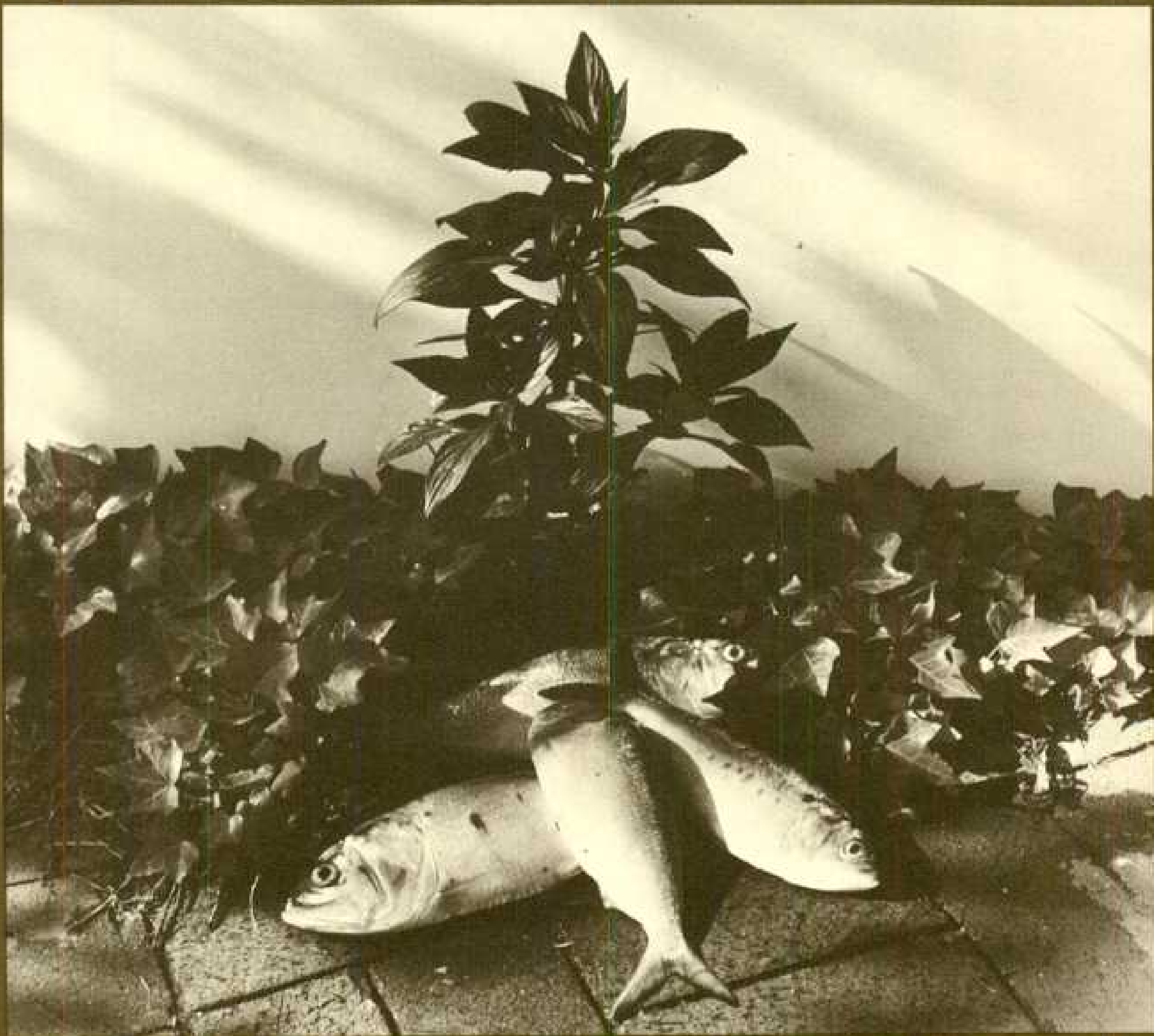
VIRGINIA INSTITUTE OF MARINE SCIENCE

Marine Resource Bulletin

VOL. XVI, NO. 1 MAY 1984



In This Issue -- a health food for plants • silage from the sea • crab meal processing • aquatic food chains

Virginia Sea Grant at VIMS/College of William & Mary

FSN health food for plants

Story and Photos by Dick Cook

fish soluble nutrients from menhaden yield good results in Sea Grant field tests

Dr. Louis Aung inspects a group of schefflera plants, just one of many ornamental species which thrive on FSN. Dark green coloration and a bright sheen foliage are typical FSN reactions.

THERE WAS A TIME WHEN the productivity of crop plants in agriculture depended upon the application of farm and green manures and the addition of animal organic material to the soil. Combined with the practices of crop rotation and intercropping, such soil enrichment methods were in general use. Not so today. The convenience afforded by inorganic fertilizers, used widely since the 1930's, has seen many of the time-tested, more natural methods shelved. One of these, however, the use of fish to nurture crops, is showing strong signs of experiencing a rebirth, and the National Sea Grant Program is lending a hand. Researchers at Virginia Tech in Blacksburg are documenting the benefits of seafood fertilization on various plants.

The idea that fish and other seafood materials contain valuable nutrients for assorted plants persisted on a large scale in the United States through the early 20th Century. Fish scraps were recognized as a fertilizer, and an industry existed to render them into a convenient form suitable for agricultural use. The practice actually has its roots in antiquity, and in this country is exemplified by the Indians showing the first colonists how to use fish to aid in growing corn.

Since about the mid-1940's the decline of the seafood fertilizer industry has been attributed to economic pressures and disinterest on the part of users. In the last 5 years, though, there has been a renewed interest in the use of seafood wastes as fertilizer. This has resulted, at least in the mid-Atlantic region, from a pressing need to find alternate solutions to the problem of seafood processing waste disposal. Recent constraints imposed by federal pollution laws governing waste disposal, plus energy shortages and the increasing cost of inorganic fertilizers, are combining to force modern agriculture to take a fresh look at the old methods.

The year 1978 was the turning point in Virginia, when the Zapata Haynie Corporation, Reedville, sought assistance from Virginia Tech scientists in solving waste water problems associated with menhaden processing. The firm processes approximately 75 percent of Virginia's 226,757 metric tons of menhaden each year, drawing its supply from a fleet of large purse seiners and smaller craft known as striker boats.

The primary products derived from the menhaden are oil and protein. Some 56 million gallons of waste water and "stick" water, that liquid remaining in the ship's hold after unloading, must be dealt with annually. The water characteristically contains fish oil, blood and small pieces of flesh. Federal criteria term it a pollutant, so it can't be dumped overboard. Zapata Haynie was very interested in finding a solution to their disposal problem.

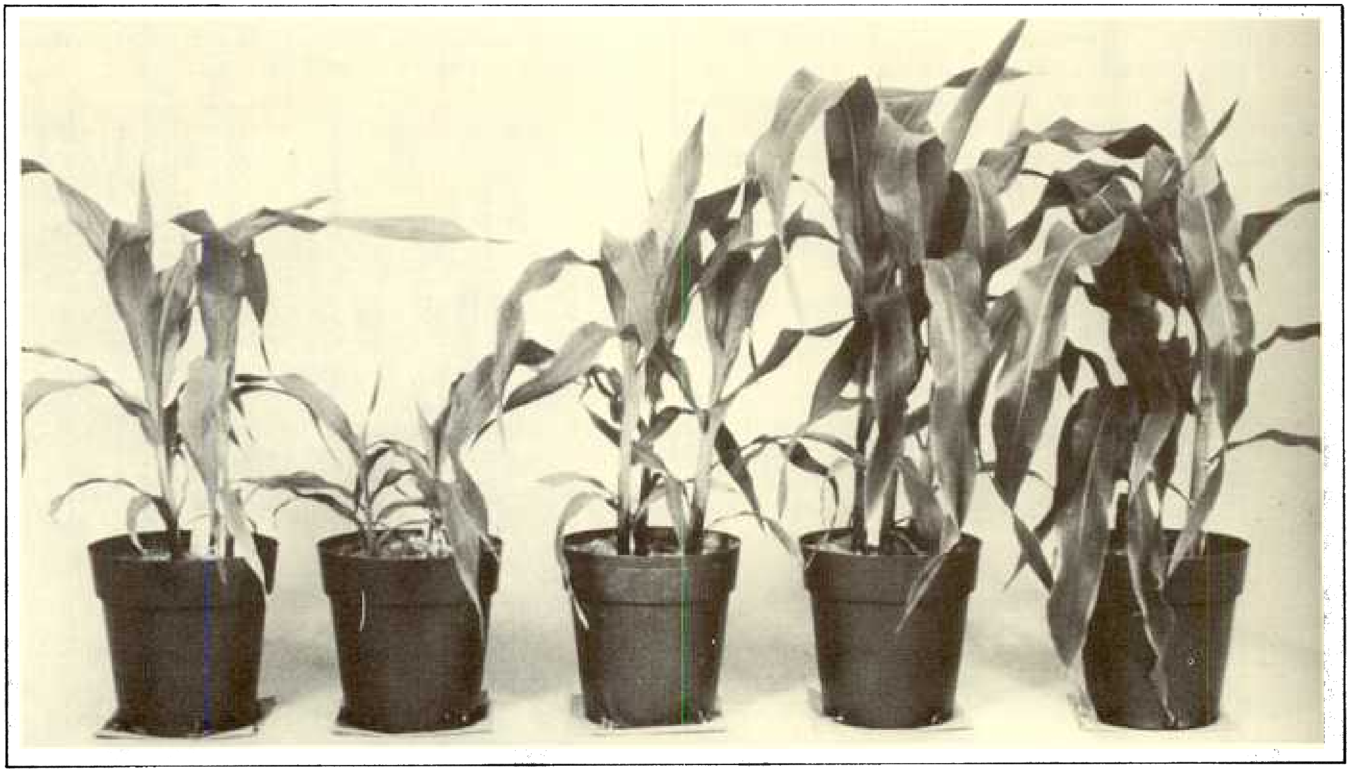
Because of this, they financed a study in 1980, conducted by Dr. Louis Aung of Virginia Tech's Horticultural Department, which entailed laboratory and greenhouse tests using menhaden processing waste water, termed Fish Soluble Nutrients (FSN), to fertilize various plants. Based on the positive results, which were published in 1981, the National Office of Sea Grant funded research on similar work in 1982. The primary aim of the project was to demonstrate in the laboratory and greenhouse the value and practicability of using FSN on commercial crops.

Aung found that a wide variety of food and ornamental plants responded favorably to fish soluble fertilization, and that while the solubles did not possess a *balanced* nutrient composition, they still contained *all* the elements necessary for growing any crop plant. Dr. George J. Flick, Department of Food Science and Technology, analyzed the food crops produced with FSN for chemical composition.

A Sea Grant project conceived as an extension of the laboratory and greenhouse studies was conducted in 1983 by Dr. Aung, who concluded that actual field testing of the fish solubles was necessary. The information derived from the laboratory and greenhouse might not correlate with crop responses in different environments.

Consequently, work with FSN was conducted on rice and soybeans in Louisiana, soybeans in Arkansas and Mississippi, corn, sorghum, peaches, grapes and strawberries in West Virginia and on ornamental plants, soybeans, corn and wheat in Virginia.

Test results on soybeans enriched with FSN, in both greenhouse and field plantings, showed good root development, excellent foliage growth and delay in aging. Below, mature beans are large and plump.



Don Massie

Growth of corn in sand cultures using, from left: inorganic fertilizer, casein hydrolysate, FSN at one tablespoon (T) per gallon of water, 3 T/gal. and 6 T/gal., weekly. Test results under field conditions in a drought area showed FSN-enriched plants stayed green two weeks longer than control plants.

Summarizing the results, Aung said "We've looked at the whole spectrum of crops and we've identified the mineral composition of FSN, something which hasn't been established before. People for ages have known that seafood and seafood wastes made plants grow better, but they didn't know why. Now we know a little more about the "why", and we are learning more precisely how much FSN is enough on specific crops to get the best results.

"Take lettuce for example. We know that lettuce needs large amounts of calcium, and that FSN is low in this mineral, although high in other essentials. A prescribed amount of FSN on lettuce, plus a calcium supplement if the soil is low in this mineral, will produce a good crop. If the soil is high in calcium, don't worry about the supplement; just add the FSN.

"With radishes we get an excellent crop in four weeks, and the radishes are larger and plumper than those aided by inorganic fertilizers.

"You can grow a crop of tomatoes on FSN alone, but the nutrition is incomplete, unbalanced. As with lettuce, if the soil tests high in calcium, no problem. If it tests low, add calcium.

"Also, FSN delays flowering and fruiting, so a grower using it on tomatoes would schedule his planting two weeks earlier for bedding plants to offset later production."

Aung highly recommends using FSN for production of seedlings, bedding plants and ornamentals, where there is a quick benefit in vigorous leaf growth and rich green color.

Perennial crops, such as peaches, need to be examined over several years. Rapid, positive results can be seen in a season where foliage growth is concerned, and Aung relates that to later crop production, but the long term results are not in.

Test results on soybeans in a drought area showed FSN enriched plants stayed green two weeks longer than control plants. Rice and corn showed similar positive results, as did all ornamentals examined. Good root development, excellent foliage growth and delay in aging were characteristic results.

In summary, Aung said "We feel good about the use of FSN across the board. Odor is no problem. A little oil of citronella takes care of it. The uptake of heavy metals is comparable to that of inorganic fertilization, and presents no danger at dilute FSN dosages which yield optimal growth. What remains to be done is a matter of documenting the optimal use of FSN on more plants, especially the perennials. We know long-term benefits can be achieved, and feel production increases are indicated." ●

Story and Photos by Dick Cook

Silage from the Sea

crab and finfish processing wastes provide protein supplement in cattle ration

Flounder racks, fresh from a processing line where the filets were removed at Amory Seafood in Hampton, Virginia, are typical of the finfish used for silage in this Sea Grant project.

THE DISPOSAL OF CRAB and fish processing wastes in Virginia and Maryland has been an increasingly serious problem over the last decade. Nationwide, there is an estimated 14 million metric tons of waste or scrap derived from fish used for human consumption, and scrap from crab processing accounts for another 135,000 metric tons. These are annual figures. In a Sea Grant funded project recently concluded at Virginia Tech in Blacksburg, Dr. Joseph D. Fontenot and his associates have successfully combined some of these wastes with crop residues to form a stable silage product which promises to lower the cost of feeding beef cattle and other livestock.

The silage made with finfish wastes has no offensive odors, is palatable to cattle and can be stored for long periods of time. Work with crab wastes in this initial project has been less successful, but the investigators hope to iron out the problems in the future.

Ensiling is basically a fermentation process in which various organic materials are combined and sealed in an airtight container. The anaerobic production of lactic acid and other acids by microorganisms drops the pH below 5, at which point fermentation ceases. The silage is then considered stable, and can be stored for a long period if air is excluded. Fish wastes and straw have been ensiled in work in Europe over the past decade, with some success. In Virginia, crab scrap, the residue from picking plant operations, has been processed by drying and combined with other products in poultry feeds, but Fontenot says the production may be economically borderline in some cases. Crab wastes have never been used in silage before.

In 1980, the disposal of crab scrap became an acute industry problem as a decrease in soybean meal prices caused a shift away from dried crab

Dr. Joseph Fontenot, left and livestock unit manager Hugh Chester-Jones inspect silage made from finfish scrap. The small cartons, 55-gallon drum and sausage silo (background) represent the three testing levels employed.

meal as a poultry feed additive. Processors were in need of an alternate solution to their waste disposal problem, and several made their plight known to Dr. George Flick of Virginia Tech's Food Science and Technology Department. Flick contacted Fontenot, and the subject of ensiling came up. They submitted a project to Sea Grant in 1980. Funding for the three-year work, which was also to involve finfish wastes, began in 1981.

Both the finfish waste and crab scrap were obtained through Flick's contacts with processors, and a total of 36 combinations of seafood waste and crop residue "recipes" were tried in the first stage of the project. In these small silo studies the fish material was monkfish processing waste. It was combined with corn stover or peanut hulls, with and without dry molasses. The first "silos" were simply 3.8 liter cardboard containers double-lined with plastic bags.

Insofar as possible, all air was expelled in the bagging of the silage. Then the containers were lidded, sealed and stored in an enclosed barn. At the end of a 6-weeks period, the containers were unsealed and the contents tested. One test was for odor.

"We experienced an abominable odor when we opened the containers containing the crab scrap," Fontenot related. "In fact it practically emptied the building. In every case involving the crab scrap, the pH was above 7, indicating that the fermentation process did not produce enough acid to stabilize the silage. When we added vinegar to the mixture, thereby effectively increasing the acetic acid, the pH dropped below 5, the odor problem was resolved and the silage was stabilized.

"The increased cost of the acetic acid as a stabilizer with the crab waste silage pretty well knocks out any economic advantage we anticipated at first, however. It's an area we'd like to work on in the future, hopefully with Sea Grant support. We have a preproposal in right now which would allow us to concentrate on the crab scrap, to try to figure out why it is not ensiling."

Twenty head of herford and angus calves, fed on the seafood silage mixture for several months, have shown good weight gain when compared to animals fed a normal ration.

ge mixtures contained varying amounts of seafood scrap, ground wheat straw and dry s. Stability, odor, nutritional value and palatability to livestock were evaluated.

Of the 36 original combinations, five were selected for the next stage of trials. These mixtures, all containing varying amounts of seafood scrap, ground wheat straw and dry molasses, were ensiled in 55-gallon drums double-lined with plastic. Acetic acid was added to crab waste mixtures to lower the pH to 4.5. These were sealed and allowed to ferment for 7-8 weeks. The resulting silage mixtures were evaluated for stability, odor, nutritional value and palatability to livestock.

Silage in the final stage was put down in sausage silos, 100-foot long plastic bags which, when filled to capacity, could hold 100 tons. A combination of finfish waste, wheat straw and dry molasses, that mixture which gave the best results in the test with the 55-gallon drum silos, was used in the sausage silos.

According to Fontenot, results to date have been good:

"We are extremely pleased with the silage made from finfish wastes. We've been feeding 20 head of angus and herfords on the mixture for several months, and they seem to like it fine."

At the end of the 150-180 day feeding period, the cattle will be slaughtered and carcass grade and taste panel evaluation will be compared to those of cattle fed conventional silage. A normal rations contains 10-15% soybean meal, 10-25% hay and 60-80% corn grain, salt, calcium, Vitamin A, phosphorus and trace minerals. One of the finfish silage rations contains silage made with equal parts of straw and finfish wastes, plus 5 percent dry molasses, 50 percent corn grain and salt and Vitamin A.

"I believe the fish silage will definitely do away with the need to put a protein supplement in the ration," Fontenot said. "It involves utilizing two relatively inexpensive sources of feed, which comprise one-half of the ration. The other half consists of corn grain for finishing the cattle.

Fish scrap was obtained from species processed for human consumption. The area where both the fish scrap and crab scrap were accumulating was also characterized by extensive grain and peanut production. Consequently, corn stover (leaves, husks and stalks), peanut hulls and wheat straw were the crop residues chosen for use in the experimental silages. Digestion and metabolism of the components was worked out on tests with sheep after chemical analyses and ensiling were completed.

"As far as a cost savings is concerned," Fontenot said, "I think it will be significant. Right now, the cost of feed per pound of finishing cattle is around 60 cents. A stockman using the silage made from finfish scrap should be looking at a 10-20% cost savings. When you figure that the cost of finishing a 700-pound animal to 1,100 pounds is about $250, the cost savings could amount to somewhere between $25 and $50.

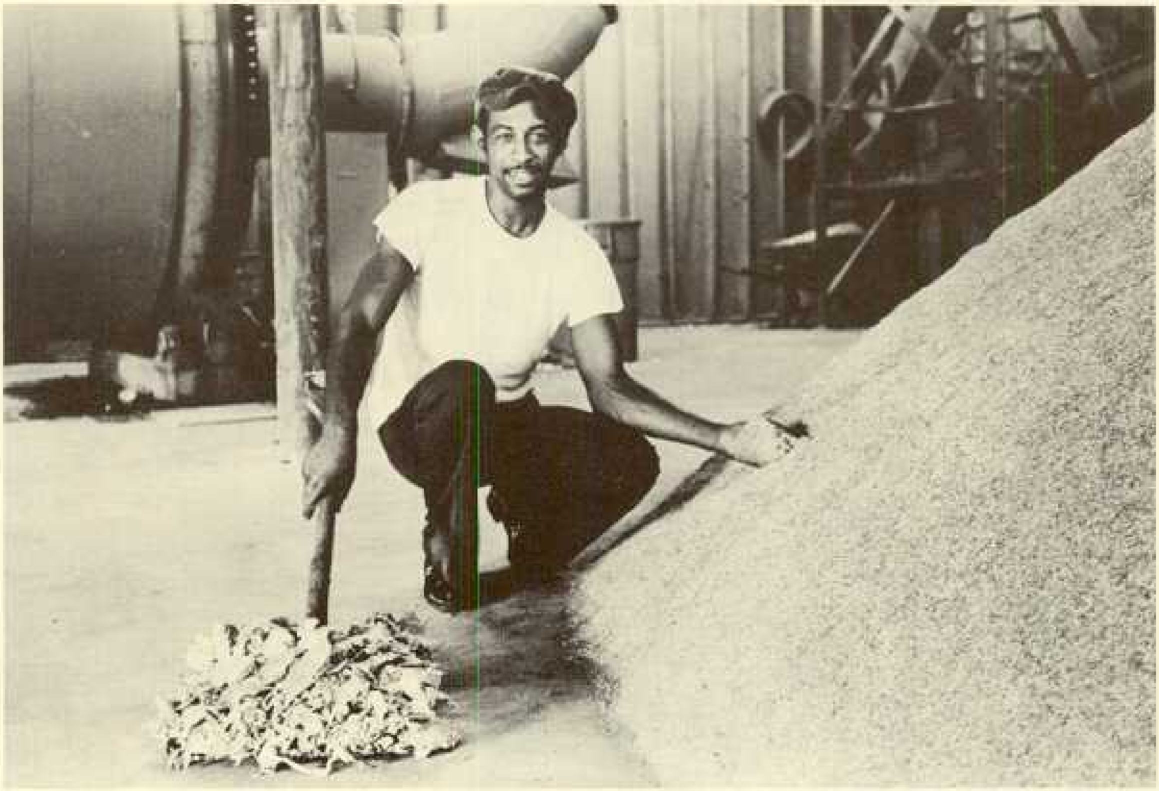
"That's good news for everyone. The livestock people are always looking for ways to cheapen the ration and anytime we improve the efficiency of any segment of beef cattle production, that change is reflected in retail stores by a price drop."●

CRAB MEAL PROCESSING...

a waste recovery option with continuing promise

by Ron Grulich

Dick Cook



Liability changed to asset, crab scrap to crab meal, is shown at the RCV Seafood processing plant in Morattico, Virginia.

THE BLUE CRAB INDUSTRY in Virginia is a major component of the state's seafood economy. In 1983, Virginia blue crab landings were estimated at 46,044,180 pounds with a dockside value of a $11,010,843. In a recent study conducted by Virginia Tech, it was estimated that the net economic impact on the State from both the harvesting and processing sectors during 1979 was $30,193,987. With numbers like these, there is reason for concern when the blue crab industry faces a serious problem.

One which has plagued the industry for years is the disposal of hard crab processing wastes. The disposal of all seafood processing wastes, crab and finfish alike, is becoming more acute as federal and state environmental pollution laws become tougher. This problem has been so serious at times in the hard crab industry as to threaten the viability of this vital segment of Virginia's seafood economy.

There are several problems which must be dealt with in the disposal of crab processing wastes:

1) Only 10-15 percent of the crab is recovered for human consumption. The remainder is discarded. In 1983, alone, an estimated 41,439,762 pounds of crab waste were generated in Virginia. This posed immense logistical problems for crab processors.

2) Crab waste undergoes rapid decomposition, and the resulting odor and pest attraction characteristics make rapid disposal mandatory.

3) The hard shell of a blue crab limits the disposal options available to the processor: i.e., it cannot be fed directly to livestock as can many other food processing wastes.

The unique character of crab waste, coupled with the importance of the industry to the Chesapeake Bay economy, has stimulated several Virginia Sea Grant research projects exploring alternate

Continued on Page 11

WAVELETS

Marine Schoolhouse Series No. 22

by Mary E. Sparrow

Where's the fish?

an aquatic food chain

Look at the cartoon and answer the following questions:

1 What things do you think are going to happen in this picture?

2. What is Fish A going to do? Fish B? Fish C?

3. What in the picture suggests that Fishes A, B and C are carnivores (meat eaters)?

4. What do you think will happen to Fish C?

5. The fish swimming together in a group (also called a "school") are menhaden. What do you think they eat?

6. It is unlikely the human would catch menhaden on a hook and line. Does this mean the menhaden are safe from predators? Are they safe from humans? What in the picture causes you to make these inferences (something you think is true)?

The cartoon shows a simple food chain - a series of organisms that are interrelated in their feeding habits, each being fed upon by a larger one that in turn feeds a still larger one. In the picture, it looks like Fish A will eat the worm, Fish B will eat Fish A and Fish C will eat Fish B. These fish are carnivores; they eat meat. The clue in the picture that suggests they are carnivores is the appearance of their teeth. Sharp pointed teeth are needed to bite into, grip and tear meat tissue. Humans are omnivores. We eat meat AND plants. Our teeth come in several different shapes and sizes. This helps us eat a wide variety of foods. Animals which eat only plants are known as herbivores. Menhaden are herbivores. Some herbivorous fish have teeth which are chisel-like, or blunt. These are suitable for grazing underwater plant growth from rocks and other structures. Other herbivores have teeth which are slender and brushlike, or small and jagged. Some, like the menhaden, have no teeth at all. Instead, they have gill rakers. These red feathery-looking appendages, visible through the open mouth of a menhaden, act as strainers. They filter out microscopic plants called phytoplankton, which are present in the water.

The phytoplankton level is actually where all aquatic food chains start. Like other green plants, phytoplankton uses energy from the sun and nutrients from the environment to produce nourishment for growth. This process, called photosynthesis, produces oxygen as a byproduct. Most of our oxygen on Earth is produced by aquatic plants. Plants are the only organisms that can produce their own food. For this reason, they are called primary producers.

Zooplankton are microscopic animals that feed directly on phytoplankton. Not all phytoplankton eaters are very tiny, however. Some types of whales feed on phytoplankton. Animals that eat plants are called primary consumers. The animals that eat zooplankton are second order consumers (sometimes called secondary consumers) and these are eaten by third order consumers, and so on.

Starting with the level of secondary consumers, all animals are considered predators. They must capture and eat other animals in order to survive. When an animal is sought as a source of food, it is referred to as prey. An animal can actually be both predator and prey. When a small fish captures zooplankton, it is the predator. When that same fish is sought by a larger fish, it is the prey.

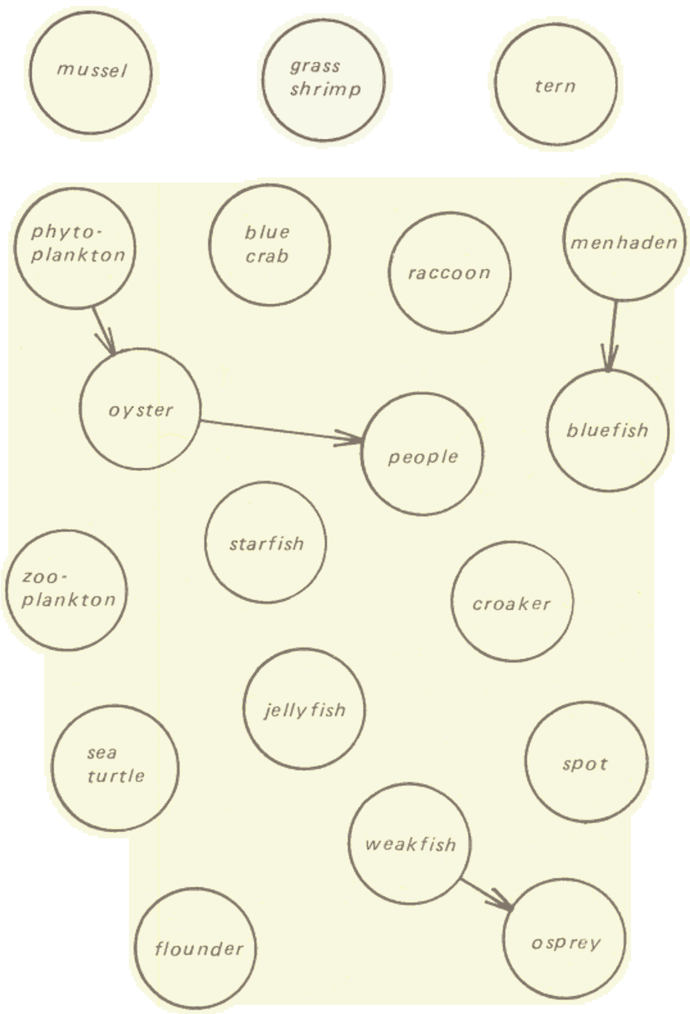
In the cartoon, it appears that a larger fish is chasing the school of menhaden. What happens to the menhaden population when phytoplankton disappear? There is not enough food to support as large a population of menhaden. The menhaden may not produce as many offspring as usual and some may starve to death. This in turn means there is not as much food for the larger fish.

The food chain is called a "chain" because all of the organisms are linked together for survival. Each link in the chain depends on the link before it.

The original chain we talked about was that of the Worm → Fish A → Fish B → Fish C. There is yet another organism shown in the cartoon, which will become the next link in the chain. Who or what is it? The human, of course. Although we don't usually consume menhaden as a food fish in the United States, it is eaten elsewhere in the world. It should be plain to all by now that the existance of food chains is vital to all animal life. This is why it is so important to guard the health of our oceans, because any prey species that is wiped out threatens countless others.

Draw an arrow from each organism to the organism or organisms that eat it. The arrow points to the animal doing the eating. Several food chains are done for you. When you are finished you will have drawn a food web.

Can you figure out the difference between a food chain and a food web?



(Continued from Page 8)
uses for crab by-products. Where crab waste is concerned, the projects, detailed in other articles in this issue, have met with limited success to date. Neither fully accommodates the present needs of crab processors.

Traditional avenues of disposal have been restricted, exerting more pressure on processors. In the past, many have used sanitary landfill sites. Unfortunately, these facilities are gradually phasing out crab waste handling because of health concerns and high handling costs. Using another disposal method, crab processors in rural areas formerly were able to spread their waste materials over adjacent farm lands as fertilizer. Unfortunately, odor and health considerations, as well as the coordination demands with existing growing seasons, limits the usefulness of this disposal technique.

One method which has endured over time however, is the conversion of crab by-products into crab meal. As pointed out in a Virginia Sea Grant project concluded in 1981 entitled "Feasibility of Crab Meal Processing in the Chesapeake Bay Region," by Thomas Murray and William D. DuPaul of Virginia Institute of Marine Science (VIMS), the production of crab meal can turn a large disposal problem into an asset. Crab meal can be used as a protein supplement in livestock and poultry diets. Murray and DuPaul indicated that, under most market and operating constraints, crab meal processing remains an economically sound venture.

Restraints of the business are significant, but not prohibitive. For example, many poultry producers have begun to use computers to determine which feed formulations offer the lowest cost for the highest growth rates. This modernizing change has put increased pressure on all meal producers to reduce production costs and lower wholesale prices. The increasing foreign production of feed grains, which to a certain extent substitute into poultry diets, is another competition factor.

Also, the strength of the American dollar in the last few years, coupled with relatively low labor costs in many developing nations, has made these commodities more competitive in American markets. In addition, crab meal processors are part of a capital and fuel intensive industry. This means they are subject to large fluctuations in profit margins as interest rates and fuel prices escalate.

Even with these problems, crab meal processing remains a viable disposal option. Meal producers who can absorb the short-term increases in operating costs and decreases in product price can find willing markets for their product. Bo Lusk, a commodity dealer from the Eastern Shore of Virginia, commented on this phenomenon:

"Many poultry producers are willing to maintain crab meal in their feed for formulations as long as a consistent supply can be guaranteed."

Dick Cook

Only 10% - 15% of the delicious blue crab is recovered for human consumption. The remainder represents a seasonal disposal problem in Virginia and elsewhere.

Poultry producers use different feed formulas during different stages of the growth cycle to provide the necessary dietary requirements of the birds as they grow and mature. The unique amino acid composition of crab meal makes it an attractive component in several of the specialized diets developed in the poultry industry.

Another area which may offer substantial market opportunities is aquaculture. Many aquatic species need feed supplements to achieve maximum growth in the shortest period of time. Preliminary results from a recent VIMS Sea Grant study by graduate student Pat Duncan and VIMS Eastern Shore Laboratory Director Michael Castagna indicate that juvenile clams fed crab meal achieve faster growth than those fed other feed supplements. Ultimately, thus could result in lower hatchery production costs for seed clams raised to planting size. This project and other development efforts in aquaculture could provide significant opportunities for crab meal processors in the future.

One option that must be discussed in any analysis of crab meal processing is the formation of a cooperative among local crab processors to build and manage a crab meal plant. Because it is a capital-intensive, high-risk business, a crab meal cooperative would allow processors to spread the operating risk among all of its members in return for a bonafide waste disposal option. The cooperative should be formed to permit equal participation in the profits and losses of the crab meal processing plant.

A well managed, properly located and cooperatively operated crab meal facility remains the best present disposal option for crab waste. Until new techniques become available, no other option can handle the huge volumes generated by crab processing plants in Virginia. ●

SEA GRANT PUBLICATIONS

The publications listed in this section are results of projects sponsored by the VIMS Sea Grant Marine Advisory Service. Order publications from Sea Grant Marine Advisory Service, Publications Office, Virginia Institute of Marine Science, Gloucester Point, VA 23062. Make checks payable to: VIMS Sea Grant.

MANUAL FOR HANDLING AND SHEDDING BLUE CRABS. Michael J. Oesterling. SRAMSOE No. 271, 77 pages. $6.00.

HANDLE WITH CARE: Mid-Atlantic Marine Animals That Demand Your Respect. Jon Lucy. Educational Series No. 26, 20 pages. $1.50.

BIOLOGY AND IDENTIFICATION OF RAYS IN THE CHESAPEAKE BAY. Joseph W. Smith and J. V. Merriner. Educational Series No. 20, 28 pages. $0.50.

SHORELINE EROSION IN VIRGINIA. Scott Hardaway and Gary Anderson. Educational Series No. 31, 25 pages. $1.00.

MARINE EDUCATION FIELD TRIP SITES IN VIRGINIA. Sue Gammisch. Educational Series No. 33, Booklet, 31 pages. $1.00.

TIDE GRAPHS FOR HAMPTON ROADS, VIRGINIA and TIDE GRAPHS FOR WACHAPREAGUE, VIRGINIA. Published quarterly. Free subscription obtained by written request.

COMMERCIAL FISHING NEWSLETTER. Published quarterly. Free subscription obtained by written request.

"FISH" LEAFLETS (shad, black sea bass, croaker, spot, clam, oyster, soft crab, blue crab, flounder, tuna, sea trout, monkfish and bluefish). Life history, recreational and commercial importance information, plus tempting recipes for each! Free.

AUDIOVISUAL AIDS AND PUBLICATIONS AVAILABLE FROM THE VIMS SEA GRANT MARINE EDUCATION CENTER. 40 pages. $1.00.

FISHY ACTIVITIES FOR YOUR SMALL FRY. Mary E. Sparrow, Frances L. Lawrence and Ronald N. Giese. Educational Series No. 28, 36 pages. $2.00.

MANUAL FOR GROWING THE HARD CLAM Mercenaria. Michael Castagna and John N. Kraeuter. SRAMSOE No. 249, 110 pages. $3.00.

DON'T WASTE THAT FISH: Tips on taking care of your catch. Dixie R. Berg, Theodore M. Miller and Frank B. Thomas. Leaflet, North Carolina Sea Grant Program. 20 pages. $0.25.

THE CHESAPEAKE: A BOATING GUIDE TO WEATHER. Jon Lucy, Terry Ritter and Jerry LaRue. Educational Series No. 25, 22 pages. $1.00.

Marine Resource Bulletin

A Sea Grant Advisory Service

VOL. XVI, NO. 1 MAY 1984

Dr. Frank O. Perkins . . . . . . Dean/Director, Virginia Institute of Marine Science

Dr. William Rickards.......................Director, Virginia Sea Grant

Dr. William D. DuPaul ....Director Marine Advisory Services

The Marine Resource Bulletin is a quarterly publication of the Marine Advisory Service of the Virginia Sea Grant College Program, which is administered by the Virginia Graduate Marine Science Consortium, with members at the College of William and Mary, Old Dominion University, University of Virginia and Virginia Polytechnic and State University. Subscriptions are available without charge. Address inquiries and comments to the editor.

Dick Cook.......................................Editor

Cover Note

Fish and other seafood have been used for plant fertilizer since before America was colonized. Recent studies in Virginia indicate that waste products from seafood processing contain all the elements needed for growing ornamentals and crop plants. Photo by Dick Cook.

Virginia Institute of Marine Science
Gloucester Point, Virginia 23062

Address Correction Requested