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FISHERIES DIVISION

TECHNICAL REPORT

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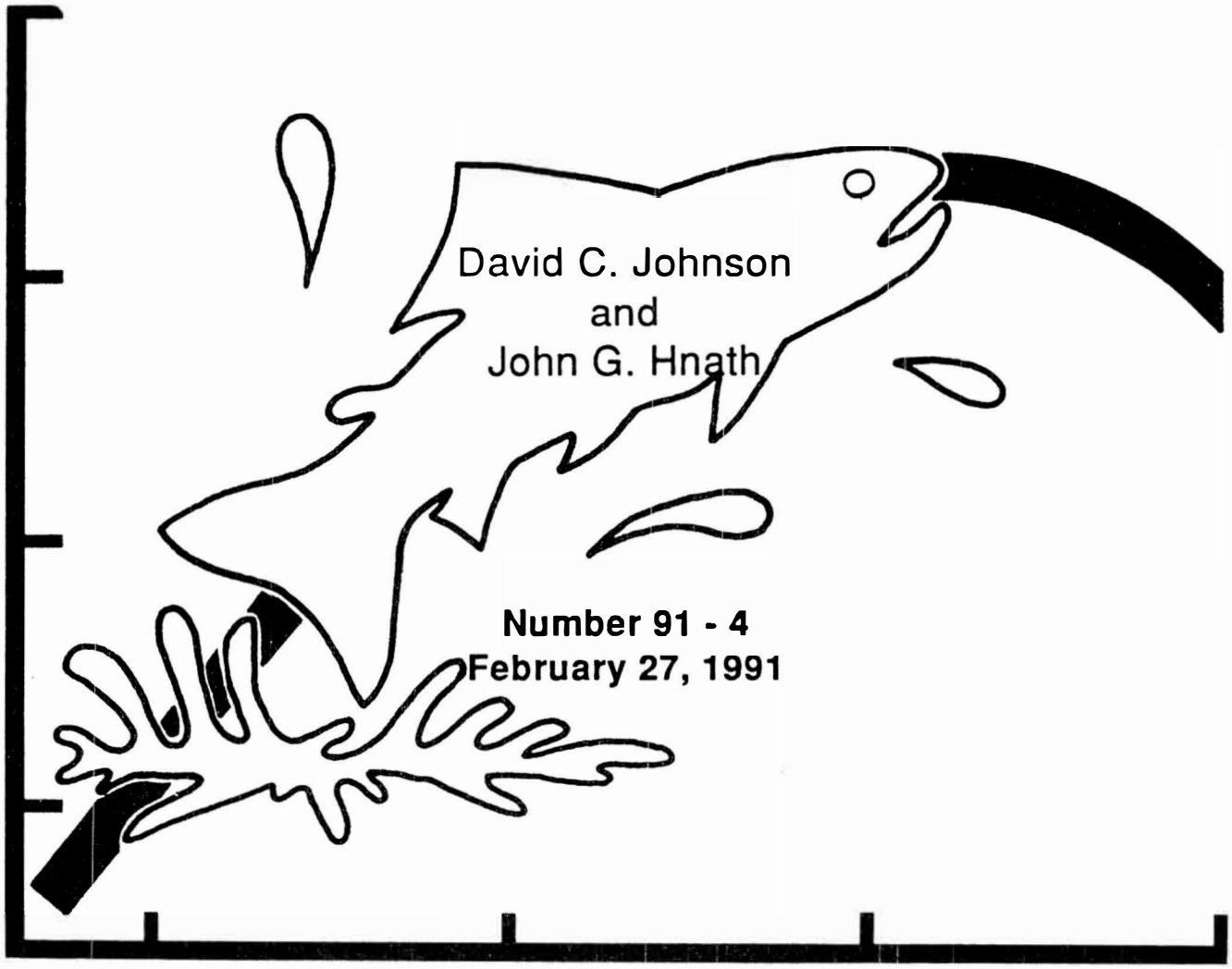

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Michigan Department of
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Abstract.—During the spring of 1988, dying and dead chinook salmon were observed in Lake Michigan. This was the first such mortality observed since chinook salmon were first stocked in the lake in 1967. Dead salmon were first observed in the southern part of the lake in early April between Michigan City, Indiana and South Haven, Michigan. Most of the affected salmon ranged from 5 to 10 pounds in weight. Throughout April, May, and early June, dying and dead chinook salmon were observed progressively farther north along the east shore of the lake. No stressed or dead salmon were observed past early June. Dying and dead fish were observed in Illinois and Indiana waters from early April through mid-May, when the mortality ended in southern Lake Michigan. The largest numbers of affected fish were found in the southern end of the lake, from about Chicago, Illinois to Muskegon, Michigan. It appeared that the fish were first affected at the southern end of the lake and were carried northward along the east shore by strong south-to-north currents.

In Wisconsin, most reports of chinook salmon mortalities came from the Two Rivers area, with a few reports from near Cheboygan. The distribution of mortality on the Wisconsin shore appeared quite different from that observed in the rest of the lake, but this may have been due to the amount of search effort in the Two Rivers area compared to the rest of the Wisconsin shoreline. Mortalities were first observed in early April and continued through at least September 9, when the last check was made.

Dying and dead fish were analyzed by pathologists from the Wisconsin Department of Natural Resources, Illinois Department of Conservation, and Michigan Department of Natural Resources, and some tissues were also analyzed by a histopathologist from the National Fish Health Research Lab at Leetown, West Virginia. Most fish exhibited bacterial kidney disease (BKD), and most cases were severe. The majority of the fish examined were chinook salmon, but one coho salmon was found in Illinois, and one in Wisconsin that also had BKD. Numerous sport-caught and gill-netted chinook salmon were also examined. A very few of these also exhibited acute BKD but the vast majority appeared to be healthy.

The bacterium for BKD occurs commonly in Pacific salmon in Lake Michigan. However, some form of environmental or other stress is necessary to weaken the fish so that

BKD can progress to the point of causing mortality. Such a stress apparently occurred in Lake Michigan in the spring of 1988, but the source of this stress is unknown.

It is estimated that the lake-wide mortality of chinook salmon in 1988 was approximately 7,000-8,000 fish, based upon reports from other states, aerial surveys, and shoreline observations at several index stations. If fair numbers of dead fish sunk and were not seen, the mortality may have exceeded 10,000 fish. These losses should not have a significant impact on the chinook salmon sport catch, which ranged from 347,012 (±60,915) to 513,780 (±98,387) annually, during 1985-87 in Michigan waters alone (Keller et al. 1990).

Coho salmon were introduced into Lake Michigan in 1966, followed by chinook salmon in 1967. Continued stocking has resulted in the development of a tremendous sport fishery (Keller et al. 1990).

Since the introduction of salmon into the Great Lakes there have been no reports of mortalities in the wild. However, in the spring of 1988, the first such mortality was observed in Lake Michigan. The purpose of this report is to detail the findings of the various state agencies that studied this event and their conclusions regarding its cause.

Observations

Michigan

The first report of a potential problem with chinook salmon in Michigan was received on April 6, 1988, from the area immediately south of the Cook Nuclear Plant, south of St. Joseph (a map of Lake Michigan and its major ports is shown in Figure 1). A fisherman reported netting two 4- to 5-pound chinook salmon swimming lethargically along the surface of the water close to shore. Both fish had light tan livers, and one reportedly had white lesions full of clear liquid. Further investigation yielded similar reports from the St. Joseph and South Haven areas.

On April 8, biologists from the Indiana Department of Natural Resources (IDNR), the Indiana Department of Conservation (IDOC), and the Wisconsin Department of Natural Resources (WDNR) were contacted, and both Indiana and Illinois biologists had received reports of chinook salmon acting strangely.

A few dying or dead salmon were reported from Michigan near Holland and Muskegon. Dead fish were also sighted at two locations between South Haven and Saugatuck.

On April 9, the first of three aerial surveys of the Lake Michigan shoreline was made to attempt to determine the range and magnitude of the problem. The aerial surveys covered shoreline stations from East Chicago, Indiana to Manistee, Michigan (Table 1). Results from the three surveys are summarized in Figure 2. Individual counts of live and dead fish were made between ports. The survey began about 2 miles north of Whitehall, which appeared to be the northern limit of the mortality, and ended at Gary, a distance of 152 shoreline miles. A total of 181 live, stressed chinook salmon and 78 dead chinook salmon were seen. The water between Portage and Gary was very turbid and visibility was poor, so the survey was terminated there. All stressed fish were swimming at the surface in a lethargic manner, close to shore and easily observed. Only positively identifiable fish were counted. The major concentrations of stressed fish appeared to be between Muskegon and Grand Haven and between South Haven and Michigan City. The size of the fish varied, but most ranged from 5 to 10 pounds in weight. A 50-mph windstorm on

April 6 may have concentrated sick and dead fish on the east shore of Lake Michigan.

During the next several weeks, counts were made at several sites from New Buffalo to Holland several times per week. Counts varied greatly, from 0 to 30+. The fish seemed to be grouped in "clusters". This was also observed during aerial surveys. As the mortality waned in this area, counts were made only once per week at eight "index" stations until no more fresh dead fish were found. The last such count was made on June 3, but no fresh fish were found after May 11. During these counts, several fresh specimens were collected and taken to the Michigan Department of Natural Resources (MDNR) Wolf Lake Fish Health Lab for analysis.

On April 26, the second aerial survey was conducted from East Chicago, to Ludington. The survey was expanded due to reports of stressed fish in these other areas. During this survey "fresh" dead salmon were distinguished from "old" dead salmon by color (silvery vs tan). On this survey, covering 205.3 miles of shoreline, a total of 155 stressed and 659 dead chinook salmon were counted. The largest concentrations of dead fish occurred between New Buffalo and Saugatuck but most of these were "old". However, very few live, stressed fish (six) were found in this stretch, indicating that the mortality was about over. Only one live fish was seen in Indiana waters despite continued reports of sick fish from that area. The largest concentrations of stressed fish were between Grand Haven and Little Point Sable, and between Whitehall and Pentwater. No fish, live or dead, were seen from Little Point Sable to Ludington. It appears that the strong south-to-north current was carrying stressed and dead fish farther north.

For the next 6 weeks, reports of dead and dying fish were received from St. Joseph to as far north as Charlevoix. By mid-May the mortality had ended south of Holland, but reports continued to trickle in from farther north. However, these reports were widely scattered and the numbers of fish seen were quite small (1-10).

On June 7, the last aerial survey was conducted from New Buffalo to Manistee. On this survey, covering 183.5 miles of shoreline, no live fish were seen and only seven "fresh" dead and 96 "old" dead salmon were seen. It appeared that the mortality was over.

In late June, a diver reportedly saw many dead salmon on the lake bottom in 50 feet of water near Frankfort. A National Oceanic and Atmospheric Administration research "sled" with underwater camera was used to cover that 50-foot contour extensively and found no dead fish. Divers were also utilized at Holland at specific sites where anglers reported catching two dead salmon and they, likewise, found nothing. The MDNR survey vessel *S/V Steelhead*, likewise, did extensive bottom trawling in the northern part of the lake and from St. Joseph to Port Sheldon, and found no dead salmon on the bottom.

Indiana

When contacted on April 8, IDNR personnel indicated that they had received a few reports from Michigan City and Gary of several chinook salmon swimming very slowly along breakwaters. They did not associate these sightings with a mortality since there were no dead fish around. Based upon the Michigan Report, IDNR personnel went to the beaches near Michigan City and observed approximately 12 dead 5- to 8-pound chinook salmon washed up in 200 yards of beach. Most of these appeared to have been dead 1-2 days. When necropsied, the fish exhibited the same tan livers as those observed in Michigan. Aside from two dead chinook salmon that washed up at the boat ramp the

previous week, these were the first dead fish seen in Indiana. A creel census clerk working the Indiana ports indicated that slow-swimming, lethargic fish had been observed over the past 7-10 days. It is likely that these fish were blown ashore by the high winds on April 6.

Observations were made at Indiana ports for the next several weeks by IDNR personnel. On April 15, a creel clerk at Pastrick Marina at East Chicago (immediately east of the Inland Steel Peninsula) observed 35-40 fish under stress near the piers. Approximately 100 stressed fish were reported from the Port of Indiana (this report was not verified). On April 22, reports of a few sick fish were still being received. At this time Indiana was experiencing its best spring chinook salmon fishery in several years. The IDNR survey vessel at Michigan City made three 0.5-mile bottom trawl tows in that area and found only one dead salmon. On April 28, Indiana personnel collected three sick fish, which were taken to the MDNR Fish Health Lab for examination. On May 2, about a dozen floundering chinooks were reported at Gary. By mid-May, the mortality appeared to be over.

Illinois

When the IDOC was contacted on April 8, they reported having received a few reports of anglers seeing slow-moving, lethargic chinook salmon in the harbors near Chicago. The first such reports were received about April 1. These fish ranged from 5 to 10 pounds in weight. Some fish were reportedly caught with lures, and when cleaned, the body cavities were reported to be full of clear or gelatinous fluid. Red spots were also seen inside the fillets. Externally the fish appeared normal. One angler reported this condition in two of five salmon caught.

On April 11, a 15-pound chinook salmon and a 1-pound coho salmon were collected and sent to the Illinois pathology lab. By this time, several creel clerks had reported seeing lethargic chinook salmon range from 5 to 15 pounds in weight at several harbors. Reports continued to come in through April, but tapered off rapidly after May 1. On May 9, IDOC biologists examined some fresh specimens and sent some to their pathology lab. No more fish were reported in Illinois after mid-May.

Wisconsin

The WDNR was contacted on April 8 and at that time they had received no reports of dying salmon. On April 12 they reported finding 13 dead fish along 6 miles of shoreline north of Two Rivers. These fish were in various stages of decomposition. No reports of sick or dead fish had been received from southern Wisconsin waters. On April 14, an aerial survey of the entire Wisconsin shoreline located only four dead fish.

The first report of fresh dead chinook salmon was received on April 24 from the Two Rivers area. In early May three specimens were collected there and sent to the WDNR pathology lab for analysis. Through-out the summer, beach checks were made following strong on-shore winds in the Two Rivers area. Salmon in various stages from "fresh" to decomposed were found there throughout the summer. On September 9 the last such beach check was made in a 6-mile section of beach and 23 dead chinook salmon were found, including some fresh specimens. During the period from April 12 through September 9, a total of 84.5 miles of shoreline were checked in Manitowoc and Kewaunee counties, Wisconsin, and a total of

360 dead chinook salmon were found. Several other species of dead fish were also found in significantly fewer numbers, but these were considered to be normal mortality numbers. The apparent concentrations of fish in that area may have been due more to the intensive search effort there compared to other areas of the Wisconsin shoreline.

The first dead salmon to appear on the beaches in the spring were suspected to have been released from nearby commercial trap nets, but later fish were found in other areas that could not be related to the commercial fishery. The farthest south that mortality was observed in Wisconsin was the Cheboygan area.

Pathology Findings

Eleven chinook salmon were examined in April and May; these had been captured alive as sick fish from South Haven south. All had bacterial kidney disease (BKD), most had severe cases. Acanthocephala (spiny-headed worms of the lower gut) were numerous, but in the three fish from which they were individually counted, the numbers (151-483) were within the range previously reported from salmonids in Lake Michigan. No other pathogens were detected. Tissue samples were also preserved for further study at the U.S. Fish and Wildlife Service Health Research Laboratory, Leetown, West Virginia (see below).

Approximately 100 angler-caught and apparently healthy fish were examined in the field on May 14 and 15 for signs of disease. All appeared healthy, but two had lesions in the kidney and one had an external "boil". These three fish later tested positive for BKD.

In July, MDNR research vessels set gill nets in several areas of lake Michigan from South Haven to Leelanau. Chinook salmon captured in these nets were given thorough necropsies, including the following: internal and external gross observations, kidney smears, FA spots from kidney, streaking of kidney and liver on BHI nutrient agar, and hematocrits. In addition, tissues were saved for total acanthocephala counts. Tissues were also preserved for further study at the National Fish Health Research Laboratory. Thirty-five chinook salmon were examined. All appeared healthy externally. Five fish were found to have BKD bacteria, however, only one fish had gross internal signs of BKD. Acanthocephala were numerous, but actual counts were similar in numbers (94-1025) to those reported in previous years. There did not appear to be any correlation with numbers of worms and the condition of the fish. Those fish with the highest numbers of worms appeared healthy, while the one fish with severe bacterial kidney disease had the fewest number of worms.

Numerous chinook salmon and at least one coho salmon were collected from all four states surrounding Lake Michigan, and these were analyzed by pathologists from three states and the U. S. Fish and Wildlife Service. Nearly all of the distressed or dead fish analyzed by pathologists exhibited signs of BKD. Numerous specimens necropsied in the field by biologists also exhibited signs of severe BKD. BKD ultimately caused the mortality of these fish.

Discussion

The 1988 chinook salmon mortality in Lake Michigan apparently began in late March or early April in southern Lake Michigan. Dead and dying fish spread slowly northward on the east shore of Lake Michigan, possibly due to the strong south-to-north currents along that shoreline. The largest concentration of these fish was observed in the southeast end of the lake, immediately following a 50-mph windstorm

on April 6. The wind was from the southwest, suggesting that sick and dead fish were carried across from the southwest part of the lake. During the first aerial flight on April 9, the largest concentrations of stressed fish were observed from Michigan City to South Haven.

The mortality ended by mid-May in southern Lake Michigan and by early June in the northern areas of the Michigan side of the lake. However, in the Door Peninsula-to-Cheboygan area of Wisconsin the mortality continued throughout the summer. Most of the mortality was confined to chinook salmon, but a very few coho salmon were also seen. The majority of the chinook salmon ranged from 5 to 10 pounds in weight.

The three aerial flights and other reports suggest that the fish might have been exposed to some stress in the southern part of the lake, and then were slowly moved northward along the east shore of the lake by the currents. Lethargic and weak fish were observed along much of this shoreline. The fact that mortality ceased in the southern part of the lake two weeks before it did in the north would further substantiate this theory. The colder northern water would slow metabolism and possibly delay mortality further.

Based upon aerial surveys; shore counts; and reports from fisheries personnel, fishermen, and other interested parties, it was estimated that the mortality affected approximately 7,000-8,000 chinook salmon lake wide. During the aerial surveys, the fish were always seen concentrated quite close to shore. Distressed fish seemed to be seeking warmer water, as they were apparent near the mouths of small tributary streams. It is unknown whether other dead fish sank in deep water and were thus undetected (although several attempts to search the bottom found no dead salmon).

Bacterial kidney disease is a slowly progressive bacterial disease of fish caused by *Renibacterium salmoninarum*, a gram positive diplobacillus common in Pacific salmon, but also found in other salmonids. It is transmitted both through the water from fish to fish, and from adult fish to their progeny through infections within the egg, and is the cause of serious saltwater losses of salmon on the Pacific Coast (Meyer 1985).

Although BKD was apparent in all the "sick" chinook salmon from Lake Michigan brought to the Fish Health Lab for necropsy this spring, BKD was not considered to be the primary cause of death. It is most often the case with BKD that subclinical infections are normally well-tolerated by the fish, and lead to death only in fish which are stressed (Meyer 1983). It is our opinion that some stress(es), unknown to us, weakened the affected fish and allowed the BKD which was already present to progress to the point of death. This opinion is also supported by the comments of Dr. Roger Lee Herman (personal communication, 1988, National Fish Health Laboratory, Leetown, West Virginia):

> ". . . there is little question that several of these fish died from an acute case of bacterial kidney disease. The question of what triggered the explosive growth of the *Renibacterium* cannot be answered from these samples. Because of the nature of bacterial kidney disease . . . one can speculate on an environmental event which stressed the fish beyond their ability to control the *Renibacterium* or other disease agents present. "What, when, where?"

The question arises as to what role BKD and also the acanthocephalan worm *Echinorhynchus salmonis* may have played in the mortality. Perhaps if the fish did not have BKD, they may have died from a

another disease agent such as *Aeromonas hydrophila* or *Pseudomonas fluorescens*, both of which are very common in Great lakes waters. The acanthocephalan worms may also play a role, as they have been incriminated in fish losses in the Soviet Union (Petrushevski and Kogteva 1954), and have also been implicated in a loss of brook trout in which a combination of acanthocephala and an undescribed bacteria were discussed along with the possibility of an environmental contaminant (Pippy and Sandeman 1967). However, the numbers of worms seen in sick fish from lake Michigan (avg. 242) were relatively low compared to those found later in healthy fish (up to 1,025 per fish), and to the numbers previously reported from healthy fish in the past (Amin 1985). Most probably the answer to the question of what caused the loss is contained in a combination of factors, not all of which are known. These factors most probably include: (1) the presence of BKD, (2) the presence of acanthocephala, and (3) other stresses contributing to an overall lack of resistance in the fish.

As to the speculation on why only a small portion of the chinook salmon population in a small portion of the lake appeared to be affected, there are several possibilities. One is that only a small portion of the chinook, those in a relatively small portion of the lake at one time, became subjected to the particular stress(es) which led to the mortality. This could have been the case in a contaminant spill, for example. Another possibility is that the affected fish may have originated from a stock of fish with a high level of BKD, or from a stock which had a "problem" with BKD while in a production hatchery, although this seems less likely since one might expect that the disease would have shown up much sooner than it did if the fish already had a "problem" when planted. Another possibility remains that an undetected pathogen, such as a viral agent, was responsible but was not detected because of the very few (2) specimens which were brought to the lab in fresh enough condition for virological screening or because a "new" viral agent was present for which there is no diagnostic test.

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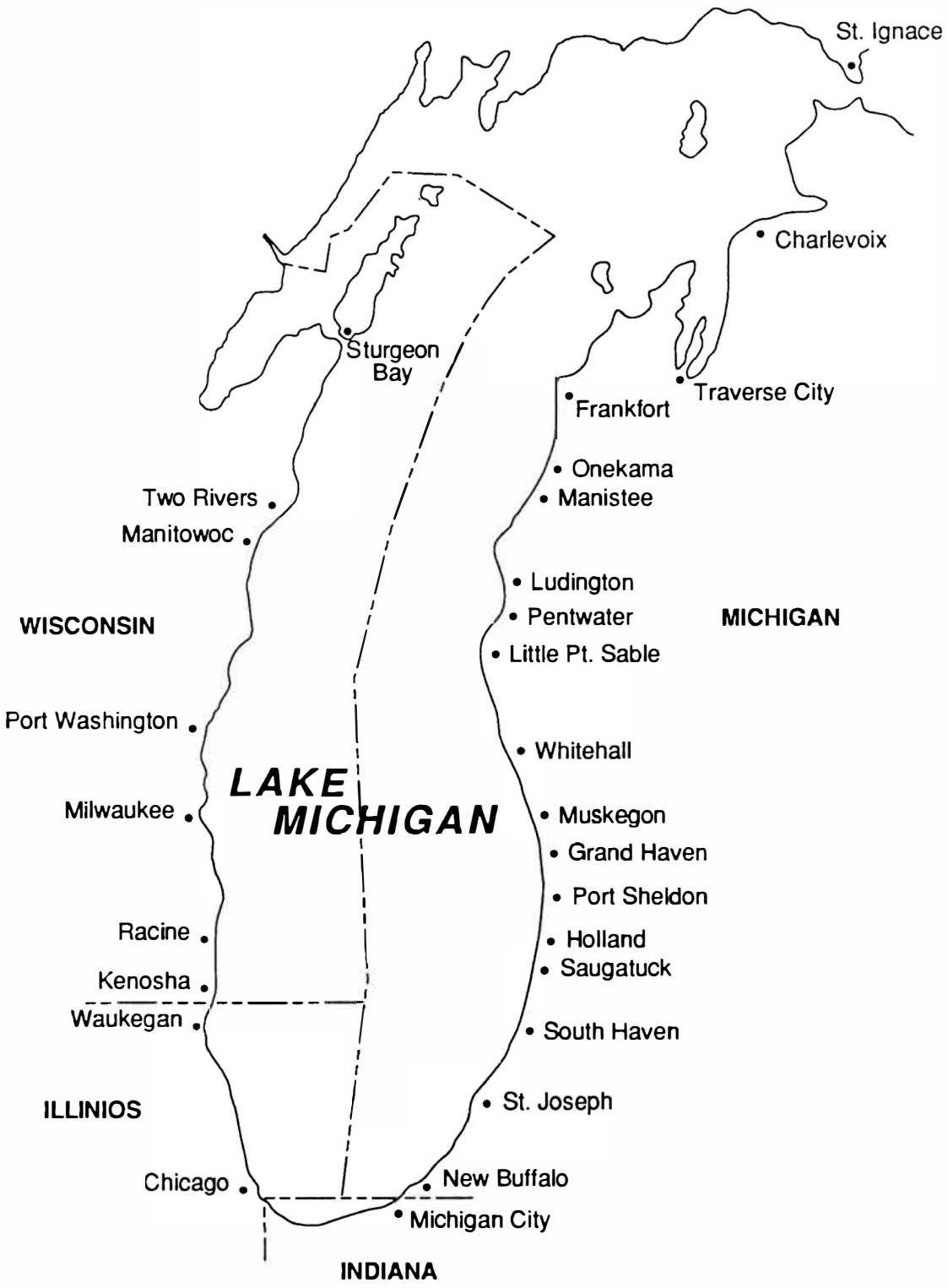

Figure 1.—Map of the affected area of the Lake Michigan chinook salmon mortality, with major ports indicated.

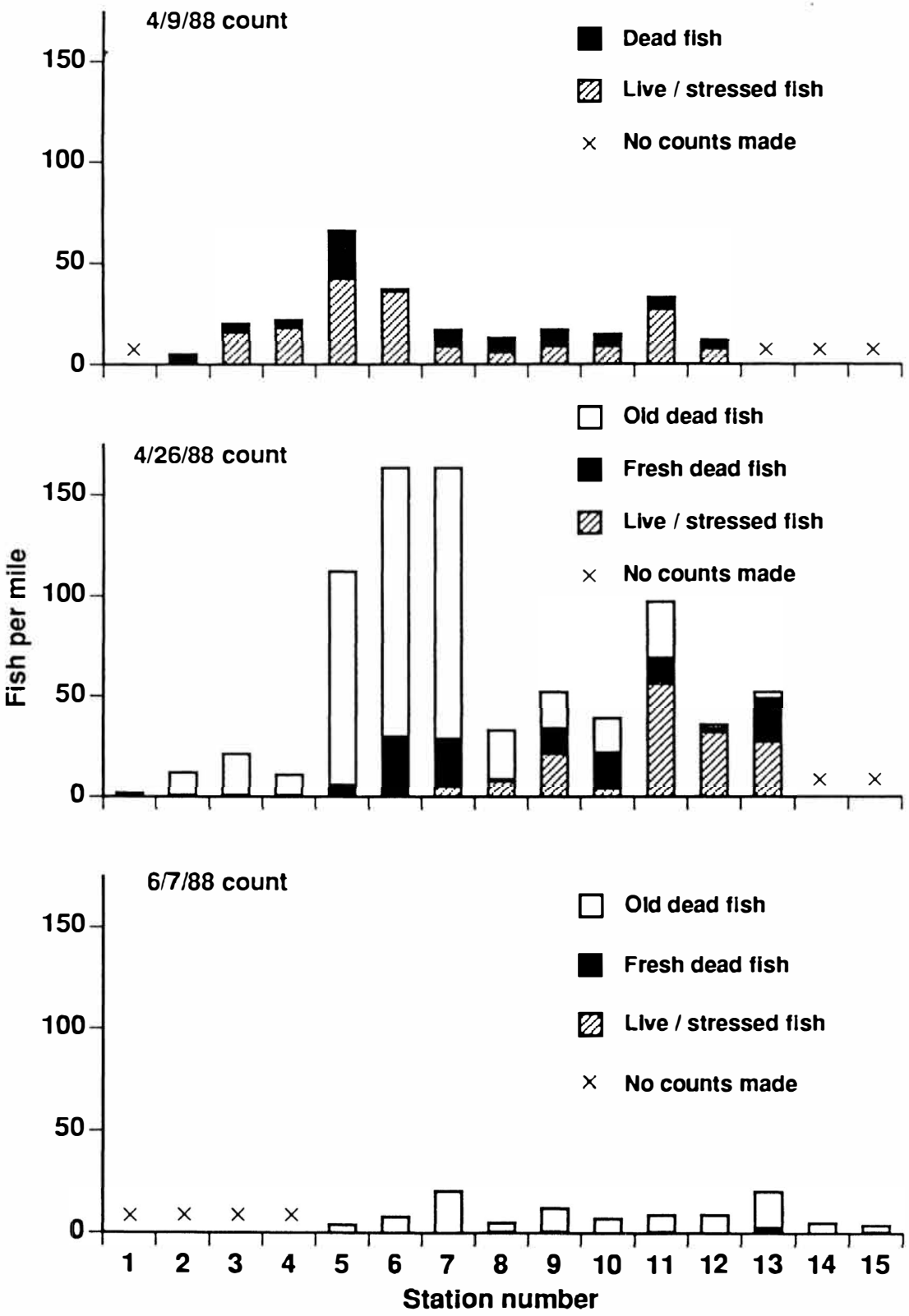

Figure 2.—Stressed and dead chinook salmon counts from aerial surveys of southeastern Lake Michigan, April 9, April 26, and June 7, 1988.

Table 1.—Station location used during the 1988 aerial survey flights along Lake Michigan beaches and distances between them.

Station number	Shore segment	Mileage
1	East Chicago, IN to Gary, IN	12.6
2	Gary, IN to Portage, IN	7.6
3	Portage, IN to Michigan City, IN	15.2
4	Michigan City, IN to New Buffalo, MI	19.9
5	New Buffalo, MI to St. Joseph, MI	25.8
6	St. Joseph, MI to South Haven, MI	22.7
7	South Haven, MI to Saugatuck, MI	19.5
8	Saugatuck, MI to Holland, MI	6.6
9	Holland, MI to Port Sheldon, MI	8.5
10	Port Sheldon, MI to Grand Haven, MI	11.4
11	Grand Haven, MI to Muskegon, MI	12.3
12	Muskegon, MI to Whitehall, MI	10.4
13	Whitehall, MI to Pentwater, MI	30.5
14	Pentwater, MI to Ludington, MI	12.3
15	Ludington, MI to Manistee, MI	23.5

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