BIOLOGICAL EVALUATION OF A FINE-MESH TRAVELING SCREEN FOR PROTECTING ORGANISMS

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ABSTRACT

A full-scale, fine-mesh (0.5 mm) traveling screen test facility has been utilized to determine the potential effectiveness of this type of collection system in reducing organism losses at Big Bend Station on Tampa Bay, Florida. Intensive sampling over a six-month period in 1980 determined survival rates of the early life stages of selected fish and invertebrate taxa under various operating conditions. Results demonstrated high survival (96-hr) for most species/life stages. These results led Tampa Electric Company to consider a fine-mesh screen intake as the best of several alternatives for the new Big Bend Station Unit 4 and to backfit existing Unit 3, if required by the Environmental Protection Agency.

INTRODUCTION

Tampa Electric Company (TECO) plans to add a fourth generating unit at the Big Bend Station. The site is located on the eastern shore of Tampa Bay in North Ruskin, Florida. Region IV of the U.S. Environmental Protection Agency has expressed concern for losses of organisms due to the operation of the Unit No. 4 cooling water intake. Accordingly, early in 1979, TECO contracted with Stone & Webster Engineering Corporation to conduct an evaluation of a fine-mesh screening system which could be utilized to protect small organisms at this site. Mote Marine Laboratory was sub-contracted to aid in this evaluation.

Preliminary studies in 1979 indicated that the concept of fine screening at Big Bend Station warranted further investigations in 1980. To ensure the validity of data to be obtained, it was decided that the 1980 test facility would be a full-scale, prototype traveling screen including all features of an in-service installation. Design efforts began in late summer with model studies which were conducted to optimize the screen's hydraulic characteristics and organism collection system. Construction of the prototype screen system was completed in time to initiate biological testing at the beginning of the entrainment season in March.

Biological investigations were conducted from March through August 1980. The study was conducted in three phases: Phase 1 (March) consisted of a shakedown period; Phase 2 (April 1 to May 16) involved daily sampling (5-day week) with one series of night samples per week; Phase 3 (June through August) consisted of sampling one week per month; various supplemental studies were also conducted in Phase 3.

During the study program, emphasis was placed on obtaining survival data for the following Representative Important Species (RIS):

Common Name	Scientific Name
Bay anchovy	Anchoa mitchilli
Black drum	Pogonias cromis
Silver perch	Bairdiella chrysura
Spotted seatrout	Cynosion nebulosus
Scaled sardine	Harengula jaguana
Tidewater silverside	Menidia beryllina
Stone crab	Menippe mercenaria
Pink shrimp	Penaeus duorarum
American oyster	Crassostrea virginica
Blue crab	Callinectes sapidus

MATERIALS AND METHODS

TEST FACILITY DESCRIPTION

The prototype screen was located in the intake canal upstream of the existing Units 1 through 3 traveling screens and pumps (Figure 1). The screen was situated on a test platform connected to land by an existing bridge. Laboratory facilities were located on the north side of the intake canal, approximately 46 m from the prototype screen. Ambient intake water was delivered to the laboratory via a series of pumps and filters located at the test platform.

Figure 2 shows a more detailed plan of the screen operating deck. The prototype screen was of the dual-flow type and incorporated all of the features required for fine screening. Seals were incorporated between screen baskets and between the baskets and the side frames to minimize the passage of organisms through these areas. The screening medium was 0.5-mm square mesh made of woven-monofilament polyester, and each of the 48 screen baskets were 0.6 m wide by 0.6 m high.

The screen was capable of operation at speeds of up to 8.5 m/min. On automatic control, the screen was designed to run continuously at 2.1 m/min; as the head differential across the screen would reach 10 and then 15.2 cm, the speed would increase to 4.3 and 8.5 m/min, respectively. On manual control, the screen could be operated at speeds between 0 and 8.5 m/min. Three speeds of 2.1, 4.3, and 8.5 m/min were selected for biological evaluation. These speeds corresponded to maximum impingement durations of approximately 7, 4, and 2 minutes, respectively.

Flow through the screen was supplied by an in-line pump (an adapted ship bow thruster pump) located under the test platform and connected directly to the screen via a transition section (Figure 3). The pump was belt-driven by a 250-hp motor located on the deck. Assorted pulleys allowed for flow adjustments. Given the size of the pump and motor, flows ranging from 521 to 3150 L/s could be achieved. Since the test screen was 0.6 m wide, these flows corresponded to screen face velocities ranging from approximately 7.6 to 45.7 cm/s. For the purpose of this study, pulleys were selected to achieve velocities of 15.2 and 30.5 cm/s.

The discharge flow from the pump, composed of fine-screened water, was conveyed by a pipe to a location far enough downstream in the intake channel to prevent recirculation (Figure 2). At the point where the pipe passed under the bridge, two taps were installed in the pipe to allow for the insertion of a flow-measuring device (for verification of pump flow rate) and an organism sampler which was used to determine the collection efficiency of the fine-mesh screen. A work platform was provided directly above this location to allow for the recording of pitometer measurements and the collection of biological samples.

A floating platform was installed directly in front of the upstream (ascending) side of the test screen which was accessible by ladder. This platform was used for observing the location and movement of organisms as

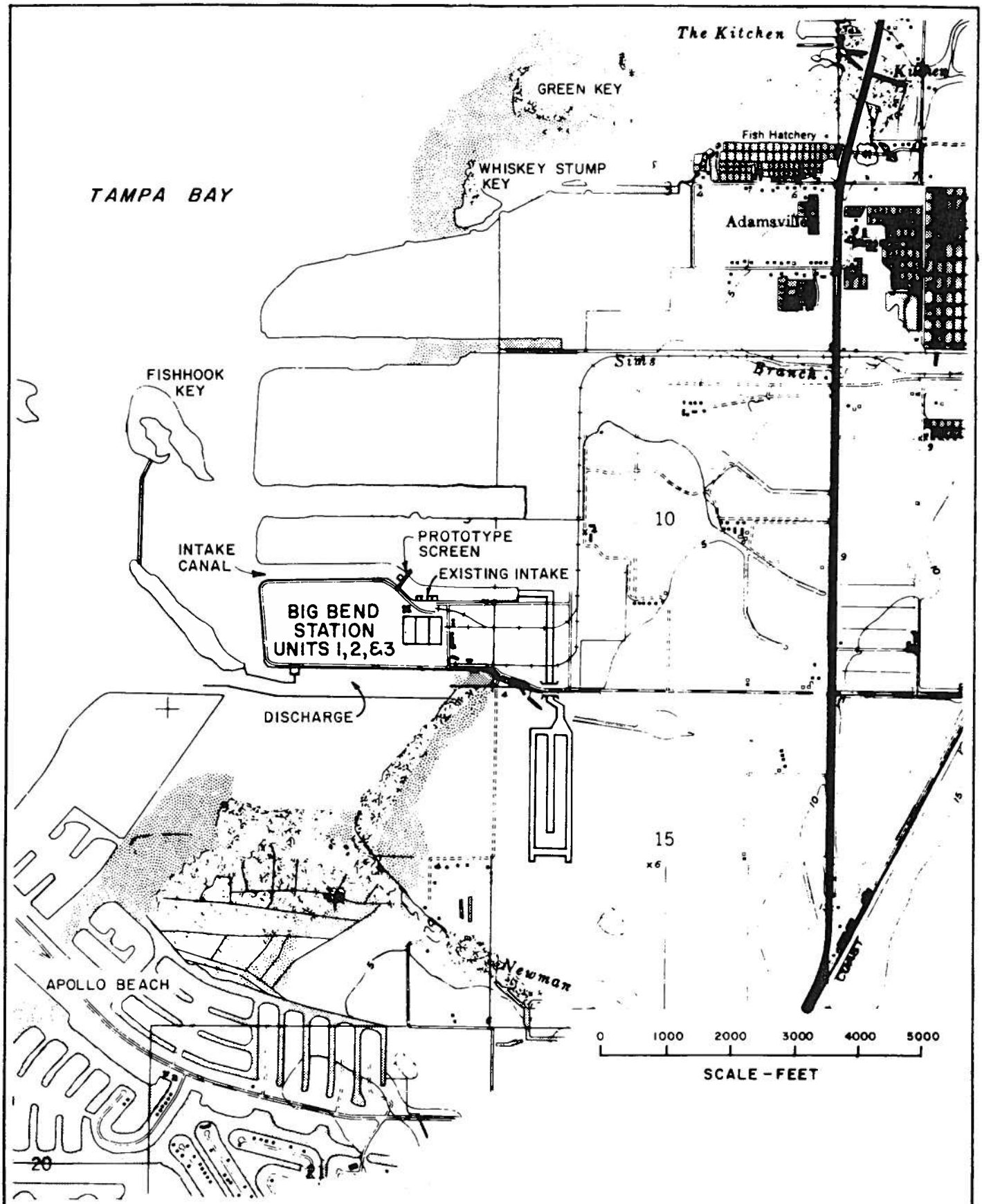

FIGURE 1
GENERAL SITE LOCATION
FINE-MESH SCREEN PROTOTYPE

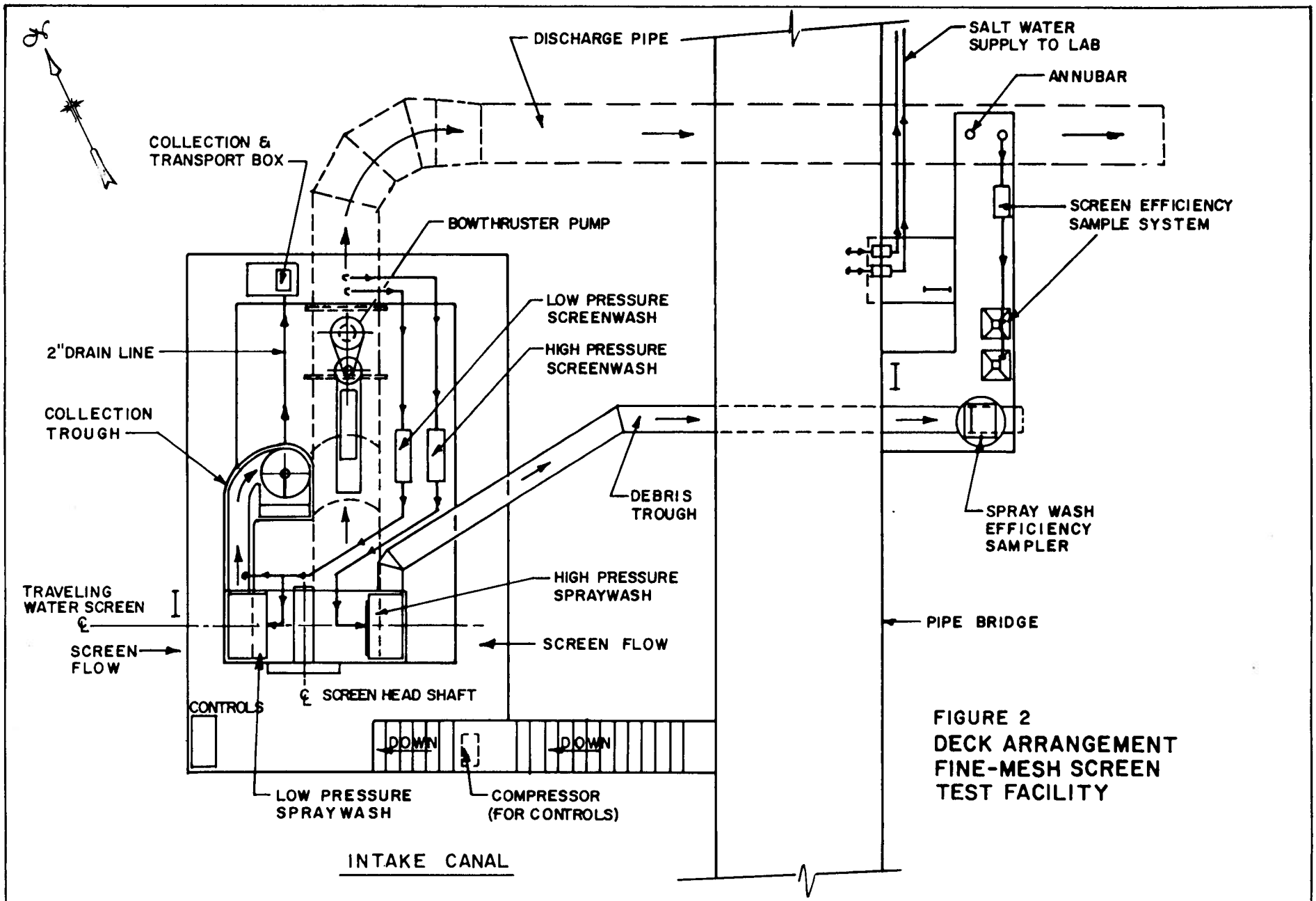

FIGURE 2
DECK ARRANGEMENT
FINE-MESH SCREEN
TEST FACILITY

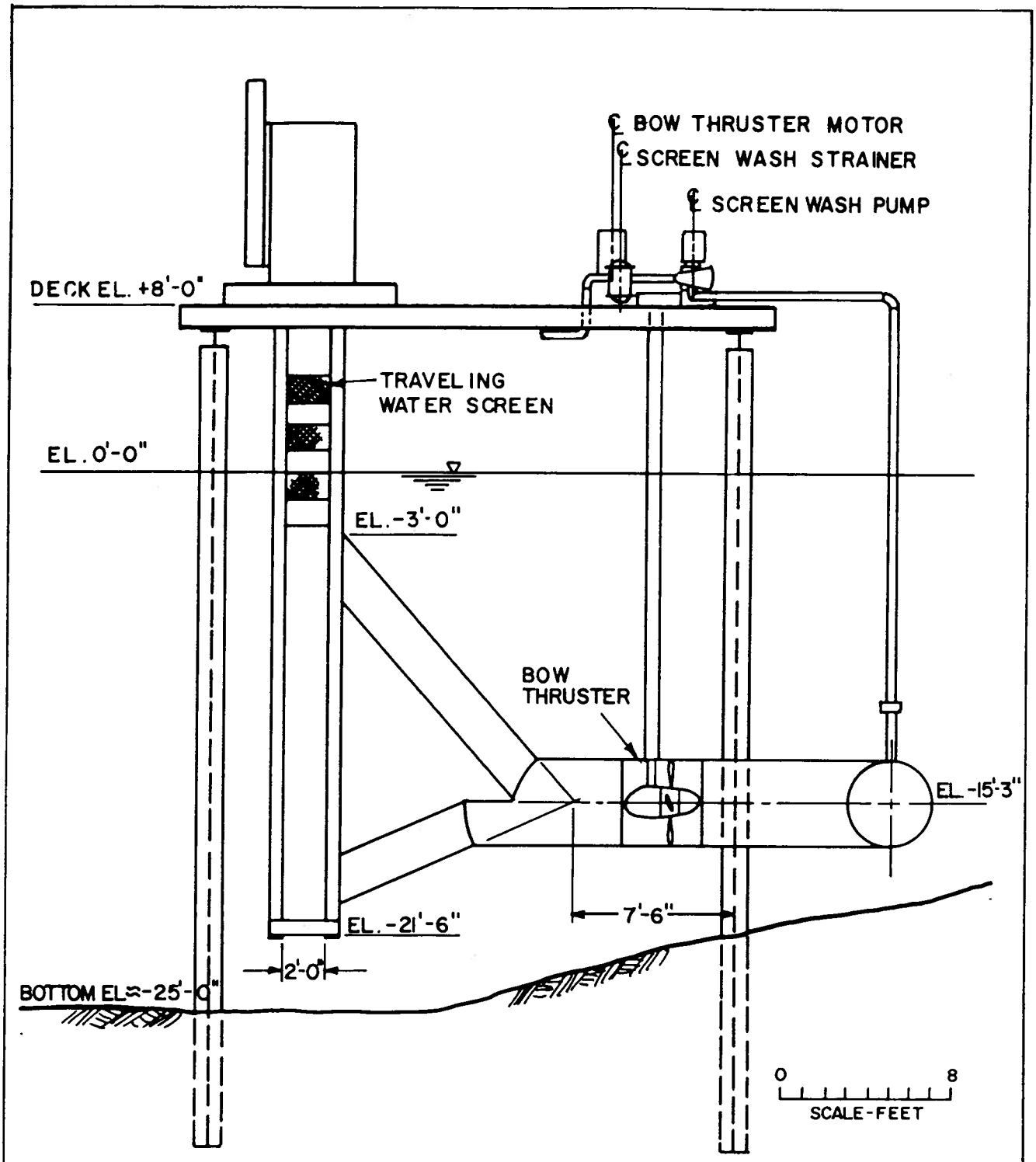

FIGURE 3
PROFILE ARRANGEMENT
FINE-MESH SCREEN PROTOTYPE

individual screen baskets cleared the water surface. It also served as a sampling location and work station from which the need for additional spray systems was evaluated.

The test screen incorporated shallow lifting buckets on each 0.6 m wide screen basket which retained approximately 2.54-cm of water. A low-pressure (10 psi) spray header, located on the ascending side of the screen, acted to remove organisms from the screen mesh surface and lifting buckets. A high-pressure (55 psi) spray header was located on the descending side of screen to remove any remaining debris into a separate trough. A screenwash pump with a strainer was located on the operating deck and took suction from the filtered water (bow thruster pump discharge). As each screen basket passed the spraywash, organisms on the mesh or in the lifting bucket were gently rinsed into a collection trough (Figure 2). Once in the trough, the organisms flowed by gravity into a primary collection tank from which they were drained into a secondary collection chamber, which also served as the container in which the organisms were transported to the laboratory.

As mentioned, a land-based laboratory was available for processing of all screen samples. Following collection, the samples were delivered to the laboratory for processing. The laboratory facility was designed to:

1. Permit sorting, counting, identification, and determination of initial mortality of planktonic organisms.

2. Hold selected organisms for up to 96 hours to determine latent mortality.

Ambient, filtered intake water was supplied to the laboratory via a system of pumps, filters, and piping. A redundant water supply system was installed as a backup in the event of a system failure. This water served as a water bath for maintaining ambient temperatures in a system of closed holding containers.

PROCEDURES - ORGANISM SURVIVAL STUDY

The primary objective of the study program was to determine the survival of organisms following impingement and removal from the prototype screen. To achieve this objective, screen samples were collected on a routine basis throughout the study program. The following discussion presents the procedures and results obtained from biological investigations conducted during the study.

Essentially the same sampling procedures were utilized during all phases of the study. As discussed previously, tests were conducted at screen travel speeds of 2.1, 4.3 and 8.5 m/min and approach flow velocities of 15.2 and 30.5 cm/s. Therefore, a complete series of tests involved screenwash collections at each of the six velocity/ screen speed combinations in the following matrix:

		Screen Travel Speed (m/min)		
		2.1	4.3	8.5
Approach Velocity (cm/s)	15.2			
	30.5			

Within a given day, the timing of the sampling procedures was such that six samples could be collected and processed in the laboratory. Since the process of changing pulleys to achieve different test velocities required several hours, it was not feasible to conduct tests at both velocities within a single day. Therefore, the pulleys were changed at the end of every second day of testing at a given velocity. Within a day, two replicates of a one-velocity/three-screen speed portion of the matrix were obtained.

During Phase 1, tests were conducted five days per week (up to six tests per day) during the daytime hours (approximately between the hours of 0900 and 1500). At the beginning of Phase 2, the sampling strategy was modified to include night collection. The intent of night sampling was to determine whether species/life stage occurrence, abundance and/or mortality differed between day and night. Under this mode, sampling was conducted Monday through Thursday during the daytime and Thursday night between approximately 1900 and 2400 hrs. During Phase 3, this strategy continued with screen sampling being conducted one week per month (June, July and August).

Regardless of phase or sampling strategy, the same procedures were utilized in all tests. Prior to sampling, the bow thruster pump and screen (Figure 3) were set at the desired operating point for the specific test being conducted. The low-pressure spraywash was preset at 10 psi and was then shut off until the sample was taken. Once the screen was in full operation and the movement of water and organisms through the test facility was in steady-state, sampling was initiated by turning on the low-pressure spray, allowing the contents of a predetermined number of screen baskets to be rinsed into the collection trough, and then shutting off the spray. The number of baskets washed differed for each water velocity/screen travel speed condition such that at each condition, the total volume of water sampled by the prototype screen was equivalent.

Organisms washed into the collection trough were carried into a primary collection area (Figure 2) which contained a screened overflow (0.25 mm mesh). In this area, large debris (leaves, shells, ctenophores) could be removed as the area drained. Once the water level reached the bottom of the overflow screen, the sample was concentrated to the point where it could be drawn down into the secondary collection and transport chamber where the sample was further concentrated. The drawdown was slow and gentle to avoid stress due to high velocities and turbulence in the drain line and container.

Once the sample had been completely transferred, the container was sealed and transported to the land-based laboratory for sorting and latent effects studies.

In addition to screenwash samples, control organisms were collected and held for comparison to latent mortality values experienced among organisms collected by the screen. During Phase 1, control organisms were collected one day per week, while in Phases 2 and 3, controls were collected twice weekly.

Control organisms were collected from the intake canal by suspending a stationary plankton net (505 μ) in the canal flow (velocity $\leq$ 12.2 cm/s) for approximately five minutes. The net was then gently washed and the contents were transported to the laboratory where the sample was sorted for RIS life stages.

As mentioned above, all samples collected from the prototype screen were transferred to the land-based laboratory where they were sorted and held by Mote Marine Laboratory. Once the transport container was delivered to the laboratory, the following procedures were carried out:

1. The transport container was placed in a water bath and temperature was recorded.

2. When RIS were abundant, the sample was gently stirred or agitated to obtain a homogeneous distribution of organisms and a volumetric subsample was drawn off.

3. The primary sample was maintained in a water bath and held for later processing.

4. The subsample (in a water bath) was sorted immediately into species/life stages, concentrating on RIS species first.

5. Up to five individuals of each species/life stage were placed in a separate container for transfer to the holding area; organisms were sorted to the lowest taxonomic level possible without delaying initiation of holding or adding incremental stress to the test organisms; crab zoea and megalops were held in lots of 48.

6. A species/life stage sample consisted of 30 organisms (48 crabs); therefore, once six lots of a species/life stage were counted and recorded, they were transferred immediately to the holding area for the latent effects study.

7. Sorting continued until samples of all RIS life stages had been placed in holding containers; the location of all organisms was carefully documented.

8. The remainder of the subsample was sorted by species, recording numbers of live, stunned, and dead organisms on data sheets. (These data were used as part of "initial survival" determinations.)

9. If the primary sample was no longer needed, it was preserved for later analysis, if needed.

10. When organism densities were low, several additional subsamples were taken in order to obtain 30 live organisms of available RIS for holding; in this case, only the first subsample was completely sorted for live, stunned and dead organisms; the remaining subsamples were drawn only to bring the total of each RIS life stage to 30 (48 crabs), if possible. All organisms now in the holding facility were checked at 3, 6, 12, 18, 24, 36, 48, 60, 72, 84, and 96 hr; the number live and dead at each check was recorded, as well as any abnormal occurrences (e.g., missing organisms).

11. All organisms which died during the holding period were preserved in labeled vials for final identification at a later time.

12. At the completion of the holding period, the final number of live and dead organisms was recorded and each group was preserved in a labeled vial.

13. Water quality parameters were recorded frequently during all holding experiments; parameters recorded include salinity, temperature, dissolved oxygen, pH, and ammonia.

14. At the end of each latent-effects test, all vials were rechecked and all organisms were identified (to species, if possible), categorized to life stage and counted.

These procedures were very effective in permitting an accurate accounting of most organisms from collection through final identification. Data gathered during each stage of the latent-effects studies were recorded on various data sheets which were subjected to frequent quality assurance checks.

PROCEDURES - SUPPLEMENTAL STUDIES

In addition to the prototype screen sampling efforts, several supplemental studies were conducted to gather information pertinent to the overall evaluation of fine-mesh screens at Big Bend Station. The purpose of each study and the methods employed are described below.

Spraywash Efficiency Sampling

Since the spraywash system incorporated into the prototype screen represented a new design, the efficiency of the system in washing organisms into the collection trough was investigated. It was not expected that the system would be totally effective in removing organisms; however, it was anticipated that quantitative and qualitative data would identify potential design changes which would optimize system efficiency.

Samples were collected in a screened collection box as the water exited the debris trough on the high-pressure spraywash side of the screen while the low-pressure spraywash was in operation (refer to Figure 2). In this way, the number of organisms removed by the low-pressure spray could be directly compared to the number carried over to the high-pressure spray, and the low-pressure spraywash efficiency could be calculated. It was expected

that the speed of the screen would influence cleaning efficiency, with efficiency expected to decrease as speed increased. Therefore, samples were taken at all three travel speeds (2.1, 4.3 and 8.5 m/min). Samples were also taken at both screen approach velocities of 15.2 and 30.5 cm/s.

Each sample was collected by washing down the screened collection box and was then preserved for later analysis by laboratory personnel. Laboratory analysis consisted of enumeration, identification to lowest feasible taxonomic level, determination of life stage, and size measurements (fish larvae only). Screen efficiency samples could then be compared to a standard screenwash sample taken at nearly the same time.

Prototype Screening Efficiency

To determine the efficiency of the prototype screen in preventing the passage of organisms either through the 0.5-mm mesh or the various sealed areas in the screen assembly, samples of organisms present in the screened water were taken during Phase 3. Samples were preserved and processed in the laboratory. Laboratory analysis consisted of enumeration, identification to lowest feasible taxonomic level, determination of life stage, and size measurements (fish larvae only).

Samples were collected via a sample pump (refer to Figure 2) which discharged into two conical plankton nets submerged in tanks. The pump was run for at least one hour to obtain sample volumes no smaller than 100 m^3.

Organism Return System Study

An integral part of an organism protection device is the design, operation, and discharge location of the organism return system. Should fine-mesh screens be employed at Big Bend Station, a trough or pipe will be utilized to transport collected organisms for discharge into the presently unused canal just north of, and parallel to the intake canal (Figure 1). Since this release site would be remote from the fine-mesh screens, it was deemed prudent to study the effects of long-distance transport on the RIS of concern at Big Bend.

In order to evaluate the effect of travel through a return trough on organism survival, studies were conducted in a circular flume. The flume measured 30.5 cm deep by 22.9 cm wide and had an outer diameter of 2.5 m. A central motor drive unit propelled paddles around the flume thereby moving the water contained therein. The paddles sealed tightly with the flume walls and bottom to prevent leakage.

Tests were conducted by placing individual groups of RIS life stages in the flume and allowing them to circulate at a velocity of 61 cm/s for 1 hr, which is equivalent to traveling a straight distance of 2195 m. This velocity is considered sufficiently high to move organisms rapidly to a release site but low enough to minimize damage due to turbulence and abrasion. Test organisms were obtained from the prototype screen. Thus, they had experienced the entire process of impingement, removal and transport by the completion of the flume test.

Control organisms collected from the prototype screen were also placed in the flume (not operating) and collected after 1 hr to determine whether the flume testing procedure contributed substantially to any observed mortality.

Following each test run, the organisms were removed from the flume by draining the water into a screened collection box. The organisms were then enumerated as live, stunned, or dead, and live individuals were held for 96 hr to determine latent mortality. Holding procedures were identical to those used in the prototype screen mortality study.

RESULTS

ORGANISMS SURVIVAL STUDY

The results of the organism survival study are given in Tables 1 through 4 as the percent initial and latent survival of the fish and invertebrate life stages which were collected from the prototype screen over the duration of the study. In order to conduct the data analysis, it was necessary to combine identified taxa into groups since, in most cases, a single species, genus or even family did not occur frequently enough to permit a meaningful analysis. The taxonomic level of each group was determined as the lowest level which would allow inclusion of all important taxa.

The test data indicate that the invertebrates had the highest survival, most often in excess of 90 percent; fragile fish larvae, such as the bay anchovy (Anchoa mitchilli), had low survivorship, as anticipated for larvae. However, it should be noted that survival among control larvae was also low. Further, as shown on Table 2, the small number of observations for some taxa limits the conclusions which might be drawn from these data.

The latent survivorship of those organisms which were initially alive following collection was studied in the laboratory holding experiments. The proportion of organisms which were alive at 48 hr and 96 hr was used as an index of latent survival. Both measures provide an indication of the success of the device; however, past experience suggested that high natural mortality at 96 hours might limit the utility of this measure.

Taxa/life stages which were used as a basis for determining 48 and 96 hr are the same as those for which initial survival was determined. The mean of the 48 and 96 hr survivorship values for various life stages are presented in Tables 1 through 4. The results indicate that survivorship is taxa-and life stage-specific, as is the relationship between 48 and 96 hr values.

The hatchability of eggs observed during the holding experiments is an index of the viability of these eggs. Since the development time of eggs for many of the species tested is quite rapid, nearly all live eggs hatched prior to 96 hr. The proportion of eggs which hatched during the holding period and the survivorship of these hatched eggs is presented in Table 1.

The results of holding experiments with control samples which had not experienced the fine-mesh screen system are also presented in Tables 1 to 4. These survivorship values indicate that natural mortality, not associated with stresses resulting from the collection and holding procedures, is a contributing factor to the mortalities observed among organisms collected

TABLE 1

FISH EGGS
PERCENT SURVIVAL AND HATCHABILITY

	Initial Survival		Hatchability		48-HR Survival		96-HR Survival	
	Test	Control	Test	Control	Test	Control	Test	Control
Sciaenidae	75.3	98.4	94.8	99.0	84.3	91.3	69.7	82.7
Bairdiella chrysura	100	100	100	100	99.1	99.4	97.9	97.8
Cynoscion spp.	100	100	100	100	99.4	99.3	89.4	96.9
Menticirrhus spp.	100	100	100	100	99.7	100	88.4	91.5
Pogonias cromis	100	-	100	-	82.2	-	85.3	-
Clupeiformes	43.2	85.5	81.0	89.3	84.4	90.3	62.4	68.6
Harengula jaguana	45.8	99.6	92.9	98.5	82.8	92.2	45.9	27.6
Anchoa mitchilli	43.3	85.0	80.0	88.6	83.9	90.0	63.7	72.0

Note: Dashes indicate no observations

TABLE 2

FISH LARVAE
PERCENT INITIAL AND LATENT SURVIVAL

	Initial Survival		48-HR Survival		96-HR Survival	
	Test	Control	Test	Control	Test	Control
Sciaenidae	18.6 (108)	44.4 (6)	10.9 (26)	0 (1)	10.1(26)	0 (1)
Bairdiella chrysura	19.2 (39)	50.0 (2)	-	-	-	-
Cynoscion spp.	15.7 (51)	0 (1)	100 (3)	-	100 (3)	-
Menticirrhus spp.	0 (15)	25.0 (4)	-	-	-	-
Pogonias cromis	42.9 (7)	100 (1)	-	-	-	-
Clupeiformes	1.5 (278)	10.4 (11)	36.4 (11)	0(1)	36.4(11)	0 (1)
Harengula jaguana	0 (15)	-	-	-	-	-
Anchoa mitchilli	1.5 (274)	11.4 (10)	22.2 (9)	0(1)	22.2(9)	0 (1)

Notes: Number of observations is given in parentheses
Dashes indicate no observations

TABLE 3

DECAPOD ZOEA
PERCENT INITIAL AND LATENT SURVIVAL

	Initial Survival		48-HR Survival		96-HR Survival	
	Test	Control	Test	Control	Test	Control
Caridea	94.3	76.7	85.0	86.8	50.0	43.8
Upogebia affinis	91.3	75.6	84.1	76.2	42.8	45.4
Brachyura	95.5	65.0	83.9	55.6	45.9	27.8
Grapsizoea	100	100	95.1	97.9	80.2	92.9
Pinnotheridae	100	100	92.2	93.4	73.0	72.1
Xanthidae	99.1	-	95.9	95.6	74.9	73.4
Menippe mercenaria	97.9	97.3	91.5	94.9	58.3	61.0
Paguridae	94.7	100	96.6	100	79.2	33.3

Note: Dashes indicate no observations

TABLE 4

DECAPOD MEGALOPS
PERCENT INITIAL AND LATENT SURVIVAL

	Initial Survival		48-HR Survival		96-HR Survival	
	Test	Control	Test	Control	Test	Control
Caridea	100	-	100	-	100	-
Upogebia affinis	100	100	97.7	100	74.3	100
Brachyura	65.1	26.7	71.8	-	15.0	-
Grapsizoea	100	100	98.1	100	93.1	91.2
Pinnotheridae	100	-	100	-	92.9	-
Xanthidae	100	100	98.3	100	94.2	96.9
Menippe mercenaria	100	-	100	-	100	-
Paguridae	100	-	90.0	-	80.0	-

Note: Dashes indicate no observations

by the fine-mesh screen. Therefore, observed test mortalities should be considered as the cumulative effects of test and natural mortality.

Analyses of variance were conducted to determine whether screen travel speed (2.1, 4.3 and 8.5 m/min), velocity approching the screen (15.2 and 30.5 cm/s), or water temperature influenced initial or latent mortality. These analyses were limited to the most abundant taxa/life stages: among fish, Anchoa mitchilli, Sciaenidae and Cynoscion spp. eggs and larvae were chosen; for invertebrates, Brachyura and Xanthidae zoeal and megalops stages and Menippe mercenaria zoeal stages were selected.

In general, the analyses did not explain a high proportion of the variation in mortality. The independent variables which were most often significant ($p \leq 0.05$) were water temperature and approach velocity. The temperature variable indicated decreasing survival with increasing temperature for all life stages except fish eggs. Lowest 96-hr survival occurred during Phase 3 when the highest temperatures occurred. Temperature did not have as great an effect on 48-hr survival. It should be noted that 96-hr survival of control organisms also decreased at higher temperatures, reflecting the difficulty of maintaining these organisms for long periods under laboratory conditions.

Relative to approach velocity, the analyses indicated that velocity had a significant effect on egg hatchability and survival of sciaenidae and on 48-hr survival of Xanthidae zoea. However, differences in survival between 0.5 and 1.0 fps were relatively small:

		Mean Value (%)	
	Dependent Variable	15.2 cm/s	30.5 cm/s
Sciaenidae	Initial egg survival	80.8	71.4
	Egg hatchability	96.6	93.3
	48-hr survival of hatched eggs	89.5	79.3
	96-hr survival of hatched eggs	76.8	64.0
	48-hr survival of Xanthidae Zoea	97.0	94.7

It must be emphasized that both approach velocity and water temperature, while statistically significant, explained a small amount of the variability in the dependent variable. Therefore, within the range of independent variables tested, the mean survivorship values presented in Tables 1 through 4 are good indicators of the performance of the fine-mesh screen facility.

SUPPLEMENTAL STUDIES

Spraywash Efficiency Sampling

A total of 15 spraywash efficiency tests were conducted during the study program: 10 tests in April, 3 tests in June and 2 tests in July. Anchoa mitchilli (eggs and larvae) was the only species which occurred frequently enough to be analyzed at the species level. All other taxa occurred in

relatively low abundance in both screenwash and spraywash samples. Accordingly, the remaining species were combined into larger taxonomic groupings.

The results of spraywash efficiency testing are given below:

Taxonomic Group	Life Stage	Range of % Carryover	Mean % Carryover
Anchoa mitchilli	Eggs	17-100	52.9
Anchoa mitchilli	Larvae	13-76	39.5
"Zoea"	Zoea	7-43	23.7
Perciformes	Eggs	26-100	52.4
Perciformes	Larvae	0-100	42.3

Eggs showed the highest degree of carryover (i.e., were not removed from the mesh and lifting bucket by the low-pressure spray). Larvae were removed more effectively, but still showed a relatively high rate of carryover. Zoea were removed relatively efficiently.

An analysis of the data was conducted to determine whether screen speed (2.1, 4.3 and 8.5 m/min) or approach velocity to the screen 15.2 and 30.5 cm/s influenced spraywash efficiency. While it was expected that increased screen speed would decrease efficiency, this relationship was not detected for any of the taxa studied. However, Anchoa mitchilli and Perciformes egg carryover appeared to be influenced by approach velocity; fewer eggs were carried over at 30.5 cm/s than 15.2 cm/s.

These results are somewhat contrary to what had been expected. First, repeated observations of the spraywash system during the study seemed to indicate that little carryover was occurring at 2.1 m/min while some carryover was definitely occurring at the higher speeds. Second, it was expected that, if approach velocity were to affect spraywash efficiency, the relationship would be opposite to what which was observed. It is possible that the answer to the apparent contradictions lies in the high degree of variability, as reflected in the range of efficiencies given above. With the exception of Anchoa mitchilli eggs, the organisms studied occurred in relatively low abundance. Therefore, the densities used to calculate efficiencies were affected by small changes in the actual number of organisms sampled. This fact, coupled with the relatively small number of samples, may have resulted in the large unexplained variability. This variability, in turn, may have limited the power of the analysis to detect expected relatonships between screen speed and efficiency.

The apparent inefficiency of the spraywash system is not considered a problem relative to the potential application of fine-mesh screens at Big Bend. Engineering modifications to the lifting buckets and spray angle can be made which should eliminate carryover almost entirely. Such modifications are presently under investigation.

Prototype Screening Efficiency

Analysis of screening efficiency was limited by a lack of data. The available data indicate that a portion of the organisms were not completely screened. These available data do not point out the causal agent. However, length data on larvae collected in the screen efficiency samples indicate that organisms had passed between the seals. Further studies are being conducted to determine with greater confidence the locations at which organisms losses are occurring.

Organism Return System Study

Results of the flume survival studes show that, although natural and handling or holding mortality can be very variable, organisms can be succesfully returned in a trough up to 2195 m in length after being collected on the fine-mesh screens.

A total of 15 flume tests and eight control tests were conducted from June to August, 1980. Anchoa mitchilli and Harengula jaguana were the only species collected in sufficient abundance to be analyzed separately. Both of these species are RIS. All other species occurred in relatively low abundance. For this reason, most of the remaining species were combined into larger taxonomic groupings for analysis.

The analyses for Anchoa mitchilli, Harengula jaguana and Perciformes (June through August) indicated no significant differences between flume test and control survival to 48 hours. Similarly, the analysis of invertebrate (shrimp and crab zoea) survival data showed no significant difference between flume test and control survival to 48 hours.

As previously discussed, 96 hour test and control mortality was much higher during Phase 3 when most of the flume and organisms survival studies were conducted. Therefore, it would have been of little value to analyze 96 hour results. It is for this reason that the analyses focused on 48 hour results, with 48 hour survival as the primary variable of interest.

In addition to the flume controls which were subjected to the same handling as the test organisms except for circulation in the flume, separate controls were collected and simply placed in ambient water without further handling. Survival among these fish and invertebrate taxa was not significantly different from either flume test or control survival. Therefore, it appears that long-distance transport of organisms collected on a fine-mesh screen at this site would not substantially decrease overall survival in the organism collection and return system.

SUMMARY AND CONCLUSIONS

The results of this fine-mesh screening study, and conclusions which can be drawn from them, are summarized below:

- Survivorship statistics were calculated for fish eggs and larvae and selected taxa of invertebrate zoeal and megalops stages. These values were calculated for samples which had been collected from the fine-mesh screen and for control samples which reflect natural mortality.

- Fish eggs showed high initial survival upon collection from the fine-mesh screen, and a high percentage of eggs hatched to larvae. Holding experiments with larvae which have hatched from eggs indicated high survival at 48 and 96 hr. These results are encouraging when compared to the control survivorship for similar conditions.

- Fish larvae showed relatively low initial and latent survivorship among both test and control organisms.

- Invertebrate taxa (zoeal and megalops stages) showed high survivorship values for initial as well as 48 and 96 hr observations. Control samples also showed high survivorship.

- The variability in survivorship within a taxa/life stage was analyzed by analyses of variance with water temperature, screen speed, approach velocity and the interaction of screen speed and approach velocity as the independent variables. These variables explained small proportions of the variability in survivorship, with water temperature and approach velocity the more significant of the variables.

- Results of spraywash efficiency testing indicate that carryover occurred. Engineering modifications to the lifting buckets and spray angle should alleviate such carryover.

- The available length data on larvae collected from the screen efficiency test indicate that a portion of the organisms were not completely screened.

- Results of the flume study revealed no difference in survival between organisms tested in the flume and control organisms. Therefore, returning organisms from a fine-screening system via a trough would not substantially affect overall system effectiveness.

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