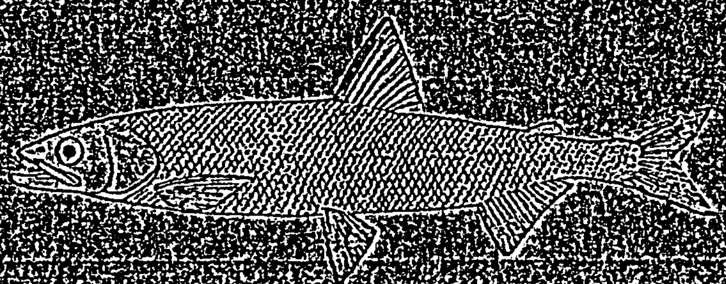
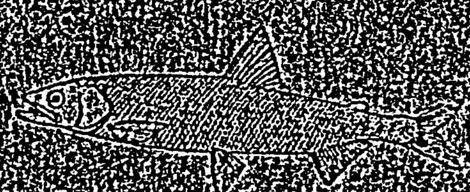
THE CONDITION OF FISHES IMPINGED AT THE C.E.I. CO. EASTLAKE AND AVON LAKE PLANTS

REPORT 78





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THE CONDITION OF FISHES IMPINGED AT THE CLEVELAND ELECTRIC ILLUMINATING COMPANY EASTLAKE AND AVON LAKE PLANTS EXCLUDING THE GIZZARD SHAD

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EXECUTIVE SUMMARY

An investigation of the condition of the non-gizzard shad fish impingement at the Eastlake and Avon Lake generating facilities was conducted from March 3 to October 28, 1983. Specifically, the study was designed to determine: 1) the biological condition of impinged fishes; 2) the species composition of the impinged fishes; and 3) the most likely cause of mortality of impinged fishes. Impinged fishes were collected from individual screens for one-hour periods on each sampling date. Samples were collected bi-weekly at each generating facility.

Following collection, impinged fishes were identified to species, visually examined, and classified into one of the following categories: 1) alive, 2) recently dead, 3) dead for more than 5 hours, or 4) decomposing. Following classification, individual fishes in the first and second categories were examined for external pathologies or physical impairments which would result in death.

The frequency of occurrence of externally identifiable pathologies was quite similar between the observed impingements at the Eastlake and Avon Lake generating facilities. Furthermore, very strong similarities were evident between the species composition of the impingements at the Eastlake and Avon Lake facilities. Peak impingement periods of fishes were also similar in time of occurrence between the two generating facilities.

Excluding the gizzard shad, a total of 27,374 fishes were collected and examined during the present study. At the Eastlake facility, a total of 13,343 fishes representing 27 species were collected and examined. Of this total, 5,666 (42.46%) had been dead for a period of more than 5 hours (categories 3 and 4); the mortality of these fish could not be attributed to impingement. Of the remaining 7,677 fish, 4,553 individuals (34.12% of all fish collected) exhibited one or more pathogenic fungal and/or parasitic infections which were considered terminal in nature. Thus, these fishes were not considered an impingement mortality. A total of 516 fish (3.87%) survived the impingement process. No discernible cause of mortality was evident for the remaining 2,608 impinged fishes. Therefore, these fish, representing 19.54% of the total observed non-gizzard shad impingement at the Eastlake facility, were considered to have potentially incurred impingement mortality.

At the Avon Lake facility, the non-gizzard shad impingement was comprised of 14,031 fishes from 26 species. Examination of these fishes found 6,455 individuals (46.01% of the non-shad impingement) to have been dead for more than 5 hours; the mortality of these fish was not considered to be impingement induced. A total of 3,577 fish (25.49%) exhibited fungal and/or parasitic conditions which were considered to be terminal in nature and not impingement related. An additional 682 fish (4.86%) survived the impingement process. Examination of the remaining 3,317 fish, representing 23.64% of the total non-shad impingement, found no readily discernible cause of mortality. These fish were considered to be potential impingement mortalities.

The analysis of the non-shad impingement at the Avon Lake and Eastlake generating facilities has demonstrated that more than 44% of the total combined impingement was comprised of fishes which were dead prior to impingement and had drifted into the intake channel from surrounding areas. An additional 29.70% of the impingement was composed of fish that were dead or dying from factors not associated with the impingement processes of the generating facilities. Thus, more than 73% of the combined total non-shad impingement examined during this study was comprised of dead or terminally ill fishes whose conditions were not a result of impingement.

The impingement mortality estimates obtained in the present study are based solely on the non-gizzard shad components of the observed impingements, and would be considerably less with the inclusion of gizzard shad impingement. Extrapolating the Eastlake impingement mortality estimate derived in the present study to the results of the Eastlake 316(b) study, potential impingment mortality of the non-shad component would encompass approximately 4% of the total annual impingement. Extrapolating the Avon Lake non-shad impingement mortality estimate obtained in the present study to the Avon Lake 316(b) data, potential mortality of the non-shad impingement would also represent approximately 4% of the total annual impingment.

It should be noted that none of the fishes evaluated for biological condition in the present study were examined internally for the presence of pathogenic agents, yet internal pathogenic conditions which are not related to normal plant activities may result in a considerable reduction of the estimated potential impingement mortalities. White (1986) reported that pathogenic conditions identifiable only by internal examination accounted for a large portion of the non-plant induced mortality for some species at a different central Lake Erie generating facility. These conditions included bacterial gill rot, liver and kidney carcinomas, septicemic Aeromonas and Pseudomonas infections, starvation, aenemia, gill flukes, and internal leeches. For example, 21% of the live (barely) and recently dead rainbow smelt impinged at this facility were found to have nearly white liver tissues, clear white gills, very low blood volumes, and no discernable heme pigments.

Similar pathogenic conditions are probably present in comparable proportions in the fishes impinged at the Eastlake and Avon Lake plants, and the lack of internal fish examination during the present study has resulted in extremely conservative estimates of the natural mortality observed in the present study. Conversely, the estimated potential impingement mortalities are probably considerably overestimated.

Thus, the actual total non-shad impingement mortalities are very likely to be less than the 19.54% and 23.64% obtained for the Eastlake and Avon Lake facilities, respectively, and internal examination of impinged fishes at the Eastlake and Avon Lake facilities would probably have resulted in estimated impingement mortality affecting 10% or less of the total non-shad impingement. When combined with the gizzard shad component of the annual impingements, this would result in a potential plant-induced impingement mortality of less than 2% of the total impingements reported in the 316(b) studies at these two generating facilities.

INTRODUCTION

The impingement of fishes at electric generating facilities has been of growing concern for many years. Numerous 316 (b) demonstration studies produced by the power industry have shown that impingement of fishes on intake screens may exceed several million fishes per year at a single facility. Furthermore, the results of some of these studies suggest that there may be an adverse environmental impact as a result of this impingement. An impact of this type may be defined as damage that occurs whenever there is impingement of aquatic organisms as a result of the operation of a cooling water intake structure. Impingement, in the most general sense, refers to the physical "pinning" of objects (such as fish) onto the intake screens of facilities that utilize natural bodies of water for cooling. These objects are subsequently washed from the screens as filtered material.

Impingement studies generally involve the collection and examination of screen-washed materials, counting and/or weighing this material, and generating species lists of the impinged organisms. This type of data collection and analysis has resulted in the frequent synonomous use of the terms "impingement" and "mortality". These terms, however, are quite different. Mortality connotes the death of an organism, irregardless of cause. Impingement asserts that an object was present on the filter screens, with no reference to the cause of death. "Impingement mortality", on the other hand, refers to mortality caused by the action of the filter screens or as a result of plant operation following impingement. Thus, only the "impingement mortality" portion of the total impingement that occurs at an electric generating facility, may be construed to cause an adverse environmental impact.

In the literature, estimates of fish mortality resulting from impingement vary considerably. For example, Manny (1984) assumed a 100% mortality level for fishes removed by intake structures. Mather et al. (1977), however, suggested that sport fish losses from impingement effects were approximately equal to losses which would be incurred by the activities of a few anglers fishing daily over the same impingement period. Thus, Mathur et al. (1977) felt that the annual loss of sport fish from impingement was not serious.

Fishes collected from the intake channel and screenwash operations often differ in biological condition. Channel collections usually include active fishes in good physical condition. In contrast, fishes collected from screenwash samples are generally in poor condition, and often exhibit varying degrees of disease, fungal infection, body damage or decomposition. Furthermore, large schools of fish may inhabit the intake channel without becoming impinged. Impingement samples often do not contain the same species that are abundant in intake channels. These observations suggest that fishes entering the intake channel are not necessarily impinged.

Thurber and Jude (1985) reached this conclusion in their investigation of impingement at a nuclear-powered generating facility. These data and observations suggest that fishes which become impinged may be suffering some sort of physical (biological) impairment prior to impingement. For example, Bardarik et al. (1973) examined impingement at the Erie generating station in Presque Isle Bay and noted that many of the impinged fishes were in a state of decomposition. The authors suggested that considerable fish mortality occurred prior to impingement. Thurber and Jude (1985) and Thomas (1984), studying other generating facilities, also suggested that some of the impinged fishes may have been dead prior to impingement.

The observation of fishes in poor condition in screenwash samples suggests that natural mortality may contribute significantly to the mortality numbers estimated at industrial and municipal facilities. Investigations of natural mortality in fishes have demonstrated that death occurs in all age classes of a species, varies on a seasonal basis, and may result from numerous sources. For example, temperature conditions during autumn and winter can result in the death of more than 30% of the young-of-the-year age class of some fish populations (Latta 1963, Oliver and Holeton 1979). Rising water temperatures in spring may result in an increased virulence for some fungal and bacterial fish pathogens (Ribelin and Migaki 1975). Spawning has been shown to be a very stressful event for numerous fish species, often resulting in various degrees of mortality. Severe spawning mortality has been documented for many species, and in some species (i.e. smelt) few adults survive the spawning period (Murawski and Cole 1978, Scott and Crossman 1973).

It is evident from the previous discussion that the observed impingement at any generating facility could include healthy fishes and also fishes which are dead or dying. These latter individuals would drift into the intake channel and become impinged. Therefore, 316(b) impingement reports should separate and identify the causes of death in impinged fishes, and also distinguish between impingement and non-impingement mortality. Few studies, however, have actually examined impingement in this manner. As a result, the relative contributions of natural and impingement mortalities to total fish impingement numbers is largely unknown.

Previous 316(b) impingement studies conducted at the Cleveland Electric Illuminating Co. (CEI) facilities at Eastlake (Applied Biology 1979a) and Avon Lake (Applied Biology 1979b) did not differentiate between actual impingement mortality and mortality due to other factors. Therefore, Environmental Resource Associates, Inc., was asked by CEI to reevaluate fish impingement at these facilities and determine the relative contributions of plant-induced and natural mortality to the total impingement at these facilities. Specifically, this study was designed to determine: 1) the biological condition of the impinged fishes; 2) the species composition of the impinged fishes; and 3) the most likely cause of mortality of dead and dying impinged fishes. This report presents the findings of this study.

SITE DESCRIPTIONS

Avon Lake Facility

The Avon Lake plant is a coal-fired electric generating station located on the south shore of Lake Erie in the city of Avon Lake, Ohio, approximately 30 miles west of the city of Cleveland. This facility has nine steam-electric generating units with a demonstrated total gross generating capacity of 1344 megawatts. Not all units were in operation during the course of this study.

Cooling waters for this facility are drawn from Lake Erie into an open intake channel approximately 1200 ft long and 200 ft wide. The once-through cooling system discharges into Lake Erie through a channel located to the west of the intake channel. The maximum cooling water flow through the plant is approximately 1,600,000 gpm.

A screen house is located at the plant end of the intake channel. Water enters under the screen house wall, passes through the screens and enters the plant. No obstructions of any kind (i.e. forbays, lift pumps) are present in the intake channel, thus allowing for the free movement of fishes between Lake Erie and the face of the screens in the screen house. The screen house contains 14 conventional traveling screens (3/8-inch diameter mesh) which are employed to prevent fish and debris (i.e. tree limbs, bottles, leaves) from entering the condensers along with the cooling water. In general, the screens are rotated once every eight hours, but may be operated continuously or manually as needed. Fish and debris collected on the screens are backwashed into a sluiceway leading from the screen house and are returned to Lake Erie via the cooling water discharge channel.

Eastlake Facility

The Eastlake facility is a coal-fired generating station located on the south shore of Lake Erie at the city of Eastlake, Ohio, immediately west of the mouth of the Chagrin River and approximately 15 miles east of the city of Cleveland. This plant has five steam-electric generating units with a demonstrated total gross generating capacity of 1372 megawatts.

Cooling waters for this plant are drawn from Lake Erie into an open intake channel approximately 1200 ft long and 150 ft. wide. The once-through cooling system discharges into Lake Erie via a discharge channel located immediately east of the intake channel. The maximum cooling water flow through the plant is approximately 1,300,000 gpm.

A screen house is located at the plant end of the intake channel, and there are no obstructions in the channel which may hinder movement of fishes between Lake Erie and the screen house. Twelve conventional travelling screens (3/8-inch diameter mesh) are located within the screen house and are employed to prevent fish and debris from entering the condensers. The screens may be operated manually or automatically. During low impingement periods, the screens are rotated once every eight hours. Fish and debris collected by the screens are backwashed into a sluiceway leading from the screen house to the discharge channel, and are returned to Lake Erie.

METHODS

Fish Collection

Sampling of screen-washed impinged fishes was conducted at each generating facility bi-weekly, from March 3, 1983 to October 28, 1983. Prior to actual sampling, all screens were washed of fish and debris, and impingement was allowed to occur for one hour. This ensured that fishes collected during sampling had been impinged on the screens for no more than one hour, thereby allowing for a more accurate assessment of the biological condition (see next section) of the impinged individuals. Following the impingement period, screens were individually washed for five minutes. This screen washing time was selected based on the results of an earlier pilot study which determined that no significant additional data would be collected utilizing a longer washing time.

Impinged fishes were removed from the sluiceways of the screenhouses prior to discharge to the outfall channel with use of box-nets and dipnets. A box-net (1/2-inch diameter mesh) was placed into the sluiceway and allowed to fill with impinged materials. Before removal of this net, a dipnet (3/16-inch diameter mesh) was placed immediately behind the box-net. When full, the box-net was removed and the collected fish and debris placed into 86-quart coolers filled with screenwash water. The box-net was returned to the sluiceway and the dip-net was then removed, emptied, and returned. This procedure ensured that there was always a net present in the sluiceway while fish samples were removed, and was repeated throughout the sampling period. Immediately following collection, fishes were classified according to species and biological condition.

When the numbers of fish impinged and subsequently washed from the screens were so large as to preclude a complete on-site examination, collected fishes were classified by condition, sorted by species, and then bagged, frozen, and returned to the laboratory of Environmental Resource Associates for processing at a later time.

<u>**Classification of Condition**</u>

Following collection, impinged fishes were identified to species, visually examined and classified into one of the following categories:

Alive: some movement evident (i.e. fins, gill covers, mouth, body),

Recently Dead: No movement evident, body in good condition, and gills bright red in color,

Dead: no movement evident, body pale, rigor mortis present, and gills pink or white in color,

Decomposing: some degree of decomposition of the body evident.

The alive category represents fishes that survived the impingement and screen washing, and would have been alive upon discharge to the outfall channel. It should be noted that this category included, in many instances, fishes of very poor condition that exhibited only minor movements. The Recently Dead category consisted of individuals that may have died immediately prior to impingement or during the impingement period. These two categories of individuals represent a potential impingement mortality fraction of the impinged fishes. The Dead and Decomposing categories include fishes that had been dead at least several hours prior to impingement, and therefore could not have suffered mortality due to impingement, (Figure 1).

Following classification, fish in the Alive category were immediately placed into 19-liter containers of outfall channel water. This procedure simulated the discharge of living, screen-washed fishes into the thermally enriched outfall channel. After a ten-minute holding time, the fish were examined and individuals still living and active were further classified as survivors. Thus, the survivor category represents fishes that would have survived impingement, screenwashing, and discharge into the outfall channel. These individuals could not be considered as a portion of the impingement mortality.

PATHOLOGICAL CONDITIONS

Following fish classification on the basis of general biological condition, live and recently dead fish were further examined for the presence of pathogens (i.e. fungus), body damage (such as wounds, imbedded hooks, and lacerations), and parasitic infections. Singly or in combination, the presence of these conditions would result in the death of a fish, and represents an avenue of mortality not directly related to plant impingement. Estimates of mortality were based on gross examinations only, and did not include possible mortalities resulting from less visible but no less harmful causes such as virus infections, internal parasites and carcinomas (Ribelin and Migaki 1975, Bauman 1984, White 1986). For example, White (1986) examined impinged fishes at a Lake Erie generating facility and found that a large percentage of impinged fishes which externally appeared normal possessed numerous internally diagnosed terminal pathogenic conditions. Thus, the estimated degree of natural mortality for screenwashed fishes in the present study is to be considered overly conservative (i.e. underestimated).

Fungal Infections

Among the many freshwater fungi known to infect fishes, those of the genus *Saprolegnia* (22 described species) are very common and widespread. Infection by this fungus is readily diagnosed as a white, cotton-like fuzzy growth on the skin, fins, or head of the infected fish. Saprolegnia rapidly penetrates the tissues and bones of infected individuals, and is invariably fatal once 20% or more of the fishes body is infected (Hoffman 1967). Tiffany (1939) has reported this fungus to be a primary pathogen and that its pathogenicity is enhanced in cold temperatures. Furthermore, Saprolegnia has been reported to have induced major mortalities of fishes in some lakes (Rothschild 1966, Brown 1968). This pathogen is closely associated with post-spawn mortality in some species, affecting fishes which exhibit spawning behaviors that expose epidermal tissue to fungal attack by removing the natural protective mucus layer of the skin. Such spawning activities may include nest excavation, male-female clasping, (Figure 2), and male territorial combat.

Parasitic Infections

Under natural conditions, it is not unusual for a healthy fish to be harboring some form of parasite. A wide variety of worms, leeches, and protozoa may be found in and on fishes, and generally have little or no effect on fish survival. However, if the parasite population associated with a fish becomes excessive, mortality or increased susceptability to secondary infection may result. In the present study, collected fishes were examined for three primary pathogenic parasite infestations: 1) Ligula intestinalis in the body cavity, 2) exopthalmos of the eyes, and 3) Glugea hertwegi, a pathogen of young smelt.

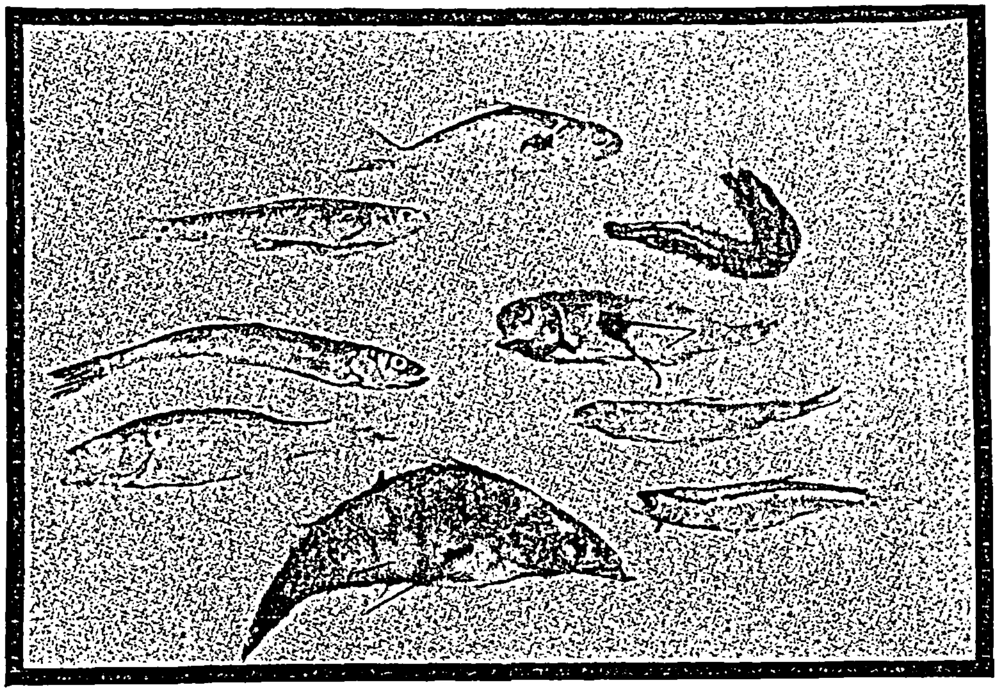


Figure 1: Typical examples of dead and decomposing fishes from screenwash: includes shad, smelt, yellow perch, drum, trout/perch, white bass, emerald and spottail shiners, and an unidentified carcass.

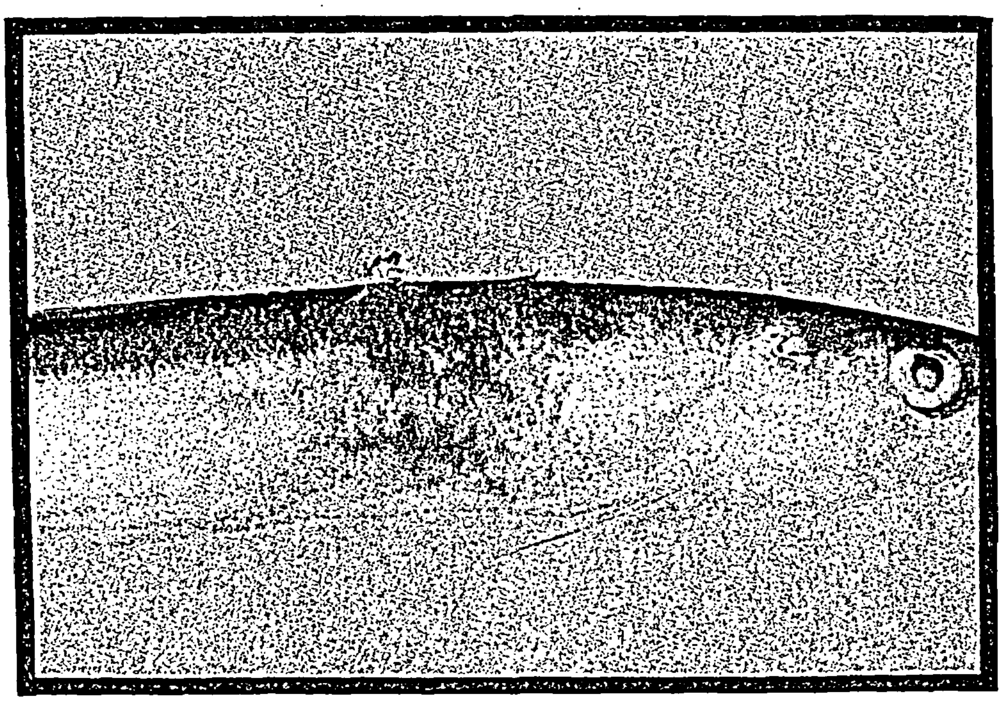


Figure 2: Dying female rainbow smelt with a typical post-spawning related fungal infection.

Ligula intestinalis

The genus Ligula represents a common tapeworm of gulls and freshwater fishes, which serve as the intermediate host for this organism. A wide variety of pisciverous birds act as the final host. Unless present in very large numbers, Ligula has little effect on birds. The ova of Ligula leave the host bird via fecal droppings and the larvae are consumed by copepods. Following ingestion of an infected copepod by a fish, Ligula burrows through the intestinal wall, enters the body cavity, and begins to grow. The phenomenal growth of this internal parasite results in a progressively distended abdomen in the fish. Often, the reproductive organs of the fish are destroyed during the growth stage of the parasite, and in the final stages, the larval tapeworm burrows through the body wall, killing the fish. As many as six tapeworms may simultaneously be inhabiting a single minnow, with individual Ligula attaining a length of 200-300 millimeters. The greatly distended belly of an infected fish impairs swimming and maneuvering abilities, and affects orientation. Infestation with Ligula will result in direct mortality of the infected fish, which is then followed by consumption by birds. Ligula in Lake Erie is a common primary pathogen of the spottail shiner, Notropis hudsonius, and the trout-perch, Percopsis omiscomaycus.

Exopthalmia

This condition is evidenced by greatly enlarged and protruding eyes, and may be caused by a wide variety of pathogenic organisms, including the bacteria Aeromonas, Flavobacter, Pseudomonas, and Vibrio, and also trematodes and nematodes. These pathogens cause hemorrhaging and swelling of the eyes, and will result in blindness and eventually death, (Figure 3). In Lake Erie, the nematode Philometra is responsible for exophthalmic mortality in young freshwater drum (Crites, personal communication).

Sporozoan Infestations

Two major types of sporozoans are known to attack fishes; myxosporidians and microsporidians. The general response of fishes to sporozoan infection is to form cysts around the invading organisms. When produced, the cysts are often clumped together into large, grape-like tumors which may cause serious deformation of the body and/or dysfunction of internal organs. Some sporozoans produce infections which are manifest as discolored muscle myomeres, visible through the skin. These bands represent atrophied muscle tissue and are associated with a weakening of swimming ability.

A microsporidian parasite common to Lake Erie is *Glugea hertwegi*. Infection by this parasite produces white cysts attached to the gonads, intestinal tract, and elsewhere in the body. In extreme infections, the cysts invade muscle tissue (Scott and Crossman 1973). These internal cysts are clearly visible through the body wall of small YOY smelt, thus were readily diagnosed with external examination.

Other Mortality

Bacterial infections, including *Aeromonas*, *Columnaris*, and others are often manifest as lesions on the external surface. Some of these infections cause a characteristic deterioration of epidermis or the fins. Fin and tail rot were commonly observed, (Figures 4 and 6) and were recorded as bacterial infections. All of the above mentioned pathogens are highly virile and cause significant mortalities in both nature and in hatchery stocks.

In addition, a wide variety of non-plant activities will

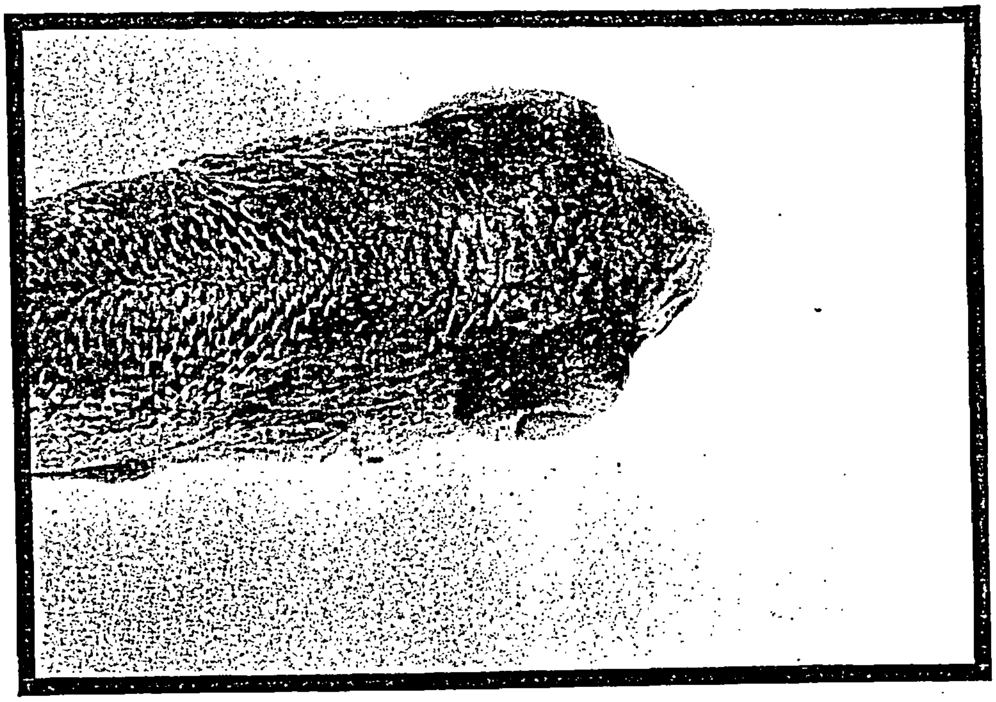


Figure 3: A young drum dying from exophthalmia caused by an infection with <u>Philometra sp</u>.

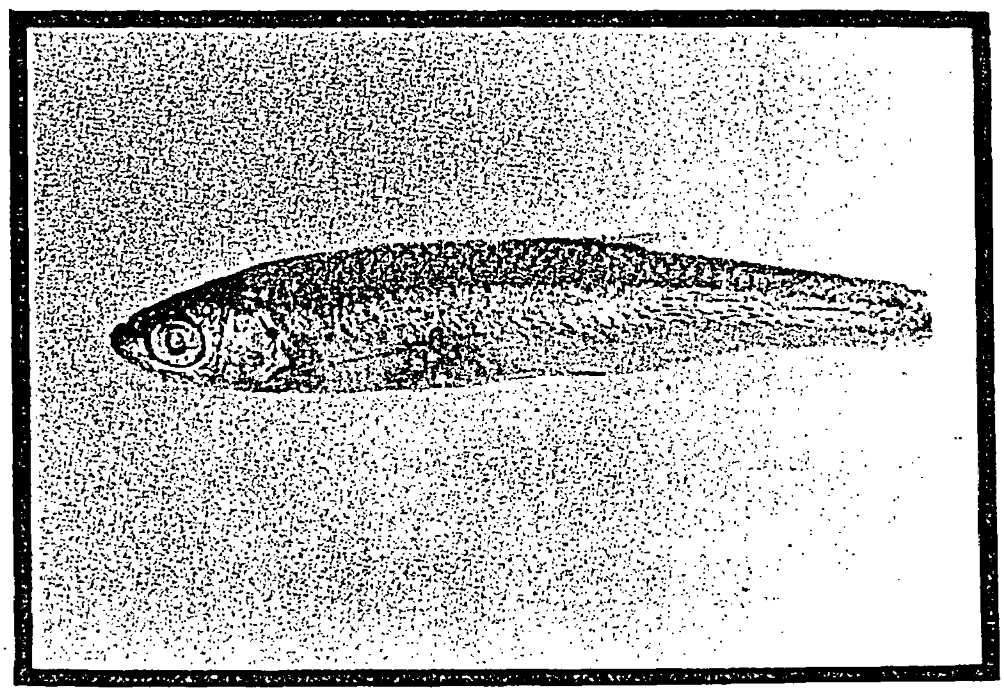


Figure 4: Tail rot and additional scale-loss due to multiple bacterial infection in an emerald shiner.

result in inducing fish mortality. For example, although the sea lamprey is well known for its ability to kill fish, many fish survive and carry wounds and scars of aborted lamprey attacks. These aborted attacks often result in secondary bacterial and fungal infections which may later induce mortality. Sportfishing is another potentially important avenue of fish mortality. Anglers often release small or unwanted individuals, accidentally hook many different species while "snagging", catch but fail to land fishes (Figure 5), and unknowingly drive boats through schools of fishes causing propeller damage. These activities will cause injury to the fish and often lead to secondary infections with fungal and/or bacterial agents. In the present study, a wide variety of "Other Mortality" was encountered. These fish, however, were usually recorded as suffering from terminal fungal infections.

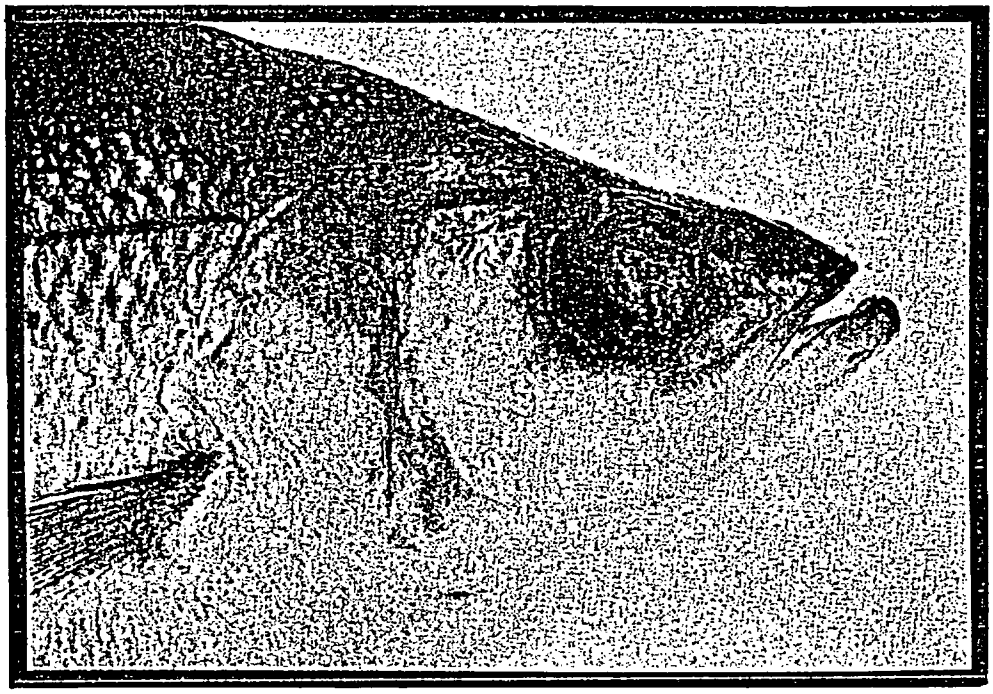


Figure 5: A dying white bass with fish hook damage and subsequent loss of the eye. An angler-induced mortality.

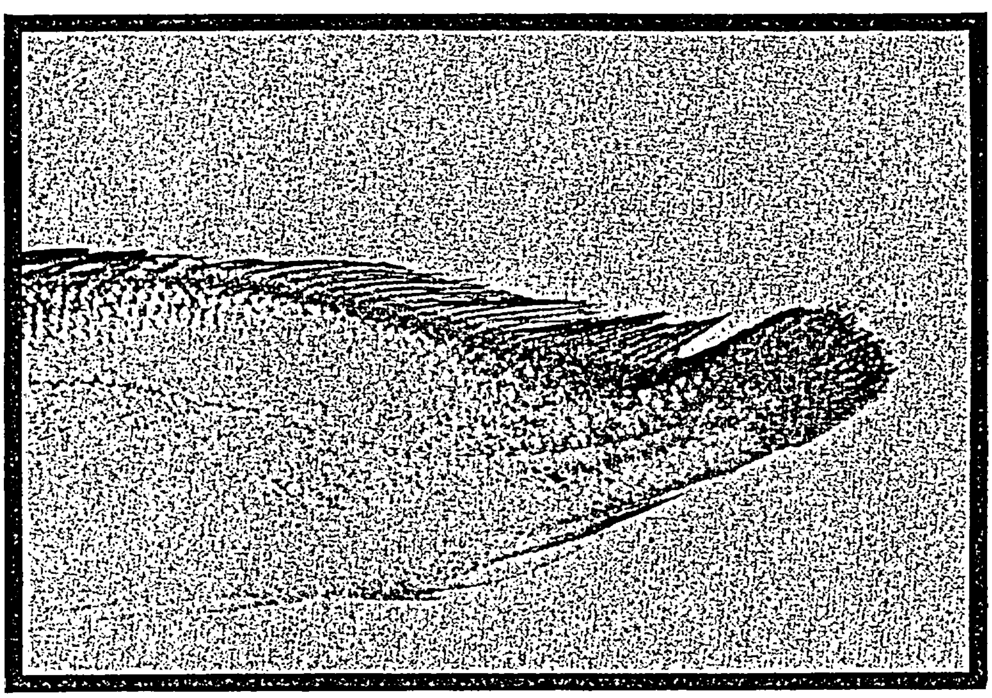


Figure 6: A terminal tail rot infection in a YOY drum.

RESULTS

Species and Numbers Collected

The present study was designed to examine the condition of impinged fishes at the Avon Lake and Eastlake generating facilities in order to ascertain the relative contributions of impingement mortality and natural mortality. Gizzard shad were collected during this study, but were not included in the mortality estimates. White et al. (1986) examined winter mortality in the gizzard shad and reported on the natural causes of terminal physiological failure in this species during winter and spring impingements occurring at the Avon Lake and Eastlake facilities. In the present study, the majority of the gizzard shad were collected in spring (March, April and May). These fishes were almost exclusively young-of-the-year individuals, and they exhibited the typical symptoms associated with natural winter and spring mortality reported by White et al. (1986). Therefore, all gizzard shad have been removed from the impingement data discussed in the remainder of this report.

It should be noted that the gizzard shad represents the majority of fishes impinged at both facilities, thus the mortality estimates in the present study should not be viewed as annual impingement. The gizzard shad represents approximately 77% of the total yearly impingement at each facility (Applied Biology 1979a, 1979b). Thus, the fishes collected and examined in the present study represent approximately 23% of the total annual impingement occurring at these facilities.

A total of 27,374 fishes representing 29 species were collected and examined during the present study. No rare or endangered species were collected at either power facility. Twenty-seven species were encountered at the Eastlake facility and 26 species were encountered at the Avon Lake facility. The rockbass, smallmouth blackbass, brook stickleback, and longnose dace were collected only at the Eastlake facility; the pumpkinseed sunfish and golden shiner were collected only at the Avon Lake facility. The ten most abundant species (in descending order of numerical abundance) were the 1) rainbow smelt, 2) emerald shiner, 3) freshwater drum, 4) spottail shiner, 5) white bass, 6) white perch, 7) alewife, 8) troutperch, 9) yellow perch, and 10) logperch darter.

A total of 13,343 fishes representing 27 species were collected at the Eastlake facility during the study period (Table 1). At the Avon Lake facility, 14,031 fishes representing 26 species were collected (Table 2). The greatest number of species collected at the two locations in any single month occurred in April (24 species); the fewest species were collected in March (11 species). The greatest number of fishes were impinged in March and the fewest fishes in September. In general, total impingement was highest in spring and decreased through autumn.

At the Avon Lake facility, examination of collected fishes revealed 46.01% (6,455 fish) to have been dead for more than five hours prior to impingement and could not have been plant-induced mortalities. Dead and decomposing fishes comprised 42.46% (5,666 fish) of all fishes collected at the Eastlake facility. Examination of the live and recently dead fishes found 3,577 (25.49% of all fishes collected) at the Avon Lake facility to be dead or dying of causes which were not plant related. At the Eastlake facility, these individuals (4,553) accounted for 34.12% of all fishes collected at this locality during the present study. Therefore, only the remaining 23.64% (3,317 fish) of the total observed impingement at the Avon Lake facility and 19.54% (2,608 fish) at the Eastlake facility could be considered as possible plant-induced or impingement mortalities. These were live or recently dead fish for which no gross external pathology or impairment could be ascertained. White (1986) found large numbers of impinged fishes to be suffering from a wide variety of internal fungal, viral, bacterial or parasitic infections and carcinomas, all of which are known to be terminal pathogens. The extent of these pathologic conditions in the fishes examined in the present study is unknown, but probably represent a similarly large fraction of the estimated mortalities. During the present study, fish were examined only on an external and gross level, and no investigations for internal terminal pathogens were conducted. Thus, the impingement mortality estimates obtained in this study should be considered overly high, since portions of these estimates would also include fishes with internal terminal pathogenic conditions which were not diagnosed.

Table 1. Percent occurrence of fish species in the observed impingement at the Eastlake generating facility, March - October, 1983.

Species	Number Impinged	Occurrence
Rainbow Smelt	6,664	49.94%
Freshwater Drum	1,792	13.43%
Emerald Shiner	1,767	13.24%
Spottail Shiner	1,465	10.98%
White Bass	777	5.82%
White Perch	557	4.17%
Alewife	116	0.87%
Trout-perch	79	0.59%
Yellow Perch	48	0.36%
Logperch Darter	30	0.22%
White Crappie	7	0.05%
Coho Salmon	6	0.04%
White Sucker	5	0.04%
Mottled Sculpin	4	0.03%
Rockbass	4	0.03%
Bluegill Sunfish	3	0.02%
Rainbow Trout	3	0.02%
Channel Catfish	3	0.02%
Stonecat Madtom	3	0.02%
Walleye	2	0.01%
Carp	2	0.01%
Smallmouth Blackbass	1	<0.01%
Yellow Bullhead	1	<0.01%
Brook Stickleback	1	<0.01%
Largemouth Blackbass	1	<0.01%
Longnose Dace	1	<0.01%
Fathead Minnow	1	<0.01%

Table 2. Percent occurrence of fish species in the observed impingement at the Avon Lake generating facility, March - October, 1983.

Species	Number Impinged	Occurrence
Rainbow Smelt	6,477	46.16%
Emerald Shiner	3,816	27.20%
Freshwater Drum	1,359	9.69%
Spottail Shiner	1,203	8.57%
White Bass	402	2.86%
White Perch	382	2.72%
Alewife	111	0.79%
Yellow Perch	107	0.76%
Trout-perch	106	0.75%
Stonecat Madtom	17	0.12%
Fathead Minnow	9	0.06%
Logperch Darter	8	0.06%
Carp	5	0.04%
Walleye	5	0.04%
Channel Catfish	4	0.03%
Pumpkinseed Sunfish	3	0.02%
Goldfish	2	0.01%
Yellow Bullhead	2	0.01%
Bluegill Sunfish	2	0.01%
Rainbow Trout	2	0.01%
Mottled Sculpin	2	0.01%
White Crappie	2	0.01%
Coho Salmon	2	0.01%
Golden Shiner	1	<0.01%
Largemouth Blackbass	1	<0.01%
White Sucker	1	<0.01%

INDIVIDUAL SPECIES ACCOUNTS

RAINBOW SMELT

Osmerus mordax

The rainbow smelt was the most commonly collected species during the course of this study. A combined total of 13,141 individuals were collected and examined at the Avon Lake and Eastlake facilities, with nearly identical numbers occurring at the two facilities (6,664 fish at Eastlake; 6,477 fish at Avon Lake). Peak levels of rainbow smelt were encountered in spring. At the Eastlake facility, 78% of all rainbow smelt were collected in May; at Avon Lake, 87.2% were collected in this month. Minor rainbow smelt impingement peaks were evident in August at each facility (6.90% at Eastlake, 2.75% at Avon Lake). No rainbow smelt were collected in September or October at the Eastlake facility. At the Avon Lake facility, only six smelt were collected in these months.

Eastlake

At the Eastlake facility, 3,533 (53.01%) of the 6,664 rainbow smelt collected were dead prior to impingement. These fish, therefore, were not considered as a portion of the impingement mortality estimate for this species. The remaining 3,131 (46.99%) live and recently dead rainbow smelt potentially represent impingement mortality.

Examination of these remaining individuals revealed 1,257 (18.86% of all rainbow smelt collected) to be heavily infested with Saprolegnia fungal infections. These infections are considered invariably fatal (Hoffman 1967) thus; these infected fish should not be included in impingement mortality estimates. Sixty-one fish (0.92%) exhibited terminal infestations of Glugea, and an additional 199 individuals (2.99%) possessed both fungal and parasitic infections. These 1,517 fish should not be included in determinations of impingement mortality because each exhibited some form of terminal pathological condition. A total of 45 live rainbow smelt (0.68%) survived the simulated discharge into outfall water and represent fishes that survived the impingement process.

The remaining 1,569 live and recently dead rainbow smelt (23.54%) represent potential impingement mortality of this species. Many of these individuals, however, may be a reflection of the normal postspawning mortality suffered by this species and potentially can be removed from considerations of impingement mortality. The rainbow smelt spawns in late spring and early summer, and has been reported to exhibit pronounced postspawning mortality in Lake Erie during May (i.e. Scott and Crossman 1973, Baker 1984). In the Great Lakes, normal habitat of this species is relatively deep water (80 ft); in spring this species moves to nearshore spawning areas (Rupp 1965). The greater frequency of impingement of rainbow smelt in spring and the relative absence of this species in summer and autumn at the Eastlake facility may be a reflection of movements of smelt in the vicinity of the Eastlake generating plant. Of the 1,569 fish representing potential impingement mortality, 1,050 were collected in May. Because most of these fish were spawning or post-spawn adults, it is highly probable that the mortality of these individuals was spawning-related and not plant-induced. No discernable cause of mortality was evident for the remaining 519 rainbow smelt (7.78% of all smelt collected). These were primarily young-of-the-year (YOY) fish collected in late summer.

Avon Lake

A total of 6,477 rainbow smelt were collected at the Avon Lake facility during this study. Of these, 3,898 (60.18%) were dead for at least five hours prior to impingement and, therefore, were not considered as representing impingement mortality. The remaining 2,579 live and recently dead rainbow smelt (39.82%) represent potential impingement mortality.

Examination of these individuals found 1,040 rainbow smelt (16.06% of all smelt collected) to be suffering terminal Saprolegnia infections. An additional 68 fish (1.05%) had infections of the parasite Glugea, and 106 rainbow smelt (1.64%) suffered from both terminal fungal and parasitic infections. A total of 97 live rainbow smelt survived outfall water exposure. These 1,311 fish represent individuals that either survived impingement or were dead or dying from terminal pathogenic conditions, and should be excluded from impingement mortality estimates. The remaining 1,268 live and recently dead rainbow smelt (19.58% of all smelt collected) represent the potential impingement mortality of rainbow smelt at the Avon Lake facility.

A large proportion of the potential impingement mortality estimated at the Avon Lake facility was, as at the Eastlake facility, considered to be a result of normal postspawning mortality exhibited by this species (Scott and Crossman 1973). A total of 887 adult spawning and post-spawn rainbow smelt were collected in May, and may have been dead or dying from post-spawning stress. No obvious cause of mortality could be determined for the remaining 381 rainbow smelt. These fish, mostly YOY individuals impinged in late summer, represented 5.88% of all smelt collected during this study.

Figure 7. Flow diagram of impinged rainbow smelt, Eastlake generating facility, March - October, 1983.

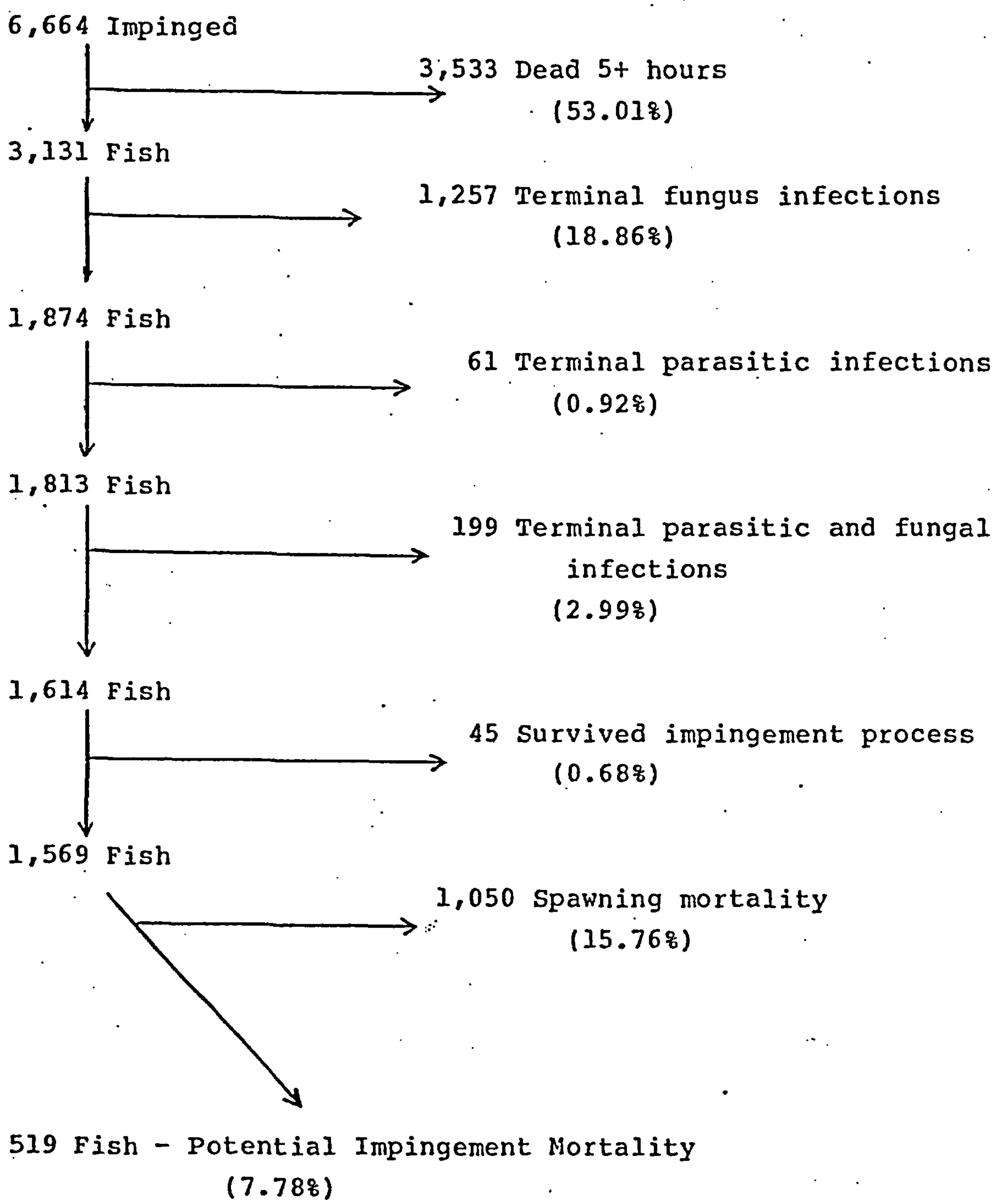
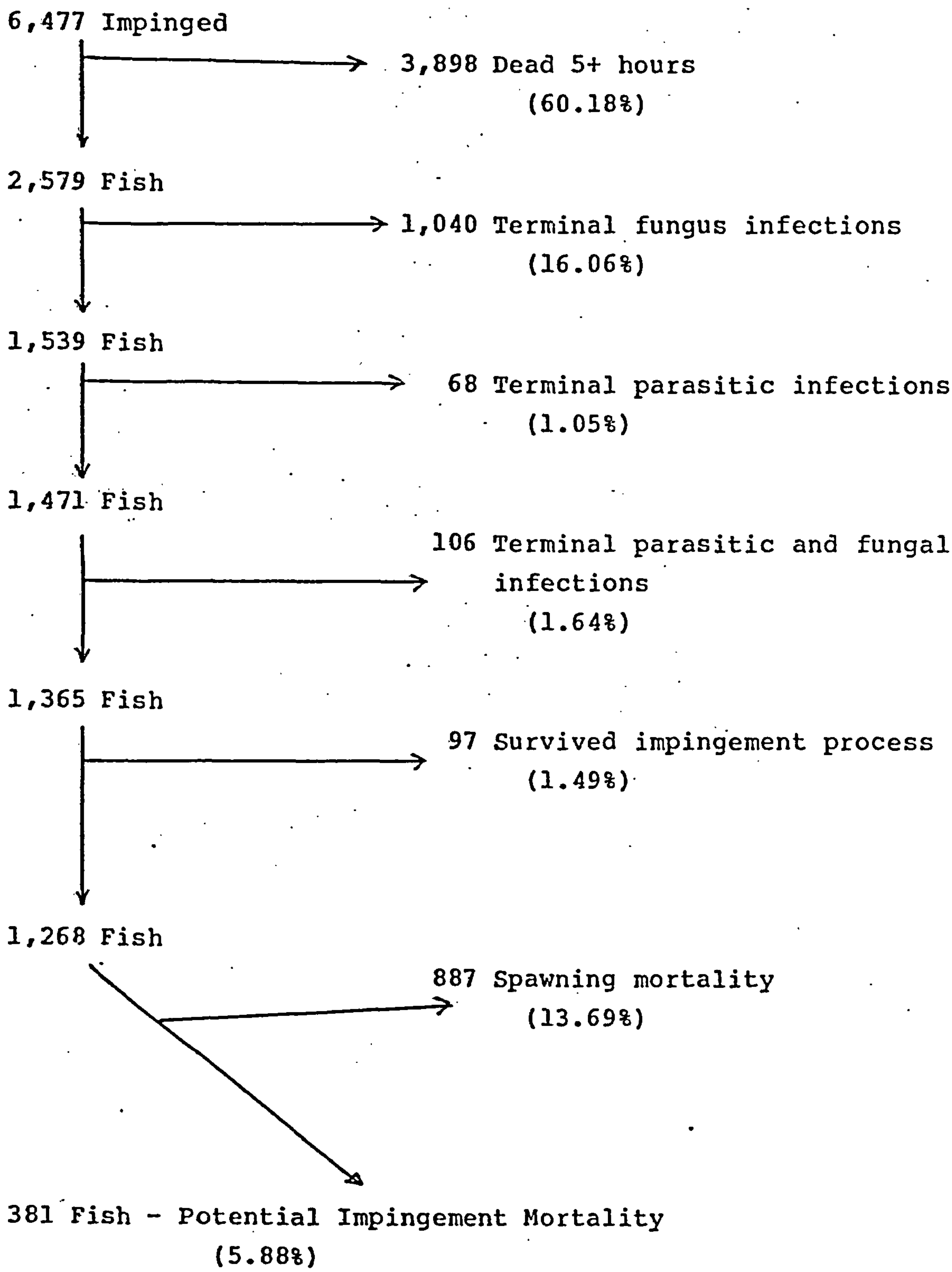


Figure 8. Flow diagram of impinged rainbow smelt, Avon Lake generating facility, March - October, 1983.



EMERALD SHINER

<u>Notropis atherinoides</u>

The emerald shiner was the second most abundant species collected during the present study. A total of 5,583 individuals were collected and examined at the two facilities, with nearly twice the number being collected at the Avon Lake plant (3,816 fish) as at the Eastlake facility (1,767 fish). However, the patterns of abundance at the two facilities were quite similar. At both facilities, peak levels of emerald shiners were encountered in spring (especially March and April). Lowest numbers of emerald shiners were collected in September and October.

<u>Eastlake</u>

A total of 487 (27.56%) of the 1,767 emerald shiners collected during this study had been dead prior to impingement; These fish were not included in the estimate of impingement mortality. The remaining 1,280 live and recently dead fish potentially represent impingement mortality.

Upon examination of these 1,280 emerald shiners, 85 (4.81% of all emerald shiners collected) exhibited terminal fungal infections, and a single individual was found to possess a terminal parasitic infestation. These individuals were excluded from consideration as impingement mortality. An additional 260 emerald shiners (14.71%) were in an apparently healthy condition and survived exposure to heated outfall water. The remaining 934 shiners (52.86%) represent the potential impingement mortality for this species at the Eastlake facility.

Avon Lake

A total of 3,816 emerald shiners were collected and examined at the Avon Lake generating facility. A total of 1,198 fish (31.39%) were found to be in dead or decomposing conditions, and were removed from consideration as impingement mortalities. Further examination of the remaining 2,618 live and recently dead emerald shiners revealed that 49 specimens (1.28%) possessed terminal fungal infections. A total of 479 live emerald shiners (12.55% of all emerald shiners collected) survived the simulated discharge into outfall water. The remaining 2,090 fish (54.77%) potentially represent individuals incurring impingement mortality.

Interestingly, this potential mortality estimate (54.77%) is very similar to the estimate determined for the emerald shiner at the Eastlake facility (52.86%). Furthermore, these estimates are very similar to the mortality estimate (55.20%) obtained at another Lake Erie power plant by White (1986). The relatively high degrees of impingement reported for this species by White (1986) and observed in the present study were strongly dependant upon the impingement of a large number of emerald shiners during a short time period. This species, however, typically inhabits the intake channels throughout autumn and winter (per. obs.), and impingement of this fish is low at these times. Thus, the cause of the impingement of the emerald shiner reported in this study may not be a result of plant operation, but a natural causative agent has not as yet been identified.

Figure 9. Flow diagram of impinged emerald shiners, Eastlake generating facility, March - October, 1983.

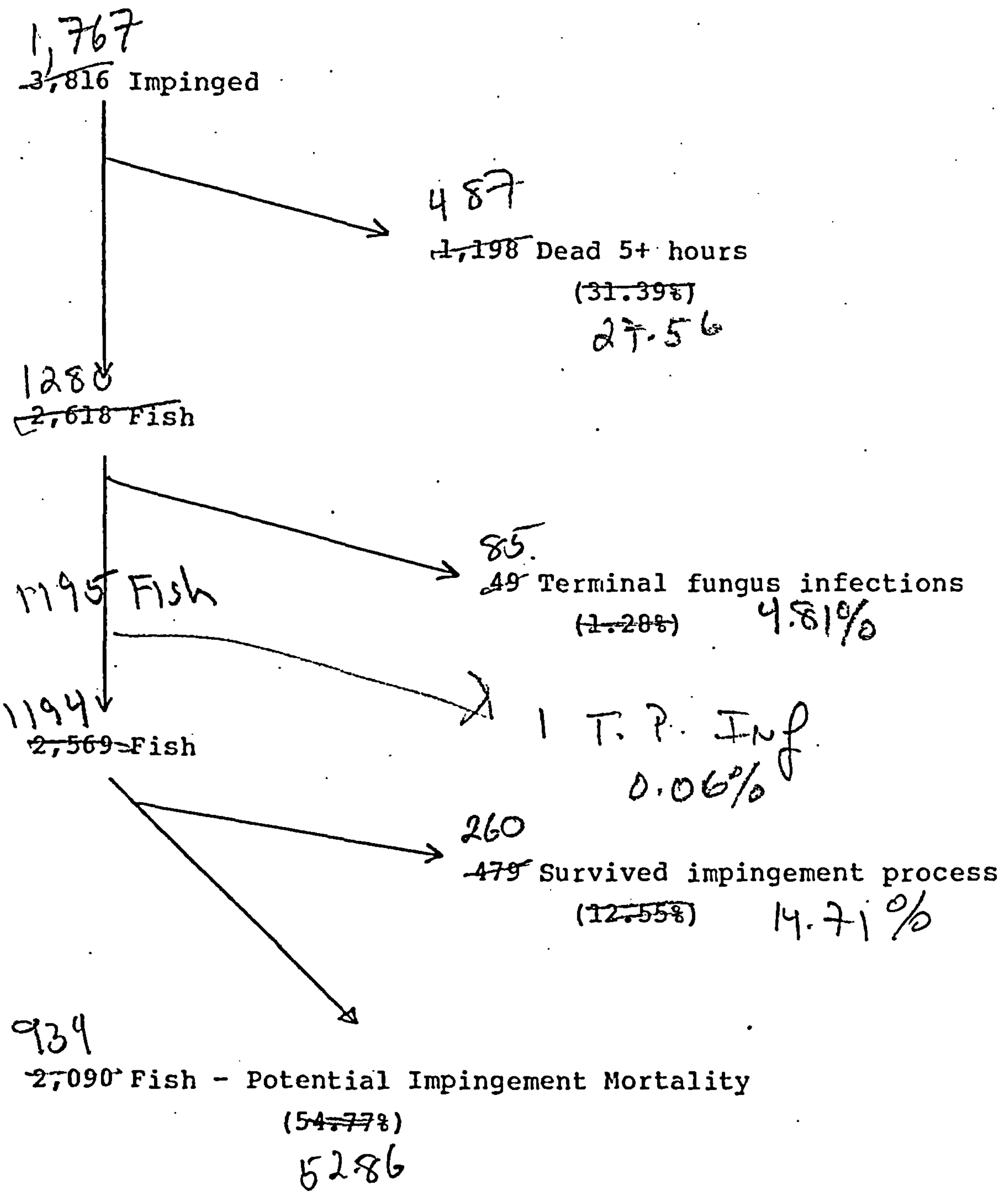
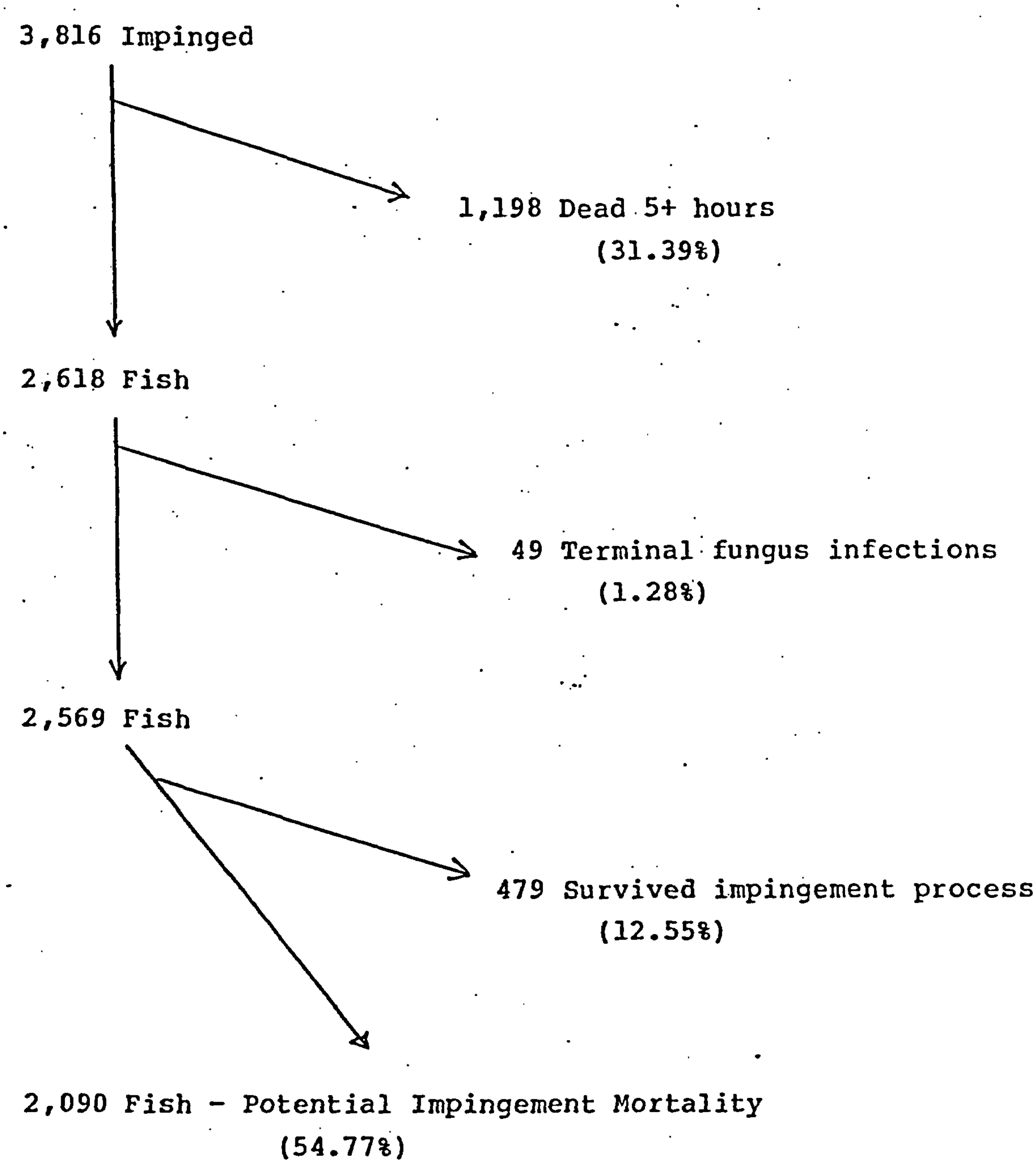


Figure 10. Flow diagram of impinged emerald shiners, Avon Lake generating facility, March - October, 1983.



FRESHWATER DRUM (Sheepshead)

Aplodinotus grunniens

The freshwater drum was the second most abundant species collected at the Eastlake facility (1,792 individuals representing 13.43% of the total observed impingement), and the third most abundant (1,359 fish, 9.69%) at the Avon Lake facility. Peak impingement at both facilities occurred in May and June (greater than 80% of all drum collected), and decreased through the remainder of the study period. White (1986) reported that at another Lake Erie generating facility, more than 50% of the drum impingement also occurred in May and June. In October, only 8 individuals were encountered at the two facilities. Many of the freshwater drum examined showed evidence of angler damage. Impinged individuals of this species have been found to suffer from a wide variety of pathologic conditions, such as nematode infections, tumors, lamprey attack, starvation, and hyperparasitism with gill flukes (White 1986).

Eastlake

A total of 1,792 freshwater drum were collected at the Eastlake facility during this study. Examination revealed 980 fish (54.69%) to have been dead prior to being impinged; these fish were excluded from impingement mortality estimates. The remaining 812 individuals represent the potential impingement mortality of this species at the Eastlake facility. However, many of these fish exhibited symptoms of non-plant mortalities. A total of 183 drum (10.21% of all drum collected) possessed terminal fungal infections and 163 individuals (9.09%) were parasitized, primarily with the exophthalmia causative pathogen *Philometra*. An additional 35 fish (1.95%) had both fungal and parasitic infestations. A total of 63 live fish survived exposure to the warm outfall water. No readily apparent cause of mortality could be determined from the external examination of the remaining 368 (20.54%) freshwater drum.

Avon Lake

During the present study, 1,359 freshwater drum were collected at the Avon Lake facility, of which more than 50% had been dead prior to impingement (766 fish representing 56.37%). Inspection of the remaining 593 individuals found 111 fish (8.17% of the total drum collected) to possess terminal fungal infections and 104 (7.65%) to be heavily parasitized, primarily with Philometra. An additional 23 individuals (1.69%) were infected with both fungal and parasitic pathogens. A total of 29 freshwater drum survived exposure to outfall water. The remaining 326 fish (23.99%) represent potential impingement mortality, with no apparent cause of mortality evident upon gross external examination.

Figure 11. Flow diagram of impinged freshwater drum, Eastlake generating facility, March - October, 1983.

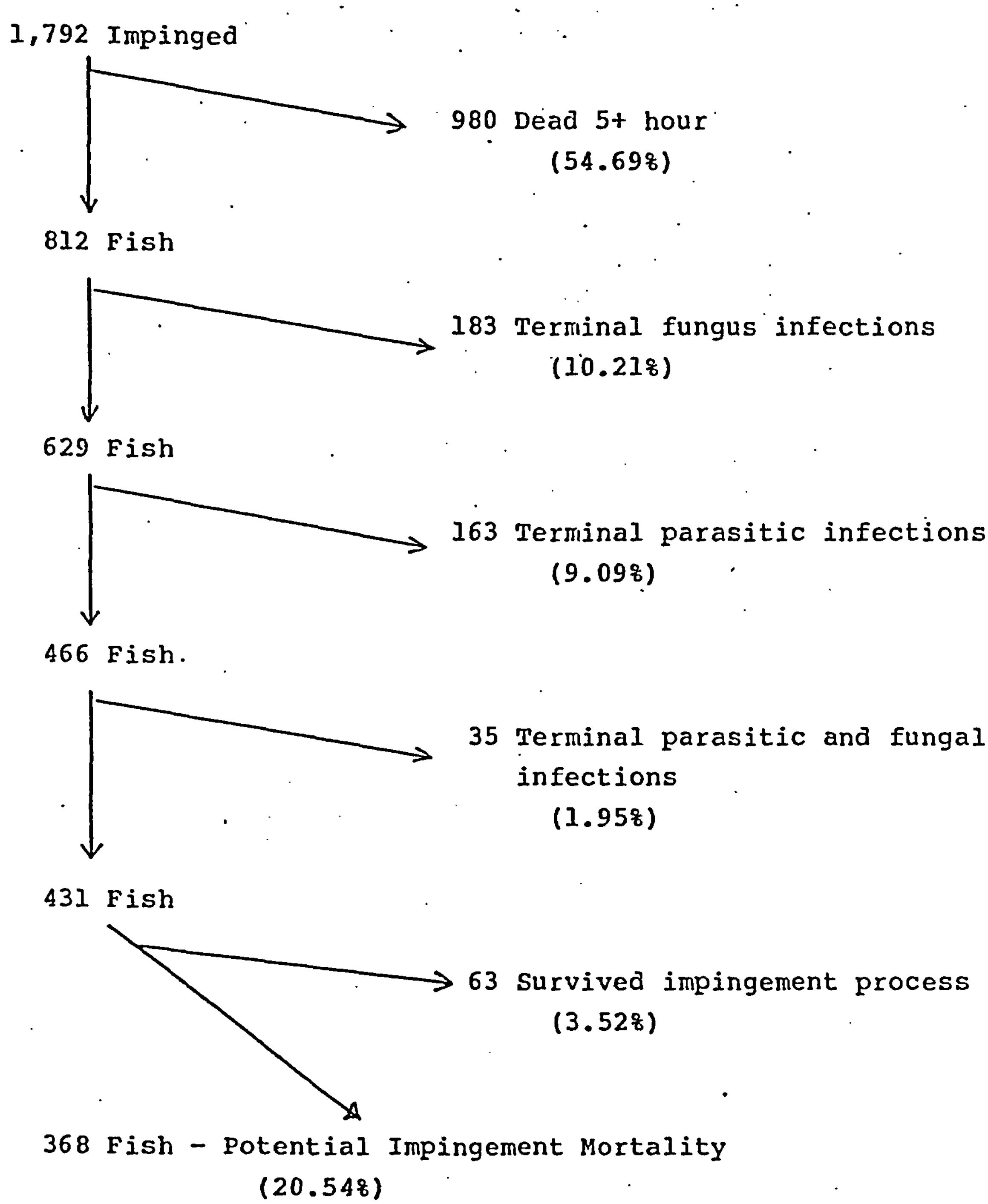
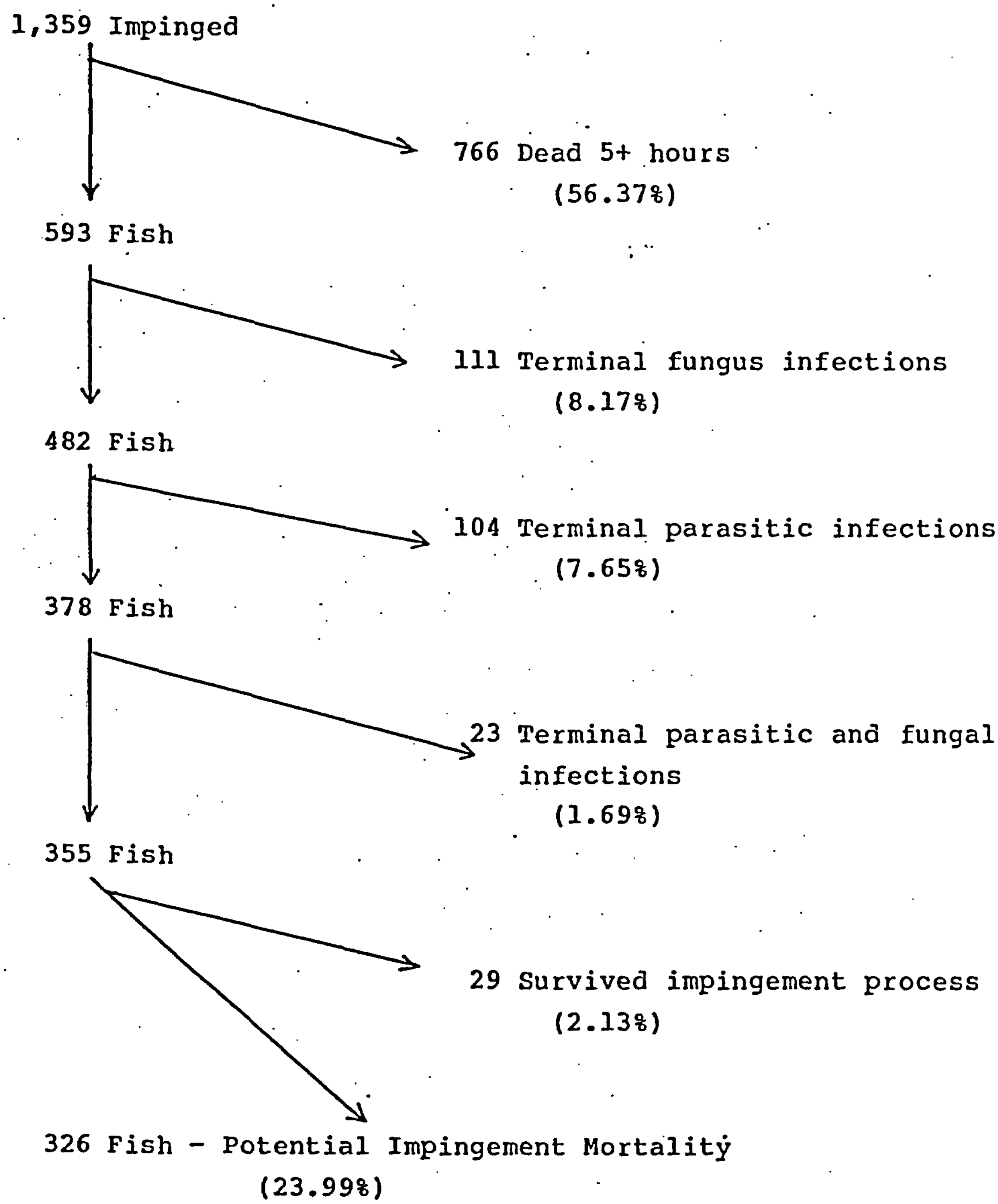


Figure 12. Flow diagram of impinged freshwater drum, Avon Lake generating facility, March - October, 1983.



SPOTTAIL SHINER

Notropis hudsonius

The spottail shiner was the fourth most abundant species encountered during the present study, with 2,668 individuals being collected and examined. The patterns of impingement exhibited by this species were similar between the two generating facilities, with peak impingements occurring in spring. More than 85% of all spottail shiners were collected in March, April, and May. These peaks of impingement correspond with the reported spawning period of the spottail shiner. In Lake Erie, this species has been reported to spawn in nearshore areas of sand and gravel in spring and early summer (Scott and Crossman 1973).

Eastlake

A total of 1,465 spottail shiners were collected at the Eastlake generating facility. This species represented 10.98% of the total observed impingement, and was the fourth most abundant species encountered. A total of 226 fish (15.43% of all spottail shiners collected at the Eastlake facility) were dead prior to impingement, and were not included in estimating impingement mortality. The remaining 1,239 live and recently dead individuals, however, potentially represents impingement mortality.

Further examination revealed 1,116 fish (76.18% of all spottails collected) to have terminal infections of Ligula. This species has been reported to suffer major infestation of this parasite (Bangham 1955). An additional 5 individuals (0.34%) possessed terminal fungal infections, and 9 spottail shiners (0.61%) exhibited both terminal fungal and parasitic infections. Eighteen fish (1.23%) survived exposure to outfall water. No apparent cause of mortality was evident for the remaining 91 spottail shiners upon gross external examination. These fish accounted for 6.21% of the total observed spottail impingement at the Eastlake facility, and represent potential impingement mortality.

Avon Lake

At the Avon Lake facility, the spottail shiner was the fourth most abundant species collected. This species represented 8.57% of the total observed impingement at this facility during the present study. A total of 1,203 spottail shiners were collected, 185 (15.38%) of which had been dead prior to impingement. These individuals, therefore, were not included in estimates of impingement mortality.

Examination of the remaining 1,018 live and recently dead spottail shiners found 890 individuals (representing 73.98% of all spottail shiners collected at Avon Lake) to possess terminal fungal infections, and an additional 10 specimens (0.83%) showed both terminal fungal and parasitic infections. A total of 30 live fish (2.49%) survived exposure to the outfall water. The remaining 44 spottail shiners, representing 3.66% of the total observed spottail shiner impingement, had no obvious cause of mortality. Therefore, these fish represent potential impingement mortality.

Figure 13. Flow diagram of impinged spottail shiners, Eastlake generating facility, March - October, 1983.

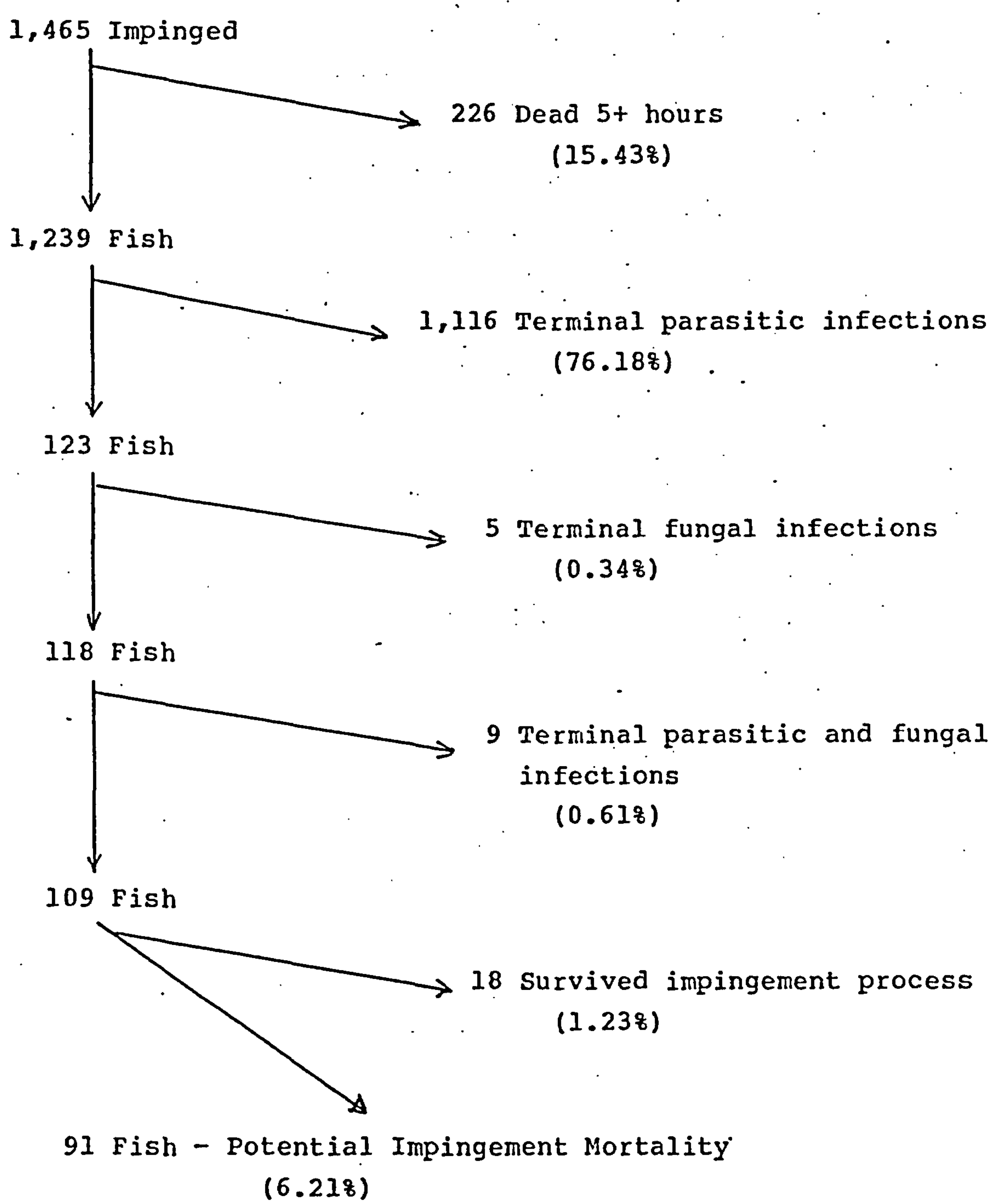
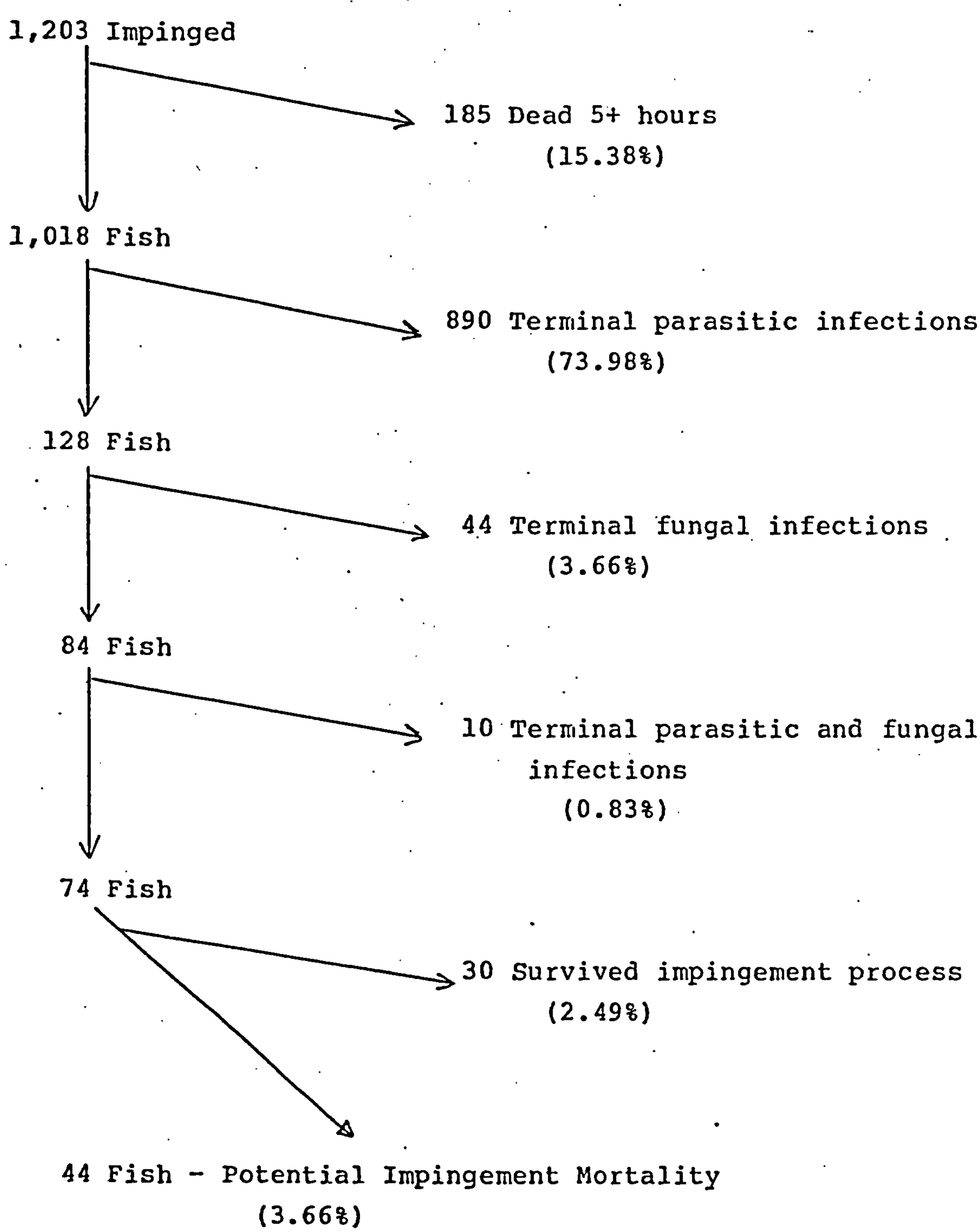


Figure 14. Flow diagram of impinged spottail shiners, Avon Lake generating facility, March - October, 1983.



WHITE BASS

Morone chrysops

A combined total of 1,179 white bass were collected during the present study. This species accounted for 4.31% of the total observed impingement and was the fifth most common species at each generating facility. Two peaks in observed impingement were evident during the present study, and the two peaks of impingement were temporally similar at the two facilities. At the Eastlake plant, the major impingement episode occurred in October, when 323 fish (representing 41.57% of all white bass collected at this locality) were collected. A slightly smaller impingement peak occurred in May and June (239 fish, 30.76%). The fish collected in October where primarily YOY individuals; white bass collected in May and June were principally spawning and post-spawn adults.

At the Avon Lake facility, peaks of collection also occurred in October and May-June. In contrast to the peak impingement periods observed at Eastlake, at Avon Lake the greatest observed impingement occurred in May and June. The 257 fish collected at this time represented 63.93% of all white bass collected at the Avon Lake facility, and consisted primarily of spawning and post-spawn adults. The smaller October impingement peak at Avon Lake totaled 51 specimens (all YOY) and accounted for 12.69% of the total observed white bass impingement.

Greater than 80% of the white bass collected at the two facilities in October were dead or dying YOY individuals. Unpublished studies by the Ohio Division of Wildlife, Sandusky Lab (Baker 1984) have reported almost 100% mortality of the smallest YOY white bass in Lake Erie populations. The high degree of mortality observed for small individuals collected in October during the present study is probably a reflection of the natural YOY fall mortality of the white bass.

Eastlake

The 777 white bass collected at the Eastlake facility accounted for 5.82% of the total impingement observed during this study. Examination of these individuals revealed 162 fish (20.85% of all white bass collected) to have been dead prior to impingement, and these were excluded from the estimated impingement mortality experienced by this species.

The remaining 615 fish potentially represented impingement mortality. Of these, a total of 33 live and recently dead fish (4.25%) were found to possess fungal infections that were considered terminal; two specimens (0.26%) were found to have both fungal and parasitic terminal infections. Eighty-seven live white bass (11.19%) survived exposure to the warm outfall water. An additional 235 white bass (30.24%) were YOY individuals collected in October. These fish represented the natural fall mortality expressed by YOY fish of this species.

No discernible cause of mortality was evident for the remaining 258 white bass collected during this study. These individuals accounted for 33.20% of the total observed white bass impingement, and represent the potential impingement mortality of white bass at the Eastlake generating facility.

Avon Lake

The white bass was also the fifth most common species encountered at the Avon Lake Facility, with 402 individuals (representing 2.86% of the total observed impingement) collected during the course of the study. Approximately 31.59% (127 fish) of these individuals were dead prior to impingement and were excluded from impingement mortality estimates.

Examination of the remaining 275 fish found 27 individuals (6.72% of all white bass collected) to possess terminal fungal infections, 2 specimens (0.49%) had terminal parasitic infections, and 27 white bass (6.72%) represented the natural YOY fall mortality exhibited by this species. An additional 34 live white bass (8.46%) survived exposure to the outfall water. A total of 185 white bass (46.02% of the white bass collected) possessed no readily apparent cause of mortality, and thus represent the potential impingement mortality of white bass at the Avon Lake facility.

Figure 15. Flow diagram of impinged white bass, Eastlake generating facility, March - October, 1983.

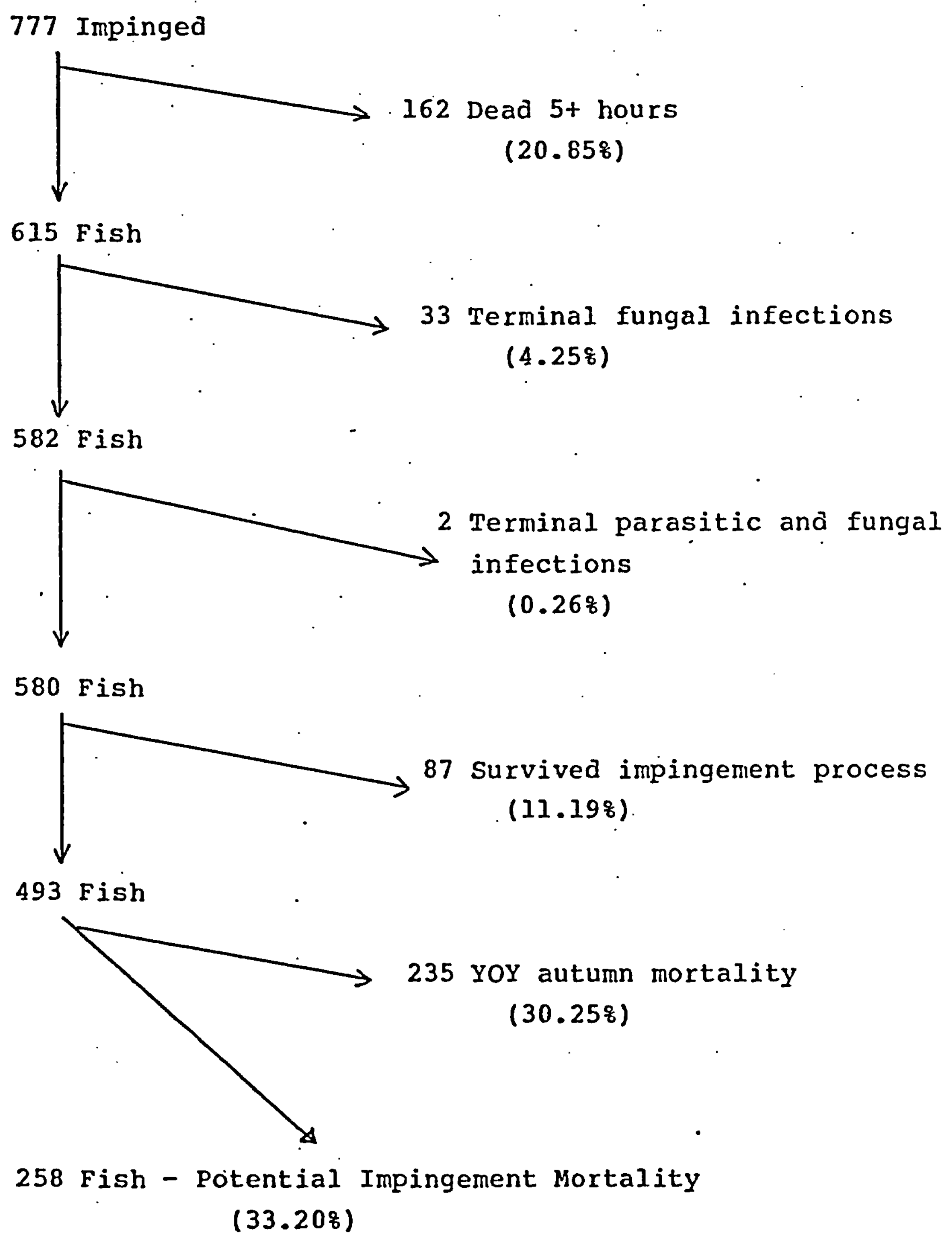
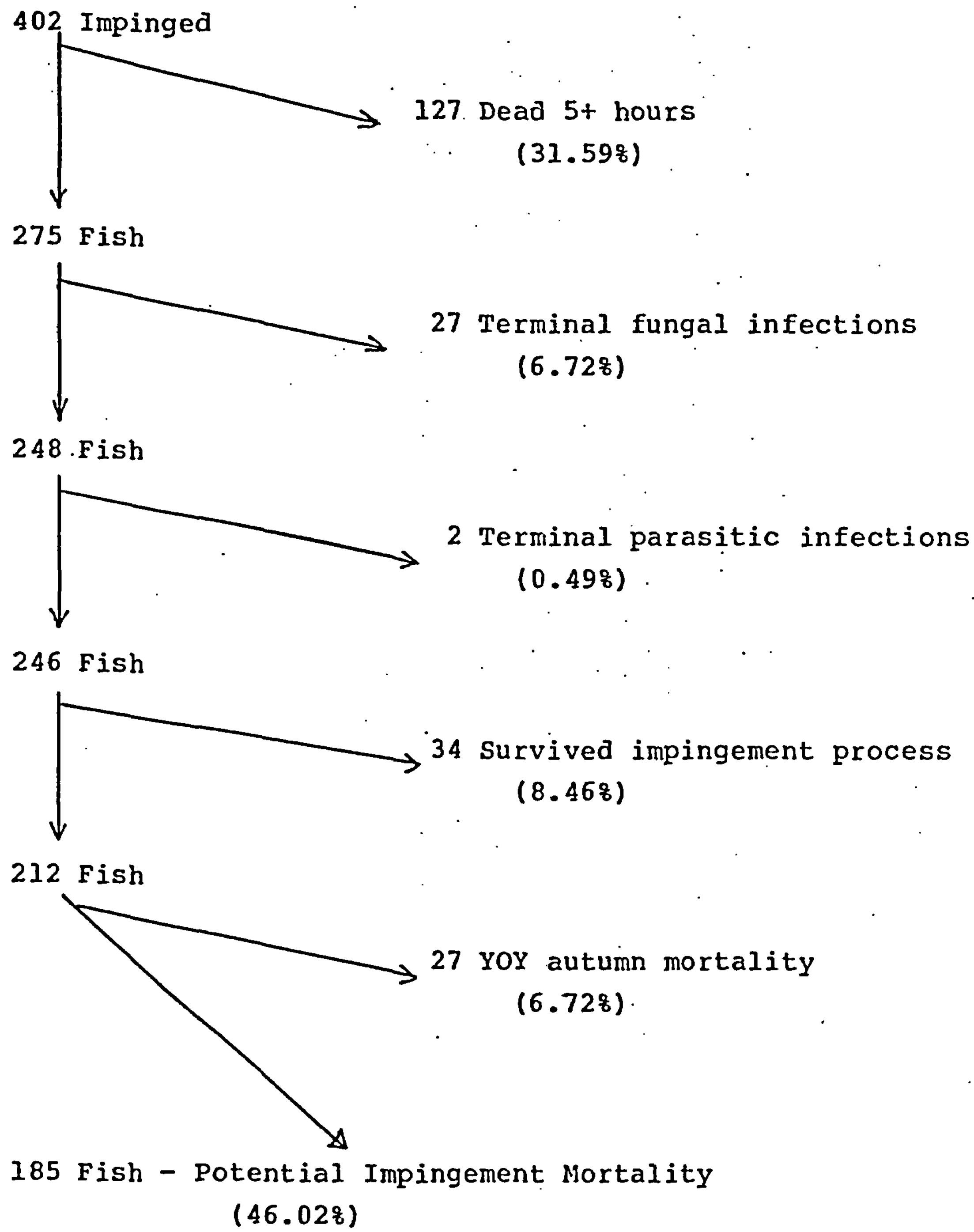


Figure 16. Flow diagram of impinged white bass, Avon Lake generating facility, March - October, 1983.



WHITE PERCH

Morone americanus

The white perch was the sixth most common species encountered at each of the generating facilities, with a combined total of 934 individuals (representing 3.41% of the total impingement) collected during this investigation. Peak observed impingement occurred in April and May, when 489 individuals (52.08% of the combined total) were collected. This peak in the observed impingement of the white bass probably reflects the presence of spawning adults in nearshore areas. The lowest impingement of white perch at either plant occurred in autumn, with a combined total of only 24 white perch collected at that time.

In contrast to the Avon Lake facility, the Eastlake plant experienced a second impingement peak of white perch in August. A total of 179 dead and dying white perch were collected on August 12, 1983. The cause of mortality for these individuals is unknown, and a similar mortality episode at the Avon Lake facility was not observed.

Eastlake

During the course of the present study, 557 white perch were collected and examined. These individuals comprised 4.17% of the total observed impingement at the Eastlake facility. A total of 165 fish (29.62% of the total white perch collected) were dead prior to impingement.

Examination of the remaining 392 live and recently dead white perch revealed 4 individuals (0.72% of the total white perch impingement) to have terminal fungal infections. Seven live white perch (1.26%) survived exposure to outfall water. The remaining 381 fish, accounting for 68.40% of the total observed white perch impingement, represent potential impingement mortality. However, 187 of the remaining 381 white perch were collected during the spawning period in spring and may actually represent spawning-related mortality.

Avon Lake

A total of 382 white perch were collected and examined at the Avon Lake facility and represented 0.79% of the total observed impingement. Individuals dead prior to impingement accounted for 35.86% (137 fish) of the total white perch impingement. An additional 10 specimens (2.62%) possessed fungal infections which were judged to be terminal conditions, and 7 white perch (1.83%) survived exposure to outfall water. The remaining 228 fish (59.69%) represent potential impingement mortality of this species. However, 202 of these fish were collected during the spring spawning period of this species. The mortality exhibited by these fish may actually be spawning related and not plant-induced.

Figure 17. Flow diagram of impinged white perch, Eastlake generating facility, March - October, 1983.

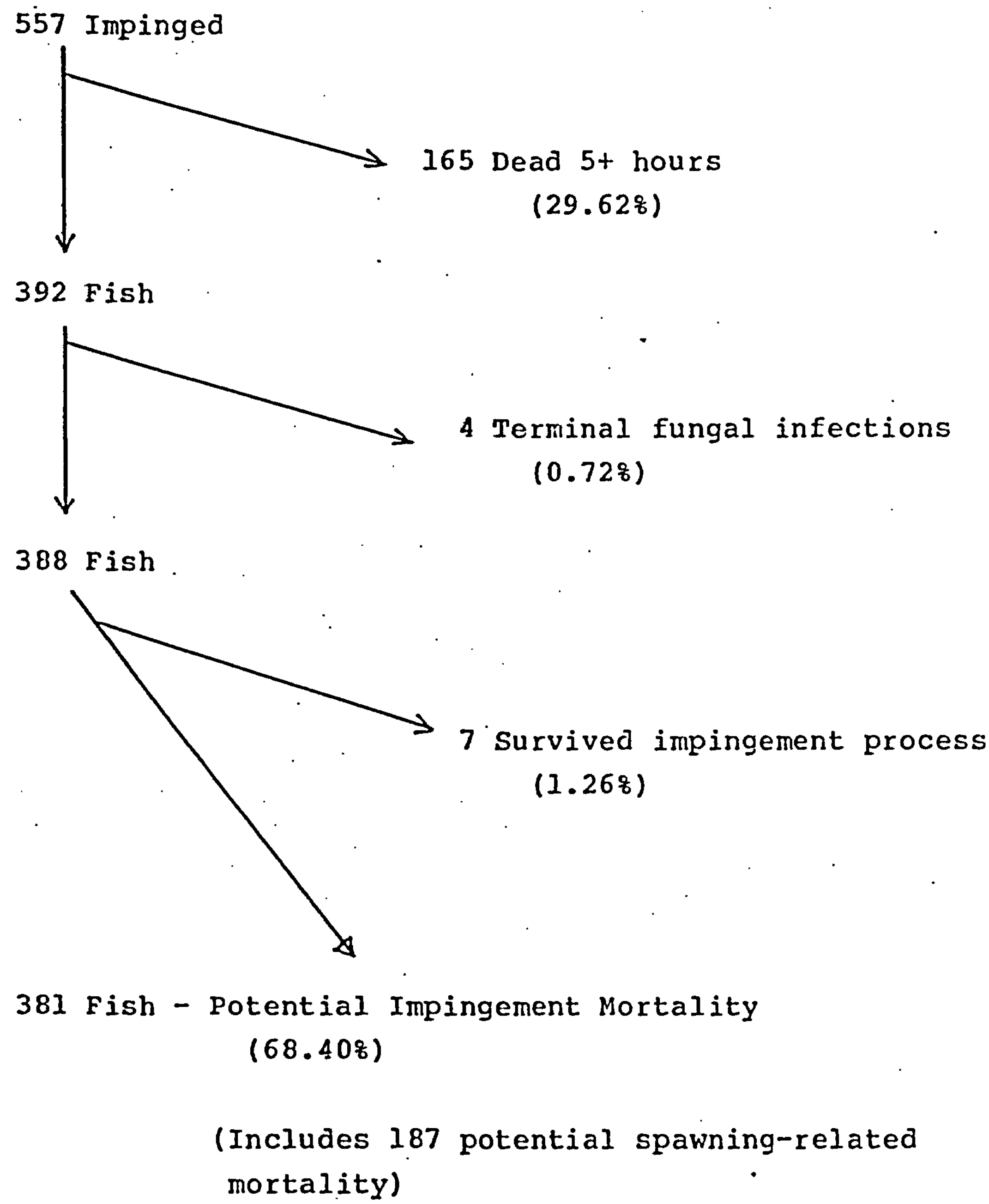
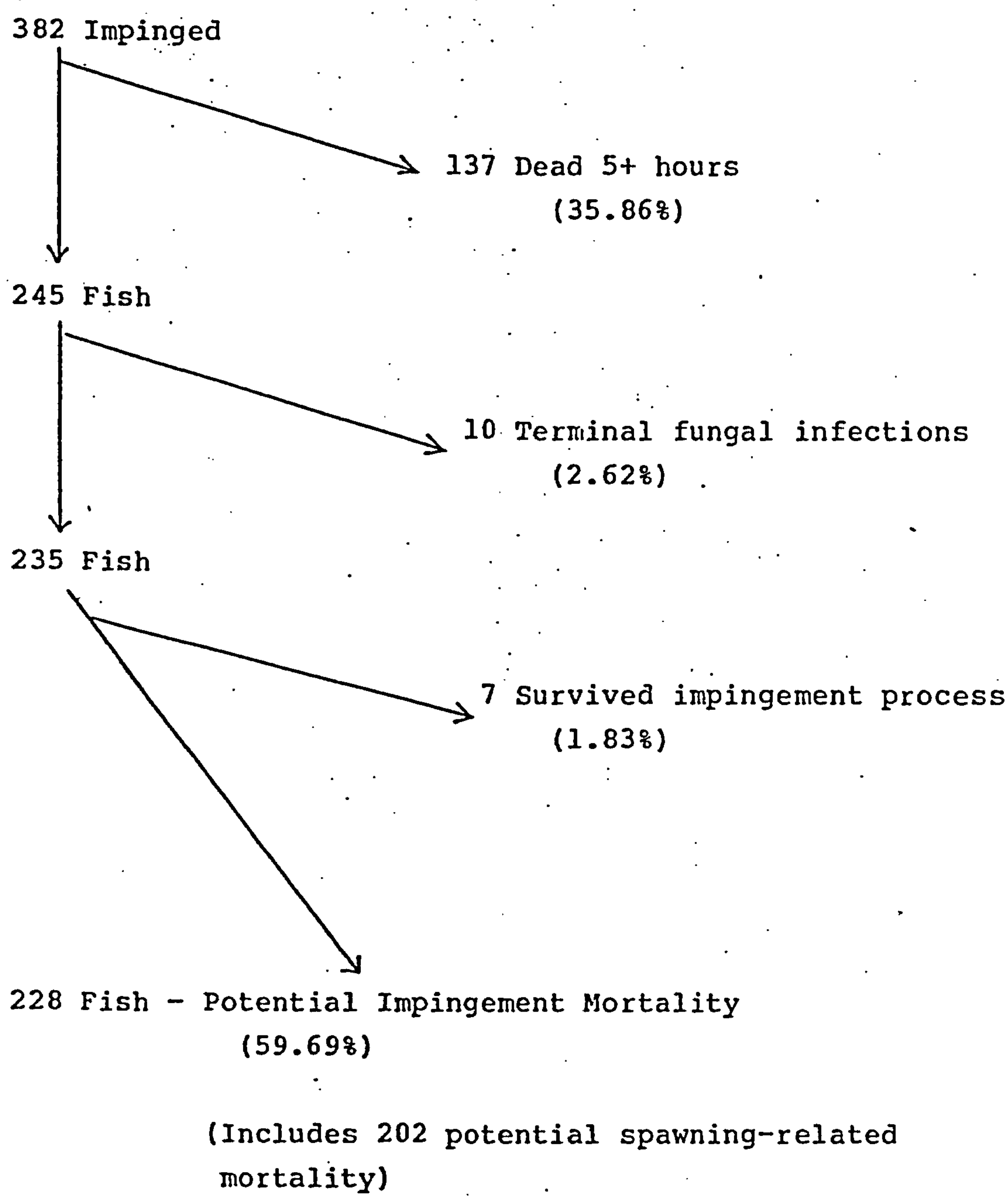


Figure 18. Flow diagram of impinged white perch, Avon Lake generating facility, March - October, 1983.



Alewife

Alosa pseudoharengus

A total of 227 alewife were collected during the present study. Peak collection occurred in late spring (April, May) and early summer (June). Few alewife were collected in summer and autumn (a combined total of 8 individuals). Similar numbers of alewife were impinged at the two facilities (116 fish at Eastlake; 111 fish at Avon Lake).

The patterns of impingement observed for this species reflects the typical seasonal movements reported for land-locked populations of this principally marine species. In lakes, this species inhabits deep water, and is absent from nearshore areas for most of the year (Graham 1956). In spring, adults move into shallow, nearshore areas to spawn. Following reproduction, the adults immediately leave the nearshore waters and migrate back to deep water (Graham 1956). During the present study, the alewife collected in April, May, and June were primarily spawning and post-spawn condition adults.

Large-scale die-offs of adult alewifes in shallow water during spring and summer have been widely reported (Scott and Crossman 1973). This mortality is believed to result from the inability of the alewife to acclimate rapidly to naturally rising or fluctuating water temperatures in spring (Graham 1956).

Eastlake

A total of 116 alewife were collected from the observed impingement; these individuals represented 0.87% of the total observed impingement at the Eastlake facility. The majority (106 fish, 91.38% of the alewife impingement) of these fish were collected in April, May, and June and probably represent the natural spring mortality experienced by this species.

Examination of the alewife showed 33 individuals (28.45%) to have died prior to impingement; these fish were not included in estimating impingement mortality of this species. An additional 3 live and recently dead fish (2.59%) possessed terminal fungal infections. Two live alewife (1.72%) survived exposure to the warm outfall water. The remaining 78 live and recently dead alewife (67.24%) represent the potential impingement mortality of this species. However, 72 of the 78 fish (62.07% of the total observed alewife impingement) were collected in spring and probably experienced natural spring mortality. The remaining 6 fish (5.17% of all alewife collected) exhibited no discernible cause of mortality and represent potential impingement mortality.

Avon Lake

The observed impingement of alewife at the Avon Lake facility produced 111 fish. These individuals accounted for 0.79% of the total observed impingement at this facility. Examination of the alewife found 27 fish (24.32% of the impinged alewife) to have been dead for at least five hours prior to impingement. Fourteen live and recently dead fish (12.61%) possessed fungal infections which were considered terminal. The remaining 70 alewife (63.06%) potentially represent impingement mortality. However, 68 of these fish (61.26% of the total alewife impingement) were collected in spring and were probably the result of the natural spring mortality widely reported for this species. The remaining 2 live and recently dead fish (1.80%) exhibited no obvious cause of mortality, and represent potential impingement mortality.

Figure 19. Flow diagram of impinged alewife, Eastlake generating facility, March - October, 1983.

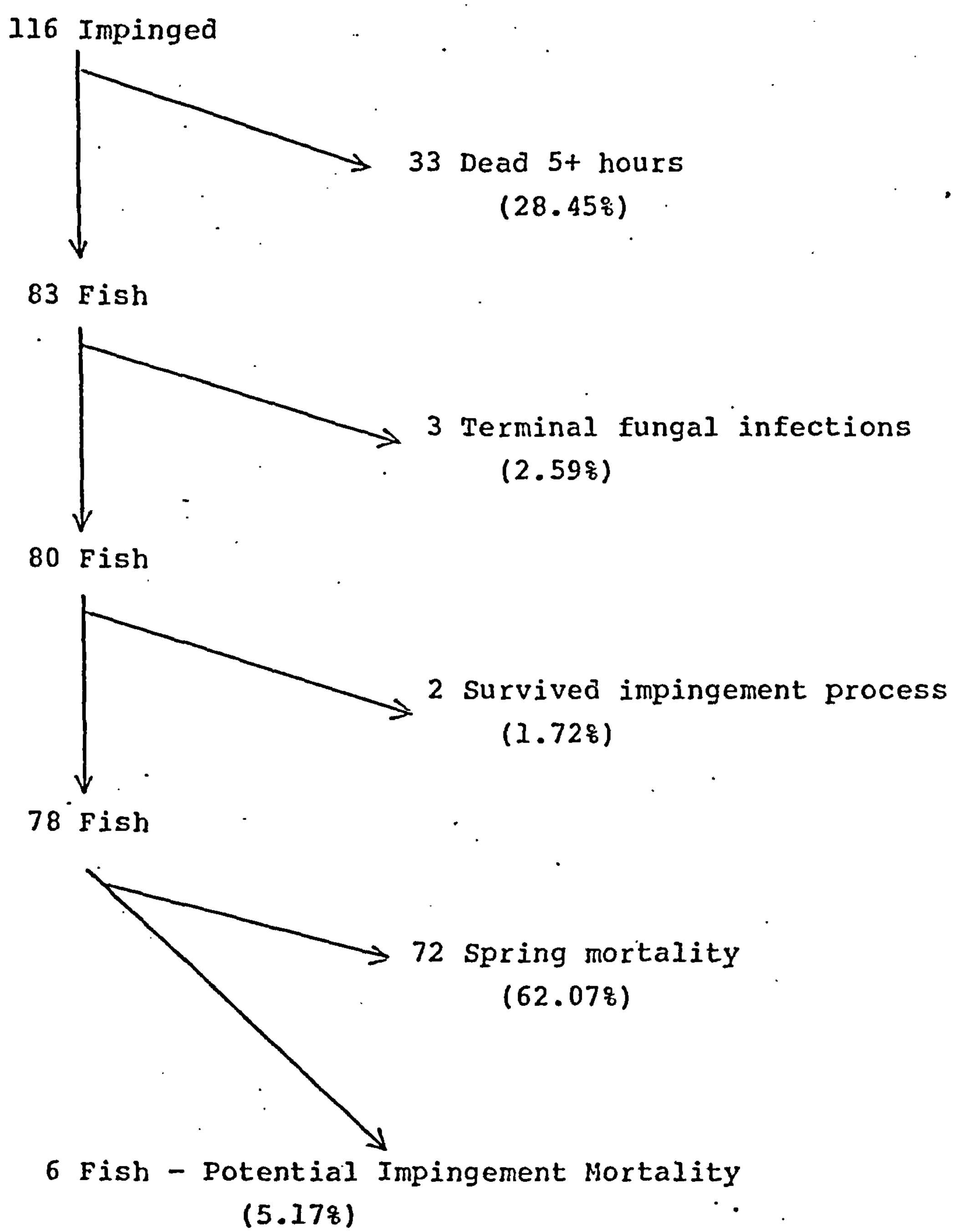
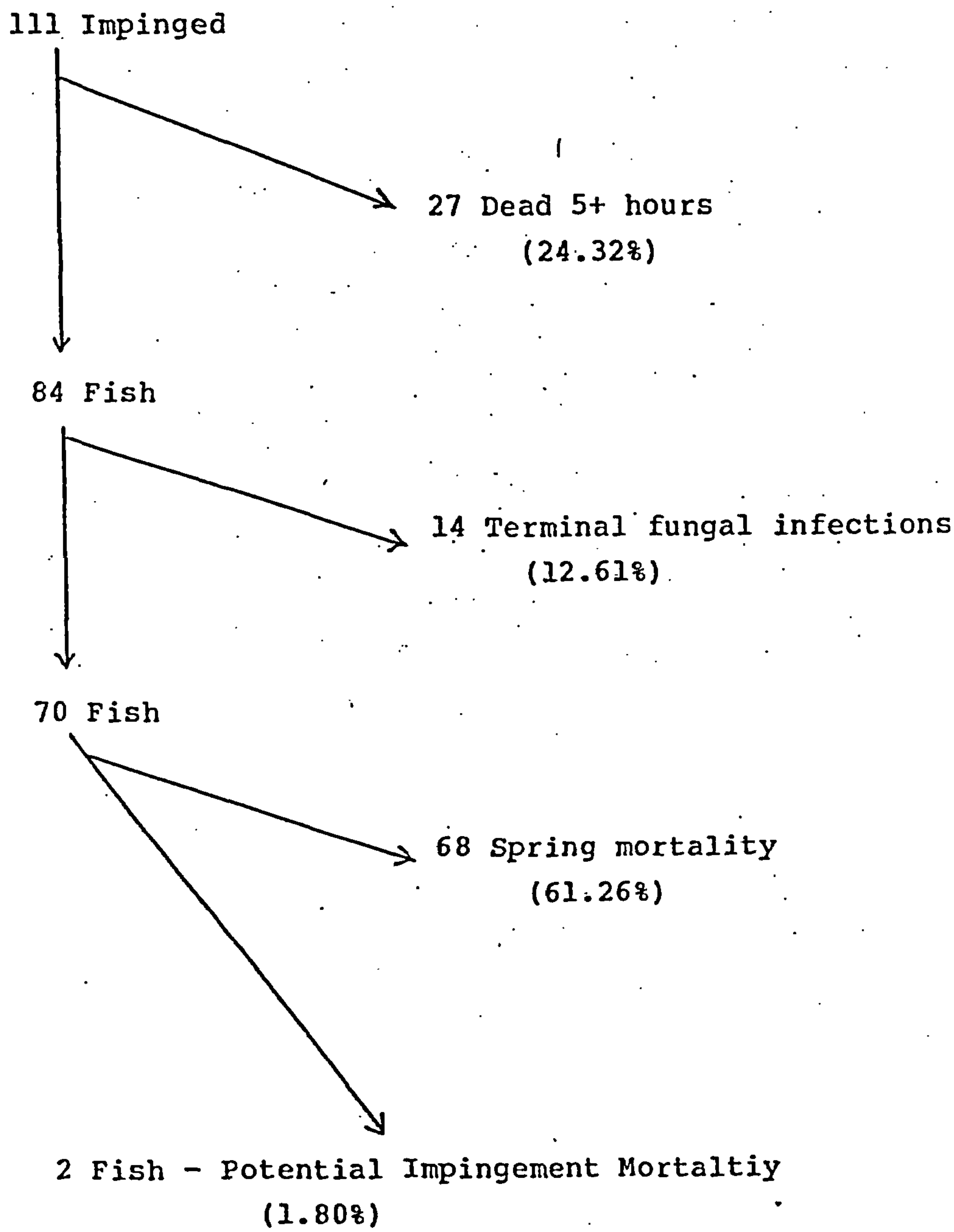


Figure 20. Flow diagram of impinged alewife, Avon Lake generating facility, March - October, 1983.



TROUT-PERCH

Percopsis omiscomaycus

This species was the 8th most abundant species encountered. A combined total of 185 individuals were collected during the present study. At both plants, most of the specimens were encountered in spring and early summer (March through June). At that time, 167 fish, representing 90.27% of the combined observed trout-perch impingement, were collected. This period of impingement coincides with the spawning period of this species. The prolonged spawning season of trout-perch in Lake Erie has been reported to continue from spring through early summer, and has a high degree of associated mortality (Scott and Crossman 1973).

Eastlake

The trout-perch was the 8th most abundant species impinged at the Eastlake facility. These individuals accounted for 0.59% of the total observed impingement. Examination of the collected trout-perch found 34 fish (43.04%) to have been dead prior to impingement. These individuals were not included in estimates of impingement mortality. A single fish exhibited a terminal parasitic infection, and 3 live trout-perch (3.80%) survived exposure to outfall water. An additional 33 live and recently dead specimens (41.77%) were collected in spring and were probably spawning-mortality related. Kinny (1950) reported that large female trout-perch and most males of this species die after spawning. The trout-perch collected in spring were all adults. The remaining 8 live and recently dead fish (10.13%), for which no discernible cause of mortality was evident, represent potential impingement mortality.

Avon Lake

The trout-perch was the 9th most abundant species collected at Avon Lake, and accounted for 0.75% of the total observed impingement. A total of 106 individuals were collected and examined; 32 fish (30.19%) were dead prior to impingement and a single specimen (0.94%) possessed a terminal fungal infection. Twenty-three live trout-perch (21.70%) survived exposure to outfall water. The remaining 50 fish represent potential impingement mortality. However, 49 of these individuals (46.23% of the total trout-perch impingement) were adults collected during the spawning period of this species and probably represent natural spawning-related mortality. No discernible cause of mortality was evident for the remaining single individual (0.94%); this fish represents potential impingement mortality.

Figure 21. Flow diagram of impinged trout-perch, Eastlake generating facility, March - October, 1983.

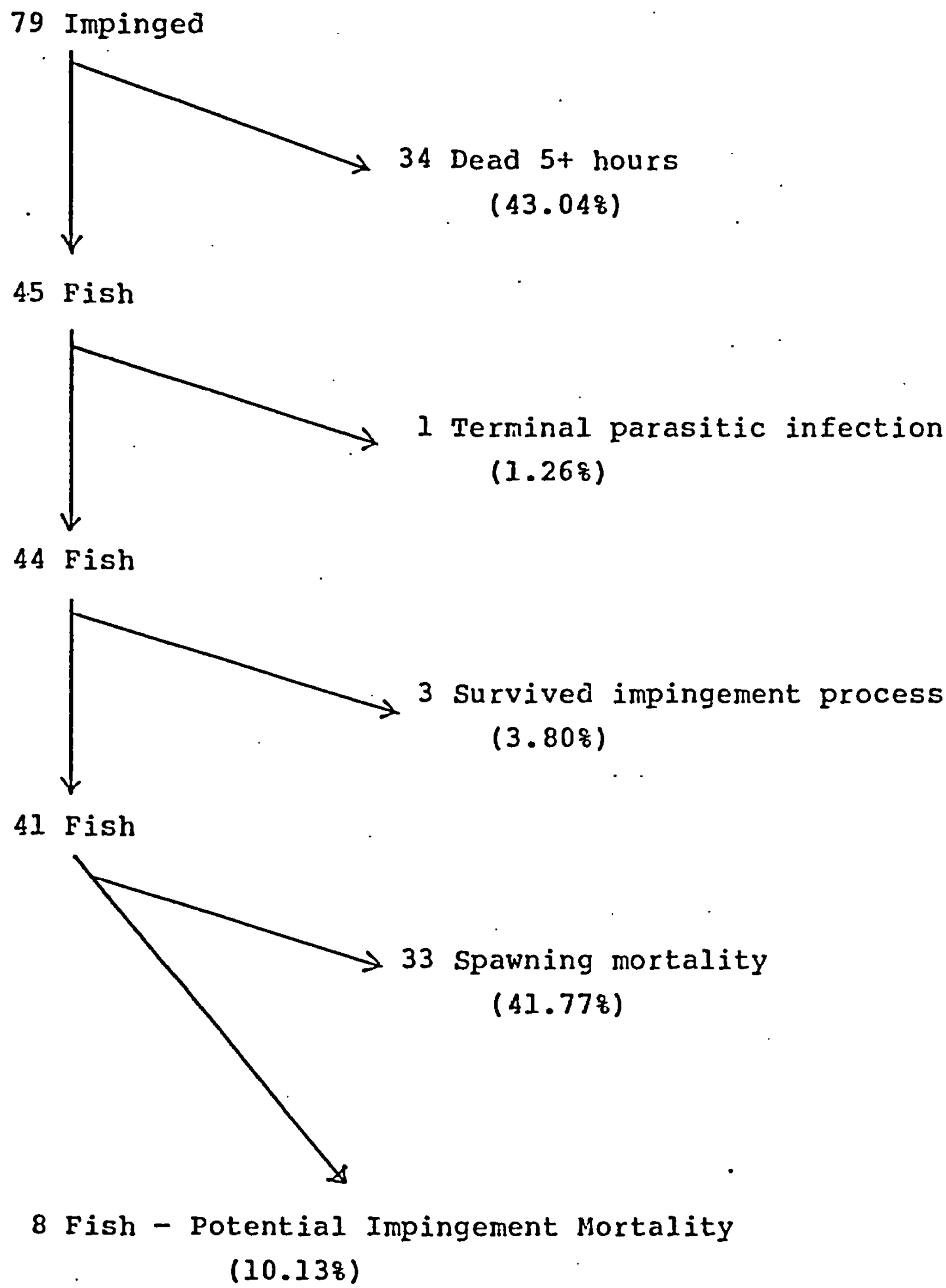
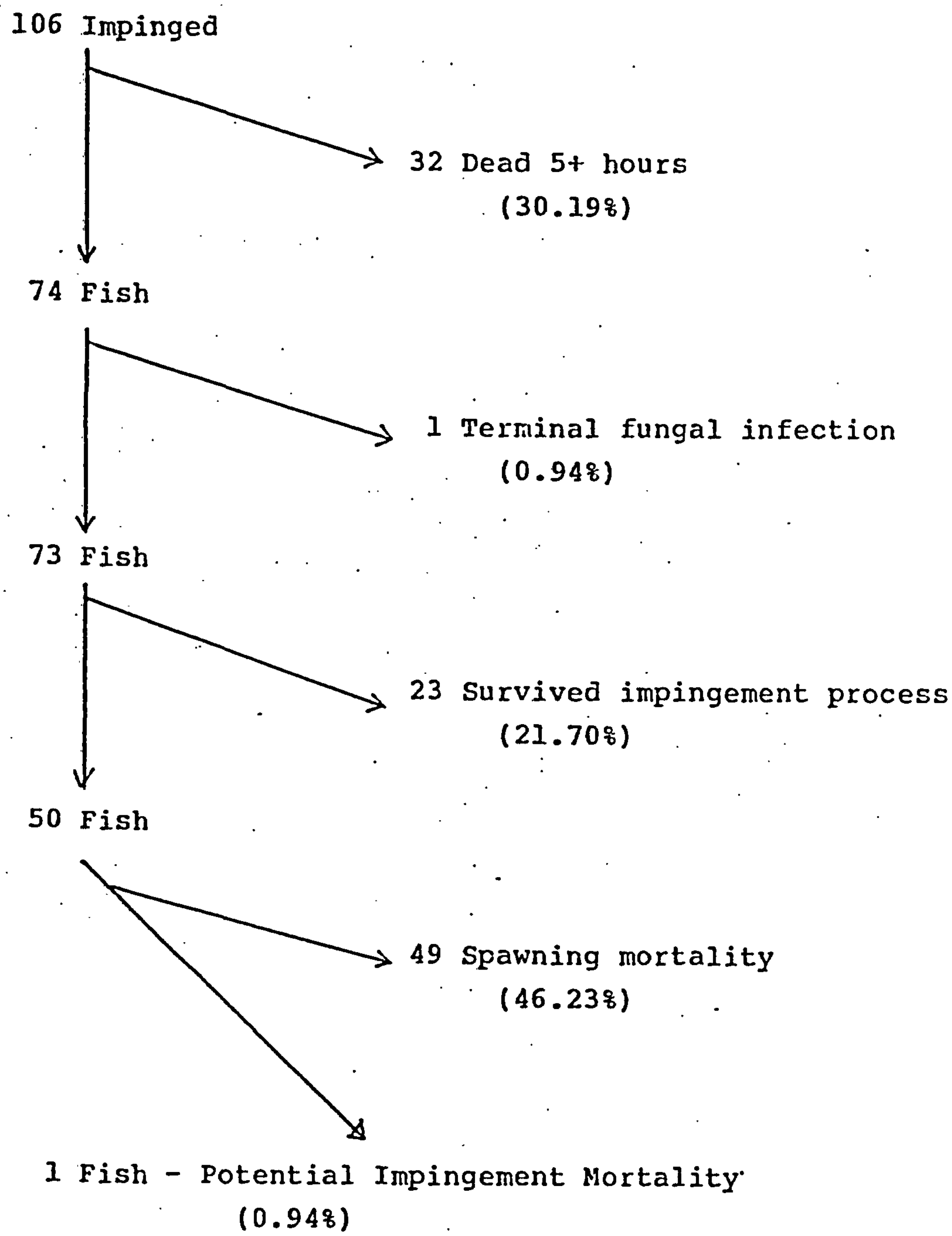


Figure 22. Flow diagram of impinged trout-perch, Avon Lake generating facility, March - October, 1983.



YELLOW PERCH

Perca flavescens

Yellow perch were the 9th most abundant species collected, yet represented only 0.57% of the total combined observed impingement. Peak impingement occurred in June at each facility, and included 27.08% of all yellow perch collected at Eastlake and 57.94% at Avon Lake. Relatively few yellow perch were collected in autumn.

Eastlake

The yellow perch was the 10th most abundant species found in the observed impingement. A total of 48 specimens, representing only 0.36% of the total observed impingement, were collected and examined. Twenty-five yellow perch (52.08%) were dead prior to impingement, and 4 live and recently dead specimens possessed fungal infections which were considered terminal. Four live fish (8.33%) survived exposure to warm water. The remaining 15 live and recently dead fish (31.25%) exhibited no externally apparent cause of mortality and represent potential impingement mortality. This species was encountered at a very low monthly rate (1-2 fish per month).

Avon Lake

In contrast to the contribution of yellow perch to the total observed impingement at Eastlake, the yellow perch was the 8th most abundant species collected at Avon Lake. However, the 107 fish represented only 0.76% of the total observed impingement at this facility.

Examination of the yellow perch revealed 55 fish (51.40%) to have been dead before impingement. Nine fish (8.41%) exhibited terminal fungal infections and one individual (0.93%) possessed a parasitic infection which was considered terminal. Ten live yellow perch (9.35%) survived exposure to outfall water. No discernible cause of mortality was evident for the remaining 32 (29.91%) live and recently dead fish. These fish represent a potential impingement mortality.

Figure 23. Flow diagram of impinged yellow perch, Eastlake generating facility, March - October, 1983.

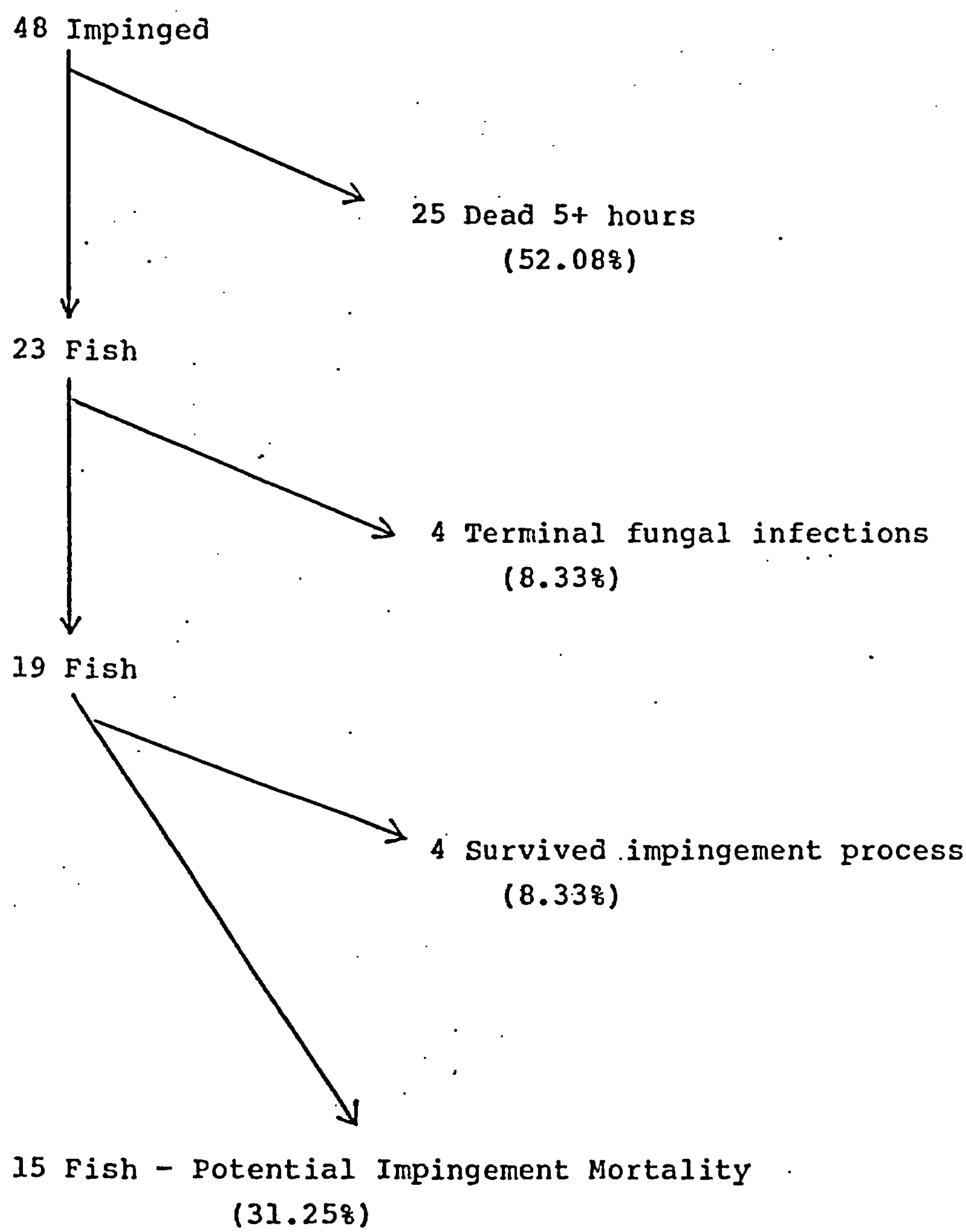
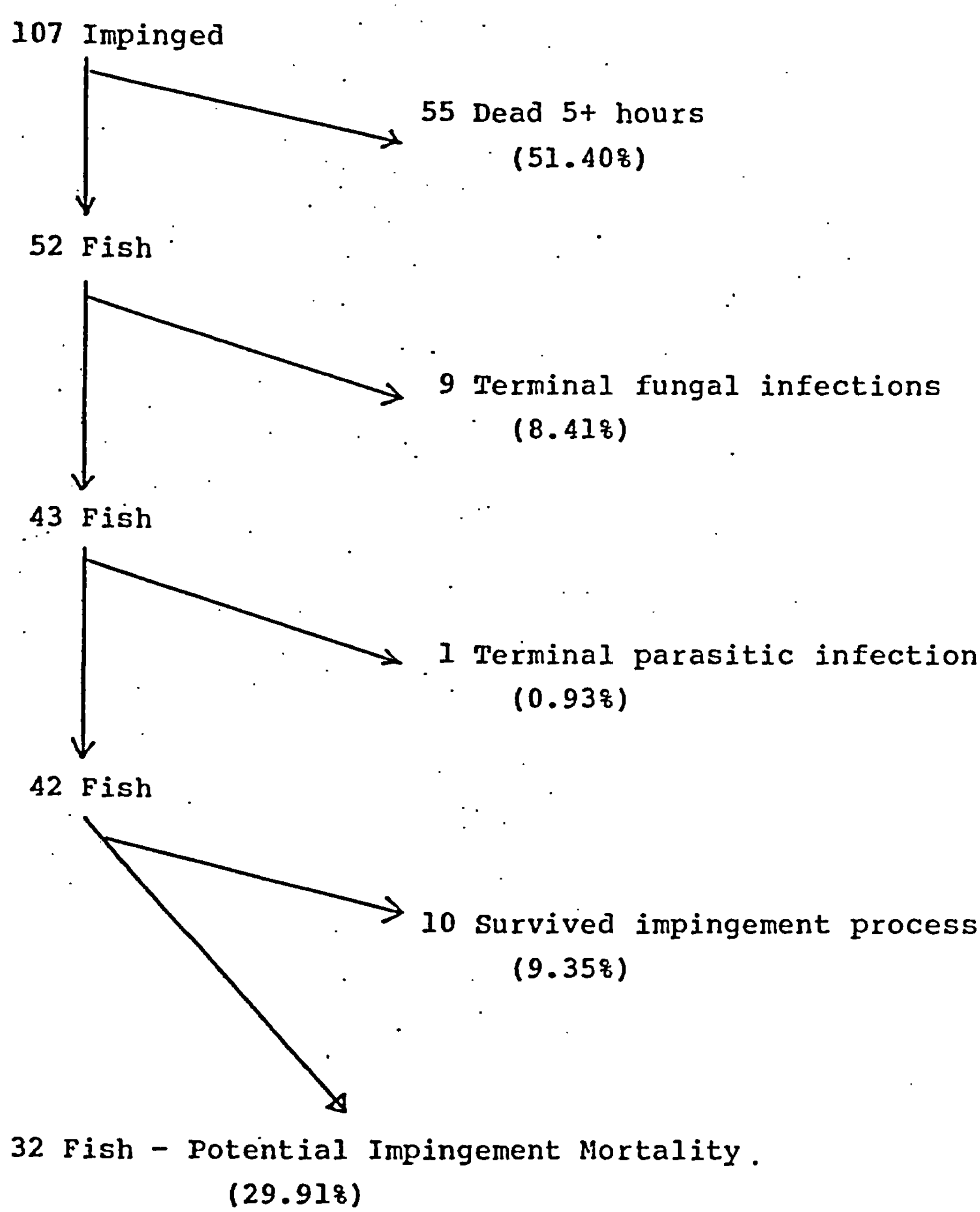


Figure 24. Flow diagram of impinged yellow perch, Avon Lake generating facility, March - October, 1983.



LOGPERCH DARTER

<u>Percina caprodes</u>

The logperch darter was the 10th most abundant species encountered during the present study. The 38 specimens collected represented 0.14% of the combined total observed impingement. The majority of the logperch darters (27 fish total) were collected in May and June at both facilities.

<u>Eastlake</u>

The logperch was the 10th most abundant species at the Eastlake facility. However, the 30 specimens collected represented only 0.22% of the total observed impingement. Most specimens were collected in May and June (21 fish representing 70% of all logperch darters). Examination revealed 6 logperch darters to have died prior to impingement. A single specimen was suffering from a terminal fungal infection. Thirteen live logperch darters survived exposure to outfall water. The remaining 10 fish had no obvious cause of mortality and represent potential impingement mortality.

<u>Avon Lake</u>

At Avon Lake, the logperch darter was the 12th most abundant species collected. However, only 8 individuals were collected during the study period. Two of these specimens were dead prior to impingement. Five live fish survived exposure to outfall water. The remaining single fish showed no apparent cause of death and was considered a potential impingement mortality.

Figure 25. Flow diagram of impinged logperch darters, Eastlake generating facility, March - October, 1983.

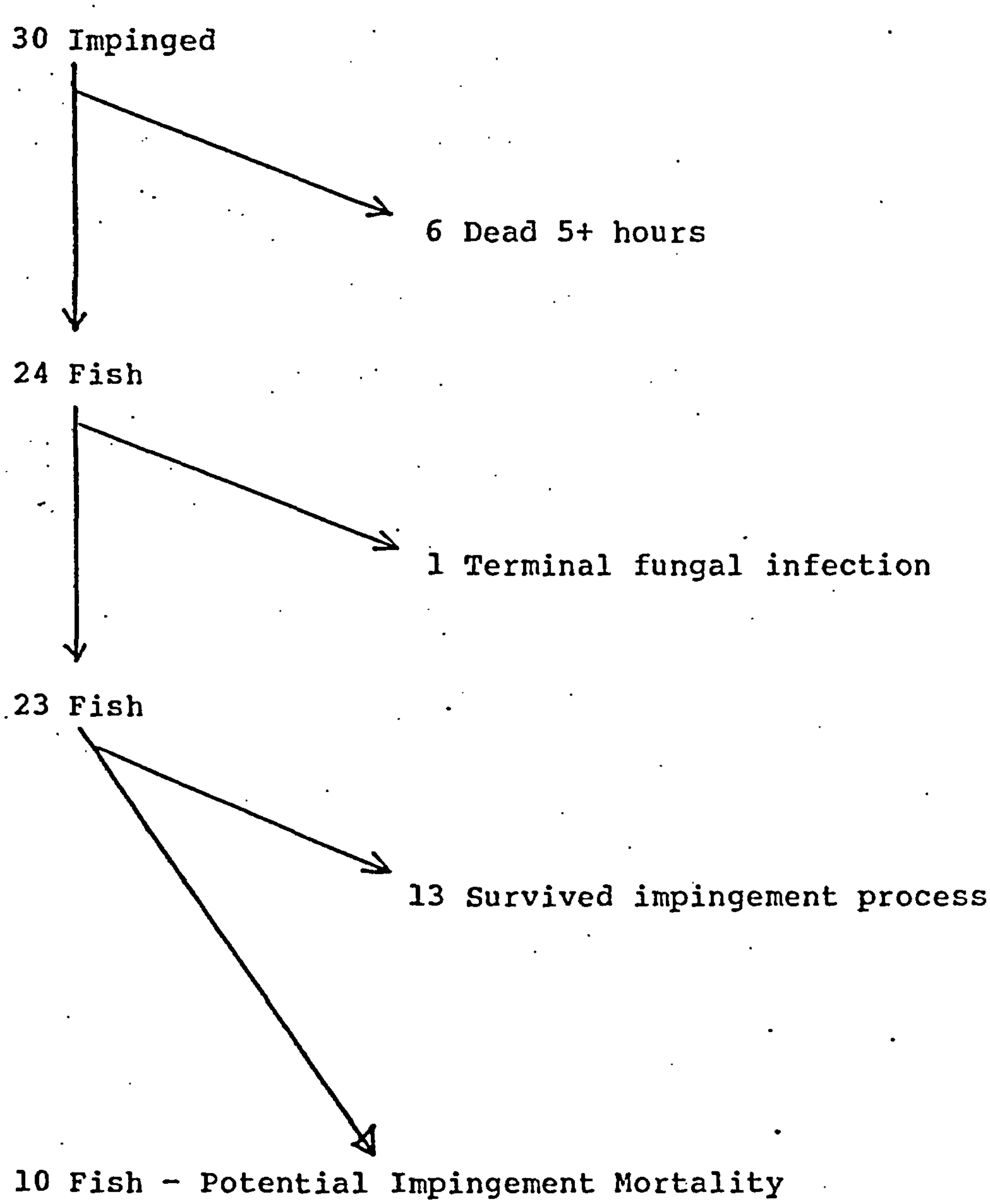
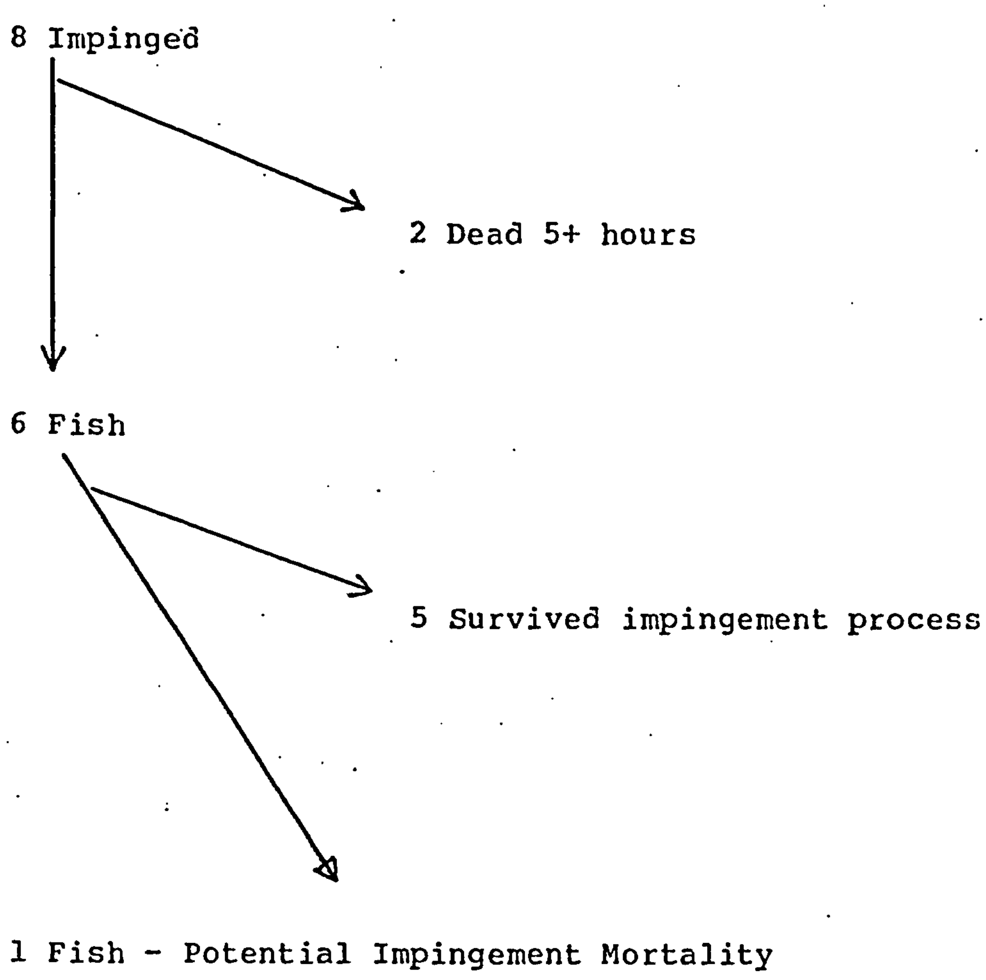


Figure 26. Flow diagram of impinged logperch darters, Avon Lake generating facility, March - October, 1983.



SPECIES WITH 20 OR FEWER INDIVIDUALS IMPINGED

The remaining species encountered during this study were represented by 108 fish, and accounted for only 0.39% of the total observed impingement. The stonecat madtom was the most abundant of these miscellaneous species with a combined total of 20 individuals. No other species was represented by more than 10 individuals. Examination of the miscellaneous species found 43 fish to have been dead prior to impingement. Four live and recently dead individuals possessed terminal fungal infections. Twenty-two live fish survived simulated discharge to the outfall channel. The remaining 39 individuals represent potential impingement mortality.

STONECAT MADTOM

Noturus flavus

A combined total of 20 individuals were collected, half of which were dead before impingement. Five live individuals survived exposure to outfall water. The remaining 5 specimens died when placed into the warm outfall water and represent potential impingement mortality.

FATHEAD MINNOW

Pimephales promelas

A combined total of 10 specimens were collected. Three of these were dead prior to impingement. A single live fish was collected, and this individual survived the warm water treatment. The remaining 6 fish were classified as recently dead, and no apparent cause of mortality was evident.

WHITE CRAPPIE

Pomoxis annularis

Nine white crappie were impinged during this study. All of these individuals were either alive or recently dead. Two live individuals survived exposure to outfall water. The remaining 7 specimens were considered potential impingement mortalities.

COHO SALMON

Oncorhynchus kisutch

A total of 8 coho salmon were collected. Six of these individuals were dead prior to impingement. No apparent cause of mortality was evident for the remaining 2 fish, which represent potential impingement mortality.

CHANNEL CATFISH

Ictalurus punctatus

Seven channel catfish were collected, of which 6 were dead prior to impingement. The remaining individual possessed a terminal fungal infection. Thus, no channel catfish incurred impingement mortality.

WALLEYE

Stizostedion vitreum

Seven walleye were collected during the present study. Five individuals were dead before impingement. The remaining two live fish failed to survive exposure to warm water and thus represent potential impingement mortality.

CARP

Cyprinus carpio

A total of seven carp were collected. Two of these fish were dead prior to impingement. Two of the live individuals survived exposure to warm water. The remaining 3 live and recently dead carp represent potential impingement mortality.

WHITE SUCKER

Catostomus commersoni

Six white suckers were collected and examined. Two individuals were dead prior to impingement. One fish exhibited a fungal infection which was considered to be terminal. One live fish survived warm water exposure. The remaining 2 live and recently dead specimens were considered to represent potential impingement mortality.

MOTTLED SCULPIN

Cottus bairdi

A total of six individuals, all of which were alive and survived warm water exposure, were collected during this study. No impingement mortality was incurred by this species.

BLUEGILL SUNFISH

Lepomis macrochirus

Five individuals were collected during this study, one of which was dead before impingement. The remaining 4 individuals exhibited no apparent cause of mortality and were considered potential impingement mortalities.

RAINBOW TROUT

Salmo gairdneri

Five rainbow trout were encountered and examined. One individual was dead prior to impingement. Two live and recently dead rainbow trout were suffering from fungal infections which were considered terminal. The remaining two fish exhibited no obvious cause of mortality and were considered potential impingement mortalities.

ROCK BASS

Ambloplites rupestris

Four individuals were collected at the Eastlake generating facility. No specimens were collected from Avon Lake. Half of the rockbass were dead prior to impingement. The remaining two individuals were considered to be potential impingement mortalities.

YELLOW BULLHEAD

Ictalurus natalis

A total of 3 fish were collected, all of which were dead before impingement. This species incurred no impingement mortality.

PUMPKINSEED SUNFISH

Lepomis gibbosus

Three individuals were collected, all from the Avon Lake facility. All were alive upon collection, and two survived warm water exposure. The remaining individual was considered to be a potential impingement mortality.

LARGEMOUTH BLACKBASS

Micropterus salmoides

Two specimens were collected. One individual was alive and survived warm water exposure. The other specimen was classified as recently dead and had no discernible cause of mortality. Thus, this individual was considered a potential impingement mortality.

GOLDFISH

Carassius auratus

Two specimens were collected at Avon Lake; none were encountered at Eastlake. Both fish had been dead prior to impingement. This species was not considered to have incurred impingement mortality.

GOLDEN SHINER

Notemigonus crysoleucas

This species was collected only at the Avon Lake facility. A single recently dead individual was collected and showed no readily apparent cause of mortality. This fish was considered a potential impingement mortality.

LONGNOSE DACE

Rhinichthys cataractae

A single individual was collected at the Eastlake facility. This fish was alive and survived warm water exposure.

BROOK STICKLEBACK

Culaea inconstans

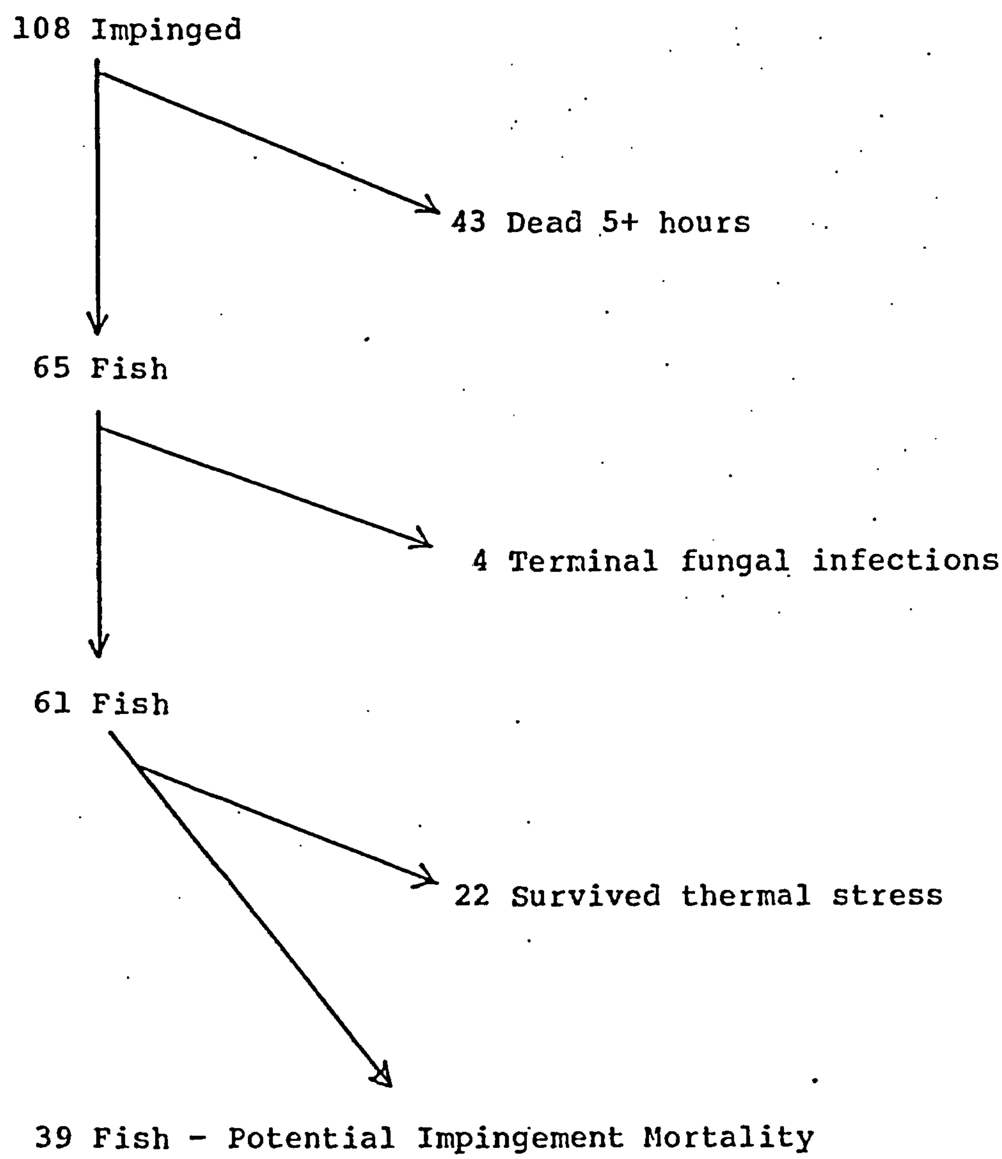
A single specimen was collected at Eastlake. This live fish failed to survive warm water exposure and was considered a potential impingement mortality.

SMALLMOUTH BLACKBASS

Micropterus dolomieui

One live specimen was collected at the Eastlake facility. This individual survived exposure to outfall water.

Figure 27. Flow diagram of impinged miscellaneous species, Eastlake and Avon Lake generating facilities, March - October, 1983.



CONCLUSIONS

The analysis of the non-shad portion of the fishes impinged at the Avon Lake and Eastlake generating facilities has demonstrated that more than 44% of these fishes was composed of individuals which were dead prior to impingement. An additional 29.70% of the total non-shad impingement consisted of fishes that were dead or dying from factors not associated with the operation of the generating facilities (Tables 3 and 4). Thus, more than 73% of the combined total non-shad impingement examined during this study was comprised of dead or terminally ill fishes whose conditions were not a result of the impingement process.

Potential impingement mortalities were estimated at approximately 21% of the combined observed non-shad impingement at the Eastlake and Avon Lake facilities. Potential impingement mortality at the Eastlake plant was estimated to represent 19.54% of the total observed impingement; at the Avon Lake plant this estimate was 23.64%. However, these values are based solely on the non-gizzard shad components of the observed impingements, and would be considerably less with the inclusion of the gizzard shad component. For example, the 316(b) study for the Eastlake facility (Applied Biology 1979a) reported a total observed impingement of 2,509,300 fishes. The non-gizzard shad component accounted for less than 23% of this total impingement. Extrapolating the mortality estimate in the present study to the results of the 316(b) study, potential impingement mortality of the non-shad component would encompass approximately 4% of the total annual impingement. The 316(b) study for the Avon Lake facility (Applied Biology 1979b) reported a total observed impingement of 694,928 fish, of which 76.6% were gizzard shad. Again, extrapolating the non-shad impingement mortality estimate obtained in the present study to the Avon Lake 316(b) data, potential mortality of the non-shad impingement would represent

Table 3. Distribution of impingement causes evaluated by species, Eastlake generating facility, March - October, 1983.

Species	Total Impinged	Dead 5+ Hours	Non-plant Mortality[a]	Potential Impingement Mortality[b]
Rainbow Smelt	6,664	3,533	2,567	519
Freshwater Drum	1,792	980	381	368
Emerald Shiner	1,767	487	86	934
Spottail Shiner	1,465	226	1,130	91
White Bass	777	162	270	258
White Perch	557	165	4	381
Alewife	116	33	75	6
Trout-perch	79	34	34	8
Yellow Perch	48	25	4	15
Logperch Darter	30	6	1	10
White Crappie	7	0	0	5
Coho Salmon	6	4	0	2
White Sucker	5	1	1	2
Mottled Sculpin	4	0	0	0
Rockbass	4	2	0	2
Bluegill Sunfish	3	1	0	2
Rainbow Trout	3	1	0	2
Channel Catfish	3	3	0	0
Stonecat Madtom	3	1	0	0
Walleye	2	0	0	2
Carp	2	1	0	0
Smallmouth Blackbass	1	0	0	0
Yellow Bullhead	1	1	0	0
Brook Stickleback	1	0	0	1
Largemouth Blackbass	1	0	0	0
Longnose Dace	1	0	0	0
Total	13,343	5,666	4,553	2,608

a - Live and recent dead fish only; includes diseased and physically impaired fish.

b - Potential impingement mortality but without consideration of pathologies which are not externally diagnosed.

Table 4. Distribution of impingement causes evaluated by species, Avon Lake generating facility, March - October, 1983.

Species	Total Impinged	Dead 5+ Hours	Non-plant Mortality[a]	Potential Impingement Mortality[b]
Rainbow Smelt	6,477	3,898	2,101	381
Emerald Shiner	3,816	1,198	49	2,090
Freshwater Drum	1,359	766	238	326
Spottail Shiner	1,203	185	994	44
White Bass	402	127	56	185
White Perch	382	137	10	228
Alewife	111	27	82	2
Yellow Perch	107	55	10	32
Trout-perch	106	32	34	8
Stonecat Madtom	17	9	0	5
Fathead Minnow	9	3	0	6
Logperch Darter	8	2	0	1
Carp	5	1	0	3
Walleye	5	5	0	0
Channel Catfish	4	3	1	0
Pumpkinseed Sunfish	3	0	0	1
Golfish	2	2	0	0
Yellow Bullhead	2	2	0	0
Bluegill Sunfish	2	0	0	2
Rainbow Trout	2	0	2	0
Mottled Sculpin	2	0	0	0
White Crappie	2	0	0	2
Coho Salmon	2	2	0	0
Golden Shiner	1	0	0	0
Largemouth Blackbass	1	0	0	1
White Sucker	1	1	0	0
Total	14,031	6,455	3,577	3,317

a - Live and recent dead fish only; includes diseased and physically impaired fish.

b - Potential impingement mortality but without consideration of pathologies which are not externally diagnosed.

approximately 4% of the total annual impingement.

The frequency of occurrence of externally identifiable pathologies was quite similar between the observed impingements at the Eastlake and Avon Lake generating facilities. For example, approximately 76% of the spottail shiner impingement at the Eastlake facility possessed terminal parasitic infections. At the Avon Lake facility, approximately 74% of the spottail shiner impingement exhibited this condition. Terminal fungal infections were found on 19% of the rainbow smelt at the Eastlake plant, and on 16% of this species at the Avon Lake location. Furthermore, very strong similarities were evident between the species composition of the impingements at the Eastlake and Avon Lake facilities. Peak impingement periods of fishes were also very similar in time of occurrence between the two generating facilities.

The numerous similarities in the observed impingements between the Eastlake and Avon Lake generating facilities suggest that impingement at other locations within the central basin of Lake Erie may be temporally and compositionally similar to that observed in the present study.

White (1986) examined impingement at the Ohio Edison Edgewater generating facility in Lorain, Ohio. This plant is located on the central basin of Lake Erie, approximately 12 km west of the CEI Avon Lake facility, and has an intake structure similar to those at Avon Lake and Eastlake. Comparing the results of White (1986) with those obtained in the present study reveals strong similarities among the species composition of the impingements at these facilities. Furthermore, the contributions of individual species to the total impingements, and also the biological conditions (i.e. dead prior to impingement, terminal fungus infection) of the impinged fishes are strikingly similar among the three generating facilities.

For example, the proportions of dead fish in the non-shad impingements at the three generating facilities were strikingly similar for many species. Dead fish comprised 54.48% of the freshwater drum impingement at the Edgewater facility (White 1986), 54.69% at the Eastlake plant, and 56.37% at the Avon Lake facility. Potential impingement mortality of the emerald shiner at the Edgewater plant was estimated at 55.19% of the total emerald shiner impingement (White 1986). At the Eastlake and Avon Lake facilities, potential impingement mortality estimates for this species were 52.86% and 54.77%, respectively.

It should be noted that none of the fishes evaluated for biological condition in the present study were examined internally for the presence of pathogenic agents, yet internal pathogenic conditions which are not related to normal plant activities can represent a considerable portion of the estimated potential impingement mortalities. White (1986) reported that pathogenic conditions identifiable only by internal examination accounted for a significant portion of the non-plant induced mortality for some species at the Ohio Edison generating facility. These conditions included bacterial gill rot, liver and kidney carcinomas, septicemic Aeromonas and Pseudomonas infections, starvation, aenemia, gill flukes, and internal leeches. For example, 21% of the rainbow smelt impingement at this facility were found to have nearly white liver tissues, clear white gills, very low blood volumes, and no discernable heme pigments. This condition was not evaluated at the Eastlake and Avon Lake facilities, but was probably present in some of the rainbow smelt classified as potential impingement mortality.

The similarities in the various components of the impingements observed between the Ohio Edison generating facility and those examined in the present study strongly suggest that the various internal pathogens observed at the Edgewater plant by White (1986) are probably present in similar proportions in the fishes impinged at the Eastlake and Avon Lake plants. Assuming comparable levels of internal pathogens to be present in impinged fishes among the three facilities, the lack of internal fish examination during the present study has resulted in extremely conservative estimates of the natural mortality component of impingement. Conversely, the estimated potential impingement mortalities would be overestimated. For example, internal pathologies accounted for approximately 18% of the mortality observed in the freshwater drum at the Edgewater facility (White 1986). Applying this mortality factor to the data obtained in the present study, the estimated potential impingement mortality for the freshwater drum at the Eastlake facility decreases from 20.54% to only 2.73% of the total drum impingement. At Avon Lake, similar treatment of the data results in a decrease of the impingement mortality estimate for this species from 23.99% to 6.18%. A similar procedure applied to the white bass data in this study results in a decrease of the estimated potential impingement mortality from 33.20% to 22.65% at the Eastlake facility, and from 46.02% to 35.57% at the Avon Lake facility.

Thus, the actual total non-shad impingement mortalities are very likely to be much less than the 19.54% and 23.64% obtained for the Eastlake and Avon Lake facilities, respectively. In the fishes examined in the present study, it is highly probable that terminal internal pathogenicity was present, and that many of the fishes with internal pathogenic conditions were included in the estimate of impingement mortality. Internal examination of impinged fishes at the Eastlake and Avon Lake facilities would probably have resulted in impingement mortality estimates approaching the 6.4% value reported for the Edgewater generating facility reported by White (1986). When applied to the total annual impingement mortalities estimated in the 316(b) studies performed at the Avon Lake and Eastlake facilities, the resultant estimates of potential impingement mortality of all impinged fishes would be in the range of 2% of the total annual impingement.

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