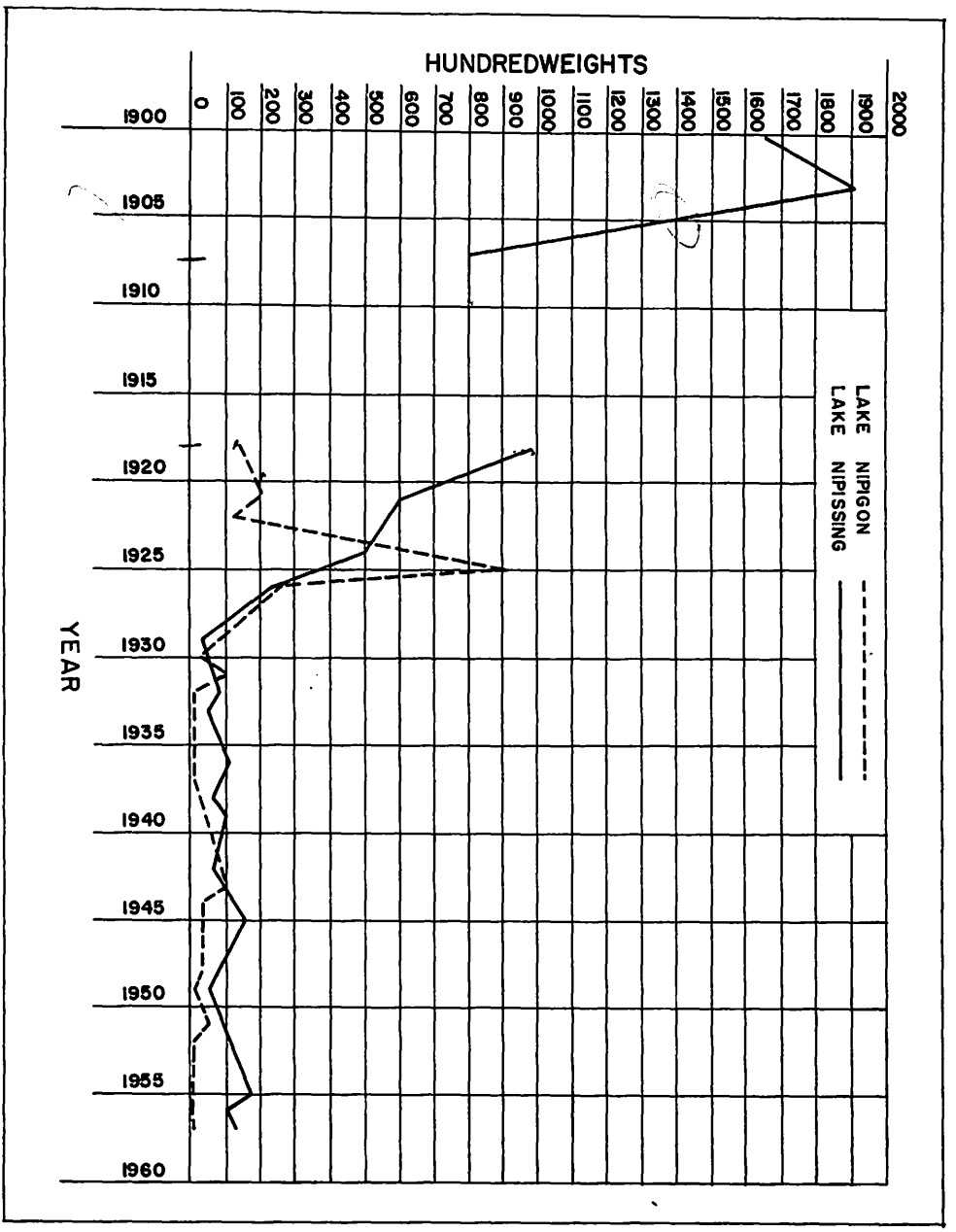
Although the rapidity and extent of decline varies from lake to lake, the similarity in the curves strikingly illustrates how rapidly an accumulated stock of sturgeon can be fished out, and how low is the yield under continuous fishing.

Within 10 years (1885-1895), the Lake Erie catch fell from over five million pounds to less than one million pounds, a decline of over 80 per cent. In the Lake of the Woods, it fell 90 per cent in seven years (1893-1900). The decline in Lake Huron, while substantial, was not as rapid—56 per cent in 10 years.

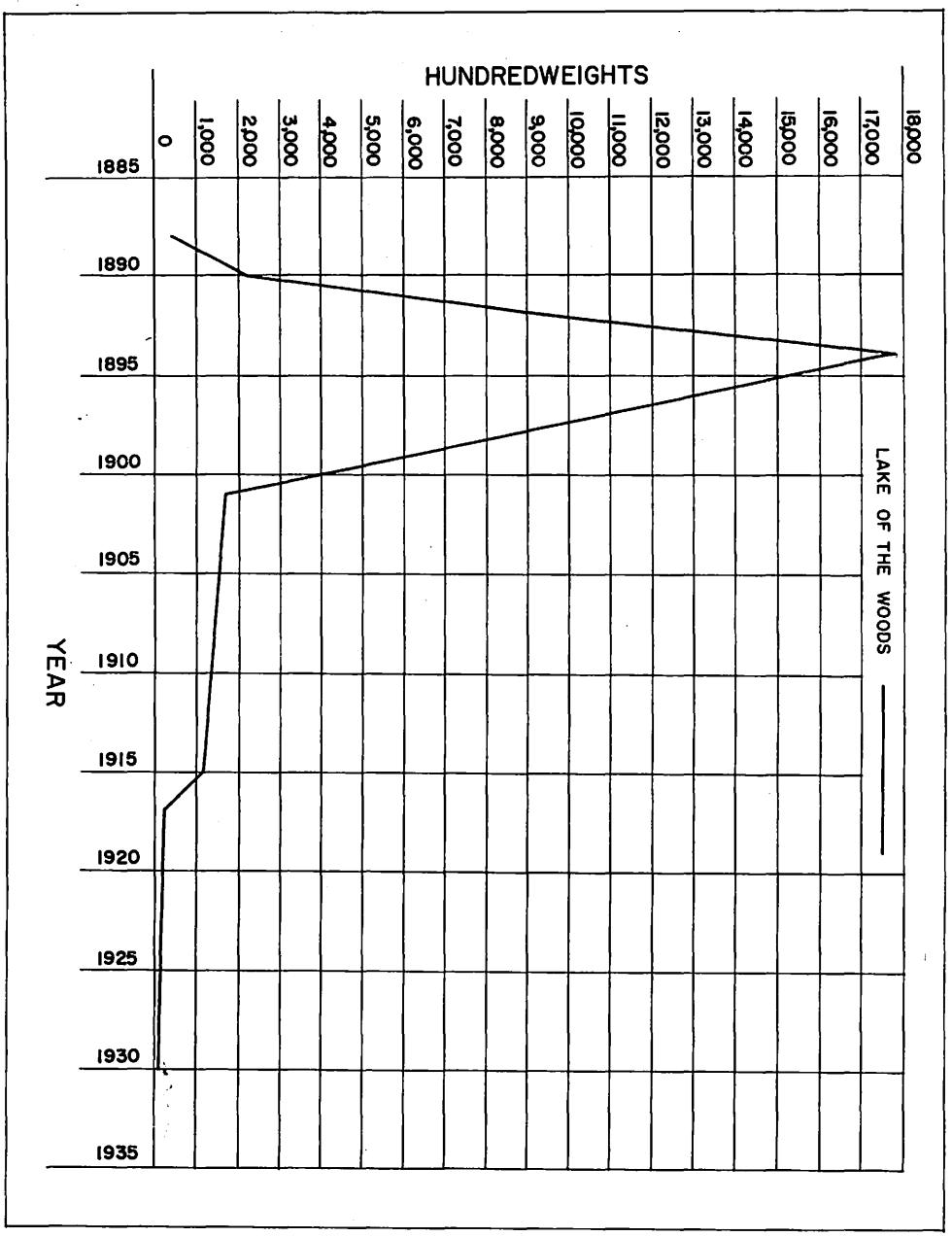


Graphs representing catch of sturgeon in U. S. and Canadian waters of Lake Erie and Lake Huron, 1879 to 1930. The catch since 1930 has been so low that it cannot be presented on a graph of this scale.

Similarly the size to which the catch declined varied from one lake to another. In Lake Erie, the average catch over the last five years for which statistics are available (1952-1956) was only 0.3 per cent of the maximum catch made in 1885. The corresponding percentage for Lake Huron was three per cent. For other lakes, the figures are: Lakes Ontario and Superior, two per cent; Lake Nipissing, six per cent; Lake Nipigon two per cent, (1947-1956). In Lake of the Woods, the sturgeon fishery is now practically non-existent, the catch in the last five years for which statistics are available (1953-1957) being less than 0.005 per cent of the 1893 maximum.



Graphs representing catch of sturgeon in Lake Nipissing, 1900, to 1958, and in Lake Nipigon, 1918 to 1958. In Lake Nipissing, there was a close season 1908 to 1917, inclusive.



Graph representing catch of sturgeon in U. S. and Canadian waters of Lake of the Woods, 1888 to 1930. Since 1930, the catch has been so low as to be impossible to represent on a graph of this scale.

(c) The Ontario Fishery The history of the Ontario sturgeon fishery for the Province as a whole has not followed the pattern shown by individual lakes—a rapid and continuous decline to an ultimate yield of zero to six per cent (usually two or three per cent) of the maximum production.

Fig. 18 shows that, although the total Ontario production has declined to a low level as compared with the maximum, the decline differs from that of individual lakes in two respects—it has not been continuous and it has not shrunk to so low a level. The average catch for the last five years is about 10 per cent of the maximum catch as compared with an average of two or three per cent for individual lakes.

Although the catch began to fall rapidly after an initial peak in 1885, it recovered and reached an all-time high in 1895 from which it has followed a pattern similar to that of all other sturgeon fisheries except that it has not yet reached such a low point.

TABLE IV.

PERCENTAGE OF TOTAL ONTARIO PRODUCTION CONTRIBUTED BY VARIOUS WATERS AT DIFFERENT PERIODS

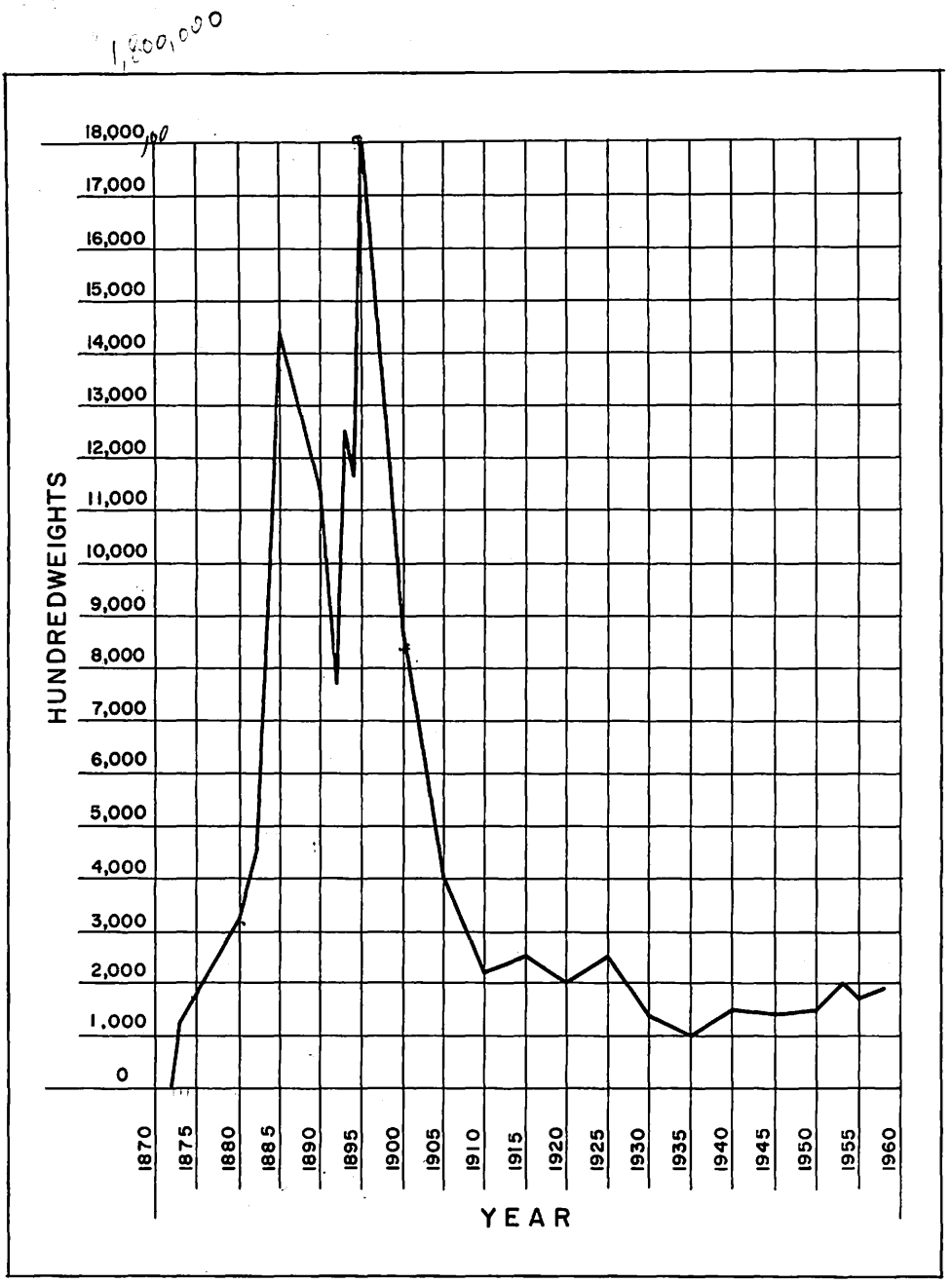
- indicates a production of less than one per cent, usually much below this amount.

	1880	1885	1895	1905	1915	1925	1935	1945	1955
Great Lakes	95	98	58	44	61	33	46	24	46
Lake of the Woods	0	0	39	16	34	1	-	0	0
Lake Nipissing	0	0	0	40	0	18	8	10	10
Lake Nipigon	0	0	0	0	0	38	-	4	-
Other northern inland waters	0	0	0	0	0	7	45	62	44
Other southern inland waters	5	2	3	-	5	3	1	-	-

Both of these differences from the history of sturgeon fisheries in individual lakes is due to the entrance into the fishery of new waters, not hitherto fished.

Although the great bulk of the early fishery was in the Great Lakes, there was from the beginning some catch in other waters. For instance, in 1879, 8,800 lbs. were taken in the Madawaska and Bonnechere Rivers and in lakes in Lanark and Renfrew counties. Fishing in the St. Lawrence River also began very early. In the Ottawa, it began at least as early as 1883. Lakes Simcoe and Couchiching were fished from 1881 to 1898 during which a total of 136,500 pounds was taken, (63). However, the species seems to have been extinct there for many years.

Fishing began in the Lake of the Woods in the 1880's although the Ontario production did not become significant until 1892. Production here was so large that by 1895 it constituted 39 per cent of the Ontario yield which reached the highest point it ever attained in this year. By this time, production in the Great Lakes was rapidly declining (Fig. 15). The total Ontario production was partially supported by the opening of Lake Nipissing about 1900 and Lake Nipigon



Graph representing catch of sturgeon in Ontario, 1872 to 1958. The decline between 1885 and 1892 was due to the decline in the catch in the Great Lakes, and the rise between 1892 and 1895 to the beginning of fishing in the Lake of the Woods. The addition of catches in Lake Nipissing, Lake Nipigon and other lakes in northwestern Ontario has not been sufficient to compensate for declines in the Great Lakes and Lake of the Woods.

in 1917. The contribution of these virgin lakes is strikingly shown by the fact that, in 1905, Nipissing contributed 40 per cent to the total Ontario production and Lake Nipigon 38 per cent in 1925, Table IV. As in the case of all other fisheries, production soon fell off rapidly, although the Nipissing yield has been much better sustained than that of either the Lake of the Woods or Lake Nipigon. The temporary cessation of fishing in Nipissing during 1908 to 1917, inclusive, accounts for the relatively high percentage contributed by the Lake of the Woods in 1915.

More recently, production has been extended to waters in the northwestern part of the Province, first in the Kenora and Thunder Bay districts, and later in Patricia. By 1935, when Lake of the Woods and Nipigon had virtually ceased production, and Nipissing was down to eight per cent of the provincial total, these northern waters were producing 45 per cent of the Ontario total and by 1945, 62 per cent of it. However, their production too has been short–lived, and many of the waters which gave good yields when first fished have now shrunk to relative insignificance.

Ontario is running out of previously unfished sturgeon waters, and production will settle down to a relatively low, continuous yield.

2. Comparison with other Species.

Sturgeon fisheries are unique in showing a sudden and permanent decline to very low levels. Most other species, when fished, while showing some decline from primitive abundance, usually give a relatively high yield so long as environmental conditions remain favourable.

It is impossible to get strictly comparable figures for most other species for the reason that fisheries for them developed more gradually and at a time before adequate statistics were collected, with the result that the earliest available statistics do not represent such a vigorous attack on an accumulated stock. However, the following figures, which are average catches over five-year periods, indicate that whitefish and lake trout yield a relatively higher and more uniform catch than sturgeon, after the fisheries have been in operation for some time. These figures represent the catch in both United States and Canadian waters, including Georgian Bay.

TABLE V.

AVERAGE PRODUCTION FOR CONSECUTIVE FIVE YEAR PERIODS OF LAKE HURON STURGEON, LAKE TROUT AND WHITEFISH.

	1896-1900	1901-1905	1906-1910	1911-1915	1916-1920
Lake Huron sturgeon	417,600	120,320	61,900	66,850	36,220
Lake Huron lake trout	5,555,680	6,257,940	6,076,470	5,491,650	5,756,300
Lake Huron whitefish	2,168,360	2,408,040	2,477,170	2,146,525	2,481,340

While it is not suggested that these figures accurately represent actual numbers of trout and whitefish in the lake, it is suggested that actual popula-

tions, in order to support a fishery of the magnitude indicated, remained at a very much higher level in comparison with original abundance than those of the sturgeon did. Since 1940, the trout fisheries have been seriously reduced owing to drastically changed conditions, including the arrival of the sea lamprey.

3. Factors Affecting Sturgeon Productivity

While the reasons for the failure of the sturgeon to maintain a higher level of production are not fully understood, several features of its life history, as well as environmental changes, appear to be important.

(a) Late Attainment of Commercial Size. While it is not strictly true to say that the sturgeon is a slow-growing fish, it does require a much longer time to reach a commercial size than most other species.

There is no fixed age at which a species reaches a given size. As indicated in discussing the growth rate of the sturgeon, this differs markedly from one body of water to another; for instance, in the south, they grow much more rapidly than in the north. There is no information on differences in growth rate of sturgeon from time to time in the same body of water, but it is known that this varies widely in some other species.

The following list of ages at which species enter the fishery in significant numbers must therefore be regarded as rough averages.

Lake Erie lake herring	2 years
Whitefish	4 years
Lake trout	5 years
Lake Huron sturgeon	10 or 11 years
Lake Nipigon sturgeon	26 years

How this characteristic of the sturgeon affects the productivity of the fishery will be discussed below (see Why Did Sturgeon Populations Decline so Rapidly?).

(b) Late Maturity. This subject is discussed above where it is stated that of all of our freshwater fish, the sturgeon takes by far the longest to attain sexual maturity. The actual age is different in the two sexes and in different waters. The range in age at which sexual maturity is attained in different waters is as follows:

Males	12 to 22 years
Females	14 to 33 years

(c) Infrequency of Spawning. Attention has already been drawn to the fact that female sturgeon do not spawn every year. The frequency of spawning varies from place to place, the usual range being from four to seven years between spawnings.

(d) Unfavourable Environmental Changes. To the above inherent characteristics of the sturgeon, limiting its reproductive capacity, have been added environmental changes affecting its spawning, hatching and survival. These have resulted from industrial and other developments.

The sturgeon is one of those species that thrive best under conditions which obtained before settlement began. In this respect, it resembles other species, such as the salmon, which spawn in streams. While the advance of civilization has affected conditions in lakes, these changes have not been nearly as great as they have been in streams.

(i) Dams in streams have a detrimental effect on the reproduction of sturgeon in many areas. Its habit of spawning among rocks in rapids means that when its access to streams is interfered with, reproduction is seriously reduced.

Very early in the history of settlement, dams to make available water power for grist and saw mills probably prevented many sturgeon from reaching their spawning grounds. Since the earliest settlement took place on the shores of Lake Ontario and Lake Erie, the injurious effect of dams must have been first felt in those lakes. By 1798, there were one grist and two saw mills in York Township on the shore of Lake Ontario. By the middle of the century, almost every stream flowing into this lake from the north had several mills on it.

These dams are believed to have been a major factor in bringing about the extinction of the lake salmon in Lake Ontario. That sturgeon were not also eliminated may be due to the fact that the salmon's spawning grounds were in the upper reaches of the streams, which the salmon were probably completely prevented from reaching, whereas some sturgeon may have been able to spawn in the swift water below the lowest dam on a river system. The Niagara River may have been used by the sturgeon and not by the salmon. Also, some sturgeon spawn in lakes.

With the advent of steam power, mills using water wheels and the associated dams began to be abandoned. However, dams, later placed in streams to provide hydro-electric power, have interfered with the use of many falls and rapids so important as spawning grounds for sturgeon. Although hydro-electric developments may not seriously interfere with conditions affecting the spawning of sturgeon below some dams, elsewhere the spawning places of sturgeon have been completely destroyed. The time at which dams may have affected the reproduction of sturgeon has varied from quite early to very recent and, accordingly, has had widely different effects in different places depending on the history of power developments in the areas concerned.

The possible effect of the manipulation of river flow in power development is shown by the fact that large sturgeon are known to have been left stranded in shallow water below falls when the gates were closed to reserve water.

(ii) Pollution is another accompaniment of industrial development which has been seriously detrimental to sturgeon reproduction in some places.

Wood fibres escaping from pulp and paper mills are among the commonest forms of pollution in many streams to which sturgeon have resorted for spawning. Rainy River provides an example of the nature and probable extent of injury to sturgeon reproduction, from this cause. The Soo Rapids on this river are reported to have been the principal spawning ground of the Lake of the Woods sturgeon (32, 29). Carlander, (17) who found that the Rainy River had also been an important spawning area for the walleye, reported that in 1945 "and for several years past, these (walleye) spawning beds are buried under a blanket

of pulp fibre." The paper mills at Fort Frances have been in operation since 1907.

A study of the pollution of the Spanish River in 1950 and 1951 (27) showed that deposits of fibre varying in thickness from a fraction of an inch to two and one half feet accumulated on the bottom during summer, autumn and winter in a 20-mile section below a pulp and paper mill. Occasionally a raft of fibres two feet and more in thickness would rise to the surface and be carried downstream. These bottom deposits of fibre were at times scoured out of the river by spring floods.

In spring, floating fibres would be particularly detrimental to the hatching of sturgeon eggs which are deposited at this season and remain in the stream for sometime, attached to rocks, stones and other solid objects to which they become attached, in virtue of their adhesive nature, when first deposited. While still adhesive, the eggs would be particularly susceptible to the accumulation of fibres on their surface. There can, therefore, be little doubt that waste fibres from pulp mills are seriously detrimental to the reproduction of the sturgeon.

Wood fibres deposited on the bottom of lakes and streams are also detrimental to many of the bottom organisms constituting preferred food of the sturgeon, including mayfly nymphs, chironomid (midge) larvae, aquatic snails and clams. In the Spanish River, it was found that all of these were drastically reduced in the first 20 miles below the pulp and paper mill as compared with those in the same river above the mill.

Waste liquor from sulphite paper mills have been shown to be lethal to fish life. During the Spanish River study, (27) it was shown that, on two occasions, "slugs" of toxic wastes released from the kraft mill killed large numbers of fish; on the second occasion, the kill extended to the mouth of the river.

Pollution by other industrial wastes and by domestic sewage has occurred, and still occurs, in some places, but little or no information is available as to their possible effects on sturgeon.

Bark is another waste from paper mills which must have a detrimental effect, especially when it settles on the bottom where the sturgeon gets all its food.

The widespread pollution of rivers is suggested by the results of studies reported by MacKay (59).

Bark and waste pulp was found on the bottom of the Sturgeon River below the paper mill to the mouth of the river and for some distance into Lake Nipissing. Vegetation at the water's edge was coated with slime and waste pulp. There was an absence of life on the bottom, particularly one mile below the mill.

Below a pulp mill at Timiskaming, bark and waste fibres were carried downstream six or seven miles and settled out near Beauchene and beyond for some miles.

Below Iroquois Falls, the bottom of the river was very dirty with pulp and bark for at least six miles.

Below Smooth Rock Falls, bark and pulp was found for seven miles downstream, and reported to have extended 12 to 15 miles farther. Vegetation along the shore was coated with deposits of pulp.

At Kenora, waste from a pulp mill polluted the river for about eight miles.

(iii) Disturbance of Spawning. Reference has been made to sturgeon forsaking the spawning grounds in the Gull River, Lake Nipigon, as a result of disturbance. This type of interference with spawning must have been common in many places, even in the early days of commercial exploitation, and has been continually extending ever since.

(iv) Where Have Environmental Changes Been Most Serious? Environmental changes detrimental to the sturgeon differ widely from one part of its range to another. It is quite possible that the extent to which production has declined during the history of the fishery in different areas is proportional to environmental changes which affect the sturgeon.

In the Nelson River, where original conditions have been little affected by industrial development, the average catch for the last five years for which statistics are available is still 13.9 per cent of the maximum catch. In the case of Lake Erie, the catch for the last years was 0.3 per cent of the maximum for that lake. In the Lake of the Woods, the corresponding figure was .0045 per cent. Natural conditions in the Lake Erie area have obviously been destroyed to a very much greater extent than on the Nelson River. As to the Lake of the Woods, the principal spawning beds have for many years been buried under a blanket of pulp fibres (see account of Pollution under The Fishery). The fact that, on the Nelson River, the percentage of young fish increased from 1953 to 1956 suggests that a good deal of reproduction is taking place. The same conclusion is also suggested by the fact that, after a five year closed period (1948 to 1952), the catch rose from an average of 10,880 lbs. for the five years immediately preceding closure to an average of 27,200 lbs. after closure.

These percentages are not strictly comparable since, on the Nelson River, there have been, during the fifty-three years, four closed periods totalling twenty-one years, whereas in Lake Erie and the Lake of the Woods, fishing was continuous. Nevertheless, it is believed that reproduction on the Nelson River has been less seriously interfered with than has been the case of the Lake Erie and Lake of the Woods populations. Dams and pollution have not yet affected the Nelson River, whereas on Lake Erie and Lake of the Woods environmental, changes have drastically reduced the suitability of these areas for the reproduction and, perhaps, also for other phases of the life history of the sturgeon.

The fact that production in Lake Erie has declined to a much greater extent than in other Great Lakes is probably a reflection of the greater industrial development around this lake as compared with the others.

4. Why Did Sturgeon Populations Decline So Rapidly?

It takes sturgeon much longer than most fish to reach a size at which they may be caught. This is one of the features of this fish responsible for its rapid decline when it is subjected to commercial fishing. How this comes about may perhaps be understood by comparing the harvesting of fish to the cutting of trees.

In a woodlot where no trees have previously been cut, there are usually trees of many ages and sizes. Every year, millions of seedlings spring up from seeds shed by the older trees, but practically all soon die because there is no living room. Similarly, in an unfished population, there are fish of every size and age. Every year, millions of young are hatched from eggs deposited by the mature fish and, as happens in a woodlot, practically none survive, and for the same reason—no living room. There is a limit to the number of fish that can find living room in a body of water at one time, just as there is a limit to the number of trees that can grow on an area of land. In the case of a population of fish, the number that can live in a body of water is called its carrying capacity.

When a large tree in a woodlot dies or is cut, there is space for some of the seedlings to survive that would otherwise have died. As they grow, more and more of the young die until, by the time one has grown to the size of the tree that had been removed, the others have lost out in the struggle for existence. Similarly, when an adult fish dies or has been caught, there is room for some young to survive that would otherwise have died early; but, as in the case of trees, only one can find living room as an adult.

Now, when unnatural death is introduced into the woodlot or water in the form of cutting trees or catching fish, more of the seedlings or young fish survive than under natural conditions. If many big trees or fish are removed, large numbers of young begin to grow up to take their places. Since it takes many years for a tree to grow, it will be a long time before there will be as many big trees as there were before. Similarly, in the case of sturgeon which in some areas take twenty years or more to reach catchable size, the yield of sturgeon to fishermen will rapidly fall if large numbers of adults are removed through fishing. In the case of lake herrings or whitefish, which reach catchable size in two to five years, a catch more nearly that of the original is maintained.

This explains why the catch of a fish, that takes as long as the sturgeon does to reach catchable size, declines so rapidly when it is intensively fished.

5. Sustained Yield

If the comparison of a sturgeon fishery to the cutting of trees in a woodlot has any validity, it will be obvious that the number of sturgeon of commercial size, which may be removed from a body of water year after year indefinitely, is very much smaller than the number that can be taken for a few years after the fishery is first exploited. One of the reasons for this, as discussed above, is the munber of years it takes a sturgeon to grow to commercial size. Other factors, including destruction of habitat conditions necessary for reproduction, survival and growth have also been discussed above.

An unfished population of sturgeon may be compared to a stand of maples where none has ever been cut. So many years are required for a maple or a sturgeon to reach marketable size that only a few can be harvested each year without depleting the supply.

Another of the features of the sturgeon, which affects its productive capacity, is that it is adapted to a shallow water habitat. The effect of this characteristic is illustrated by figures presented in TABLE VI. From this table, it is seen that the catch of sturgeon even at the peak of its production in Lake Superior, a very deep lake, was only seven pounds per square mile, compared to 522 pounds per square miles in Lake Erie, a shallow lake. However, when we compare the relative production per square mile of water less that 60 feet deep in the two lakes, the comparative figures are Lake Superior 110 pounds, Lake Erie 1094 pounds. This means that, comparing total areas, Lake Erie was nearly 75 times as productive as Lake Superior, whereas, on the basis of the area of water less than 60 feet deep, Lake Erie was only ten times as productive. Other factors notably temperature, are also involved in bringing about these results.

TABLE VI.

MAXIMUM AND RECENT CATCH OF STURGEON PER SQUARE MILE OVER THE ENTIRE AREA AND IN RELATION TO THE AREA OF WATER LESS THAN 60 FEET DEEP IN DIFFERENT LAKES.

	Maximum Catch		Average Catch 1952-1956	
	Entire Area	60 Ft. Water	Entire Area	60 Ft. Water
Lake Superior	7	110	0.1	2.1
Lake Huron	45	222	1.3	6.4
Lake Erie	522	1094	1.6	3.3
Lake Ontario	77	587	1.6	12.0

In contrast to the present low yields of sturgeon in the Great Lakes, Lake Winnebago in Wisconsin produced an average of a little less than 160 pounds per square mile from 1955 to 1959, inclusive, after many years of intensive fishing. Lake Winnebago is shallow throughout its entire area, having a maximum depth of only 21 feet.

Attention has already been drawn (Table V.) to the fact that, over a period of years, such species as whitefish and lake trout maintain a relatively high yield as compared with sturgeon. In terms of pounds per square mile, Lake Huron produced only 6.6 pounds of sturgeon from 1891 to 1939, as compared with 134 pounds of whitefish and 248 pounds of lake trout. Soon after 1939, the depredations of the sea lamprey began to seriously affect the productivity of the fisheries, especially the lake trout. While 1891 does not include the peak production of sturgeon, the yield of the sturgeon fisheries in that year and for sometime thereafter were at a relatively high level. See Figure 15.

From the point of view of management, the question arises as to what yield should it be possible to sustain under continuous fishing. In other words, what sustained yield is possible under proper management methods. It is quite certain that nothing approaching the yields obtained when sturgeon were first fished is possible under continuous fishing.

The fact that sturgeon catches increase so little, after periods of closure up to twenty years, suggests that the sustained yield of the fishery is quite low; during closure, natural mortality removes most of the annual increment to the stock of legal-sized fish. A longer period of closure would probably result

in building up a much larger accumulation. Such closures, however, would result in economic loss through failure to harvest the fish which otherwise die naturally each year.

Whether the low production yielded today, by waters that have been fished for many years, is the maximum sustained yield is impossible to determine except by long-term experiments. Such experiments would involve closing the fishery for perhaps forty of fifty years to determine to what size the population could be built up, and then fishing under a given quota. Depending on the result, the experimental quota could be increased or decreased until a catch was found which could be maintained indefinitely. The fact that environmental conditions affecting the success of spawning, hatching, survival and growth will undoubtedly continue to change in the future, as they have in the past, means that the possible sustained yield will also continually change.

6. Value of Present Sturgeon Fishery

In spite of the fact that the volume of the sturgeon fisheries are now only a small percentage of what they once were, they are still a significant item in the fisheries of Ontario. This is due in part to the high price per pound at which their flesh sells and to the value of the roe for the making of caviar. The standing of the sturgeon in the Ontario fisheries is indicated in the following table.

TABLE VII.

VALUES OF THE MOST IMPORTANT SPECIES CONSTITUTING THE FISHERIES OF ONTARIO.

Values are averages for the five years 1955 to 1959.

Yellow Pickerel	$1,783,437
Whitefish	$1,184,851
Perch	$1,155,176
Blue Pickerel	$ 926,618
White Bass	$ 402,838
Lake Trout	$ 244,859
Smelt	$ 219,792
Sturgeon including Caviar	$ 162,201

XVII CONSERVATION

1. History

There is no more striking example of the reckless and wasteful exploitation of a natural resource than that of the sturgeon.

We look back with something akin to horror at the way in which the natural resources of the continent were exploited by the pioneers. However, we should not condemn them too strongly; they had no experience to warn them of the consequences of their reckless and wasteful methods. The concept of conservation or prudent use had not yet arisen.

The decline of the sturgeon was noted as early as 1850. Kirtland, (52) an Ohio physician and naturalist, reported that, "While the tributaries of Lake Erie and the Ohio River were unobstructed with dams and were not swept by seines, they abounded with large and valuable species of fish which, in their vernal migrations, crowded in immense shoals on the ripples. Sturgeons and muskellonge often run up the Cuyohoga several miles . . . . . The Sturgeon has nearly forsaken this shore of the lake."

Similar reports continued to be made as settlement and industrial development spread After the turn of the century, this concern took on a new note of urgency It may be that the stock-taking natural, in looking back over one century and forward to another, led to a realization of the recklessness with which many resources had been exploited.

Tower (104) summed up what must have been the conclusion of anyone familiar with the history of the sturgeon when in 1908 he wrote, "It seems scarcely comprehensible that a fish so widely distributed through the country, so abundant, and so little used less than three decades ago, has so rapidly disappeared that the end is already in sight."

Similar concern at the state of many other resources led to the initiation of a conservation movement of which Gifford Pinchot was a leader. In his book, "Breaking New Ground," published in 1907, he defined Conservation as "use of the natural resources for the greatest good of the greatest number for the longest time" which is still the definition accepted by most conservationists.

The President of the United States, Theodore Roosevelt, convened a North American Conservation Conference on February 18th, 1909, at which the United States, Canada, Newfoundland and Mexico were represented. This conference stimulated much activity in conservation throughout North America. In Canada, a National Conservation Commission was created in 1910 and functioned until 1921.

At least three commissions for the study of fisheries problems were set up at this time, viz., an International Fisheries Commission between Canada and the United States, an Ontario Game and Fisheries Commission and a Manitoba Fisheries Commission.

The purpose of the International Commission was to bring about "uniform and effective measures for the protection, preservation and propagation of the food fishes in the waters contiguous to the Dominion of Canada and the United States." A convention for these purposes was signed at Washington on April, 11th, 1908, (15).

In the matter of sturgeon conservation, the International Commission proposed that Canada and the United States should carry out a total prohibition of of sturgeon fishing in the boundary waters along the international border for a period of four years. A Code of Regulations, embodying this and other measures for the management of the fisheries, was agreed on.

During the following session of the Canadian Parliament, the Fisheries Act was amended to enable these regulations to be proclaimed, but the United States Congress failed to approve the regulations and to provide the necessary legislation to enable them to be enforced in that country, (16).

This was not the first International Commission that had tried to secure agreement on means for the better management of the fisheries in boundary waters between Canada and the United States. A Commission which operated from 1892 to 1896 (50) had as its objectives

1. Prevention of destructive methods of fishing.
2. Prevention of pollution and obstruction of waters.
3. Adoption of close seasons
4. Restocking, replenishing and other means of preserving and increasing fish production.

Among the measures recommended in the case of sturgeon were:

> All sturgeon measuring less than four feet long taken by any means should be returned to the water.
>
> Taking sturgeon by means of naked hooks or grapnels should be prohibited.
>
> Restriction of the number of nets to be used in fishing for sturgeon.
>
> Fishing for sturgeon in Rainy River, except for domestic use should be prohibited.

While it was admitted that a close season covering the spawning season could not fail to be beneficial, in order to be effective it would require (because of the lack of detailed knowledge at that time) to begin at such a date and to be continued for so long a time as to interfere with the entire spring and early summer fishery which was the most profitable in the year.

We have been unable to discover how many of these measures were immediately adopted. In 1903, a federal Order-in-Council was passed, fixing the minimum size for sturgeon at four feet, and prohibiting the taking of sturgeon by bare hooks and by grappling irons. However, the Ontario Department of Fisheries, which took over administration of the Ontario fisheries in 1898, decided not to enforce regulations with reference to size and close season

until such time as the States bordering on the Great Lakes might pass similar legislation. To this day, there is no close season in most of the Great Lakes.

In addition to these attempts to secure international agreement which dealt with all of the boundary waters between Canada and the United States, many international conferences have been held in efforts to procure uniform legislation for the protection of Great Lakes fisheries. A partial history of these efforts is contained in a supplement to the report of the International Board of Inquiry for the Great Lakes Fisheries established in 1940, (48).

We have determined that at least 18 meetings between Ontario officials and those of States bordering on the Great Lakes were held, between 1891 and and 1938, before an International Board of Inquiry for the Great Lakes Fisheries was created in 1940.

At least on two occasions, 1917 and 1933, agreement among the officials concerned resulted in Orders-in-Council being passed at Ottawa declaring a close period of four and five years respectively for sturgeon fishing on Lake Erie, providing similar regulations were passed by the States bordering on Lake Erie. In neither case was the necessary legislation passed and enforced by all of the states.

So far as common regulations are concerned, the 1940 International Board of Inquiry recommended that "insofar as investigation shows fisheries to be dependent upon a common stock or to have the same conditions, regulations for management of these fisheries be formulated and tested by a common or joint agency."

The Ontario Game and Fisheries Commission, 1909-1911, made a number of extreme and far-reaching recommendations, (70). Their two basic assumptions were: "Under economic management, these fisheries could have been made a permanent asset of enormous value to their owners" and "In the hands of the ordinary commercial net fishermen, no matter in what class of water, the pursuit of the fish results in its rapid disappearance, and it would, therefore, seem advisable to debar the net fishermen, totally or in part, from profiting by the capture of this fish, for where there was little or no profit to themselves to be derived from its capture, they could at least be counted on not deliberately to pursue it."

Recommendations of the Final Report of the Commission published in 1912 included the following:–

(1) That the sturgeon be declared a perquisite of the Crown, and that commercial fishing for the sturgeon be prosecuted, in such waters as may be deemed desirable, by or under the immediate direction of Government officials, the expenses being borne by the Government; and the fish sold for the benefit of of the public Treasury.

(2) That where, under the ordinary commercial fishing license a sturgeon is inadvertently captured and cannot be returned uninjured to the waters, it be required of the licensee to ship forthwith to the nearest government fish agency at the expense of the government.

(3) That illegal trading in sturgeon be punished by a fine of $100.00 for the first offence on each of the parties concerned, together with the cancellation of the licences, if any, under which either or both parties are conducting their business.
(4) That in certain localities where the sturgeon is one of the principal foods of the Indians, the above provisions be relaxed so as to allow of the Indians taking this fish for their own use in the vicinity of their reservations or habitations, but that under no circumstances shall Indians so privileged be allowed to trade or barter the fish outside of their reservations.
(5) That special attention be paid to restocking the Canadian waters of the Great Lakes and of the Lake of the Woods with sturgeon.
(6) That all trading, trafficking in, or shipping of the roes of the sturgeon or whitefish, or of black caviar composed of or secured from the roes of sturgeon or any other fishes of the Province whatsoever, be prohibited throughout the Province, excepting when such roes or caviar shall have first been secured from a duly authorized Government official and a certificate for the same issued; and that any infringement of this regulation be punishable by a fine of not less than $100.00 on each of the parties concerned, together with a cancellation of the licence, if any, under which either or each of the parties concerned are conducting their business."

The Manitoba Fisheries Commission recommended (62) the prohibition of the export of sturgeon and caviar from the Province.

At the time these Commissions were studying the fisheries, two ideas appear to have dominated thinking about the sturgeon;–

1. It could have been made a permanent fishery of great value; and that
2. Unless some drastic action to protect the sturgeon were taken it would become extinct.

Results of measures taken with special reference to the sturgeon, illuminated by accumulating knowledge of fisheries in general, has shown how ill-founded early measures and proposals were.

In Canada, Prince, (72) Commissioner of Fisheries, reported in 1896 that the methods of protection and restoration adopted by the Department of Marine and Fisheries were;–

1. Close seasons, preventing the capture of spawning fish;
2. Fishing licences, specifying the kind of net, amount, mesh, etc.;
3. Prohibition of obstructions, pollution, etc.;
4. Protection of spawning grounds, spawn, immature fish, etc.
5. Artificial fish culture, as a means of supplementing natural reproduction, and introducing fish into new waters.

Experience has shown that some of these techniques are important while others are of doubtful value.

2. Conservation Techniques.

Efforts to conserve the sturgeon have followed the same pattern as in the case of most other fish and wildlife. Historically, the order in which management measures have usually been taken are:

1. Restrictions on the catch including a size limit;
2. Close seasons;
3. Artificial replenishment;
4. Preservation of the habitat.

The following quotations make it clear that at the time the greatest concern was being expressed over the rapid and drastic decline of sturgeon fisheries, most of the emphasis was placed on restrictive measures.

The United States, Commissioner of Fisheries, in his report for 1890-94 in discussing how the supply of sturgeon in Lake Ontario could be preserved, suggested three measures;– legal restrictions on the capture of immature fish; protection of adults during the spawning season; and artificial propagation. In his 1913 report, (96) he said that what was demanded was a closure for at least ten years. He also suggested the introduction of one of the Russian species.

(a) Licensing. Limiting the number of those permitted to fish sturgeon, through licensing a limited number of fishermen, is one of the devices early adopted in efforts to limit the catch. The first license for the taking of sturgeon in Ontario appears to have been instituted in 1915. Licensing, in itself, is not effective in limiting the catch so long as the catch permitted under license is is not fixed.

If stocks decline in size and fishing techniques become more effective, fewer fishermen can profitably exploit the fishery. The question arises-which of several fishermen should be permitted to retain licences in the interest of economy and efficiency. Economic and sociological, as well as biological, problems are thus involved.

Unless the number of licensees is reduced, the situation is likely to arise where they take the attitude: "What do I care for conserving for the future or for somebody else? I intend to live and get all I can now." This attitude leads to violations of regulations in efforts to make a living where this cannot be done legally by all licensees.

(b) Size Limits. Limiting the size, at which fish may be legally caught, has been one of the devices adopted in efforts to increase the yield of a fishery.

The theory on which the value of permitting fish to grow to a large size before being caught, made two assumptions,–

1. By permitting fish to remain in the water to grow, a greater weight of fish would be available for capture.
2. If fish are caught before they have grown to the size

at which they begin to spawn, reproduction is interfered with.

The first of these assumptions overlooks the possibility that natural mortality may outweigh increase in weight. If one hundred two-pound fish have been reduced through natural death to sixty by the time the fish have reached a weight of three pounds, a loss of twenty pounds has been sustained. In the case of some species, there is good reason for believing that mortalities in excess of the order assumed in the above example actually occur but we have no knowledge of the mortality of sturgeon at different ages and sizes.

So far as weight is concerned, fish should be taken before loss in weight through natural mortality is greater than gain in weight through growth. There is, however, a size below which each species cannot be profitably marketed. To determine the size at which fish should be harvested therefore requires knowledge of at least three factors–growth rate, natural mortality rates and market price at different sizes. For few, if any, species is all this information available.

In 1922, the minimum size of sturgeon was fixed at 42 inches, measured from the point of the nose to the centre of the tail. In 1927, an exception was made in the case of sturgeon in Lake St. Francis and the Ottawa River where the minimum size was fixed at 36 inches. A new method of measuring length applicable to dressed sturgeon was adopted in 1954. See tabulation of fishery regulations under Conservation.

With reference to the second of the assumptions mentioned above, it was long believed that the legal size at which a species might be caught should be fixed so as to permit females to spawn at least once before being subject to capture. One difficulty in administering such a regulation is that the same species reaches sexual maturity at different sizes in different bodies of water, so that a size regulation which permitted a species to spawn at least once in one body of water would not do so in another.

If enough individuals escape capture to produce all the young necessary to replace those removed by natural death, plus fishing, it does not matter at size they are permitted to be caught. The size limit should be that which permits the maximum poundage to be taken in view of the rate of weight increase, the mortality rate and number necessary to produce enough eggs to maintain the population. In the case of the sturgeon, we lack the last two of these pieces of information.

Evidence is now available to suggest that even in fairly heavily fished waters, in which regulations permit the taking of a species before it reaches spawning size, enough escape and reach spawning size to produce all the young necessary to maintain good fishing, provided conditions for the successful spawning, hatching and growth of the species are favourable. Such conditions as temperature, food supply, predators and others do not appear to be favourable every year.

There are still other factors which determine the size at which fish may be most advantageously caught. One is the price at which fish of different sizes sell. If big fish sell for more than small fish, it may pay to leave them in the water even if the total poundage is less at the larger size.

The problem is complicated, in the case of sturgeon, because of the high price at which their eggs sell when made into caviar. The size of fish producing eggs and the weight of eggs produced by fish of different sizes, therefore, have a bearing on the fixing of the weight at which sturgeon may most profitably be caught.

(c) Close Seasons are of two kinds,–

1. Annual close season (a) to limit the catch and/or (b) to protect the fish at spawning time.
2. Closure of the fishery for a period of years.

Reducing the length of the open season will not in itself restrict the catch unless, at the same time, the amount of effort as represented by the extent of gear used or other factors contributing to the number of fish caught in a unit of time are also controlled. The significant factor is the number of fish caught and not the length of time it takes to catch them.

Close seasons, designed to protect fish during the spawning season, are desirable if fishing so disturbs the fish that they desert the spawning grounds and fail to spawn. Otherwise, catching fish at spawning time is no more objectionable than taking them at any other time. So far as number of eggs available for spawning is concerned, it makes no difference whether the female is killed the day before she spawns, a week before she spawns or a month or more before she spawns.

The sturgeon is said to be unusually timid especially at spawning time and to abandon its spawning grounds if disturbed at that time. There is also evidence that, if the eggs are not deposited, they disintegrate. It is therefore possible that a close season at spawning time is desirable in the case of the sturgeon. The fact that the value of the eggs for making caviar adds so greatly to the value of the sturgeon fishery and that fish with eggs suitable for making caviar can be taken much more readily on the spawning grounds, led fishermen to pursue them vigorously at that time.

In 1903, an Order-in-Council passed at Ottawa prohibited fishing for sturgeon during May and June. In 1927, the close season in Ontario waters other than the Great Lakes was changed to June 1st to June 30th. No close season was designated for the Great Lakes and connecting waters. In 1954, the dates of the close season were changed to May 15 to June 14th.

Closure of the sturgeon fishery for a period of years was formerly considered necessary to permit the population to return to something like its original abundance. For instance, the United States Commissioner of Fisheries said in 1914, (96) "What is demanded in every State in which these fishes exist,

or have existed, is absolute prohibition of capture or sale for a long term of years, certainly not less than ten. To advocate any less radical treatment would only be trifling with the situation." It was hoped that such a close season would permit the population to build up to a much higher level, and that some form of management would then enable it to give greater annual yields than those then being realized.

Another form of close season is complete closure every other year, as is now practised in some Wisconsin lakes. This is equivalent to reducing an annual close season to one half. It is doubtful if it has any other value so far as conservation is concerned.

Experience has not fulfilled the expectations on which most of the closures were made. Lake Nipissing, Ontario, was closed for a period of ten years (1908-1917) without any evidence of improvement. The average catch for five years before closure was 144,856 lbs. and, after closure, 88,138 lbs.

A twenty-one year closure of Lake Michigan (1929-1950) had no apparent effect on production. In the three years preceding the closed season, the average annual catch amounted to 2,282 lbs. In 1951-1954, the average was 2,732 lbs. (108)

A ten-year closed period in Manitoba, beginning in 1927, was insufficient to permit the fishery to recover (45). During this period, the fishery was chiefly in the southern part of the Province.

Failure of most fisheries to recover during a close period up to twenty years is probably due to the fact that in some waters it takes a sturgeon that long or longer to reach a size at which it may be legally caught, so that fish hatched at the beginning of such a close season only begin to enter the fishery when it is opened again. There is also the possibility that conditions for successful reproduction have been so interfered with that natural mortality removes most of those hatched before they reach commercial size.

There are suggestions, however, that in some waters, especially those in which reproduction has not been seriously interfered with, closing the fishery for a period of years may be beneficial. On the Nelson River, Manitoba, the catch rose from an average of 10,880 lbs. for the five years immediately preceding closure to an average of 27,200 lbs. after closure from 1948 to 1952. In this area, conditions for spawning are essentially the same as they have always been.

In Michigan, sturgeon were completely protected in all state waters from 1929 to 1950, inclusive. According to Gerald E. Eddy, Director of the Michigan Department of Conservation, "It is apparent that these fish did increase in number. Spawning fish were evident in streams, and commercial fishermen reported that they took small sturgeon in their nets."

(d) Prevention of Overfishing. Many of the devices that have been tried, in efforts to maintain or increase the number of fish available to be harvested, have had as their objective the maintenance of a sufficiently large spawning population to assure that enough young are produced. This objective has usually been described as an attempt to prevent over-fishing.

Comparing a fish population to a stand of trees helps us to realize that, if conditions remain favourable, a few trees or fish will produce enough seeds or eggs to provide all the young that can find living room in a woodlot or body of water. One mature tree usually produces enough seeds to cover a large area, and the number of eggs produced by most fish is so great that, if conditions for hatching and survival are favourable, a few spawners will produce all the young that can find living room.

In the open waters of lakes and the sea, the removal of so many adults as to affect reproduction is not usually to be feared. Under such conditions, fishing usually becomes unprofitable before the population is reduced to the point when not enough eggs are available to produce all the young needed to fill up the habitat if conditions remain favourable.

That this conclusion has the support of authoritative fishery biologists is indicated by the following statement of Beverton and Holt (10) in a book in which they brought together the results of all the studies bearing on the dynamics of exploited fish populations. They wrote, "The general indications from the behaviour of many species are that there is no marked relationship between the abundance of spawners and the number of recruits within the range of population size for which data are available." Because of characteristics peculiar to some species, they are no doubt more susceptible to over-fishing than most.

Although fishing, even in heavily fished waters, may seldom reduce the spawning population below the number needed to produce all the young that can be accommodated, the danger of overfishing cannot be overlooked. It is most likely to occur when a spawning population from an open lake or the sea crowds into a river, as in the case of salmon. Here the population is exposed to destruction in a very restricted area. Although some sturgeon are believed to spawn on beaches, most appear to enter streams where they may be exposed to heavy exploitation at spawning time.

However, so many of the spawning places formerly used by sturgeon have been destroyed by dams, pollution and other conditions detrimental to their reproduction, that even a larger population could probably not spawn to advantage in many of the sites which they formerly used. The maintenance of habitat suitable for a species is therefore the most effective of all conservation measures.

(e) Artificial Replenishment. Belief in the efficacy of planting hatchery-reared young in maintaining or increasing fish stocks was still widely held at the time sturgeon populations had drastically declined. The point of view held in 1892 is reflected in the statement of the U. S. Commissioner of Fisheries, who suggested, (94) "(1) that legal restrictions should be placed on the capture of immature fish, and that adult individuals should be protected during the spawning season; and (2), that artificial propagation should be resorted to." As to the expediency of enacting more fishery laws for Lake Ontario, he agreed there might be considerable difference of opinion, "but in regard to the desirability of carrying out the second suggestion there can be no doubt." For a statement of the place of artificial fish culture in maintaining fish stocks, see Experiments in Artificial Propogation.

(f) Introduction of Exotic Species. One of the methods widely employed for adding to the biological productivity of an area, where environmental changes incident to clearing of the land and industrial development have made it unsuitable for native species, is the introduction of exotics. It was for this reason that brown trout were brought to southern Ontario when streams became warmer and otherwise less suited to the requirements of the native brook trout. However, disastrous results have arisen from the introduction of some of these exotic species, e.g., the carp.

As long ago as 1872, the possible value of introducing the sterlet (Acipenser ruthenus), a Russian freshwater species, was suggested (67). Later it was proposed (96) that, "A possible relief may be afforded through the transplanting in our waters of young sturgeon from other countries. A supply of young fish of a very desirable species inhabiting the Danube River and the Caspian Sea has been kindly offered by the Roumanian Government."

In view of the number of cases in which the introduction of exotic species has had disastrous results, every possible effort should be made to determine the probable consequences of the proposed introduction.

(g) Preservation of Habitat. It is now agreed, by those concerned with the maintenance of fish and wildlife populations, that the most important single factor in conservation is maintenance of conditions necessary for the reproduction, survival and growth of each species. The importance of this factor was, however, seldom mentioned in early discussions of ways to conserve the sturgeon. Most of the emphasis was on overfishing. In Tower's 1909 discussion of The Passing of the Sturgeon, (104) there is not one word about the possible effect of man-made changes in the waters. Neither does Smith, U. S. Commissioner of Fisheries, who discussed the decline of sturgeon fisheries in his 1890 and 1913 reports, (94, 96) mention the possible effect of habitat changes.

Kelly Evans, Ontario Game and Fish Commissioner 1909-1911, recorded (70), that, "Various reasons have been advanced from time to time to account for the decrease in the fisheries, some maintaining that the increased shipping on the waters was largely responsible; and others that it was due mainly to the pollution of spawning beds and feeding grounds, owing to the sewage poured into the lakes, and other deleterious matter carried into them by streams boasting mills and manufactories on their banks." However, he adds, "Doubtless, each of these causes has played its part, but all experts seem now to be agreed that, without question, the main and outstanding reason has been and is overfishing." The role of overfishing and the nature and extent of habitat changes affecting the sturgeon have been discussed above. There can be no doubt that these habitat changes have very seriously reduced the capacity of our waters to produce sturgeon through preventing access to spawning grounds, interfering with hatching of eggs, reducing the abundance of bottom organisms on which sturgeon feed, and in other ways. It is likely that, with the continued growth of industry, our waters will become increasingly unfavourable for sturgeon. Something should be done to reduce pollution, but dams and other changes involved in hydro-electric power development may be permanent unless atomic power makes hydro-electric power obsolete. In the foreseeable future, our sturgeon fisheries are not likely to improve and may decline still further as a result of man-made changes in our waters. This is one of the prices we pay for industrial expansion.

3. Management In Wisconsin

Studies to determine the maximum take of sturgeon which may be permitted, year after year indefinitely, have been under way in a number of lakes in Wisconsin, (74, 89, 90, 112, 113, 114, 115).

The lakes involved form a chain and include Winnebago, the largest inland lake in the State, having an area of 137,708 acres (215 sq. miles). Three other lakes (Poygan, Winneconne and Butte des Morts) have a combined area of 18,761 acres (29 sq. miles). Winnebago is the lowest lake of the series and has a maximum depth of 21 feet. The three smaller, upstream lakes have a maximum depth of 11 feet or less. These lakes appear to be quite productive, as compared with most other waters in which sturgeon occur.

Spearing, the only legal method of fishing, has been carried on for many years in Lake Winnebago, but in the upper lakes has only been permitted since 1952.

Fishing is carried on through the ice in winter, usually in February. Spearing is done in 13 to 16 feet of water from shanties, placed over holes in the ice, over large mud flats which are the feeding grounds of the sturgeon. Decoys are suspended from the hole. They usually resemble small fish, eight to 16 inches in length, painted a variety of colours, but many other objects are used, including oranges, lemons, ears of corn, and tin cans.

Before 1955, estimate of the harvest were based on creel census cards. Because of the poor return of these cards and their questionable accuracy, a registration system was initiated in 1955. Spearers are required to register each sturgeon speared at an official registration station where the length and weight are recorded and a fin bone for age determination taken. The fish is then tagged with a registration tag. In addition, numbers of sturgeon are caught, tagged and returned to the water. From a consideration of the number of these latter sturgeon which are subsequently speared by fishermen, the number of sturgeon in each of the lakes has been estimated, as well as the percentage taken each year. A reward of $10.00 is offered for the return of tags.

The nature of the conclusions drawn from these studies is indicated by the fact that, in 1941, there was a bag limit of five sturgeon per season, but this has been steadily reduced until, at present, the limit is one per season. The minimum size of fish which may be caught has in the same time been raised from 30 to 40 inches, total length, measured to the tip of the upper lobe of the caudal fin. The length of the season has also been reduced. There is now an open season of 19 days every year on Lake Winnebago. On the upper smaller lakes there is a three-day season every other year. Other conclusions based on these studies are as follows:-

The occurrence of considerable numbers of young fish indicates that reproduction is taking place. A six per cent recruitment into the fishery was indicated by age studies of fish registered in 1955 from Lake Winnebago. Recruitment estimates for Lakes Poygan and Winneconne, based on ages of fish registered from these lakes in 1955, 1956 and 1957, averaged 8.1 per cent. The recruitment estimates refer to the number of fish that enter the size-range

of fish harvested each year. The reason the percentage is higher for the upper lakes is because the size–range and age of fish harvested in these lakes is smaller and younger. These recruitment estimates are considered to be somewhat lower than the true figures for the reason that faster growing fish of an age group are harvested before the slower growing fish of the same age group reach legal size.

The number of fish occurring in the lakes has been estimated on the basis of returns of tagged fish. They, therefore, refer only to legal–sized fish, that is, those at least 40 inches long. The number estimated as occurring in Lake Winnebago is given in the following table. The first number is based on the assumption that none of the tags is lost by sturgeon; the number in parentheses is the estimate based on the assumption that 10 per cent of the tags are lost. The first estimate each year is based on fish tagged during the year just prior to that in which they were speared.

1955	20,700 (18,800)
	29,400 (26,500)
1956	12,700 (11,300)
	15,900 (14,400)
1957	12,500 (11,300)
	16,700 (15,000)

The first estimate is probably more accurate because it minimizes the tag loss. The corresponding figures for Lakes Poygan and Winneconne are:-

1955	5,180 (4,603)
1956	3,970 (3,782)
1957	3,750 (3,366)

The percentage of legal-sized fish taken each year has varied widely From 1953 through 1957, from 11 per cent to 14 per cent of the maximum number of tagged fish available each year in Lakes Poygan and Winneconne were caught each spearing season. In 1957, the catch of tagged sturgeon in Lake Winnebago indicated a 7.6 per cent harvest of legal-sized fish.

Tagging studies indicate that the populations of Lake Winnebago, on the one hand, and of the smaller lakes on the other, are as discrete as if the populations were in two land-locked lakes. This means that these bodies of water must be managed on a separate basis.

From 1955 to 1959, inclusive, Lake Winnebago produced a total of 3,652 fish weighing 169,941 lbs., which is an average of a little less than 0.25 lbs. per acre.

Bag limits, size limits and establishment of refuge areas are not effective in significantly reducing the harvest. The length of the season is the most effective method. It is considered that size limits would be effective if they were practicable. Because of the difficulty of estimating the size of fish under water by sight, spearers reportedly spear fish less than the legal length of 40 inches. These are assumed to be returned; many probably do not survive the spear wounds It is believed that 40 inches is somewhat shorter than would be ideal for a sustained yield, management harvest.

4. Conclusion

For reasons already discussed (see Causes of Low Productivity), the sturgeon will give only a relatively small sustained yield. We still do not have information adequate to enable us to decide whether, under different management policies, higher continuous yields than those now being realized could be attained. There is reason to doubt, however, whether much, if any, larger sustained yields are possible than those now being secured in waters where conditions are still essentially primitive. Where natural conditions favourable to the sturgeon have been seriously interfered with, only very low yields can be expected.

TABLE VIII.

MINIMUM SIZE, CLOSE AND OPEN SEASON, LEGAL FISHING METHODS AND NUMBER OF STURGEON THAT MAY BE CAUGHT IN DIFFERENT AREAS.

Area	Minimum Total Length or Weight	Season	Legal Fishing Methods	Number Permitted to be Caught
ONTARIO - Great Lakes and connecting waters.	42"[1]	No closed season	)))Pound nets;)Trap nets;	))))
Lake St. Francis and Ottawa River	36"[2]	Closed: May 15 to June 14.	)Gill-nets;)Set lines)	)No limit))
Elsewhere	42"[1]	Closed: May 15 to June 14.	)	)
Areas as above	None	Season as above	Angling by rod, hook and line	1 per day
QUEBEC - Lake Abitibi District	36"	No closed season	)))Hoop nets;	
St. Lawrence River	28"	Closed: May 15 to June 14.	)Gill-nets)Weirs;)Night lines.	No limit
Elsewhere	36"	Closed: May 15 to June 14.	))	
MANITOBA - Lake Winnipeg	18 lbs. round weight	Open: June 1 to Aug. 8	12" gill-nets	No limit
An area on Churchill River	"	Open: June 10 to August 8	"	Quota of 10,000 lbs.
Elsewhere	"	Open: June 10 to August 8	"	Quota of 25,000 lbs. in each of 8 areas
Throughout Manitoba	None	Open: June 15 to March 31.	Angling	1 per day

1. 25" measured from the most posterior limit of the gill opening to the point where the posterior edge of the dorsal fin joins the flesh of the body, or 23" measured from the mid-lateral point of the anterior cut edge of the skin to a point where the posterior edge of the dorsal fin joins the flesh of the body.

2. 23" or 21" measured as under 1.

Area	Minimum Total Length or Weight	Season	Legal Fishing Methods	Number Permitted to be Caught
SASKATCHEWAN - Cumberland House area Saskatchewan River drainage and Sandy Bay area of Churchill River system	40"	June 5 - Sept. 30	12" mesh gill-nets	Quota of 22,000 lbs.
Throughout Province	None	First Saturday in May to March 31.	Angling	1 per day; bag limit 2.
ALBERTA Total prohibition of taking sturgeon has been in effect for fifteen years.		No open season	None	None
MINNESOTA - St. Croix River and its tributaries	30"	Closed: Nov. 1 to April 30	Angling	1 per day
Minnesota-Canada boundary waters	None	Closed: June 1 to June 30.		
Elsewhere in inland waters and in Lake Superior		No open season		
WISCONSIN - Lake Winnebago	40"	Open only 19 days in February.	Spearing	1 per season
Upper lakes of Fox and Wolf River system	40"	Open only 3 days in February every other year	Spearing	1 per season
Other inland waters and in lakes Michigan and Superior	40"	Sept. 5-Oct. 15.	Hook and line.	1 per season
Wisconsin-Michigan boundary waters	30"	Sept. 5-Oct. 15.	Hook and line	2 per season
Wisconsin-Iowa boundary waters		No open season.		
Wisconsin-Minnesota boundary waters.	30"	April 30 - Oct. 31	Hook and line.	1 per day

Area	Minimum Total Length or Weight	Season	Legal Fishing Methods	Number Permitted to be Caught
MICHIGAN Inland Waters	42"	Open February	Hook and line; spearing in certain waters	)))))Except in)commercial
Great Lakes and connecting waters	42"	No closed season.	Pound nets; trap nets; gill-nets; set hook lines, baited or unbaited; hook and line.	)fishing,)creel)limit is)2 per.)season.)))))
Lake St. Clair and St. Marys, St. Clair and Detroit Rivers	42"	Through the ice.	Spearing; bow and arrow.	))))
OHIO	None	No closed season	Angling	No limit
PENNSYLVANIA	48"	No closed season	Pound nets Trap nets Gill-nets Set lines Hook and line angling.	No limit
NEW YORK	42"	No closed season	Licensed nets not less than 10" mesh, licensed bait or traplines, angling.	No limit
VERMONT	None	Closed: July 16 to April 14.	Gill-nets (mesh not less than 11" stretched), angling.	No limit

I. STURGEONS OF THE WORLD

The most recent list of the sturgeons of the world (60) contains 25 species. Of these, 18 belong to the same genus (Acipenser) as our lake sturgeon; two are in the genus (Huso) to which the largest of all sturgeons belongs; two are shovelnose sturgeons (scaphirhynchus); and three are Pseudoscaphirhynchus.

The list is as follows:

1. *Acipenser*

A. baeri Brandt. Siberian Sturgeon

a freshwater species, sometimes semi-migratory; found in river Lena, Kolyma, Ob, Taz and lakes Baikal and Zaisan. A hybrid A. baeri X A. ruthenus is said to frequent all the Siberian rivers tributary to the Arctic Ocean particularly in the Yenisey.

A. brevirostrum Le Sueur. Shortnose Sturgeon

Anadromous; east coast of North America from the Gulf of Maine to Florida?

A. fulvescens Rafinesque. Lake Sturgeon

Freshwaters of North America including Mississippi, Great Lakes including St. Lawrence and Hudson Bay drainage basins.

A. guldenstaedti Brandt.

Anadromous; found in the Black Sea, Sea of Azov and Caspian Sea; entering the principal rivers which flow into them including Danube, Dnieper, Don, Volga and Kuro.

A. medirostris Ayres. Green Sturgeon

Migratory; entering rivers on the west coast of North America from San Francisco northward; also in the rivers of China and Japan.

A. nacarii Bonaparte

Rare in the high Adriatic.

A. nudiventris Lovetzky

Migratory; the only sturgeon found in the Aral Sea; rare in the Black Sea and Sea of Azov from which it enters the Danube and Don; from the Caspian Sea a few ascend the Volga, more abundantly the Oura, Kura and other southern rivers.

A. oxyrhynchus Mitchill. Atlantic Sturgeon

Anadromous; east coast of North America from Labrador to the Gulf of Mexico.

A. primigenius Chalicov.

Caspian Sea, ascending the Volga river.

A. ruthenus Linnaeus. Sterlet

Freshwater, but enters brackish water in the northern part of the Caspian Sea; rivers of Siberia including Ob, Yenisey and Lena; rivers tributary to the Black Sea and Sea of Azov including Danube, Dnieper, Don and Volga tributary to the Caspian Sea; said to occur in Gulf of Quarnero.

A. shrenki Brandt. Amur Sturgeon

Fresh and brackish water; basin of the Amur; also in Sea of Okhotsk.

A. sinensis Gray.

In the basins of the Yang-tse-kiang, Min and Liao-ho in north-eastern China.

A. dabryanus Dumeril.
Rare; only in the Yang-tse-kiang river of China.

A. micadoi Hilgendorf.
Rare; Japan.

A. kikuchii Jordan and Snyder.
Rare; Japan.

A. stellatus Pallas
Rivers of the Black Sea and Sea of Azov, Danube, Kouban, Dnieper, Dniester; also enters rivers of the Caspian, Volga, Ural, Kura, Kama; rare in The Adriatic and Italian waters of the Mediterranean.

A. sturio Linnaeus. Atlantic Sturgeon.
Migratory; coasts of Europe including North Sea, Black Sea, Baltic; rare in Mediterranean and Adriatic; entering rivers.

A. transmontanus Richardson. White Sturgeon.
Migratory; Pacific coast of North America; entering rivers.

2. *Huso*

H. buso Linnaeus. Beluga
Migratory; Black and Caspian seas; entering Danube, Dnieper, Volga, Ural and Kura; rare in Adriatic.

H. dauricus Georgi. Kaluga.
Freshwater, semi-migratory; Amur basin.

3. *Scaphirhynchus*

S. albus (Forbes and Richardson) Pallid Sturgeon.
Freshwater; rare; Mississippi and Missouri rivers.

S. platorhynchus (Rafinesque) Shovelnose Sturgeon
Freshwater; Mississippi Valley.

4. *Pseudoscaphirhynchus*

P. kaufmann Bogdanov
In the basin of the Aral Sea.

P. kermanni Kessler
In the basin of the Aral Sea.

P. fedtschenkoi Kessler
In the basin of the Aral Sea.

II DETAILED DISTRIBUTION OF THE LAKE STURGEON.

- 1 -

In Ontario, sturgeon were found in every part of the Province, including all of the Great Lakes and their connecting waters and virtually all of the larger, interior lakes and rivers. Among Ontario waters, other than the Great Lakes and their connecting waters in which sturgeon have been fished commercially, are the St. Lawrence River; Lakes Simcoe(63) and Couchiching and the Holland and Severn rivers (now probably extinct in these waters); Lake Nipissing and the French River; the Ottawa River and its lake-like expansions; and such tributary waters as the Mattawa River, Mississippi River and Lake, Calabogie Lake on the Madawaska River (42), Lake Scugog, Rice Lake and Trent River, Lake Timiskaming, Abitibi Lake and River, Lake Nipigon, Lake of the Woods, and such tributary waters as Rainy River and Rainy Lake. Lakes and rivers in northwestern Ontario which have been fished commercially include 19 lakes and two rivers in Kenora District, 24 lakes and 11 rivers in Patricia District, and 14 lakes and four rivers in Thunder Bay District. The lower reaches of all the larger rivers flowing into Hudson and James Bays contain sturgeon which migrate between the rivers and the brackish waters of the bays. These include the Moose, Albany and Attawapiskat (58,66).

In Quebec, sturgeon fisheries occur on the lake-like expansions of the St. Lawrence (St. Francis, St. Louis, St. Peter) and in the river, itself, until salinities too high for sturgeon are met at St. Roch des Aulnaies, about 70 miles below Quebec City, (105). Rivers tributary to the St. Lawrence most frequented are those on the south shore–Richelieu, St. Francis and Nicolet. They are not in Lake St. John nor the Saguenay River, (105). Boundary waters between Ontario and Quebec in which sturgeon occur are the Ottawa River, Lake Timiskaming and Lake Abitibi. Quebec rivers, flowing into Hudson and James bays containing sturgeon, include the Nottaway (and lakes Mattagami and Olga near its head), Rupert (and its expansion Lake Nemiskan), Eastmain, Fort George (Big), and Harricanaw, (57,66,84).

In Manitoba, the sturgeon occurs in the waters draining into Hudson Bay as far north as the Seal River, north of the Churchill (51). In Lake Winnipeg, (45) it was in all the large rivers which enter the lake from the east but "practically absent from western portions and also from Lakes Manitoba and Winnipegosis. Its occurrence during the spring season in the Red and Assiniboine rivers was common at the beginning of the century and is not unknown at the present as, occasionally in spring or early summer, sturgeon are taken in the Red River below Lockport." "Still taken on the Assiniboine River as far west as Brandon." (51) Occurrence upstream, in the Red River in Minnesota, included in references for that state. The Nelson River, through which the waters of the Saskatchewan River, the Red River, Lake Winnipeg and Lake of the Woods enter Hudson Bay, has been fished intermittently since 1907. Peak productions of nearly 150,000 lbs. were attained in 1917 and 1924, (100).

In Saskatchewan, according to F.M. Atton of the Fisheries Branch, Saskatchewan Department of Natural Resources, the sturgeon is found in the Churchill River to Trade Lake, about 70 miles west of the Manitoba–Saskatchewan boundary.

Alberta. In the North Saskatchewan, according to R.B. Miller, the sturgeon formerly spawned in creeks, entering the river near Edmonton. The Edmonton Journal, June 23, 1923, reported a 75-lb. specimen, caught in the Saskatchewan River at Edmonton.

Mr. Atton has informed us that sturgeon occur in the South Saskatchewan River at the mouth of the Red Deer River. The sturgeon is not known to occur in the Athabasca drainage area.

South Dakota. Evermann and Cox (31) in reporting on the occurrence of the sturgeon in the Missouri River basin, wrote "not seen by us, but Mr. Walker informs us that sturgeon are often taken in White and Missouri Rivers near Chamberlain in the spring, and we have learned from others that this species is of considerable importance as a food fish in this portion of the Missouri River. In the vicinity of Yankton, considerable numbers were formerly caught, but the fish is less abundant during the last few years."

Nebraska. In a letter to Harkness from R.P. Miller Sept. 28, 1942, knowledge of the distribution of Acipenser fulvescens in Nebraska is said to be based on two records contained in an unpublished Ph.D. thesis of Raymond E. Johnson entitled, "The Distribution of Nebraska Fishes". One record was made at the mouth of the Platte River, June, 1940; the other, an adult female, weighing 64 lbs., 5 ft. 6 in. long, from the Elkhorn River, near Elk City, Douglas County, June, 1940.

In Minnesota, the sturgeon has been recorded (29) from all three drainage systems—Hudson Bay, Great Lakes and Mississippi. Sturgeon "formerly occurred in some abundance in the upper Mississippi River but are now becoming scarcer each year." According to Surber in a memo sent to Harkness, "Evidently, it occurred in greatest numbers in the Hudson Bay drainage system. It is reported to have occurred in nearly all the larger lakes drained by the Ottertail and Red Lake River tributaries of the Red River of the North, and is still found in Red Lake . . . . . From Lake of the Woods, it spread up Rainy River and all its tributaries, particularly up the Big Fork River as far as Bow String Lake, Itasca County, from which point it may have gained access to the upper Mississippi, even within the past 100 years. Up the Little Fork River, it penetrated to within a mile or two of the St. Louis system at Sturgeon and Duvey Lakes, just north of Hibbing. At the present time, it is probably most common in Pokegama Lake, Pine County, and in the Snake and Kettle tributaries of the St. Croix River."

In Wisconsin, apart from its occurrence in the Mississippi River, including its expansion, Lake Pepin, and Lakes Superior and Michigan, the sturgeon is largely confined to the Fox River basin, including Lakes Winnebago, Winneconne, Butte des Morts and Poygan, (40). In a letter dated September 10, 1942, Dr. Lloyd Smith reported that a 140–pound sturgeon had recently been taken in Red Lakes, Wisconsin.

Iowa. Available evidence indicates that the lake sturgeon is rare in Iowa, and probably always has been. Meek, (65) in a report on the fishes of the Cedar River basin, said that the lake sturgeon "no doubt inhabits the lower part of the Cedar River, as specimens have been frequently taken from the Iowa River at Iowa City." "The few, remaining lake sturgeon (in Iowa) are

largely confined to the Mississippi River where it is taken only rarely in commercial operations" (44).

In a letter to Harkness, September 18th, 1942, Reeve M. Bailey said the species "may be assumed rare all along the Iowa portion of the Mississippi . . . I have never heard of the lake sturgeon in the inland waters of Iowa . . . . . nor do I know of its occurrence in the Missouri River, along the western border of the State, though it may live there in small numbers." He referred to isolated specimens taken five miles above Lansing in the northeast corner of the State and at Keokuk at the southeast corner.

Similar evidence has been afforded by W.W. Aitken of the Iowa State Conservation Commission, who wrote, "I have spent many years on the Missouri River and have made many collections along the entire course of the stream that touches Iowa, and I have never seen nor have I ever heard of commercial fishermen catching one of these fish."

He also wrote, "I have also had considerable experience on the Mississippi River the past sixteen years, and I have never seen this fish in either these waters or any of the tributaries of the "Big" River. I have talked to many of the commercial fishermen of eastern Iowa, and they tell me of early abundance, which may have been few or many. However, fulvescens occurs occasionally in the commercial catch between Dubuque and the Minnesota State line on the Iowa side."

Illinois. David H. Thompson, in a letter to Harkness, September 5th, 1942, reported that in twenty years of almost continual fishing by the State Natural History Survey in Illinois waters, the lake sturgeon had not been taken except in the Rock River between Rockford and the mouth, and in the Kaukakee River between Momence, Illinois, and the mouth. It was also, he said, occasionally taken along the borders of Illinois in the Mississippi, Ohio and Wabash Rivers. It apparently disappeared completely from the Illinois River about 1900.

As to its occurrence in the Mississippi along the western border of Illinois, Barnickol and Starrett (7) while collecting between Caruthersville, Missouri, and Dubuque, Iowa, took only one specimen, weighing 32 lbs. at New Boston, Illinois. They reported that it was taken in that area only occasionally by commercial fishermen.

Forbes and Richardson (33) said that the sturgeon had been formerly abundant throughout the Mississippi Valley, but had been "steadily decreasing of late years and now rarely taken in the Mississippi in our own borders . . . . . seldom caught in the Illinois."

Indiana. Besides its occurrence in Lake Michigan, the lake sturgeon occurs or has occurred in the Ohio and Wabash rivers, (36) and White River, —W.E. Ricker letter.

Ohio. Trautman, (103) reviewing the past and present distribution of sturgeon in Ohio, refers to "the former presence of this sturgeon in Lake Erie, in the Ohio River upstream as far as western Pennsylvania, and in the larger inland rivers of Ohio." However, the only inland rivers in which any significant

number of records are indicated on a distributional map is the Maumee River, flowing into Lake Erie, and the Scioto River, a tributary of the Ohio. Almost all the other records appear to be for Lake Erie or the Ohio River.

New York. Lake sturgeon in New York waters are limited to Lake Ontario, Lake Champlain, the St. Lawrence River and the lower parts of some of the larger rivers tributary to Lake Ontario and the St. Lawrence (38). In Lake Champlain, they appear always to have been much more numerous on the Vermont side.

"A large specimen in the museum of Cornell University is reported as being from Cayuga Lake. Seth Green informed Dr. Meek that sturgeons had occasionally been taken in that lake; but, so far as he knew, they had never been found in any other of the small lakes of central New York. No record of sturgeon from Cayuga Lake since 1880, but quite a number before that date"(9).

Vermont. Once, the sturgeon was sufficiently abundant in Lake Champlain so that it was chosen in 1900 as the site for efforts to develop means for artificial propagation. Good spawning migrations were found in two tributary streams, the Missisquoi and Lamoille Rivers. There was also a run to the Winooski River, (18,98,99).

In a letter dated Sept. 9th, 1942, Geo. W. Davis, Director, Vermont Department of Conservation and Development, stated that sturgeon were taken in both Otter Creek and Winooski River, both tributary to Lake Champlain. None is known in Vermont, east or south of the Lake Champlain drainage.

Pennsylvania. Recorded as Acipenser maculosus from the Ohio River as far as Pittsburgh (76).

West Virginia. Trautman (letter) has reported a speciman seen by Frank Allen at Bridgeport, Ohio, opposite Wheeling, West Virginia.

In Kentucky, reported from the Ohio River near Louisville; Cumberland River near Kuttawa; and from the Tennessee River, near Paducah (30).

Missouri. Mississippi River, near St. Louis, a single specimen by (Geo) Harry, R.R. Miller, letter, 1943. Recorded from the Osage River, a tributary of the Missouri, under the name Acipenser (Huso) Rauchii (26).

Kansas. Kansas River at Lawrence, Kansas (31).

Arkansas. Joe Hogan, Superintendent of Fisheries, Arkansas, in a letter, dated Sept. 29th, 1942, reports Acipenser fulvescens in the St. Francis River as far north as Parkin, in White River as far north as Clarenden, and on the Quachita River, probably a few miles north of the Louisiana line.

Tennessee. The letter from C. Tarzwell to Harkness, quoted under Mississippi and Alabama, indicates the occurrence of the lake sturgeon in Tennessee.

Mississippi. "In the Tennessee River, at least from Pickwick Reservoir or the Alabama-Tennessee state line up to Chickamauga Reservoir, or to the mouth of the Hiwassee River." Letter from C. Tarzwell, Sept. 15th, 1942.

Alabama. In addition to the information in the above paragraph, Dr. Tarzwell reported that, "It probably occurs throughout the Tennessee River."

Recorded from the Tennessee River, near Huntsville, Alabama, (30).

If sturgeon ever occur in the waters of Louisiana, the specimens are probably strays from farther north.

III A HISTORY OF ARTIFICIAL STURGEON CULTURE IN THE UNITED STATES

The importance placed on the discovery of ways to propagate sturgeon artificially in the United States is indicated by a statement made in 1900 by W. de C. Ravenel, who was in charge of the propagation and distribution of food fishes for the U.S. Fish Commission (98). He said: "There is no subject in fish culture, excepting the lobster, that we have given more time and thought to in the last few years. The sturgeon fisheries, from being very important on the Atlantic Coast and Great Lakes, have dwindled to practically nothing-------- As far as hatching the eggs of the sturgeon is concerned, we need not worry about that. We can hatch the eggs of any fish just as we hatch the eggs of the grayling or trout in jars and on trays. If we can find a place where sturgeon spawn, we will guarantee next year to go there and propagate them. We are prepared to do more for the sturgeon than anything else except the lobster."

The first efforts to propagate sturgeon artificially in America were made in 1875 on the Hudson River when Seth Green successfully hatched four pans of eggs of the marine sturgeon (A. oxyrhynchus) (39). The fish were obtained from commercial fishermen, and the eggs and milt obtained by opening the body cavity of the fish and removing the ovaries and testes. The hatching-boxes, used in most attempts to rear sturgeon artificially, had been devised by Green in 1867 for hatching shad.

The U.S. Fish Commission did not undertake work on the artificial propagation of sturgeon until 1888. Hatchery operations were not contemplated when the Commission was established, but were instituted in 1872 at the instigation of the American Fish Cultural Association, the forerunner of the American Fisheries Society. The species to which attention was first given were the shad, the Atlantic salmon and the whitefish. At that time, the belief in the value of artificial propagation was so strong that hatchery operations were rapidly expanded until they soon overshadowed all other branches of the work of the Commission (95).

In 1888, experiments were carried out for the U.S. Fish Commission by Dr. J. A. Ryder, Professor of Biology of the University of Pennsylvania, on the Delaware River, again using the marine sturgeon. He reported on the results of his work, in part, as follows: (88), "The results were to some extent unsatisfactory, owing to the difficulty of obtaining an abundance of living ova and the difficulties attending their fertilization by artificial means, as well as rearing the embryos--------The only ova which I succeeded in fertilizing were obtained from females of the common sturgeon by cutting open the abdomen of the still-living fish. Forcing out the ova by pressure, as practised with the shad and salmon, is not feasible in the case of the sturgeon, and the removal of the ripe ova from the abdominal cavity of the parent fish may be far more expeditiously effected by slitting open the body cavity. The milt is most readily obtained in a similar way from the recently captured and living ripe males."

Another difficulty encountered by Ryder, which was to plague all future attempts at the artificial propagation of sturgeon, was the scarcity of ripe females among those taking part in the migration at spawning time. Even

among the small number found to be ripe, the eggs found loose in the abdominal cavity were worthless for purposes of fertilization.

In spite of the difficulties encountered, Dr. Ryder was optimistic over the future of propagating sturgeon artificially. He wrote; "The success which followed the usual methods of fertilization proves conclusively that vast numbers of embryos could be hatched annually from eggs thus obtained and treated. The number of millions which could be reared in this way would depend entirely upon the number of trained spawn takers promptly on duty when spawning fish are taken by the fishermen, and the extent of the facilities for hatching them and protecting them against the attacks of Achlya and Saprolegnia, forms of fungus which were found to be most seriously destructive to the life of the ova of the sturgeon."

A second attempt at artificial propagation on the Delaware River was made by Dr. Bashford, Dean of Columbia College, in 1893 (24). Contradictory accounts have been given of Dean's efforts. According to Rathbun, (77), abundance of ripe sturgeon of both sexes were secured. No difficulties were encountered in fertilizing the eggs and in holding them in good condition until they hatched. "With proper facilities, Dr. Dean is confident that he could have produced enough fry to have made his work exceedingly profitable from a practical standpoint." On the other hand, Leach (55) says, "The same drawbacks—viz., difficulty in finding ripe eggs and milt at the same time, imperfect aeration of the eggs during the incubation period, and the unusual tendency of the eggs to develop fungus" were encountered by Dean.

An account of subsequent work on the Delaware River has been given by Meehan (64), Commissioner of Fisheries for Pennsylvania, as follows: "A few years ago--------New Jersey and Pennsylvania--------set up a co-operative plan for work on propagation of the sturgeon of the Delaware River. The U.S. Government, assigned L. Stone to assist. Experienced sturgeon fishermen were engaged to assist in taking the sturgeon and handling them."

The first season's work, extending over several weeks, was an utter failure. About two dozen, large fish were secured, of both sexes. Some were spent; some had hard eggs or milt. Three of four ripe females were captured, but at no time were ripe specimens of both sexes caught near enough together to allow the eggs to be fertilized.

Next year, both states made another effort, but with no better success. Later, Pennsylvania tried again alone but without avail. At no time, could ripe males and females be obtained at the same time.

The first recorded attempt to propagate lake sturgeon artificially was made in the Detroit River area. Whether accounts, referred to below, concern the same or two different attempts is uncertain.

The President of the American Fisheries Society, speaking at a meeting of the Society, said in the discussion of a paper by Carter (18) that one of the Fish Commission's superintendents had been foreman at their Alpena station from 1883 to 1887, and some experiments with sturgeon were made on the Detroit River during that time. They did not succeed in catching any sturgeon that were full of eggs, but got some that had partially spawned out, and got a

few of their eggs. There was no difficulty whatever in getting a good impregnation—about 90 per cent. He had no information on hatching, but presumably the estimate of impregnation was based on the percentage that hatched.

According to Post, (71) an attempt to fertilize and hatch sturgeon eggs was made in 1889 at Algonac, Mich., on the St. Clair River, by Mr. Aaron W. Marks. This site was chosen because a caviar factory, to which sturgeon were brought, was located there. From early June until June 27, although 4,000 sturgeon were handled, only six spent fish and two ripe females were taken. One of these two, a half-spent female, was placed across a tub, slit open and the eggs allowed to fall into the tub, milt was obtained by opening a a ripe male. About 20,000 eggs were successfully fertilized. Of these, 8,000 to 10,000 hatched in a dozen Seth Green shad-hatching boxes anchored in the river current. All were released into the river, 12 days after the eggs were taken.

Another attempt to propagate sturgeon on the Detroit River was made by the U.S. Fish Commission in 1890. Frank N. Chapman, Superintendent of the Commission's Northville (Mich.) station, was in charge. Although 142 females and 32 males were examined between May 26th, and June 14th, only five females and nine males were found to be in spawning condition. Of 20,000 eggs fertilized, 95 per cent developed to the eyed stage. Shortly afterwards, fungus developed and few hatched (55).

Much better authenticated is the work of the Michigan Fish Commission. Mr. Dwight Lydell, who was in charge of their work, described it in a letter to Harkness dated Nov. 19th, 1923. A ripe male and female were caught on a set line, placed across the stream with numerous hooks dangling below. To secure the eggs, the female was laid over a large tub and opened from vent to throat. The male was also opened at the same time. After sperm derived from mashed testes had been spread over the eggs, they were thoroughly mixed, and a little water added. To keep them from sticking together they were stirred occasionally. More water was added from time to time until the eggs were thoroughly hardened, which required about an hour and a half. They were then placed in floating boxes in the current. About 75 per cent of the eggs hatched on the third day. More work was done, both in 1893 and in 1894, the total number of young sturgeon hatched and planted being 580,000. These were the only successful efforts of the Michigan Conservation Commission to propagate sturgeon artificially (68,110).

About this same time, the Ohio Game and Fish Commission attempted to propagate sturgeon artificially. This work appears to have been under the the direction of William Lanz, Superintendent of Hatcheries. The report of the Commission for 1891 reports that "On May 31st, with the assistance of Mr. Samuel Currie, we got some 6,000,000 sturgeon eggs and hatched them in boxes in open water about the islands at the mouth of the Detroit River--------succeeded in hatching about 5,000,000. Some, we planted at the mouth of the river at various places, and the remainder, about the islands of Put-in-Bay. The eggs placed in the Sandusky hatchery proved to be a failure."

In 1898, the United States Government seriously considered establishing a sturgeon hatchery on either Lake Erie or Lake Ontario, but were discouraged by failure to find a location where spawning females and ripe males were

sufficiently plentiful to support such operations. In this year, Brice published and outline of methods used collecting, fertilizing and hatching the eggs.

The record of attempts at artificial propagation suggests frantic rushing about, trying to find a place where sturgeon were abundant enough to support such an operation.

In 1900, the U.S. Fish Commission moved the locale of its work to Lake Champlain where good spawning migrations were found in two tributary streams, the Missisquoi and Lamoille Rivers. Livingstone Stone, (98) who was in charge of the work, succeeded in taking and impregnating a few eggs, from which fry were hatched. Efforts to ripen green sturgeon by holding them in artificial enclosures proved utterly futile (55).

The next year, the work was continued at Lake Champlain (99,78) and again a few thousand eggs were fertilized. Some, taken to the Swanton Hatchery, were successfully hatched, but those retained locally were killed when the temperature fell to 45°F. The eggs appear to have been secured by catching them as they ran from a female as she was lifted from the water. A picture of the primitive nature of this early work is given by Mr. Stone in describing efforts to prevent the loss of eggs from ripe females as they were removed from the water. He says "the men stopped the flow of eggs by stuffing their handkerchiefs into the vent. The fish were then towed across the river where the males had been secured and were instantly killed by being knocked on the head."

After a lapse of three years, the work was taken up again at Lake Champlain in 1904 (18). Although 1,500,000 eggs were secured and fertilized this year, they all died when fungus developed on them.

Still another attempt was undertaken in the Lake of the Woods region which had been one of the most productive areas for sturgeon. In 1911, Thaddeus Surber who was then at the Fairport Iowa Biological Station, constructed an enclosure in Rainy River in which he wintered a number of adult sturgeon, five to six feet long. Although other specimens, caught in the spring of 1912, were added, none matured and, in the following October, all were released without having produced any eggs. Another trial was made in the following year with the same result (29,55).

It has been found impossible to secure much information about some investigations conducted at Put-in-Bay during 1903 and 1904. In a letter dated June 26th, 1942, to Harkness, Dr. Elmer Higgins, at that time Chief of the Division of Fishery Biology of the U.S. Fish and Wildlife Service, stated: "These studies were conducted principally by members of the faculty of the University of Michigan who were working on a cooperative basis with the old U.S. Fish Commission." Those concerned were Dr. Jacob Reighard, Dr. Raymond Pearl and Dr. H.S. Jennings. Efforts to locate their records were unsuccessful.

So far as the published record is concerned, 1912 appears to have been the last year in which active steps were taken the United States to develop techniques for the artificial propagation of sturgeon.

IV DEVELOPMENT OF THE LAKE STURGEON EGG AND FRY

The following observations on the gross anatomical changes during the development of the sturgeon egg and fry were made in connection with the attempt by Harkness to develop methods for the artificial propagation of the species as described in Chapter X.

The eggs are demersal. Having a smooth, adhesive membrane, they adhere to sticks and stones on the bottom, or to debris floating in the water.

The eggs are deposited singly or, at least, not in chains or clumps, although, owing to the adhesive nature of the membrane, there is a tendency for them to form clumps after emission unless well distributed by water currents.

Since development occurred under temperature conditions obtaining in the stream and not under controlled laboratory conditions, time alone does not provide an adequate measure of conditions affecting the rate of development. Approximation to a more satisfactory measure was sought in thermal units suggested by Wallich (109). This unit is one degree Fahrenheit above 32°F for a period of 24 hours. Accumulated thermal units for the various stages described below are given in Table IX.

Although several series of sections of eggs at different stages of development were made, no detailed study of histological development was undertaken. Such sections were used in more accurate interpretation of gross features, and served as the basis for some of the general statements on development.

Measurements of size of eggs and of fry were made by means of a microscope with a hair line in the eyepiece and a vernier scale on a travelling eye stage.

Unfertilized eggs, which are spherical and averaged 3.3 mm in diameter (3.1 to 3.4), may be divided into three regions: germinal disc (blastodisc) which is the darker area, lenticular in shape, at one side of the main body of the egg; the main body which is yolk; and the transparent egg membrane. The average diameter of the germinal disc was 0.7 mm (0.4 to 1.0). The average diameter of the body of the egg including the germinal disc was 2.5 mm (2.3 to 2.6).

Four hours after fertilization, all eggs had undergone the first stage of cell division and were at the two-cell stage. The diameter of the egg had changed in that the diameter across the two cells was greater than that along the line of division. The former diameter was 3.5 mm; that of the latter, 3.2mm.

At this stage, the egg floated with the germinal disc uppermost. It was dark but surrounded by a lighter border. Below it was brownish.

After 20 hrs. (21.8 thermal units), rapid division was taking place at the animal pole, which consisted of a large number of cells from 0.1 to 0.2 mm. across, while division was much slower at the vegetal pole where there was a small number of larger, ill-defined cells, 0.6 to 1.0 mm. across. A small blastocoele was evident.

TABLE IX

TEMPERATURES (CENTIGRADE) OF THE WATER IN WHICH EGGS AND FRY DEVELOPED AND ACCUMULATED THERMAL UNITS.

The eggs were fertilized at 4:15 p.m., June 12, 1924.

Date	Time	Temperature	Accumulated Thermal Units
June 12	8.15 p.m.	14.25	4.4
13	12 noon	14.5	21.8
13	8 p.m.	15.0	30.8
14	8 a.m.	15.0	44.3
14	7 p.m.	15.0	56.7
15	9 a.m.	15.0	72.4
15	8 p.m.	15.7	85.4
16	8 a.m.	15.5	99.4
16	8 p.m.	15.8	113.6
17	8 a.m.	15.3	127.4
17	8 p.m.	16.0	141.8
18	8 a.m.	15.6	155.9
18	4 p.m.	15.8	165.4
19	4 p.m.	15.2	192.8
20	4 p.m.	15.3	220.4
21	11 a.m.	16.1	243.4
21	3 p.m.	18.0	248.8
22	4 p.m.	18.0	282.5
23	4 p.m.	17.8	314.5
24	4 p.m.	17.8	346.5
25	4 p.m.	17.8	378.5
26	4 p.m.	17.7	410.4
27	4 p.m.	16.6	440.3
28	4 p.m.	16.1	469.3
29	4 p.m.	16.1	498.3
30	4 p.m.	15.8	526.7
July 1	4 p.m.	15.2	554.1
2	4 p.m.	16.1	583.1
4	4 p.m.	19.0	651.5
6	4 p.m.	20.0	723.5
8	4 p.m.	21.5	800.9
10	4 p.m.	20.6	874.9
12	4 p.m.	21.0	950.5
13	4 p.m.	20.0	986.5
14	4 p.m.	20.0	1022.5
15	4 p.m.	19.3	1057.2
16	4 p.m.	19.0	1091.4
17	4 p.m.	17.5	1122.9
18	4 p.m.	16.0	1151.7
19	4 p.m.	17.2	1182.7
20	4 p.m.	17.5	1214.2

After 28 hrs. (30.8 t.u.), the eggs were in an early gastrulation stage. The more numerous cells of the animal pole were from 0.038 to 0.057 mm. across; the fewer cells of the vegetal pole larger, 0.133 to 0.570 mm. across.

After 40 hrs. (44.3 t.u.), a yolk plug, 1.28 to 1.36 mm. across had appeared.

After 51 hrs. (56.7 t.u.), there was considerable variation in the stage of development reached by different eggs in the same hatchery baskets. The plate was broad and thick.

After 76 hrs. (85.4 t.u.), the embryo, 6.7 mm. long, was apparent, tightly coiled around the yolk. The head and tail were becoming separated from the yolk. There was a considerable amount of pigment on the surface of the body and over the adjacent surfaces of the egg. The neural groove was distinct. The egg membrane was quite tough and adhered closely to the egg; when pierced by a sharp needle the embryo and yolk popped out.

After 88 hrs. (99.4 t.u.), the body of the embryo was becoming raised above the yolk. The whole was pigmented.

After 100 hrs. (113.6 t.u.), embryos had attained lengths of 6.48 to 9.57 mm. The pigmentation was denser over the head region. The tails of some of the embryos were beginning to turn sidewise. Depressions were appearing in the yolk, particularly on either side of the head.

After 112 hrs. (127.4 t.u.), the embryo, 8.7 mm. long, lay coiled on the yolk. The body was free from the yolk in the tail region for about three-fifths of its length. The head, too, was becoming progressively freer from the yolk. When the membrane was removed from one embryo, it became active and was still living 12 hrs. later.

Fraser, (34) who used some of the same material for a study of the development of the pronephros of the sturgeon, reports that after 76 hrs. after fertilization, the embryo possessed about 27 somites, 41-42 after 88 hrs., and about 46 after 112 hrs., but the number was difficult to determine accurately. She found that a neurenteric canal, which was still present 88 hrs. after fertilization was about to close after 112 hrs. and had completely closed after six or seven days. At the latter stage, the enteric cavity was separated from the exterior by a narrow partition of cells, but after nine days the gut communicated with the exterior by an anus.

Hatching

The first naturally hatched fry were observed after five days (124 hrs. 141.8 t.u.). At 144 hrs. (165 t.u.), they were hatching in increasing numbers and, at 192 hrs. or eight days (220.4 t.u.) after fertilization, all had hatched. It was about this time that the gut developed an opening to the exterior. Ryder (87) found that the eggs of the common sturgeon (Acipenser oxyrhynchus) hatched on the sixth day after fertilization.

Disappearance of the Yolk Sac

Because of the gradual diminution in the size of the yolk sac and of variation amony individual fry, it is impossible to fix definitely the time at which it may be said that the yolk sac disappeared. So far as it can be fixed, it may be said to have occurred about nine days after hatching.

Increase in Size

The embryo and fry grew in length at a relatively uniform and rapid rate until the 18th day after hatching, when growth in length ceased. This was more than a week after the disappearance of the yolk sac. The origin of the nourishment to support growth after this time is not clear.

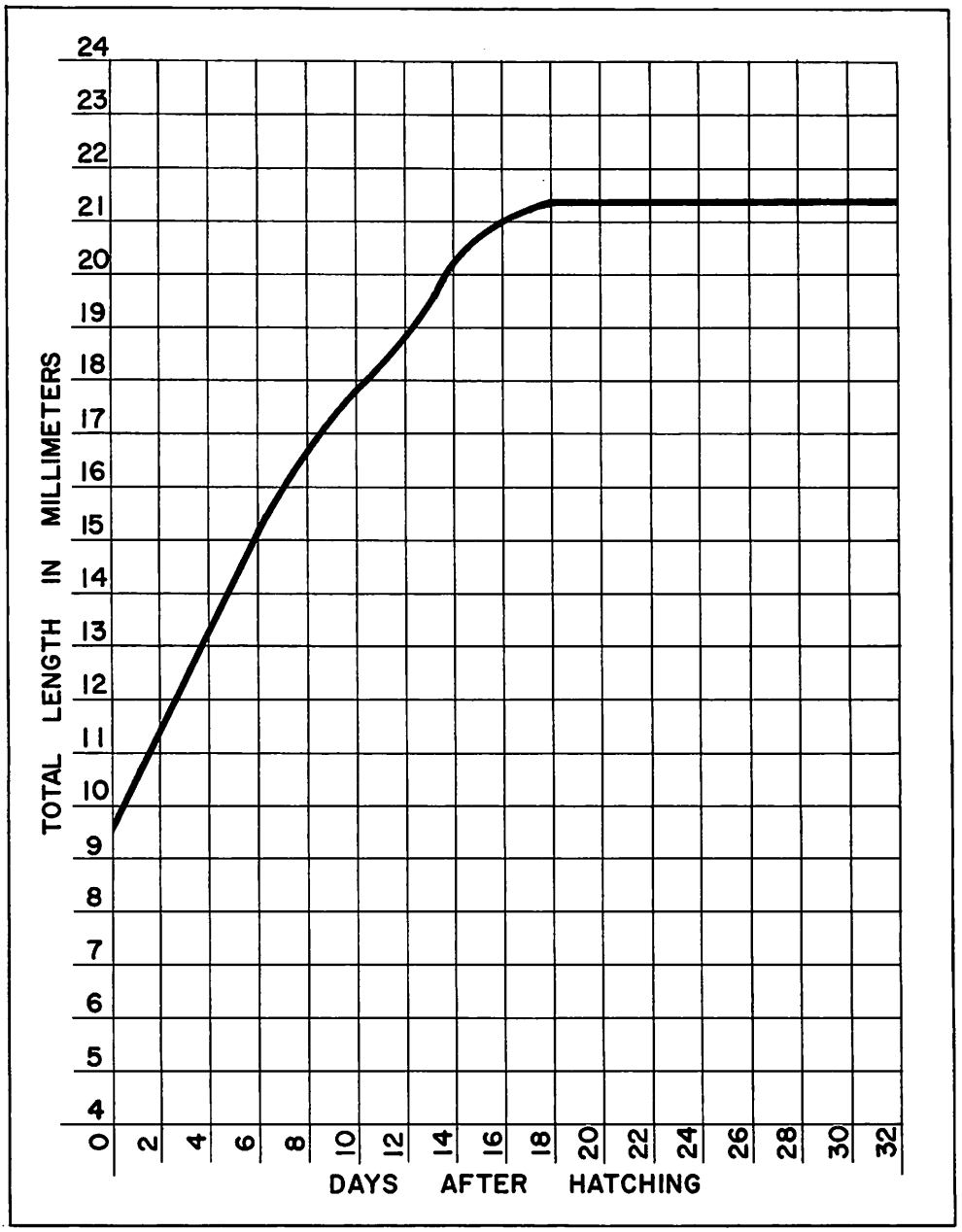
There was some evidence that the fry were actively searching for food and, possibly, taking some. It was on the 30th day after fertilization that usually large numbers of the fry first died. The high rate of mortality continued from this time until only eight remained alive on the 38th day after fertilization. It seems likely that feeding, if carried on after the yolk sac disappeared, failed within about five days after the disappearance of the yolk sac on the 17th day after fertilization, and that death resulting from starvation occurred within another week or two, during which no growth in length took place. On the other hand, yolk, although not evident externally, may have been sufficient to maintain growth for another five days after there was no longer external evidence of it.

Although morphological changes are continuous, there are periods during which changes take place much more rapidly than at other times. Marked changes follow the hatching process. The fry soon become more fish-like in appearance and the paired fins appear. Changes, especially marked during the period from one to two weeks after hatching, are almost in the nature of a metamorphosis. It is during this period that the general form changes from that of a relatively short, yolk-carrying fry to a more elongate form with the general appearance of a sturgeon. The snout becomes quickly longer, more slender and dorsoventrally flattened, and fins become more rapidly differentiated.

Behaviour of Fry

Soon after hatching, the fry huddled together in dark corners. When rough stones were placed in the aquarium to which they had been transferred on hatching, they took shelter under them. However, by the end of the first week after hatching, the fry were becoming less dependent on the shelter of the rocks and were moving about more independently of each other. This behaviour pattern was correlated with the virtual disappearance of the yolk sac. They appeared to be searching for food, and some appeared to be trying to feed on material on the rocks and bottom. A few days later, black material was seen coming from the anus.

The mouth opening had appeared two or three days after hatching. It increased rapidly in size and, after a day or two, had assumed something of the adult shape.



Growth in length of young sturgeon for 32 days. Growth in length ceased after 18 days owing to exhaustion of yolk and failure to find food which the young would or could eat.

Until about two weeks after hatching, most of the fry appeared to be doing well but, soon afterwards, they began to die in considerable numbers. About three weeks after hatching attempts, were therefore made to feed them. Bread, soaked in milk, finely chopped pike liver, plankton and chironomid larvae, and organisms of similar size, collected from aquatic plants, were placed in the aquaria. Attempts by the fry to eat some of these materials were apparently unsuccessful. Some were seen to seize chironomid larvae in their mouths but, after a brief struggle, would release them, being apparently unable to sallow them. Some appeared to eat ravenously at the liver. However, mortality continued. On the 29th day after all the fry had hatched, only eight were still alive of the many thousands which hatched from the 100,000 eggs fertilized. These were killed and preserved.

Gills

Gills were seen protruding from the sides of the head after 168 hrs. (192.8 t.u.). After 214 hrs. (248.8 t.u.), they had begun to develop finger-like projections. After 240 hrs., (282.5 t.u.), one had five such projections.

After 11 days (314.5 t.u.), three gills protruded on each side, the anterior one much the largest, all with finger-like projections. The first pair appeared to be attached to the inside of a flap-like structure that suggested an operculum. After 12 days (346.5 t.u.), the operculum extended backward over the protruding gills. After 13 days (378.5 t.u.), the gills still protruded from under the operculum which was becoming hard anteriorly, with a softer flap behind. By the 20th day, the gills had become virtually covered by the operculum.

Sense Organs

When the fry hatched, the eyes were quite prominent. Two or three days later, four stubs which developed into barbels appeared. On these, sensory buds were evident four days after the appearance of the barbels. Ten days after the fry hatched, sensory organs appeared on the lower surface of the head in front of the mouth.

Median Fins

The beginning of the median fin fold became apparent during the fifth day after fertilization. It extended from the dorsal surface around the tail on to the ventral surface.

By the 14th day, a portion of the dorsal fold, destined to become the dorsal fin, was becoming differentiated as a higher part. By the next day, the development of rays was indicated by rows of pigment spots. By the 18th day, the beginning of the development of caudal rays was also indicated by rows of pigment spots. By the 20th day, the differentiation of the median fin had proceeded to the point where notches were beginning to separate the developing dorsal and anal fins from the caudal. By the 22nd day, in some of the fry, the dorsal fin was completely separated from the caudal.

A portion of the fin fold had persisted to the 24th day. The persistence of the median fin fold through a period of about 20 days was in strong contrast to that of the lateral fin fold which was in evidence for only about four days.

Paired Fins

At 214 hrs. (248.8 t.u.), the pectoral fins had begun to appear as fold-like outgrowths of the body wall. Later, during the 14th day, continuous lateral fin folds appeared which included the beginnings of both the pectoral and pelvic fins. Posteriorly, it extended to the anus. By the 18th day, the anterior half of the lateral fin fold had disappeared, and all of it during the 19th day.

With the disappearance of the lateral fin folds, the pectoral and pelvic fins flattened out, parallel to the ventral surface of the body. Rays had begun to develop in the pectoral fins during the 14th day, and in the pelvic fins by the 20th day.

LITERATURE CITED

It has not been considered necessary to cite every publication containing reference to the lake sturgeon. Only those to which specific reference is made in the preceding account are cited in the following list:

1. ADAMSTONE, F.B. 1924. The distribution and economic importance of the bottom fauna of Lake Nipigon. Univ. Tor. Stud., Pub. Ont. Fish. Res. Lab., 24.

2. AMERICAN FISHERIES SOCIETY. 1960. A list of common and scientific names of fishes from the United States and Canada. 2nd ed. Spec. Pub., No. 2.

3. ANON. 1933. Mystery of sturgeon "41" solved. The Fisherman, 2(7):12.

4. ATZ, J.W. and PICKFORD, GRACE. 1959. The use of pituitary hormones in fish culture. Endeavour, 18:127.

5. BAJKOV, A. and NEAVE, F. 1930. The sturgeon and sturgeon industry of Lake Winnipeg. Can. Fish. Manual, 1930:43-47.

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

7. BARNICKOL, P.B. and STARRETT, W.C. 1951. Commercial and sport fishes of the Mississippi River between Caruthersville, Missouri and Dubuque, Iowa. Bu. Ill. Nat. Hist. Surv., Vol. 25, Art. 5.

8. BAYER, H. von. 1910. A method of measuring fish eggs. Bull. U.S. Bur. Fish., 28:1009-1014.

9. BEAN, T.H. 1903. Catalogue of the fishes of New York. N.Y. State Mus. Bull. 60.

10. BEVERTON, R.J.H. and HOLT, S.J. 1957. On the dynamics of exploited fish populations. London. Her Majesty's Stationery Office.

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

12. BUCKLAND, F. 1883. Natural history of British fishes. London.

13. CAMPBELL, P. 1793. Travels in the interior inhabited parts of North America in the years 1791 and 1792. Edinburgh.

14. CANADA DEPARTMENT OF FISHERIES. 26th Ann. Rpt. Dept. Mar. & Fish., Ottawa, 1893:lxxvii-lxxxvii.

15. CANADA DEPARTMENT OF FISHERIES. 42nd Ann. Rpt. Dept. Mar. & Fish., Ottawa, 1908-9:xiv-xvii.

16. CANADA DEPARTMENT OF FISHERIES. 46th Ann. Rpt. Dept. Mar. & Fish., Ottawa, 1912-13:xv.

17. CARLANDER, K.D. 1945. Age, growth, sexual maturity and population fluctuations of the yellow pike-perch, Stizostedion vitreum vitreum. Mitchill with reference to the commercial fisheries, Lake of the Woods, Minnesota. Trans Amer. Fish. Soc., 73:90-107.

18. CARTER, E.N. 1904. Notes on sturgeon culture in Vermont. Trans. Amer. Fish. Soc., 33:60-75.

19. CHARLEVOIX, P.F.X. 1761. Journal of a voyage to North America, 1:221. 1923 ed Caxton Club, Chicago.

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

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

22. CUERRIER, J.P. 1951. The use of pectoral fin rays for determining age of sturgeon and other species of fish. Can. Fish. Cult., no. 11: 10-18.

23. CUERRIER, J.P. and ROUSSOW, G. 1951. Age and growth of lake sturgeon from Lake St. Francis, St. Lawrence River. Report on material collected in 1947. Can. Fish. Cult. no. 10:17-29.

24. DEAN, B. 1894. Recent experiments in sturgeon hatching on the Delaware. Bull. U.S. Fish Comm., 13:335-339.

25. DUBREUIL, R. and CUERRIER, J.P. 1950. Rapport sur l'étude du cycle de maturation des glandes génitales chez l'esturgeon de lac (A. fulvescens Raf.) de la rivière Ottawa, 1949. Mimeo.

26. DUMÉRIL, A.H.A. 1870. Histoire naturelle des poissons, 2:118.

27. DYMOND, J.R. and DELAPORTE, A.V. 1952. Pollution of the Spanish River. Ont. Dept. Lands and Forests, Div. Res., Res. Rpt., 25.

28. DYMOND, J.R. 1926. The fishes of Lake Nipigon. Univ. Tor. Stud., Pub. Ont. Fish. Res. Lab., 27:33-34.

29. EDDY, S. and SURBER, T. 1943. Northern fishes. Sturgeon, pp. 57-61. Univ. Minn. Press.

30. EVERMANN, B.W. 1918. The fishes of Kentucky and Tennessee. Bull. Bur. Fish., 35:333.

31. EVERMANN, B.W. and COX, V.O. 1896. A report upon the fishes of the Missouri River basin. Rpt. U.S. Fish. Com., 20:385.

32. EVERMANN, B.W. and LATIMER, H.B. 1910. The fishes of the Lake of the Woods and connecting waters. Proc. U.S. Nat. Mus., 39:121-126.

33. FORBES, S.A. and RICHARDSON, R.E. 1920. The fishes of Illinois. Ill. Nat. Hist. Surv.

34. FRASER, ELIZABETH A. 1927. Observations on the development of the pronephros of the sturgeon, Acipenser rubicundus. Quart. J. Micr. Sci., 71:75-112.

35. GARLICK, T. 1857. A treatise on the artificial propagation of certain kinds of fish, with the description and habits of such kinds as are the most suitable for pisciculture. Cleveland.

36. GERKING, S.D. 1945. Distribution of the fishes of Indiana. Inv. Indiana Lakes and Streams, 3:29.

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

38. GREELEY, J.R. 1927-1940. Fishes in biological surveys of the watersheds of New York State. Supplements to the Annual Reports of the N.Y. Conservation Department.

39. GREEN, S. 1879. Fish hatching and fish catching. Rochester.

40. GREENE, C.W. 1933. The distribution of Wisconsin fishes. Wisc. Conserv. Comm.

41. GUDGER, E.W. 1934. The largest fresh-water fishes. Nat. Hist., 34:282-286.

42. HALKETT, A. 1912. Check list of the fishes of the Dominion of Canada and Newfoundland. Ottawa.

43. HARKNESS, W.J.K. 1923. The rate of growth and the food of the lake sturbeon (Acipenser rubicundus (Le Sueur)). Univ. Tor. Stud., Biol. Ser. 24, Pub. Ont. Fish. Res. Lab., 18.

44. HARLAN, J.R. and SPEAKER, E.B. 1956. Iowa fish and fishing. State Conserv. Commission.

45. HINKS, D. 1943. The fishes of Manitoba. Manitoba Dept. Mines and Nat. Res.

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

47. HUBBS, C.L. and TRAUTMAN, M.B. 1937. A revision of the lamprey genus Ichthyomyzon. Misc. Pub. Mus. Zool., Univ. Mich., 35:13.

48. INTERNATIONAL BOARD OF INQUIRY FOR THE GREAT LAKES FISHERIES. 1943. Report and Supplement. Washington.

49. JARVIS, N.D. 1943. Principles and methods in the canning of fishery products. U.S. Fish and Wildlife Service, Res. Rpt. 7, Sturgeon caviar pp. 302-304.

50. JOINT COMMISSION RELATIVE TO THE PRESERVATION OF THE FISHERIES IN WATERS CONTIGUOUS TO CANADA AND THE UNITED STATES, REPORT. Ottawa, 1897.

51. KELEHER, J. and KOOYMAN, B. 1957. Supplement to Hinks' "The fishes of Manitoba". Manitoba Dept. Mines & Nat. Res.

52. KIRTLAND, J.P. 1850. Fragments of natural history. Family Visitor, 1:1.

53. KOELZ, W. 1926. Fishing industry of the Great Lakes. Rpt. U.S. Fish. Comm. for 1925,:553-617.

54. LA HONTAN, BARON. 1703. New Voyages to North America.

55. LEACH, G.C. 1920. Artificial propagation of sturgeon, Review of sturgeon culture in the United States. Rpt. U.S. Fish Comm. for 1919, app. III.

56. LeSUEUR, C.A. 1818. Description of several species of chondropterygious fishes. Trans. Amer. Amer. Philos. Soc., 1:388.

57. LOW, A.P. 1896. Report on explorations in the Labrador Peninsula along the East Main, Koksoak, Hamilton and Manicuagan portions of other rivers in 1892-93-94-95. Ann. Rpt. Geol. Surv. Canada, 8 (Part L):326.

58. LOWER, A.R.M. 1915. A report on the fish and fisheries of the west coast of James Bay. App. Ann. Rpt. Dept. Naval Service, 1914:43. Ottawa.

59. MACKAY, H.H. 1930. Pollution problems in Ontario. Trans. Amer. Fish. Soc., 60:297-305.

60. MAGNIN, E. 1959. Repartition actuelle des Acipenserides. Rev. Trav. Inst. Peches Marit., 23:277-285. Paris.

61. MAGNIN, E. et BEAULIEU, G. 1960. Déplacements des esturgeons (Acipenser fulvescens, et Acipenser oxyrhynchus) du fleuve Saint-Laurent d'après les dounées du marquage. Nat. Canad., 87:237-252.

62. MANITOBA FISHERIES COMMISSION 1910-11. 1911. Report and Recommendations. Government Printing Bureau, Ottawa.

63. McCRIMMON, H.R. 1956. Fishing in Lake Simcoe. Ont. Dept. Lands and Forests.

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

65. MEEK, S.E. 1891. The fishes of the Cedar River basin. Proc. Iowa Acad. Sci., 1:105-112.

66. MELVILL, C.D. 1915. Report on east coastal fisheries of James Bay. App. Ann. Rpt. Dept. Naval Service, 1914:20-21. Ottawa.

67. MILNER, J.W. 1874. The fisheries of the Great Lakes. Rpt. U.S. Fish Comm., 2:67-75.

68. MICHIGAN STATE BOARD OF FISH COMMISSIONERS. 11th Biennial Rpt., p. 28.

69. ONTARIO GAME AND FISH COMMISSION, Report 1892.

70. ONTARIO GAME AND FISHERIES COMMISSION. 1909-1911. Final Report 1912.

71. POST, H. 1890. Sturgeon experiments in hatching. Trans. Amer. Fish. Soc., 19:36-40.

72. PRINCE, E.E. 1896. The fisheries of Canada. Ann. Rpt. Dept. Mar. Fish for 1896.

73. PRINCE, E.E. 1899. The food of the sturgeon. Special Report appended to 31st Ann. Rpt. Dept. Mar. Fish for 1898. Ottawa.

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

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

76. RAFINESQUE, C.S. 1820. Ichthyologia Ohiensis or natural history of the fishes inhabiting the Ohio river and its tributary streams.

77. RATHBUN, R. 1894. Embryology of the sturgeon. Rpt. U.S. Fish. Comm. for 1893:48-49.

78. RAVENEL, W. de C. 1902. Report on the propagation and distribution of food-fishes. Rpt. U.S. Fish. Comm. for 1901:38-42.

79. RICHARDSON, J. 1836. Fauna Boreali-Americana. Pt. III, The Fish. London.

80. RODD, J.A. 1924. Propagation of sturgeon. Fish Cultural Service, Dept. Mar. & Fish., Ottawa. Mimeo. Also published (1925) in Ann. Rpt. on Fish Culture, Fisheries Branch, Dept. Mar. & Fish. 1924.

81. ROSTLUND, E. 1952. Freshwater fish and fishing in native North America. Univ. Calif. Pub. Geog. Vol. 9:

82. ROUSSOW, G. 1955. Les esturgeons du fleuve Saint Laurent en comparison avec les autres espèces d'acipenséridés. Office de Biologie Ministere de la Chasse et des Pêcheries, Prov. Que.

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

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

85. ROUSSOW, G. 1960. Quelques anomalies des gonads chez l'esturgeon de lac (Acipenser fulvescens Rafinesque) du nord de la Province de Quebec. Jour. Bord. L'Office Biol., Min. Chasse et Pêcheries, Quebec, 2:319-323.

86. RUSSELL, FRANK. 1898. Explorations in the far north. Univ. Iowa Press.

87. RYDER, J.A. 1888. On the development of the common sturgeon. Amer. Nat., 22:659-660

88. RYDER, J.A. 1890. The sturgeon and sturgeon industries of the eastern coast of the United States with an account of experiments bearing upon sturgeon culture. Bull. U.S. Fish. Comm., 8:231-328.

89. SCHLUMPF, C.A. 1941. The spearing of sturgeon in Lake Winnebago. Wisc. Conserv. Bull., 6(8):33-36.

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

91. SCHULTZ, P.T. 1958. King of fishes. Wisc. Conserv. Bull. Jan. 1958.

92. SCOTT, W.B. 1954. Freshwater fishes of eastern Canada. Univ. of Tor. Press, 1954.

93. SMALL, H.B. 1865. The animals of North America. Ser II Fresh-water fish, pp. 64-65

94. SMITH, H.M. 1892. Report on an investigation of the fisheries of Lake Ontario. Bull. U.S. Fish Comm., 10:185-187.

95. SMITH, H.M. 1910. The United States Bureau of Fisheries. Its establishment, functions, organization, resources and achievements. Bull. U.S. Bur. Fish., 28:1365-1411.

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

97. SMITH, H.M. and SNELL, M-M. 1891. Review of fisheries of Great Lakes in 1885. Rpt. U.S. Fish Commission for 1887.

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

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

100. SUNDE, L. 1959. The sturgeon fishery in Manitoba with recommendations for management (analysis of Nelson River data: 1953-1956). Fisheries Branch, Dept. of Mines and Resources, Manitoba. MS.

101. SUNDE, L. 1959. The royal fish. Fishing, A Bulletin for Commercial Fishermen, 1:20-23. Fisheries Branch, Dept. Mines and Resources, Manitoba.

102. SURBER, T. 1920. A preliminary catalogue of the fishes and fish-like vertebrates of Minnesota. App. Bien. Rpt. State Game & Fish Comm. for the period ending June 30, 1920.

103. TRAUTMAN, M.B. 1957. The fishes of Ohio. Ohio State Univ. Press.

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

105. VLADYKOV, V.D. 1955. Fishes of Quebec - Sturgeons. Quebec Dept. Fish. Album 5.

106. VLADYKOV, V.D. et BEAULIEU, G. 1946. Étude sur l'esturgeon (Acipenser) de la Province de Quebec. I.Distinction entre les deux especes d'esturgeon par le nombre de boucliers osseux et de branchiospines. Nat. Canad., 73:143-204.

107. VLADYKOV, V.D. et BEAULIEU, G. 1951. Etude sur l'esturgeon (Acipenser) de la Province de Quebec. II.Variation du nombre de branchiospines sur le premier arc branchial. Nat. Canad., 78:129-154.

108. VAN OOSTEN, J. 1956. The lake sturgeon in Our Endangered Wildlife 9-10. Nat. Wildlife Fed. Washington.

109. WALLICH, C. 1901. A method of recording egg development for use of fish culturists. Rpt. U.S. Fish. Comm. for 1900, 26:187-194.

110. WILLIAMS, J.E. 1951. The lake sturgeon. Mich. Conserv., 20(6):15-18.

111. WILMOT, S. 1870. Report of S. Wilmot, Esq., on the fish-breeding establishment at Newcastle, Ontario during the season of 1869. App. 9, Ann. Rpt. Dept. Mar. & Fish. for 1869.

112. WIRTH, T. 1956. The lake management report for 1956. Wisc. Conserv. Dept., Mimeo.

113. WIRTH, T. 1958. Winnebago studies. Ann. Prog. Rpt., Wisc. Conserv. Dept. Fish Management Division, Research Section.

114. WIRTH, T. 1959. Sturgeon tagging operations on Wolf River - 1959. Wisc. Conserv. Dept. Memo.

115. WIRTH, T. and CLINE, C. 1955. The harvest of lake sturgeon (Acipenser fulvescens) by spearers in Lake Winnebago and connecting waters, Wisconsin. Wisc. Conserv. Dept., Mimeo.

116. WRIGHT, R. 1892. Preliminary report on the fish and fisheries of Ontario. Rpt. Ontario Game & Fish Commission.