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new procedures, and developed new techniques. We modified the larval rearing tanks by adding bulkhead fittings and valves to the bottom of each tank. This arrangement and the addition of a filter screen, which threads into the bulkhead fitting, make it possible to filter, drain, or recirculate the water by opening or closing two valves (fig. 2). A high-pressure power washer (500 pounds per square inch) now used for cleaning equipment in the hatchery enables us to wash and rinse a tank in minutes.

Procedures were developed for estimating numbers of food organisms and larval shrimp. We use a hemocytometer to count diatoms and an electronic counter for first- and second-stage nauplii of the larval shrimp as well as Artemia nauplii. To estimate numbers of more advanced shrimp larvae and postlarvae, we photograph aliquot samples that we place in a petri dish. These pictures are then placed under a dissecting scope and the shrimp counted. We calculate the mean, standard deviation, mortality rate, and confidence limits of the population from these counts.

Gravid white and pink shrimp that we captured offshore spawned successfully in the laboratory. Spawning occurred in the 950-liter (250-gallon) rearing tanks and several 19-liter (5-gallon) carboys. After a female spawned in a carboy, we removed her and put the eggs in the large rearing tanks. We fed the diatom Cyclotella nana to the protozoeal stages and Artemia to the mysis stages. Survival from protozoea to mysis was poor for both species. Although we increased the amount of diatoms fed to the shrimp from 30,000 cells per milliliter to 750,000 cells per milliliter, shrimp larvae continued to die. Only 11 percent of the pink shrimp and 18 percent of the white shrimp survived. We attributed this poor success directly to the diatom Cyclotella, which is an unsuitable food when used alone.

The successful hatching of white shrimp was no doubt due to the fact that their ovaries were fully ripe. Their eggs were a dark olive green. We examined each female and found no attached spermatophore. Water temperature in the spawning tanks were 26.9° to 28.2° C. (80.4°-82.8° F.), and the salinity 29.1 to 31.2 p.p.t. EDTA at a level of 0.1 g. per liter (0.01 ounce per gallon) was placed in each tank and carboy before the shrimp spawned.

Diatoms are now cultured in artificial sea water in 300-liter (79-gallon) tanks in a temperature-controlled light room. Banks of fluorescent lamps that can be raised or lowered were constructed to provide the required intensity of light. At present, electric pumps transfer the diatoms to the harvesting tanks; however, construction is underway to provide space in the attic where the algae culture room can be transferred. From the attic the algae will be able to flow by gravity to the rearing tanks.

Algal culture.--The diatom, Cyclotella nana, was grown for shrimp food in carboy cultures and in mass cultures with Instant Ocean[1] artificial sea salt (mixed in tap water and prepared without heat) as the basic culture media. To this salt water we added Tris buffer, EDTA, KNO_3, Na_2SiO_3, vitamins B-12 and thiamin, and iron, either as $FeCl_3$ or $FeNH_4(SO_4)_2$. We counted 3 to 6 million diatom cells per milliliter. After the number of diatoms reached a peak (usually 2 days), we harvested about two-thirds of the volume daily and replaced it with new medium to maintain the quality of the culture. We maintained cultures for as long as 14 days.

We studied how artificial sea-salt media would be affected by adding three sources of iron--ferric sequestrine, ferric ammonium sulfate, and ferric chloride. Ferric sequestrine and ferric ammonium sulfate supported good growth of Skeletonema sp. in test-tube cultures, whereas ferric ammonium sulfate supported the best growth of Thalassiosira sp. in tube and carboy cultures.

General suitability of the Instant Ocean-tap water medium for certain flagellates, dinoflagellates, and diatoms in tube cultures was indicated by good growth of 19 to 22 organisms tested.

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Food and Experimental Environments

The purpose of our research has been to find a suitable food for raising shrimp. Once we have accomplished this, we can turn our energies to selective breeding. We studied the growth of shrimp fed various foods prepared in our laboratory and fed commercially available foods. We have also completed studies to determine if shrimp prefer certain sizes of food particles.

We continued to use the fish protein concentrate pellet developed last year and modified it to test additional proteins. Pellets were made with fish protein concentrate, cottonseed meal, and soybean meal as the source of protein, either singly or in combination. Test shrimp ate pellets made with fish protein concentrate but not pellets made only with cottonseed meal or soybean meal. The animals tore apart the pellets containing fish and vegetable meals and appeared to extract as much of the fish protein concentrate as possible. A great portion of the vegetable material was left on the bottom of the tank. All experiments had negligible growth and poor survival, apparently from a heavy growth of micro-organisms, fouling of the water, or a combination of these factors.

[1] Trade names referred to in this publication do not imply endorsement of commercial products.

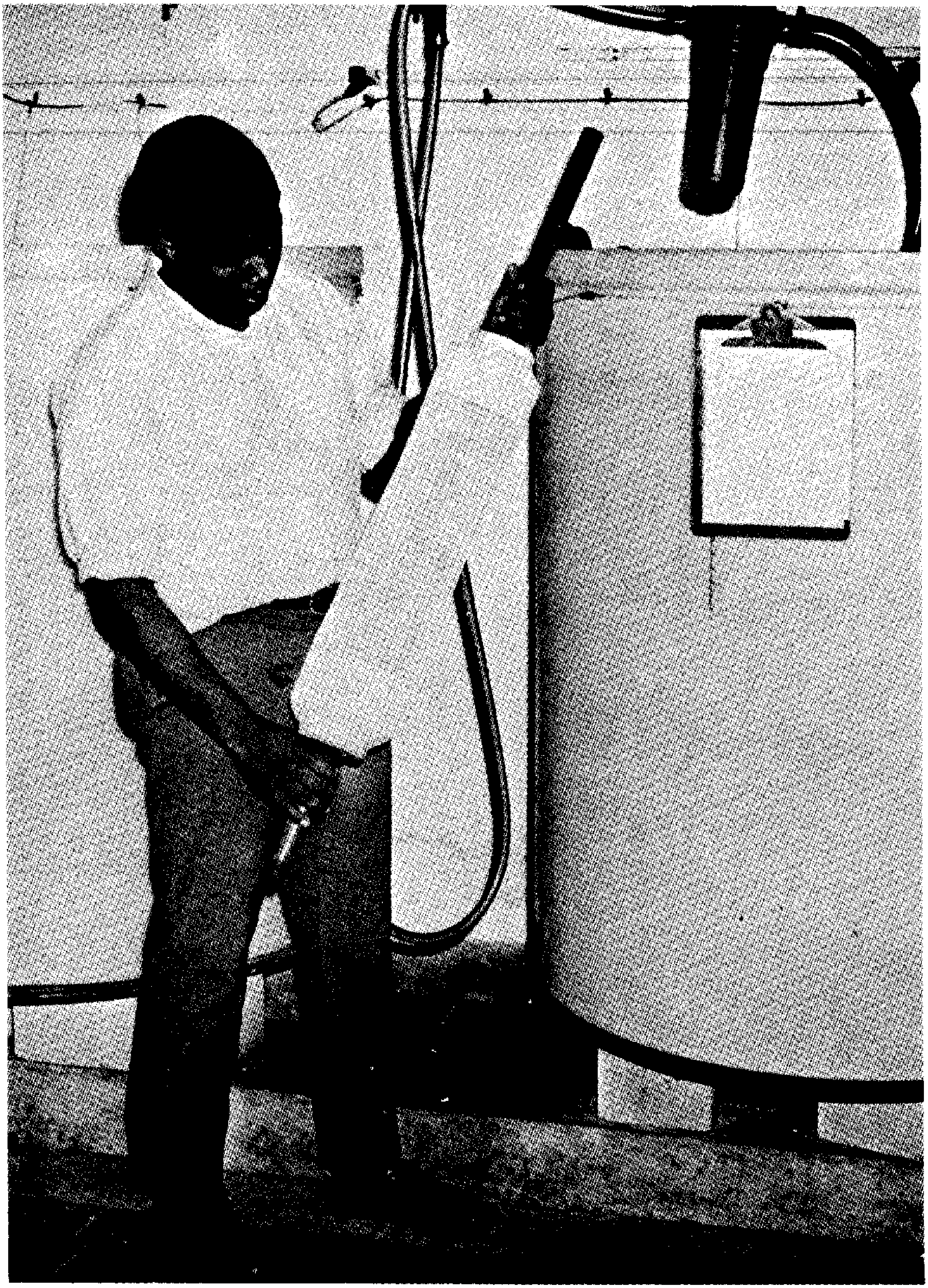

Figure 2.--Modification of larval-rearing tank permits more efficient operation by Laboratory worker.

The most promising food prepared in the laboratory is a gelatin-bound diet of fish protein concentrate, homogenized clams, and vitamins. The shrimp reacted to this food as when they were fed marine worms. The shrimp moved rapidly about the tank probing the bottom with their first three walking legs. The shrimp grew little, but we believe that with more experiments with other combinations of ingredients, we can prepare a suitable diet.

The size of food particle may be an important factor in whether the shrimp accepts or rejects an artificial food. To test this theory we used shrimp that were 25 mm. (1 inch) to 76 mm. (3 inches) long. The shrimp were fed either 6-mm. (0.3-inch) cubes of gelatin-bound food or some of the same food "riced" through a screen with 14 meshes per inch. In every test, the shrimp ate the cubes first; sometimes they left the riced food untouched for 24 hours.

At the East Lagoon Laboratory, we held shrimp in outdoor cement tanks supplied with running sea water filtered through a fine mesh bag (fig. 3). These animals were fed various commercial foods and foods developed in the laboratory. In the first test we tried two gelatin-bound diets, two trout diets, one catfish diet, and one salmon diet. With the exception of the salmon food, we tested each diet in duplicate. We kept 30 white shrimp that averaged 95 mm. (3.8 inches) total length in each tank for 4 weeks. Growth was similar for all animals, regardless of diet, and the average increase in length over the 4-week period was about 4 mm. (0.2 inch). We attributed poor growth to the low water temperature of 19° to 24.5° C. (67° - 76° F.). Survival was 97 percent or better in 9 of the 11 tanks.

Juvenile brown shrimp that averaged about 76 mm. (3 inches) total length were used as test animals in a second experiment in the outside tanks. The commercially prepared foods fed in this 4-week experiment were cat food, hog food, two dog foods, puppy food, and salmon food. Shrimp fed one of the dog foods and puppy food were significantly smaller than shrimp fed the other four diets. Those animals fed salmon food grew best with an average increase in length of 23.5 mm. (0.9 inch). Survival was 90 percent or better in all tanks. These shrimp may have grown more because of the higher water temperature--25° to 29.5° C. (77° - 85° F.)--than during the previous test.

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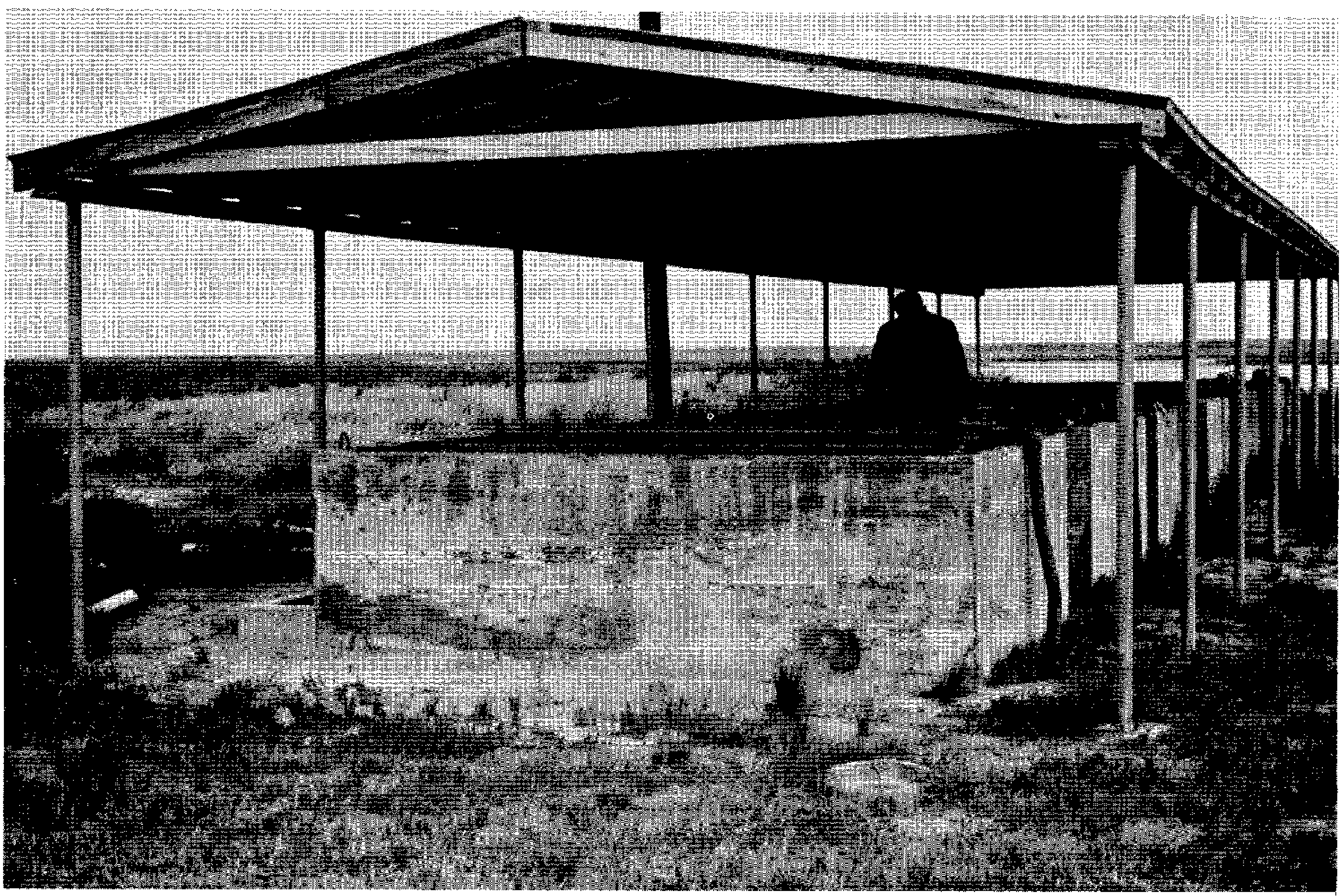

Figure 3.--Cement tanks in which shrimp were held during food studies. Workers tested various diets to determine which food(s) supported the best growth and survival.