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Eighteen-Month Evaluation of the Ristroph Traveling Fish Screens

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INTRODUCTION

On May 1, 1974, a new concept in vertical traveling screens for power station intakes was declared to be in commercial operation at the Virginia Electric and Power Company (VEPCO) Surry Power Station. The new screens include basic modifications to and departures from the design and operation of conventional traveling screens, changes specifically designed to protect fish that might become impinged on the screens during the cooling water withdrawal phase of power generation.

This paper will describe the modified screens and will give an assessment of their performance during the first 18 months of operation. The screens, manufactured by Envirex Inc., are popularly known as the Ristroph traveling fish screens, so named for their basic designer Mr. J.D. Ristroph, retired Executive Manager of VEPCO's Environmental Services Department.

SITE DESCRIPTION

The Surry Power Station is located on Gravel Neck peninsula adjacent to Hog Island on the James River, Virginia, about 25 nautical miles upstream from the confluence of the river with Chesapeake Bay (Figure 1). The station consists of twin nuclear units (Westinghouse pressurized water reactors), each rated at 788 MW_e. Cooling water is withdrawn from the James River on the downstream side of the peninsula through a shoreline intake structure by eight pumps, each rated at 220,000 gal/min (13.88 m^3/sec). The water is pumped into a 1.7-mile (2.74 km) long elevated concrete-lined canal, where it flows by gravity through the condensers of both units, and is then discharged at a velocity of 6 ft/sec (1.8 m/sec) on the upstream side of the peninsula.

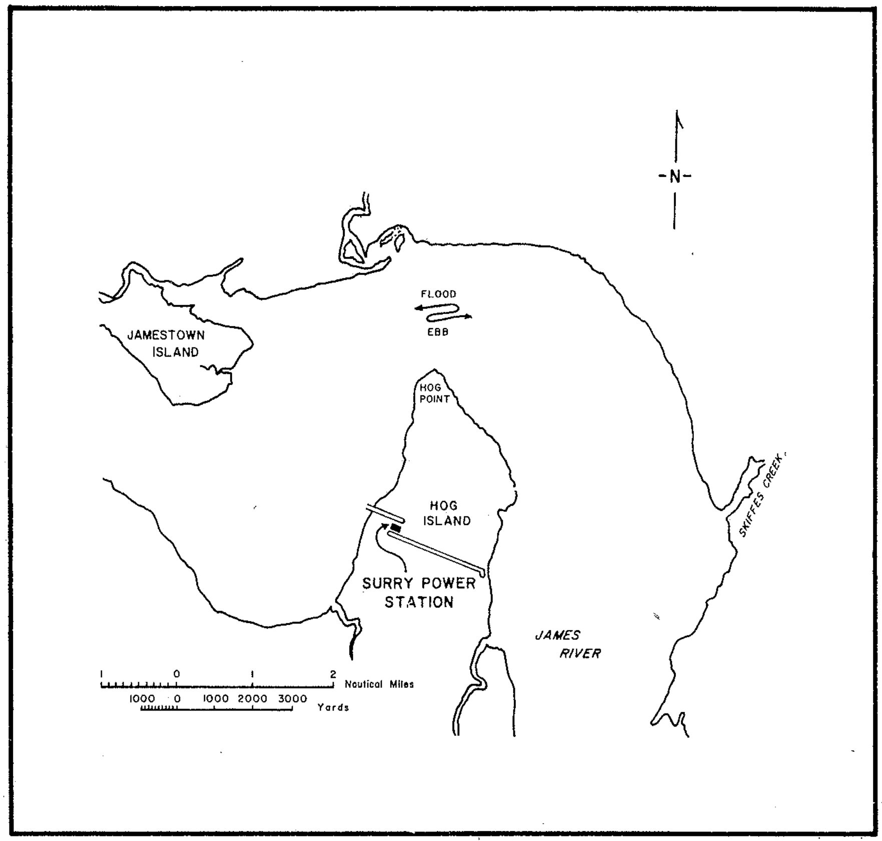

Figure 1. Location of the Surry Power Station near Hog Island on the James River, Virginia.

The tidal James River estuary in the vicinity of the station can be classed as oligohaline, although salinities in the range of 14 ppt have been measured during extreme drought conditions. Because of this wide range of salinities, freshwater, estuarine, and oceanic species of fish are found in the tidal segment that encompasses Hog Point at some or all times of the year.

The James River estuary in this area has extensive shallow water zones, is about 3 miles wide, and has a maintained shipping channel along its main course.

SCREEN DEVELOPMENT HISTORY

Developers of the Ristroph traveling fish screens were faced with a retrofit situation. The Surry intake structure that houses the eight circulating water pumps had been in use since shortly before unit 1 became commercial on December 22, 1972. The structure, 198 ft (60.35 m) in length with eight fore-bays, had trash bars but no screens, although it had been originally constructed with slots to receive conventional traveling screens.

The necessity for screens outboard of the pumps had become evident when relatively large numbers of juvenile fish were found in the high-level canal. These fish were being removed from the canal by eight conventional traveling screens located at a second intake structure immediately in front of the condenser water boxes. Because installation of conventional screens outboard of the pumps would not reduce impingement mortality levels below those encountered at the high-level screens in the canal, a decision was made to attempt to design a new traveling screen that would accomplish the following:

1. Permit the maximum possible fish survival by providing safe removal of fish from the screens and transport back to the river.
2. Permit installation in the existing intake structure without major modifications to the structure.
3. Permit operation in a manner that would not jeopardize the cooling water supply to the condensers.

With these objectives as guides, the screens were designed and engineered by biologists and engineers who were willing to sit in open discussion sessions where each listened and learned from the other.

RISTROPH TRAVELING FISH SCREEN DESCRIPTION

The Ristroph traveling fish screens (Figure 2) in operation at the Surry Power Station incorporate significant departures from the design and operation of conventional vertical traveling screens. We believe that many, if not all, of these departures, which were brought about by a conceptual change in thinking from engineering for the removal of debris to engineering for the survival and subsequent transport of fish, are necessary for the successful operation of vertical traveling fish screens. Major design changes are shown in Table 1.

Each Ristroph traveling fish screen, as engineered for the Surry Power Station intakes, contains 47 screen panels each 14 ft (4.27 m) wide by 2 ft (0.6 m) high, with a screen mesh size of 3/8 in. (0.45 cm). Operation is continuous at a speed of 10 ft/min (3.05 m/min), with an alternate capability of 20 ft/min (6.1 m/min).

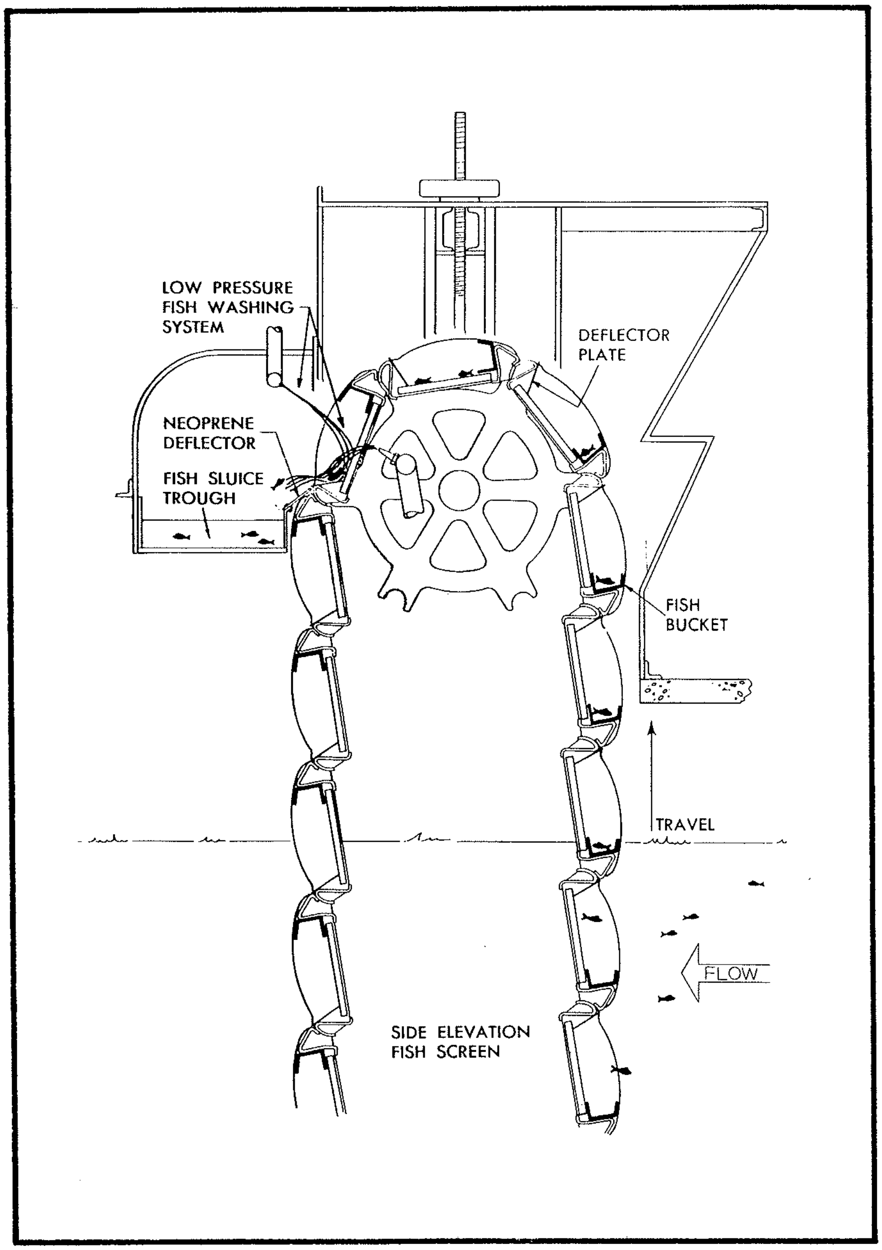

Figure 2. Schematic diagram of the Ristroph traveling fish screen.

Table 1
A Comparison of a Typical Conventional Traveling Screen with the Ristroph Traveling Fish Screen

Conventional Screen	Ristroph Screen
Pressure differential operation (increases impingement time).	Continuous operation (decreases impingement time).
Ledge between each screen panel (fish out of water during screen elevation).	Trough containing 2 in. of water between each screen panel (fish remain in water during screen panel elevation).
Screen washwater pressure 80-120 lb/in.^{2} (may descale or otherwise injure fish).	Screen washwater pressure 15-20 lb/in.^{2} (prevents descaling and injury).
Washwater trough or flume empty (except during screen operation).	Washwater trough maintains 2 in. of water (fish gently washed into water).
Collection basket at end of washwater trough (results in dead end for fish).	Fishway with continuous water supply (returns fish to river).

Screen panels are washed on the back side of the screen structure by water sprayed from two header pipes, one inside the rotating screen and another located outside the screen and above a collection trough, after each panel has rotated over the top of the head sprocket. The inside header pipe contains 24 individual spray nozzles, while the outside header pipe contains 48 sprays. Collectively, the nozzles are designed to supply approximately 200 gal/min (0.76 m^3/min) of washwater at 15-20 lb/in.^{2} to each of the eight screens.

Fish that become impinged remain on the face of a screen panel for a maximum of 2 minutes or until that panel clears the air-water interface. It is at this point in the cycle that significant mortality occurs on operating conventional screens, because fish can flip back into the water and be reimpinged repeatedly until in a moribund condition. The Ristroph screen employs a trough of water 2 in. (5.08 cm) deep by 5.5 in. (13.97 cm) wide that runs the full width of the screen along the base of each panel (Figure 2). When each panel clears the air-water interface, fish drop into the trough and remain in water until the panel passes over the top of the sprocket. As the panel goes from vertically upward travel to horizontal, fish are out of the water for a few seconds, slide down the panel as it becomes vertical going downward, and are gently washed into a backside fiberglass fish sluice trough designed to maintain a water depth of 2 in. (5.08 cm).

The fish return system is an open top U-shaped fiberglass trough that contains about 2 ft (60.96 cm) of water into which screen washwater from each fish sluice trough and augmentation water flow to carry fish and other collected material back to the river to a point of discharge about 1,000 ft (304.8 m) downstream from the screens and about 300 ft (91.4 m) offshore. The trough is fitted with a Y-shaped section that contains a flop gate whereby the entire washwater volume of about 2,500 gal/min (9.46 m^3/min) can be diverted into a 17,000-gal (64.3 m^3) fiberglass holding pool for sampling purposes.

SAMPLING METHODOLOGY

Two consecutive samples for impinged fish are taken Monday through Friday each week. Each sampling consists of diverting the entire screen washwater volume from the flume into a fiberglass pool 28 x 20 x 4 ft (8.5 x 6.1 x 1.2 m) for a 5-minute interval. Filling of the pool is followed by a 10-15 minute "quiet" period, during which time the level of the sometimes highly turbid James River water in the pool is slowly lowered. As soon as fish become visible, they are dip-netted and determined to be either alive or dead. All specimens of each species are then measured and classified into 20-mm total length (TL) ranges. Dead fish are bulk weighed to the nearest 0.1 g.

RESULTS AND DISCUSSION

From May 1, 1974 through October 31, 1975, 58 species of fish, which represented 27 families, were collected from the Ristroph screens during daily sampling. The average survival of all species of fish for the first 18 months of operation was 93.3%. Lengths of fish collected by the screens generally ranged from 30 to 200 mm TL, with occasional exceptions on either side of this range.

An analysis of the number of species and percentage of survival shows that the majority of the species (52 of 58) had more than 80.0% survival, with the majority of these species having a survival in excess of 90.0% (Table 2). More than 99.0% of the total number of fish sampled had more than 80.0% survival, with 87.6% of the total number falling between 90.0% and 99.9% (Table 2).

The oligohaline zone of an estuary such as that of the James River can be expected to support a wide variety of fish species. Salinities ranged between 0.0

Table 2
Percentage Alive, Number of Species, and Percentage of Total Number Caught for Fishes Taken May 1, 1974 to October 31, 1975

Percentage Alive	Number of Species	Percentage of Total Sampled
0.0	1	< 1.0
50.0-59.9	1	< 1.0
60.0-69.9	4	< 1.0
80.0-89.9	6	11.3
90.0-99.9	20	87.6
100.0	26	1.0

and 12.1 ppt during these 18 months. By use of the American Fisheries Society general guide to fish distribution (American Fisheries Society 1970), "Atlantic-freshwater" species were the most numerous in the area and constituted more than 70% of the total number taken (Table 3). The overall percentage of survival for "freshwater" species was slightly higher than the survival of "Atlantic" and "Atlantic-freshwater" species (Table 3). The impinged fish species composition reflects the partial function of this section of the James River as a pathway for anadromous species and a low salinity area for estuary-dependent species.

The family Clupeidae, represented by seven species, accounted for 58.1% of the total number of fish sampled (Table 4). Of these seven species, six are designated as "Atlantic-freshwater," while the seventh *(Brevoortia tyrannus)* is designated as "Atlantic." Because *B. tyrannus* constituted about 30% of the total for the family Clupeidae and almost 17% of the total for all fish taken, and due to the fact that juveniles of this species show an obvious low-salinity distribution in this and other areas (Mansueti and Hardy 1967), consideration should be given to reclassifying the designation for this species to "Atlantic-freshwater" or even a new "Atlantic-estuarine" classification for all species that live part of their life cycles at salinities between 0.5 and 20.0 ppt.

The family Sciaenidae, represented by five species, accounted for 18.1% of the total number of fish sampled (Table 4). Of these five, *Leiostomus xanthurus* and *Micropogon undulatus* comprised 99.5% of the total sciaenids taken.

Survival of fish by family was very high (Table 4). Individual species within multispecies families showed a wider survival range, although survival rates less than 80% were generally caused by low numbers of individuals of a given species (Table 5). Two related species, *Cynoscion nebulosus* and *Cynoscion regalis,* had

Table 3
Distribution of Fishes in the Surry Area by American Fisheries Society (AFS) Designation

AFS Designation	Number of Species	Average Percentage Survival	Percentage of 18-Month Total
Atlantic	13	94.3	19.1
Atlantic-freshwater	26	92.3	70.1
Freshwater	19	98.1	10.8

Table 4
Major Families Represented, Showing Percentage Survival by Family, Range of Survival within a Family, and Percentage of the Total Fish Taken Represented by Each Family

Family[a]	Species	Percentage of Survival	Percentage of Survival Range	Percentage of 18-Month Total
Clupeidae	7	93.3	82.3-94.3	58.1
Sciaenidae	5	93.4	59.2-100.0	18.1
Engraulidae	1	82.0	--	6.6
Ictaluridae	3	98.6	96.8-99.2	5.5
Cyprinidae	5	96.8	92.9-100.0	4.2
Atherinidae	3	91.7	81.7-94.6	1.9
Percichthyidae	2	99.4	99.4-100.0	1.5
Anguillidae	1	98.9	--	1.0
Centrarchidae	7	99.5	99.5-100.0	< 1.0
Gobiidae	2	99.7	99.7-100.0	< 1.0
Cyprinodontidae	5	100.0	--	< 1.0
Percidae	2	100.0	--	< 1.0

(a) There are 15 additional families, each represented by one species, each species representing less than 1.0% of the 18-month total. Survival range is 0.0% to 100.0%.

Table 5
Impinged Fish by Family and Species, Showing Percentage Alive and Percentage of Total Taken within Family

Family	Species	Percentage Survival	Percentage of Total within Family
Clupeidae, herrings			
	Dorosoma petenense	93.6	44.9
	Brevoortia tyrannus	94.9	29.3
	Alosa aestivalis	90.4	14.0
	Alosa pseudoharengus	90.7	5.5
	Dorosoma cepedianum	93.1	5.0
	Alosa sapidissima	93.5	1.2
	Alosa mediocris	82.3	< 1.0
Sciaenidae, drums			
	Leiostomus xanthurus	96.7	76.6
	Micropogon undulatus	82.7	23.0
	Cynoscion regalis	59.2	<1.0
	Bairdiella chrysura	100.0	<1.0
	Cynoscion nebulosus	60.0	<1.0
Engraulidae, anchovies			
	Anchoa mitchilli	82.0	100.0
Ictaluridae, freshwater catfishes			
	Ictalurus catus	99.2	54.3
	Ictalurus punctatus	98.8	28.9
	Ictalurus nebulosus	96.8	16.8
Cyprinidae, minnows and carps			
	Notropis hudsonius	96.6	87.0
	Notemigonus crysoleucas	100.0	9.9
	Cyprinus carpio	92.9	2.2
	Hybognathus nuchalis	100.0	<1.0
	Semotilus atromaculatus	100.0	<1.0
Atherinidae, silversides			
	Menidia menidia	94.0	72.9
	Membras martinica	81.7	18.8
	Menidia beryllina	94.6	8.3
Percichthyidae, temperate basses			
	Morone americana	99.4	99.7
	Morone saxatilis	100.0	<1.0

Table 5 (Continued)

Family	Species	Percentage Survival	Percentage of Total within Family
Anguillidae, freshwater eels			
	Anguilla rostrata	98.9	100.0
Centrarchidae, sunfishes			
	Lepomis gibbosus	99.5	91.4
	Lepomis macrochirus	100.0	3.5
	Enneacanthus gloriosus	100.0	3.1
	Lepomis auritus	100.0	<1.0
	Pomoxis nigromaculatus	100.0	<1.0
	Lepomis sp.	100.0	<1.0
	Centrarchus macropterus	100.0	<1.0
Gobiidae, gobies			
	Gobiosoma bosci	99.7	97.4
	Gobiosoma ginsburgi	100.0	2.6
Cyprinodontidae, killifishes			
	Fundulus heteroclitus	100.0	71.0
	Fundulus diaphanus	100.0	16.0
	Cyprinodon variegatus	100.0	11.7
	Fundulus majalis	100.0	<1.0
	Fundulus confluentus	100.0	<1.0
Percidae, perches			
	Perca flavescens	100.0	50.0
	Etheostoma olmstedi	100.0	50.0
Soleidae, soles			
	Trinectes maculatus	96.5	100.0
Pomotomidae, bluefishes			
	Pomotomus saltatrix	85.3	100.0
Bothidae, lefteye flounders			
	Paralichthys dentatus	97.2	100.0
Amiidae, bowfins			
	Amia calva	100.0	100.0
Scombridae, mackerels and tunas			
	Scomberomorus maculatus	64.7	100.0

Table 5 (Continued)

Family Species	Percentage Survival	Percentage of Total within Family
Carangidae, jacks and pompanos		
Caranx hippos	85.7	100.0
Lutjanidae, snappers		
Lutjanus griseus	100.0	100.0
Petromyzontidae, lampreys		
Petromyzon marinus	100.0	100.0
Mugilidae, mullets		
Mugil cephalus	100.0	100.0
Cynoglossidae, tonguefishes		
Symphurus plagiusa	66.7	100.0
Stromateidae, butterfishes		
Peprilus alepidotus	66.7	100.0
Gasterosteidae, sticklebacks		
Gasterosteus aculeatus	100.0	100.0
Elopidae, tarpons		
Elops saurus	100.0	100.0
Trichiuridae, cutlassfishes		
Trichiurus lepturus	0.0	100.0
Salmonidae, trouts		
Salmo gairdneri	100.0	100.0

similar survivals of about 60%, but each constituted less than 1.0% of the total sciaenid population. The only species that showed 0.0% survival *(Trichiurus lepturus)* was represented by one individual.

Because the Surry Power Station is located in the "salinity gradient zone" of the James River estuary, the annual species combinations that are encountered are diverse. Survival rates vary both within genera and between genera within families (Table 5).

During the first months of sampling the Ristroph traveling fish screens, it was determined that minor modifications to the original design might result in better survival of impinged fishes. An auxiliary header wash system was installed outside of the screens to aid in the removal of fish resting on the ledge created by the bottom side of the screen bucket traveling downward. An augmentation water supply system was installed at the end of each fish sluice trough to aid in the movement of fish to the river return trough. A neoprene-nylon flap was installed along the edge of the fish sluice trough to keep fish from falling between the screen and the trough. Finally, a system was installed to slow the water velocity into the sampling pool. The results were evident, because, beginning in August 1974, with one exception, monthly survivals have been in excess of 90% (Figure 3).

The number of species shows some seasonality, as manifested by a decrease in January, February, and March, followed by a sharp increase in April (Figure 3). Several of the species, however, can be classified as "occasional," especially some of the océanic species that may be at the upriver limit of their range. In addition, the James River basin has been subjected to record and near-record floods in recent years and to springtime fish "kills." Any or all of these variables may have an influence on any apparent seasonality. It is interesting to note, however, that the number of species has remained relatively constant over time.

The largest number of impinged fish usually occurs during the winter months. This occurrence is due, in part, to juvenile anadromous species moving seaward and fall and winter spawned oceanic species moving into low-salinity areas. The increase in numbers in the winter of 1974-75 was also due mainly to an "explosion" of the threadfin shad *(Dorosoma petenense)* population in the James River. Prior to 1973, this species was seldom taken in this part of the river.

There appeared to be more fish in the river in the summer of 1975 than in previous years (Figure 3). The reasons for the apparent increase await further analysis of available data; however, it is possible that fish populations are in a "recovery" phase after the passage of floodwaters associated with Hurricanes Agnes and Camille and major nonpower station-related fish "kills" in 1971, 1973, and 1974.

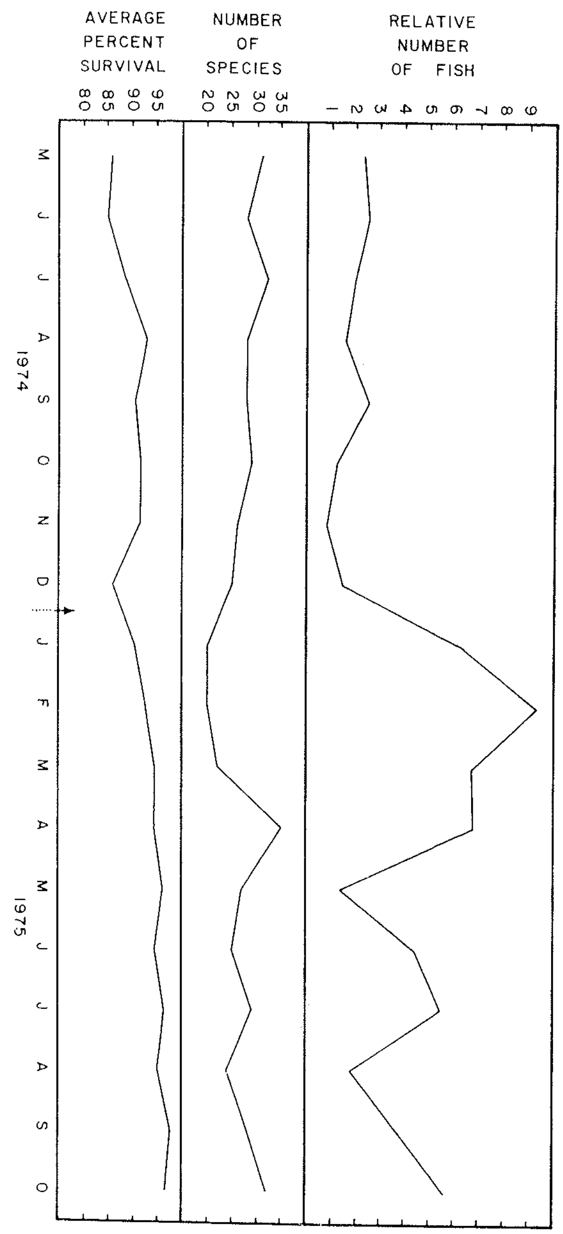

Figure 3. Relative number of fish, number of species, and average percentage of survival by month for the Ristroph traveling fish screen system at the Surry Power Station.

CONCLUSIONS

The first 18 months of operation of the Ristroph traveling fish screens at VEPCO's Surry Power Station have shown that an average of 93.3% of all impinged fish survive the impingement process. This consistently high survival rate alone serves to prove the success of the principles that have been incorporated into the design of the screens.

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