CALVERT CLIFFS NUCLEAR POWER PLANT
FINFISH SURVIVAL STUDY
FOR
BALTIMORE GAS AND ELECTRIC COMPANY
FINAL REPORT

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EXECUTIVE SUMMARY

Survival and impingement studies were conducted at Calvert Cliffs Nuclear Power Plant June-August 1986 to compare survival rates, sizes and numbers of impinged finfishes. There were no overall differences among screen types in survival of impinged finfish. Beauderey screens impinged fish of larger average size than did control screens. More fish were impinged by both experimental screens than by FMC single-speed screens. However, the difference in impingement rates may be due to screen positions rather than screen types.

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INTRODUCTION

In the summer of 1986, the Academy of Natural Sciences conducted studies to compare numbers and survival rates of finfish impinged on three different types of traveling screens at the Baltimore Gas and Electric Company's Calvert Cliffs Nuclear Power Plant (CCNPP). These screens are designed to prevent finfish, other estuarine organisms and debris too large to pass through the 8 x 8-mm opening of the screen mesh from being carried into the cooling system of the plant. As the screens rotate, impinged animals normally are washed off the screens and into a trough that returns them to the Chesapeake Bay.

FMC single-speed screens are currently used at CCNPP. Two experimental screen types, Beauderey screens and FMC dual-speed screens were installed by Baltimore Gas and Electric Company (BG&E) at Units 1 and 2, respectively, to test their effectiveness at protecting the power plant's cooling system. The purpose of the study described here was to determine whether a conversion to either of the experimental screen types would significantly increase the number of fish killed by plant operations.

MATERIALS AND METHODS

Finfish Survival Studies

Survival rates for finfish impinged on FMC dual-speed screens and Beauderey screens were compared with those of finfish impinged on the currently used FMC single-speed screens (controls). The FMC dual-speed screens were located at Unit 2, screen position 6, and the Beauderey screens were at Unit 1, position 1 (Fig. 1). FMC single-speed screens at Unit 1, position 2, and at Unit 2, position 5, were used as controls

because finfish impingement at these positions tends to be most similar to that at the positions where the experimental screens were installed (J. H. Hixson, III, personal communication).

Because each type of experimental screen was installed at only one position, this study cannot clearly distinguish between screen and position effects. The duration of this study did not allow for comparisons of survival rates of finfish impinged at the positions used for experimental screens before and after those screens were installed. It is the impression of the biologist J. H. Hixson, III, who has been conducting sampling of impinged animals at CCNPP for 10 years, that sizes and survival rates of impinged finfishes do not vary among screen positions within units. However, Mr. Hixson has observed that the outermost screen positions (Unit 1, position 1 and Unit 2, position 6; Fig. 1) impinge the greatest numbers of individuals. Based on Mr. Hixson's observations, it seems most judicious to interpret a difference in survival rates, sizes of impinged finfish or a <u>lower</u> impingement rate at experimental screens than at controls as due to differences between screen types. However, no interpretation of data can be made if impingement rates are higher at experimental screens than at control screens.

To conduct the survival study, fish and wash-water were diverted from the troughs to large concrete survival pools that measured approximately 9.3-m long x 4.3-m wide x 0.8-m deep (Fig. 1). At Unit 1, specific screens were sampled by timing the collections to begin approximately 100 sec after the screen to be sampled began to rotate; 100 sec was the approximate amount of time it took for wash-water and fish to travel from the Unit 1 screens to the Unit 1 survival pool. Wash-water and impinged animals were allowed to flow into the pool for 10 min, the duration of each screen rotation. At Unit 2, a different procedure was used because the time it took for fish to travel from the screens to the Unit 2 survival pool was longer and more variable than that at Unit 1. Unit 2 screens were manually rotated. Organisms from screens not sampled for this

study (screens 21-24) were diverted toward Unit 1 during the entire pool-filling procedure on days that Unit 2 screens were sampled. Wash-water and organisms were allowed to enter the Unit 2 survival pool for 25 min, beginning 3 min after the experimental or control screen to be sampled began its hourly rotation. At the end of the 25 min sample collection, wash-water and organisms were diverted away from the pool and the screen not targeted for sampling was manually rotated. Other than the method of collecting discrete samples from targeted screens, procedures used at Units 1 and 2 were identical.

At the end of each diversion of wash-water and organisms into the survival pools, blue crabs (*Callinectes sapidus*), coelenterates and ctenophores were removed. Dead finfish were removed and identified to species and total lengths of all dead finfish, up to a maximum of 25 randomly chosen individuals of each species, were measured to the nearest 0.5 cm.

We attempted to include all fish washed from the screen of interest during 6-7 successive screen rotations in each sample. However, the actual number of screen rotations included in samples was often fewer than 6 (Table 1), generally because screens were placed in continuous rotation during some portion of the day or, occasionally, because we collected large numbers of fish in less than 6 rotations. When heavy impingements required continuous rotation of screens, all screens at a unit rotated simultaneously and it was impossible to collect discrete samples from the screens of interest.

After the final screen rotation was included in the day's sample, data on environmental parameters were taken. Dissolved oxygen (D.O.) levels were measured with a Y.S.I. model 57 D.O. meter. Salinity was measured with a Y.S.I. model 33 Salinometer. Water temperature (°C), water depth and weather were also recorded. Salinity, D.O. and water temperature were measured at middepth in the pools. These data are summarized in Table 2.

Approximately 24 h after pools were filled, salinity, D.O. and water temperature were remeasured (Table 2). All finfish

except hogchokers (*Trinectes maculatus*) were then removed, identified and classified as live, dead or exhibiting loss of equilibrium (LOE). Loss of equilibrium was defined as the inability of the fish to maintain a normal position in the water. Total length of all individuals, up to a maximum of 25 (haphazardly chosen) individuals of any one species, was measured to the nearest 0.5 cm. *Trinectes maculatus* was not included in this study because previous research indicated that impingement does not increase mortality of this species (Burton, 1976).

Sampling was conducted 6-7 days per week from June 1 through August 22, 1986, except during plant outages, when screens were not in operation, or when screens were continuously rotated. A total of 9 samples was collected from the Beauderey screens, 20 samples from Unit 1 control screens, 17 samples from FMC dual-screens, and 9 samples from Unit 2 control screens (Table 1).

Impingement Study

Numbers and kinds of finfishes and numbers of blue crabs (*Callinectes sapidus*) impinged on experimental and FMC single-speed screens were determined by netting finfish and crabs directly from the screen-water troughs during June, July and August 1986. At each operating unit, a 1.27-cm stretch-mesh collecting net was placed in the screen-wash trough during one 10-min rotation of each of the six pairs of rotating screens. Raw data were adjusted to account for the amount of time it took to lift the net out of the trough and empty its contents into collection buckets since nets needed to be emptied as often as several times each minute. Each pair of screens rotates 10 min out of each hour and then remains stationary during the remaining 50 min. Thus, each 10-min sample taken and adjusted as described above, can be used to estimate the number of finfish and blue crabs impinged on the screen in one hour. For this portion of the study, data from all FMC single-

speed screens at a unit were combined and used as the control against which experimental screens at that unit were compared.

Sampling frequency was based on 6-day cycles separated by 2- or 3-day intervals. On each sampling day, 1-h collections were made at each of the two generating units. If one unit was not in operation, samples were collected only at the operating unit. Samples were not used for experimental vs. control screen comparisons when screens were placed in continuous rotation.

The unit to be sampled first alternated each day. The initial 6-day sampling period, and succeeding odd-numbered 6-day periods, were scheduled as follows: the first collection began at 0000, 0400, 0800, 1200, 1600, 2000 h on the first, second, third, fourth, fifth and sixth days, respectively. The second 6-day sampling period, and succeeding even-numbered sampling periods were scheduled as followed: the first collections began at 0100, 0500, 0900, 1300, 1700 and 2100 h on the first, second, third, fourth, fifth and sixth days, respectively. On each day the second collection began 2 h after the first had begun. Therefore, all hours of the day were sampled in two 6-day sampling periods. A total of 32 samples taken from Beauderey screens, 33 samples from Unit 1 control screens, 28 samples from FMC dual-speed screens and 35 samples from Unit 2 control screens were included in comparisons of impingement rates at experimental and control screens.

Statistical Analyses

Survival rates of impinged finfishes were calculated separately for each species at each screen as

$$\bar{p} = \frac{\Sigma a_i}{\Sigma n_i}$$

where a_i = the number of live individuals in sample i and n_i = the total number of individuals in sample i. The standard error of $\bar{p}$ was calculated for all species represented by a

total of ≥ 30 individuals and present in at least three samples from that screen. The formula used was

$$\text{s.e. } \bar{p} = \frac{1}{\bar{n}} \sqrt{(\Sigma a_i^2 - 2\bar{p}\Sigma a_i n_i + \bar{p}^2 \Sigma n_i^2)/C(C-1)}$$

where C is the number of samples and

$$p_i = \frac{a_i}{n_i} : N = \Sigma n_i : \bar{n} = \frac{N}{C}$$

(Snedecor and Cochran, 1967).

To compare survival rates at experimental and control screens, data were transformed using the logistic transformation (Cox, 1970) such that

$$Z = \log \left(\frac{d_i + \tfrac{1}{2}}{n_i - d_i + \tfrac{1}{2}} \right)$$

where d_i = the number of dead individuals in sample i. These transformed data were weighted for sample size as

$$\text{weight} = 1/V$$

where
$$V = \frac{(n_i + 1)(n_i + 2)}{n_i (d_i + 1)(n_i - d_i + 1)} .$$

Data were analyzed using the SAS GLM procedure (SAS Institute, 1982). Samples containing at least four individuals of a species were included in the statistical analysis for that species.

T-tests and approximate t-tests were used to compare numbers and sizes of impinged individuals.

RESULTS AND DISCUSSION

Finfish Survival Rates

Twenty-nine species of finfish representing twenty-two families were collected in the survival pools at CCNPP (Table 3). Survival rates at each sampled screen were calculated for all finfish except hogchoker impinged on that screen (Tables 4a-d). Survival rates based on few samples or few individuals per sample are poor estimators of actual survival rates, how-

ever. In general, survival rates were lowest for schooling, midwater species (e.g., bay anchovy [*Anchoa mitchilli*], Atlantic menhaden [*Brevoortia tyrannus*], blueback herring [*Alosa aestivalis*]) and highest for benthic species (e.g., oyster toadfish [*Opsanus tau*] and flatfishes).

Data from Units 1 and 2 control screens were combined for statistical analyses in order to increase sample sizes for comparisons of survival rates at experimental and control screens. Sufficient numbers of individuals of four species were collected to statistically compare survival rates of fish impinged on Beauderey screens with those impinged on control screens. These species were Atlantic menhaden, oyster toadfish, spot (*Leiostomus xanthurus*) and northern searobin (*Prionotus carolinus*). Seven species were sufficiently abundant to compare their survival rates when impinged on FMC dual-speed screens with those when impinged on controls: oyster toadfish, bay anchovy, spot, winter flounder (*Pseudopleuronectes americana*), skilletfish (*Gobiesox strumosus*), northern searobin and blackcheek tonguefish (*Symphurus plagiusa*). Species included in statistical analyses were those with at least four individuals present in at least four samples for each screen-type considered in that comparison.

There were no consistent differences in survival rates among finfish impinged on the three types of traveling screens tested in this study. Of the 11 comparisons made, only 2 were statistically significant ($p \leq 0.05$): survival of spot was lower when impinged on Beauderey screens than when impinged on controls, and survival of bay anchovy was lower on FMC dual-speed screens than on controls (Tables 5a and b). Proportions were arcsin transformed before t-tests were performed (Sokal and Rohlf, 1969).

Sizes of Impinged Finfishes

Mean lengths of live, dead and LOE fish collected for the survival study from each screen are presented in Tables 6a-d. Sizes of fish impinged on the different screen types are compared in Table 7 for those species represented by at least 10 individuals in both the experimental screen of interest and the combined controls. The mean size of individuals impinged on Beauderey screens was larger than that on controls for 7 of the 10 species compared: bay anchovy, Atlantic menhaden, weakfish (*Cynoscion regalis*), spot, oyster toadfish, harvestfish (*Peprilus alepidotus*), and blackcheek tonguefish. Thus larger individuals of both water column and demersal species are impinged on Beauderey screens. Only winter flounder was represented by larger individuals in samples from controls than in those from Beauderey screens. There was no significant difference in size of skilletfish or northern searobin impinged at Beauderey and control screens.

No general differences in lengths of fishes were apparent between those impinged on FMC dual-speed screens and those impinged on control screens. Of 12 species compared, mean lengths of two (weakfish and winter flounder) were significantly greater in fish impinged on control screens, and lengths of three (spot, northern searobin and blackcheek tonguefish) were significantly greater for fish impinged on the FMC dual-speed screens. There were no significant differences between screens for lengths of the other fish compared.

Numbers of Impinged Finfish and Blue Crabs

Numbers of finfish impinged by experimental and control screens at each unit were compared for the five most abundant species at each unit and for all species combined (Tables 8a and b). Impingements were higher at experimental than at control screens for three of the five most abundant species at Unit 1, for four of the five most abundant species at Unit 2

and for all finfish species combined at both units. Species for which impingements were not significantly different between screen types followed the same trend; no species were impinged in higher numbers on control screens than on experimental screens. There were also no apparent differences between water column and benthic species.

More blue crabs were impinged by Beauderey screens than by Unit 1 controls (Table 8a). The difference in crab impingement on FMC dual-speed screens and Unit 2 control screens was not significant (Table 8b).

As discussed in the Methods section, it is impossible to determine whether higher impingement rates at experimental screens than at controls is due to differences in screen type or screen position.

SUMMARY

1) Survival and impingement studies were conducted at CCNPP June-August 1986 to compare survival rates, sizes and numbers of impinged finfishes.
2) There were no overall differences among screen types in survival rates of impinged finfish. Of 11 statistical comparisons, only 2 significant differences were found between experimental and control screens.
3) Beauderey screens impinged fish of larger average size than did control screens. Because the economic value of fish is based on size, the value of fish impinged by Beauderey screens may be higher than the value of fish impinged by FMC single-speed screens. FMC dual-speed screens and FMC single-speed screens impinged fish of similar average size.
4) More fish were impinged by both experimental screens than by FMC single-speed screens. However, the difference in impingement rates may be due to screen positions rather than screen types. Experimental screens were installed in the positions that The Academy of Natural Sciences biol-

ogists believed had the highest impingement rates in an effort to improve chances of obtaining adequate sample sizes for analyses of survival rates.

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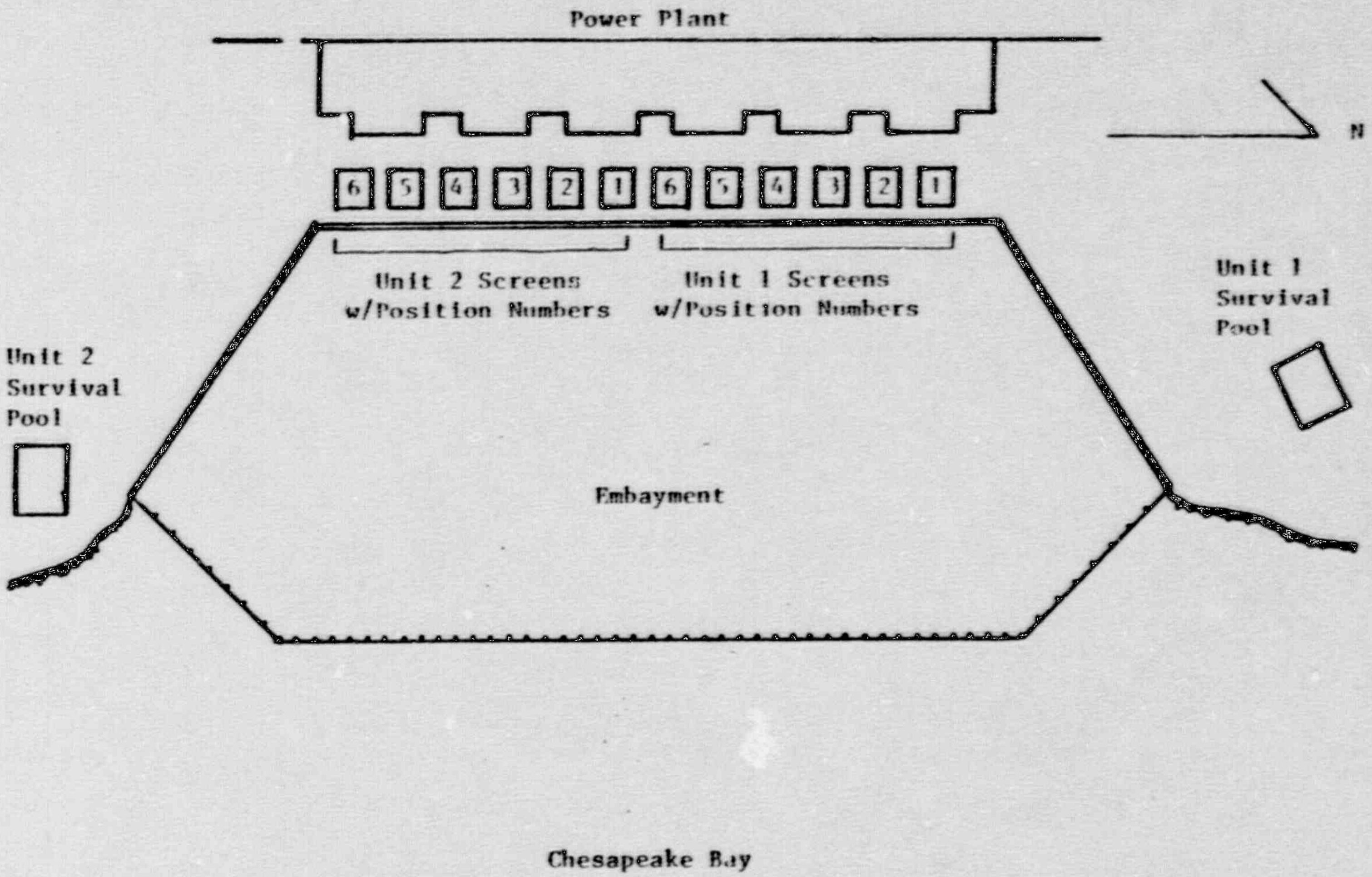

Figure 1. Diagram of CCNPP. Approximate relative locations of rotating screens, survival pools and embayment are shown.

Table 1. Dates on which survival pools were filled for 1986 the finfish survival study and the mean number ($\bar{x}$) of screen rotations included in each sample. Prior to 10 June we were unable to collect discrete samples from the desired screens at Unit 2. (SE = Standard Error)

Sample Dates			
Beauderey Screens	Unit 1 controls (FMC single-speed screens)	FMC dual-speed screens	Unit 2 controls (FMC single-speed screens)
June 5	June 1	June 12	June 10
10	8	15	17
19	12	23	19
24	15	27	25
	17	30	
	22		
	26		
	29		
July 8	July 1	July 2	July 9
15	6	7	16
29	10	14	23
	13	18	
	17	21	
	20	28	
	24		
August 5	August 3	August 1	August 6
14	7	4	13
	10	8	
	17	11	
	21	15	
		20	
$\bar{X}$ (SE) number of rotations per sample:			
5.3(0.5)	5.4(0.4)	5.6(0.3)	5.0(0.5)

Table 2. Dissolved oxygen, salinity and temperature of water in survival pools. F = data taken on day pool was filled, E = data taken approximately 24 h later, on the day the pool was emptied. All data are presented as $\bar{X} \pm 1$ SE.

Screen	Dissolved Oxygen ($mg \cdot L^{-1}$)		Salinity (ppt)		Water Temperature (°C)	
	F	E	F	E	F	E
Beauderey	7.6±0.2	5.6±0.7	14.2±0.5	13.7±0.1	25.6±0.9	24.5±0.7
FMC dual-speed	6.7±0.2	3.7±0.3	14.2±0.2	13.9±0.3	26.4±0.4	24.7±0.4
Unit 1 control	7.6±0.3	5.9±0.4	14.2±0.3	14.1±0.3	25.8±0.4	24.2±0.4
Unit 2 control	7.1±0.2	4.3±0.8	14.3±0.3	13.5±0.3	25.9±0.5	24.3±0.8

Table 3. Finfish species collected from experimental and control screens for the 1986 finfish survival study at CCNPP. Hogchokers, *Trinectes maculatus*, were also impinged but were not included in the study.

FAMILY	SCIENTIFIC NAME	COMMON NAME
Anguillidae	*Anguilla rostrata*	American eel
Clupeidae	*Alosa aestivalis*	blueback herring
	Alosa pseudoharengus	alewife
	Brevoortia tyrannus	Atlantic menhaden
Engraulidae	*Anchoa mitchilli*	bay anchovy
Ophidiidae	*Ophidion marginatum*	striped cusk-eel
Batrachoididae	*Opsanus tau*	oyster toadfish
Gobiesocidae	*Gobiesox strumosus*	skilletfish
Gadidae	*Urophycis regia*	spotted hake
Cyprinodontidae	*Cyprinodon variegatus*	sheepshead minnow
Poeciliidae	*Gambusia affinis*	mosquito fish
Atherinidae	*Menidia menidia*	Atlantic silverside
Syngnathidae	*Syngnathus fuscus*	northern pipefish
Triglidae	*Prionotus carolinus*	northern searobin
Percichthyidae	*Morone saxatilis*	striped bass
Sciaenidae	*Menticirrhus americanus*	southern kingfish
	Cynoscion regalis	weakfish
	Cynoscion nebulosus	spotted seatrout
	Leiostomus xanthurus	spot
Bothidae	*Paralichthys dentatus*	summer flounder
	Scophthalmus aquosus	windowpane
Pleuronectidae	*Pseudopleuronectes americanus*	winter flounder
Soleidae	*Trinectes maculatus*	hogchoker
Cynoglossidae	*Symphurus plagiusa*	blackcheek tonguefish
Tetraodontidae	*Sphoeroides maculatus*	northern puffer
Blenniidae	*Chasmodes bosquianus*	striped blenny
	Hypsoblennius hentzi	feather blenny
Gobiidae	*Gobiosoma bosci*	naked goby
Stromateidae	*Peprilus alepidotus*	harvestfish

Table 4a. Survival rates of finfishes impinged in 1986 on Beauderey screens at CCNPP Unit 1.

Species	Percent survival %	Percent survival SE*	number of samples on which percent survival is based**	number of individuals in samples included in calculation of percent survival $\bar{X}$	number of individuals in samples included in calculation of percent survival SE
Alosa aestivalis	0.0	-	2	1.0	-
Anchoa mitchilli	6.3	2.8	8	6.0	3.4
Anguilla rostrata	0.0	-	3	1.0	-
Brevoorti[illegible] cyrannus	6.2	3.3	7	9.3	1.9
Chasmodes bosquianus	100.0	-	2	1.0	-
Cynoscion regalis	31.6	-	4	4.8	2.2
Gambusia affinis	100.0	-	2	2.5	0.5
Gobiesox strumosus	100.0	-	6	3.2	0.8
Gobiosoma bosci	100.0	-	2	1.0	-
Leiostomus xanthurus	45.6	20.6	9	122.3	51.7
Menidia menidia	0.0	-	4	1.5	0.5
Opsanus tau	97.4	1.4	9	8.7	2.1
Paralichthys dentatus	44.4	-	5	1.8	0.4
Peprilus alepidotus	18.3	-	2	41.0	12.0
Prionotus carolinus	51.0	1.3	6	277.5	249.0
Pseudopleuronectes americanus	78.8	11.2	3	11.0	2.9
Scophthalmus aquosus	100.0	-	1	1.0	-
Sphoeroides maculatus	87.5	-	6	1.3	0.2
Symphurus plagiusa	47.8	-	3	15.3	12.3
Syngnathus fuscus	33.3	-	2	1.5	0.5
Urophycis regia	11.1	-	4	2.3	0.9
Unknown	0.0	-	1	1.0	-

*Standard errors for survival rates are calculated for all species represented by a total of at least 30 individuals and found in at least 3 samples.

**The survival rate of a species is calculated using all samples that included at least one individual of that species.

Table 4b. Survival rates of finfishes impinged in 1986 on FMC dual-speed screens at CCNPP Unit 2.

Species	Percent survival %	Percent survival SE	number of samples on which percent survival is based	number of individuals in samples included in calculation of percent survival X̄	number of individuals in samples included in calculation of percent survival SE
Alosa pseudoharengus	0.0	-	1	1.0	-
Anchoa mitchilli	0.0	0.0	15	89.6	84.7
Brevoortia tyrannus	0.0	-	7	1.6	0.2
Chasmodes bosquianus	89.5	-	5	3.8	2.6
Cynoscion regalis	21.4	-	7	4.0	1.5
Gambusia affinis	100.0	-	2	2.5	0.5
Gobiesox strumosus	98.6	0.6	12	23.3	13.0
Gobiosoma bosci	93.8	-	7	2.3	0.6
Leiostomus xanthurus	91.0	4.2	16	22.9	8.3
Menidia menidia	12.5	-	2	4.0	2.0
Morone saxatilis	100.0	-	1	1.0	-
Ophidion marginatum	100.0	-	2	1.0	-
Opsanus tau	96.8	1.0	16	25.3	6.6
Paralichthys dentatus	89.2	7.1	12	8.3	7.9
Peprilus alepidotus	36.4	-	4	2.8	1.4
Prionotus carolinus	38.8	5.1	13	7.9	1.9
Pseudopleuronectes americanus	47.6	11.2	9	7.0	2.5
Scophthalmus aquosus	0.0	-	1	1.0	-
Sphoeroides maculatus	66.7	-	4	1.5	0.3
Symphurus plagiusa	65.2	9.7	15	12.3	4.7
Syngnathus fuscus	22.2	-	6	1.5	0.3
Urophycis regius	75.0	-	5	1.6	0.6

Table 4c. Survival rates of finfishes impinged in 1986 on Unit 1 control screens at CCNPP.

Species	Percent survival %	Percent survival SE	number of samples on which percent survival is based	number of individuals in samples included in calculation of percent survival $\bar{X}$	number of individuals in samples included in calculation of percent survival SE
Alosa aestivalis	17.1	-	2	58.5	53.5
Anchoa mitchilli	18.3	3.6	19	65.8	36.7
Brevoortia tyrannus	12.8	3.4	18	16.9	10.5
Chasmodes bosquianus	66.7	-	2	3.0	2.0
Cynoscion nebulosus	100.0	-	1	1.0	-
Cynoscion regalis	26.0	3.4	6	8.3	5.0
Gambusia affinis	100.0	-	1	3.0	0.0
Gobiesox strumosus	100.0	0.0	13	4.8	1.2
Gobiosoma bosci	100.0	-	3	1.7	0.3
Hypsoblennius hentzi	0.0	-	1	1.0	-
Leiostomus xanthurus	61.1	5.8	19	99.9	27.3
Menidia menidia	10.7	-	13	2.2	0.3
Menticirrhus americanus	0.0	-	1	1.0	-
Ophidion marginatum	0.0	-	1	1.0	-
Opsanus tau	96.5	1.5	19	5.9	0.9
Paralichthys dentatus	35.3	-	9	1.9	0.5
Peprilus alepidotus	9.3	3.0	4	10.8	9.4
Prionotus carolinus	44.5	8.1	15	23.7	9.6
Pseudopleuronectes americanus	46.3	11.6	10	4.1	0.9
Scophthalmus aquosus	40.0	-	3	1.7	0.7
Sphoeroides maculatus	87.5	-	7	1.1	0.1
Symphurus plagiusa	45.3	11.1	10	6.4	2.0
Syngnathus fuscus	44.4	-	5	1.8	0.6
Urophycis regia	35.7	-	5	2.8	1.1

Table 4d. Survival rates of finfish impinged in 1986 on Unit 2 control screens at CCNPP.

Species	Percent survival %	Percent survival SE	number of samples on which percent survival is based	number of individuals in samples included in calculation of percent survival $\bar{X}$	number of individuals in samples included in calculation of percent survival SE
Anchoa mitchilli	9.4	3.5	9	3.6	1.3
Anguilla rostrata	100.0	-	1	1.0	-
Brevoortia tyrannus	0.0	-	6	1.3	0.3
Chasmodes bosquianus	100.0	-	1	1.0	-
Cynoscion nebulosus	0.0	-	1	1.0	-
Cynoscion regalis	2.4	3.8	3	13.7	11.2
Cyprinodon variegatus	100.0	-	1	1.0	-
Gobiesox strumosus	91.7	-	6	4.0	1.1
Gobiosoma bosci	91.7	-	3	4.0	1.5
Leiostomus xanthurus	82.9	6.6	7	5.0	2.2
Menidia menidia	0.0	-	3	1.0	-
Ophidion marginatum	50.0	-	2	1.0	-
Opsanus tau	94.6	1.7	9	18.7	7.5
Paralichthys dentatus	75.0	-	3	1.3	0.3
Peprilus alepidotus	0.0	-	1	1.0	-
Prionotus carolinus	35.9	-	7	18.3	11.3
Pseudopleuronectes americanus	90.8	5.5	4	16.3	10.3
Symphurus plagiusa	56.3	7.0	6	11.8	6.5
Syngnathus fuscus	75.0	-	4	1.0	-
Urophycis regia	100.0	-	1	4.0	0.0

Table 5. Statistical comparisons of survival rates of finfish impinged in 1986 on a) Beauderey and control screens and b) FMC dual-speed and control screens. Only samples that contained at least four individuals of the species of interest are included in means or statistical comparisons. Mean survival rates represent averages of the percent survival calculated for all samples containing ≥ 4 individuals of that species.

a.

Species	$\bar{X}$ percent survival (number of samples)		F	p>F
	Beauderey screens	combined controls		
Brevoortia tyrannus	7.8(7)	5.0(8)	0.67	0.427
Leiostomus xanthurus	41.2(9)	70.4(18)	6.52	0.017
Opsanus tau	100.0(7)	95.4(19)	0.38	0.542
Prionotus carolinus	44.4(6)	48.5(14)	1.65	0.216

b.

Species	$\bar{X}$ percent survival (number of samples)		F	p>F
	FMC dual-speed screens	combined controls		
Anchoa mitchilli	0.0(8)	9.8(16)	8.46	0.008
Gobiesox strumosus	97.4(7)	100.0(11)	2.71	0.119
Leiostomus xanthurus	84.5(9)	70.4(18)	3.89	0.060
Opsanus tau	97.3(14)	95.4(19)	2.38	0.133
Prionotus carolinus	45.9(9)	48.5(14)	0.06	0.808
Pseudopleuronectes americanus	53.2(4)	65.1(7)	0.67	0.435
Symphurus plagiusa	80.7(9)	56.2(10)	0.46	0.507

Table 6a-d. Total lengths of finfish collected for the finfish survival study at CCNPP, June-August 1986. (n = number of fish measured in each category.)

a) Beauderey Screens

Species	Total Length (cm)								
	Live Individuals			Dead Individuals			LOE Individuals		
	$\bar{X}$	SE	n	$\bar{X}$	SE	n	$\bar{X}$	SE	n
Alosa aestivalis	-	-	0	5.3	0.8	2	-	-	0
Anchoa mitchilli	5.8	0.3	3	7.1	0.1	42	-	-	0
Anguilla rostrata	-	-	0	33.5	10.6	3	-	-	0
Brevoortia tyrannus	16.0	0.8	4	17.6	0.5	61	-	-	0
Chasmodes bosquianus	7.5	0.5	2	-	-	0	-	-	0
Cynoscion regalis	11.7	2.4	6	9.4	1.5	12	7.0	-	1
Gambusia affinis	4.3	0.2	5	-	-	0	-	-	0
Gobiesox strumosus	4.1	0.3	19	-	-	0	-	-	0
Gobiosoma bosci	5.0	1.0	2	-	-	0	-	-	0
Leiostomus xanthurus	9.0	0.3	121	10.2	0.2	181	11.5	1.0	5
Menidia menidia	-	-	0	9.4	1.0	6	-	-	0
Opsanus tau	12.2	0.8	76	6.5	0.5	2	-	-	0
Paralichthys dentatus	11.9	2.4	4	22.6	3.9	5	-	-	0
Peprilus alepidotus	7.4	0.2	12	7.1	0.1	59	-	-	0
Prionotus carolinus	11.2	0.2	59	11.6	0.1	92	11.5	0.6	3
Pseudopleuronectes americanus	6.9	0.2	25	8.4	1.4	7	-	-	0
Scophthalmus aquosus	4.5	-	1	-	-	0	-	-	0
Sphoeroides maculatus	13.0	1.2	7	5.5	-	1	-	-	0
Symphurus plagiusa	11.6	0.3	22	11.4	0.3	24	-	-	0
Syngnathus fuscus	16.5	-	1	17.0	1.5	2	-	-	0
Urophycis regia	12.5	-	1	15.9	0.5	8	-	-	0
Unknown Fish	-	-	0	18.5	-	1	-	-	0

Table 6a-d (continued). Total lengths of finfish collected for the finfish survival study at CCNPP. (n = number of fish measured in each category.)

b) FMC Dual-Speed Screens

	Total Length (cm)								
	Live Individuals			Dead Individuals			LOE Individuals		
Species	$\bar{X}$	SE	n	$\bar{X}$	SE	n	$\bar{X}$	SE	n
Alosa pseudoharengus	-	-	0	4.0	-	1	-	-	0
Anchoa mitchilli	-	-	0	6.6	0.1	94	-	-	0
Brevoortia tyrannus	-	-	0	16.6	1.7	11	-	-	0
Chasmodes bosquianus	5.0	0.4	17	6.3	1.3	2	-	-	0
Cynoscion regalis	4.8	0.3	6	4.5	0.2	22	-	-	0
Gambusia affinis	4.1	0.2	5	-	-	0	-	-	0
Gobiesox strumosus	4.2	0.1	100	4.3	0.7	4	-	-	0
Gobiosoma bosci	4.7	0.3	15	6.5	-	1	-	-	0
Leiostomus xanthurus	11.2	0.2	163	11.3	0.7	33	-	-	0
Menidia menidia	-	-	0	8.9	0.9	8	-	-	0
Morone saxatilis	17.5	-	1	-	-	0	-	-	0
Ophidion marginatum	15.5	0.5	2	-	-	0	-	-	0
Opsanus tau	10.8	0.4	2	6.9	0.3	0	-	-	0
Paralichthys dentatus	19.5	1.0	223	25.6	4.4	8	-	-	0
Peprilus alepidotus	7.4	0.3	33	6.6	0.6	4	-	-	0
Prionotus carolinus	11.6	0.2	4	11.7	0.2	8	13.0	1.0	0
Pseudopleuronectes americanus	7.2	0.4	30	7.0	0.2	32	20.0	-	1
Scophthalmus aquosus	-	-	0	9.5	-	1	-	-	0
Sphoeroides maculatus	11.8	2.5	4	11.3	1.3	2	-	-	0
Symphurus plagiusa	11.9	0.2	98	11.2	0.2	62	11.5	0.0	2
Syngnathus fuscus	20.0	0.0	2	16.8	1.3	7	-	-	0
Urophycis regia	16.8	1.1	7	16.5	-	1	-	-	0

Table 6a-d. (continued). Total lengths of finfish collected for the finfish survival study at CCNPP. (n = number of fish measured in each category.)

c) Unit 1 Control Screens

Species	Total Length (cm)								
	Live Individuals			Dead Individuals			LOE Individuals		
	X̄	SE	n	X̄	SE	n	X̄	SE	n
Alosa aestivalis	4.0	0.0	20	4.1	0.1	35	-	-	0
Anchoa mitchilli	6.5	0.2	33	6.5	0.1	234	6.3	0.3	9
Brevoortia tyrannus	16.3	0.8	26	15.1	0.4	135	-	-	0
Chasmodes bosquianus	4.0	0.5	4	5.0	2.0	2	-	-	0
Cynoscion nebulosus	6.0	-	1	-	-	0	-	-	0
Cynoscion regalis	5.5	0.9	13	7.0	0.8	36	0.5	-	1
Gambusia affinis	3.8	0.2	3	-	-	0	-	-	0
Gobiesox strumosus	4.3	0.2	64	-	-	0	-	-	0
Gobiosoma bosci	5.1	0.4	5	-	-	0	-	-	0
Hypsoblennius hentzi	-	-	0	8.5	-	1	-	-	0
Leiostomus xanthurus	9.7	0.2	319	8.7	0.2	230	8.2	1.0	6
Menidia menidia	6.8	0.7	3	10.5	0.4	25	-	-	0
Menticirrhus americanus	-	-	0	32.0	-	1	-	-	0
Ophidion marginatum	18.9	-	1	-	-	0	-	-	0
Opsanus tau	11.2	0.6	109	7.0	0.5	4	-	-	0
Paralichthys dentatus	17.9	4.1	6	23.5	2.5	11	-	-	0
Peprilus alepidotus	6.3	0.4	3	6.8	0.2	31	-	-	0
Prionotus carolinus	11.2	0.2	101	11.4	0.1	132	13.0	-	1
Pseudopleuronectes americanus	8.9	1.4	17	8.5	0.8	21	-	-	0
Scophthalmus aquosus	8.8	4.3	2	9.8	0.3	3	-	-	0
Sphoeroides maculatus	14.2	1.1	7	4.5	-	1	-	-	0
Symphurus plagiusa	11.7	0.2	29	10.5	0.2	35	-	-	0
Syngnathus fuscus	17.3	0.6	4	16.3	2.2	5	-	-	0
Urophycis regia	15.5	0.6	5	16.4	0.7	9	-	-	0

Table 6a-d. (continued). Total lengths of finfish collected for the finfish survival study at CCNPP. (n = number of fish measured in each category.)

d) Unit 2 Control Screens

Species	Total Length (cm)								
	Live Individuals			Dead Individuals			LOE Individuals		
	$\bar{X}$	SE	n	$\bar{X}$	SE	n	$\bar{X}$	SE	n
Anchoa mitchilli	7.3	0.4	3	7.1	0.1	29	-	-	0
Anguilla rostrata	8.5	-	1	-	-	0	-	-	0
Brevoortia tyrannus	-	-	0	16.0	2.0	8	-	-	0
Chasmodes bosquianus	6.0	-	1	-	-	0	-	-	0
Cynoscion nebulosus	-	-	0	6.5	-	1	-	-	0
Cynoscion regalis	6.0	-	1	4.1	0.2	29	-	-	0
Cyprinodon variegatus	4.0	-	1	-	-	0	-	-	0
Gobiesox strumosus	4.4	0.2	22	4.5	0.0	2	-	-	0
Gobiosoma bosci	4.9	0.3	11	6.0	-	1	-	-	0
Leiostomus xanthurus	9.4	0.5	29	6.8	0.8	6	-	-	0
Menidia menidia	-	-	0	10.2	0.2	3	-	-	0
Ophidion marginatum	18.0	-	1	17.0	-	1	-	-	0
Opsanus tau	9.5	0.5	113	7.2	0.3	8	9.0	-	1
Paralichthys dentatus	18.7	3.1	3	19.0	-	1	-	-	0
Peprilus alepidotus	-	-	0	6.5	-	1	-	-	0
Prionotus carolinus	10.6	0.3	42	11.5	0.1	48	-	-	0
Pseudopleuronectes americanus	8.1	0.5	38	7.5	0.4	6	-	-	0
Symphurus plagiusa	10.8	0.2	35	10.7	0.2	31	-	-	0
Syngnathus fuscus	15.8	3.6	3	15.5	-	1	-	-	0
Urophycis regia	17.3	0.7	4	-	-	0	-	-	0

Table 7a-b. Results of t-tests comparing sizes of finfish impinged in 1986 on experimental and control screens at CCNPP. (B = Beauderey, C = control screens, D = FMC dual-speed screens.)

a. Beauderey Screens vs. Controls

Species	p>t	Screen type impinging individuals with largest average size
Anchoa mitchilli	0.001*	B
Brevoortia tyrannus	0.001	B
Cynoscion regalis	0.003*	B
Gobiesox strumosus	0.538	-
Leiostomus xanthurus	0.025	B
Opsanus tau	0.022*	B
Peprilus alepidotus	0.008	B
Prionotus carolinus	0.201	-
Pseudopleuronectes americanus	0.047*	C
Symphurus plagiusa	0.008	B

b. FMC Dual-Speed Screens vs. Controls

Species	p>t	Screen type impinging individuals with largest average size
Anchoa mitchilli	0.756	-
Brevoortia tyrannus	0.330	-
Cynoscion regalis	0.011*	C
Gobiesox strumosus	0.389	-
Gobiosoma bosci	0.570	-
Leiostomus xanthurus	0.001	D
Opsanus tau	0.345	-
Paralichthys dentatus	0.658	-
Peprilus alepidotus	0.732	-
Prionotus carolinus	0.012	D
Pseudopleuronectes americanus	0.048*	C
Symphurus plagiusa	0.001	D

*Approximate t-tests were used where variances were significantly heterogeneous (SAS Institute, 1982).

Table 8. Number of finfish and blue crabs impinged per hour in 1986 on experimental and control screens at CCNPP. a) Unit 1, b) Unit 2. (ns = p>0.05)

a. Beauderey vs. Unit 1 Control Screens

Species	$\bar{X} \pm 1$ SE number of individuals impinged per hour		t or approximate t	p>t
	Beauderey screens	Control screens		
Anchoa mitchilli	5.8±1.6	1.6±0.5	2.45†	0.019
Leiostomus xanthurus	18.4±3.6	7.1±2.0	2.73†	0.009
Opsanus tau	5.9±1.7	1.5±0.7	2.44†	0.019
Prionotus carolinus	14.0±4.1	10.1±6.0	0.53†	0.600 ns
Trinectes maculatus	98.4±54.2	17.5±6.6	1.48†	0.140 ns
All finfish	151.3±55.3	39.1±10.1	2.00†	0.054
Callinectes sapidus	39.0±4.6	26.4±4.1	2.06	0.043

b. FMC Dual-speed vs. Unit 2 Control Screens

Species	$\bar{X} \pm 1$ SE number of individuals impinged per hour		t or approximate t	p>t
	FMC dual-speed screens	Control screens		
Anchoa mitchilli	4.1±1.5	0.8±0.3	2.11†	0.044
Leiostomus xanthurus	5.8±1.2	2.7±0.9	2.18	0.033
Opsanus tau	3.0±0.9	0.7±0.2	2.46†	0.020
Prionotus carolinus	7.9±2.2	1.7±0.6	2.75†	0.010
Trinectes maculatus	15.8±3.8	8.6±2.9	1.53	0.132 ns
All finfish	41.4±6.7	15.7±3.6	3.35†	0.002
Callinectes sapidus	25.6±3.3	19.6±3.8	1.17	0.246 ns

*Approximate t-tests were used where variances were significantly heterogeneous (SAS Institute, 1982).