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PROBLEMS AND POTENTIALS OF RECYCLING WASTES FOR AQUACULTURE

by

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SEA GRANT PROGRAM

Administrative Statement

This study on the use of recycled wastes for aquaculture systems covers a wide range of problems, particularly those which are biological, social, political, legal, and economic in nature. The social emphasis comes from a recognition that the reuse of waste for any human consumption is a very sensitive idea, and its success heavily depends upon societal acceptance of such recycling above and beyond the need for technological developments.

To achieve broad coverage of the problems, the study team included a wide range of disciplines. The combination of perspectives has produced a study which is able to anticipate a broad range of societal needs and reactions to the proposed industry.

The primary study objectives included:

1. Definition of scientific unknowns which may adversely influence industry development.
2. Definition of technology needs required for public health assurance.
3. Identification of legal, social, political, and economic issues on which decision making will depend.
4. An analysis of consumer acceptance of marine foods derived from wastes.
5. Recommendations of directions in which to proceed to develop a stable marine-waste food recycle industry.

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Ira Dyer
Director

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Finally, all of the contributors owe thanks to Professor Ira Dyer, Chairman of the Ocean Engineering Department at M.I.T., who made the project possible and provided invaluable guidance and practical advice throughout the duration of this study.

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The focus of this study is to discuss the potentialities and problems of using thermal effluents and/or secondary sewage as inputs to a marine aquaculture system. While the current technology of marine aquaculture is relatively undeveloped, and the use of waste in such a system is even less developed, the potential for such systems appears tremendous, and there are no apparent blocks which could not be overcome by active research.

At some point in the future, the growing demands on our coastal zones for both waste disposal and food production will only be met by a sophisticated, complementary and managed system. Meanwhile, feed cost for raising fish and farm animals will probably continue to rise, making the use of recycled wastes for feed in an aquaculture system an economically attractive concept. Action taken now to develop an effective managerial capacity could well ensure a sensible and safe approach, rather than a haphazard and hurried one later on.

The economic viability of a marine waste-food recycling industry has not yet been demonstrated. Research regarding the safety of such systems, but applicable in a much broader way, will probably have to be government-sponsored. That kind of research is both too expensive for any one company to justify, and is not really appropriable by any one company, but rather by a number of industries. It is also difficult to forecast the costs of moving from small-scale pilot efforts to viable operations without knowing what costs may be involved in the prevention of chemical and biohazards in the system.

While aquaculture generally provides the economic and marketing advantages of increased productivity, decreased growth period, and the benefits inherent in a managed versus "wild" fish-catching system, a waste recycle system

a) opens up the possibility of more northerly aquaculture operations, perhaps broadening the range of species to offer for consumption, as well as further diversifying regional economies;

b) provides an opportunity, if appropriately located, to turn thermal and sewage effluent into an asset rather than a liability;

c) has potential for lowering feed costs for aquaculture.

Yet, a waste-recycle system has some current disadvantages:

a) The possible presence of carcinogenic chemicals in input wastes produces health hazards. Very little is known about tolerance levels in the fish themselves and about the transmittal and concentration processes in the food chain;

b) There will be need for legal variances and changes to allow for the introduction of technology on a large scale to a previously "uncontrolled" fishing industry. Since there is not a uniform set of enforced standards for all forms of aquaculture and fishing, there is reason to expect strict regulatory demands for monitoring and control factors.

c) The uncertainty of a guaranteed, safe, high quality product at this time brings concomitant uncertainty about the economics of production, and the responses of legal bodies and the consuming public;

d) Current coastal zone management practices make difficult sitings of operations of any magnitude, which will significantly alter the "coastal environment";

e) Consumer acceptance of the waste-grown seafood will be a significant determinant in its ultimate success, and a carefully planned public education and advertising program will have to be undertaken to ensure acceptance.

While the disadvantages mentioned herein are significant, we foresee them as surmountable. Thus, the concept of marine-waste food recycling systems will likely be adopted, but not for some time.

In view of these conclusions, we recommend that:

A. *The Federal Government should continue to fund*

1) *Research relating to chemical tolerance levels and biohazards;*

2) *Research in monitoring for these hazards.*

These areas are necessary for protecting public health, and are often expensive areas of research which are applicable to a large number of other problems of the society relevant to other industries; this research is not necessarily appropriable to any one beneficiary who might feel such a large investment warranted, yet it is research essential for the protection of public health.

B. *Investors in aquaculture* should

1) *Keep open the option for a marine-waste recycle system;*

2) *Be prepared for fairly long-term investment periods and fairly large capital inputs for a marine-waste-food recycle system.*

Before a marine-waste-food recycle system can be commercially feasible, there need to be rational, safe tolerance levels established. Until a uniform set of standards for tolerance levels can be achieved for all forms of aquaculture and fishing, we believe that less complex and costly systems of aquaculture would provide much better business opportunities. The potential costs and risks involved should inhibit others from considering this concept. They may go into regular aquaculture now with large investments and find that society's growing demands for quality control in five years or so, with accompanying higher systems costs, make old systems obsolete compelling new investments in MWFRS-type operations which they cannot afford.

C. *Those with interests in aquaculture, marine-waste-food recycle systems, and public health* should

1. *Educate and inform persons at State and Federal levels*

   a. *To assure that research money is allocated;*

   b. *To have the maximum number of persons informed when legislative initiatives are appropriate.*

This education might emphasize the inevitable food shortages in the not-so-distant future, and the compelling need for recycling our resources.

Chapter 1. Problem Definition

1.1 Introduction

The introduction of something new into society is not always an easy process. With increasing population, industrialization and rising living standards, greater demands are being made on man's resources and his resourcefulness. The growing awareness that there is not an endless supply of land, food, and other natural resources necessary to maintain a modern society has produced certain changes in attitude and activity at almost every level of society. Concern over environmental degradation, over possible energy shortages, food shortages, and a number of other problems which threaten to constrain man's activities has affected decisions in both the public and private sectors.

Many of these problems converge in the coastal zone, and as a consequence appear to exacerbate one another. A reasonable solution to crowding, pollution, and misuse of resources is the maximization of the available resources according to a carefully-thought-out plan of priorities to turn detrimental effects to advantage and to assure benefits over costs.

In specific terms, the greater number of people in the coastal areas create an increasing amount of waste which is often disposed of in coastal waters. This increased activity also results in greater demands for power, requiring additional power plants. The need for cooling systems for the many power plants has added another potential form of pollution and social cost to coastal areas. While these examples represent only part of the principal problem of resource management in the nation as well as the world, they provide a good basis for understanding and justifying the efforts which are currently underway for marine-waste-food recycle systems which this study addresses. Because the disposal of sewage and thermal wastes poses a potentially serious problem for society, these systems attempt to turn them to a positive use by making them essential ingredients in a food-production system, giving sewage and thermal effluence a degree of value where they currently represent only costs. From some points of view, the distribution of temperature and nutrients is far from ideal in the marine ecosystem, so the very real possibility exists of improving over nature with the carefully-controlled release of these products to the environment.

There are, indeed, constraints that stem from the introduction of new concepts and possibly new products into society. As risks and costs are involved to some considerable extent, the need must be demonstrated and justifications given for changing whatever must be changed to bring about the acceptance of these systems and their products.

1.2 Objectives

It is the primary focus of this study to point out the real advantages of a waste-food recycle system while bringing forward all of the current and foreseeable problems such an effort would entail. The study covers a wide range of problems, particularly those which are biological, social, political or legal in nature. The social emphasis comes from a recognition that the reuse of waste for any human consumption is a very sensitive idea, and its success heavily depends upon societal acceptance of such recycling above and beyond the need for technological developments.

To achieve broad coverage of the problems, the study team was composed of an eclectic group, able to bring a wide range of disciplines into consideration (see Table 1.1). The combination of perspectives has produced a study which is able to anticipate a broad range of societal needs and reactions to the proposed industry.

Following is a more explicit and concise definition of the study objectives:

1) Definition of scientific unknowns which may adversely influence industry development;
2) Definition of technology needs required for public health assurance;
3) Identification of legal, social, political, and economic issues on which decision-making will depend;
4) An analysis of consumer acceptance of marine foods derived from wastes;
5) Recommendations of directions in which to proceed to develop a stable marine-waste-food recycle industry.

Table 1.1. Major Study Participants

Name	Affiliation	Discipline	Interests
Prof. I. Dyer	Head, Dept. of Ocean Engineering	Co-Principal Investigator	General
Prof. Judith Kildow	Dept. of Ocean Engineering	Co-Principal Investigator Political Scientist	Public policy
John E. Huguenin	Woods Hole Oceanographic Institution (WHOI)	Co-Principal Investigator Systems Engineer	Aquaculture systems
Prof. Michael S. Baram	Dept. of Civil Engineering	Lawyer	Legal/political factors in technology
Prof. David D. Major	Dept. of Civil Engineering	Economist	Technology assessment
Prof. Charles Kimble	Dept. of Nutrition and Food Science	Food Technologist	Scientific unknowns--public health risks
Dr. Frank Aldrich	M.D., Medical Dept.	Environmental Toxicologist	Public health risks
Murli Rao	Graduate Student, Sloan School of Management	Marketing	Consumer acceptance
Steve Leverette	Graduate Student, Dept. of Ocean Engineering, M.I.T., WHOI	Marine Biologist	Monitoring and control systems
Barbara Katz	Law Student, Boston University	Law	

Consultants and Advisers

Prof. Eugene B. Skolnikoff, Head, Dept. of Political Science, M.I.T.
Prof. Samuel A. Goldblith, Prof. of Food Science, Dept. of Nutrition and Food Science, M.I.T.
Dr. John H. Ryther, Senior Scientist, Biology Dept., Woods Hole Oceanographic Institution

Chapter 2. State-of-the-Art and Potential Development

The concept of aquaculture itself is as yet very unexplored and undeveloped in the Western world. As it is our intention here to explore the possibilities of waste-fed aquaculture, it is important to point out that this adds but another dimension of assets and problems to an already large array of unknowns in the field.

The use of thermal effluent in aquaculture is far more advanced than that of sewage waste, and it is important to differentiate between the two throughout this study. Many of their problems coincide, but the number of "unknowns" is far greater for the sewage recycle concept. We therefore largely address them separately on the technical level, and address them jointly in the chapter on Legal, Political and Social Issues.

2.1 The Use of Thermal Effluents in Marine Aquaculture

2.1.1 The Problem of Thermal Waste

The total electric power-generating capacity in the United States during 1970 was about 340 million kilowatts. In the next twenty years this figure is expected to grow perhaps to triple that amount. This increased capacity will come from both fossil and nuclear fuel plants. These plants are likely to be very large units. Many nuclear plants now in the planning stages will generate over one million kilowatts of electric power and eject more than two million kilowatts of energy to the environment. This implies a water-cooling flow of over 1,000 cubic feet per second, with a water temperature rise of 15° to 30°F. If traditional straight-through cooling is used, such high flows strongly favor plant sites adjacent to large bodies of water.

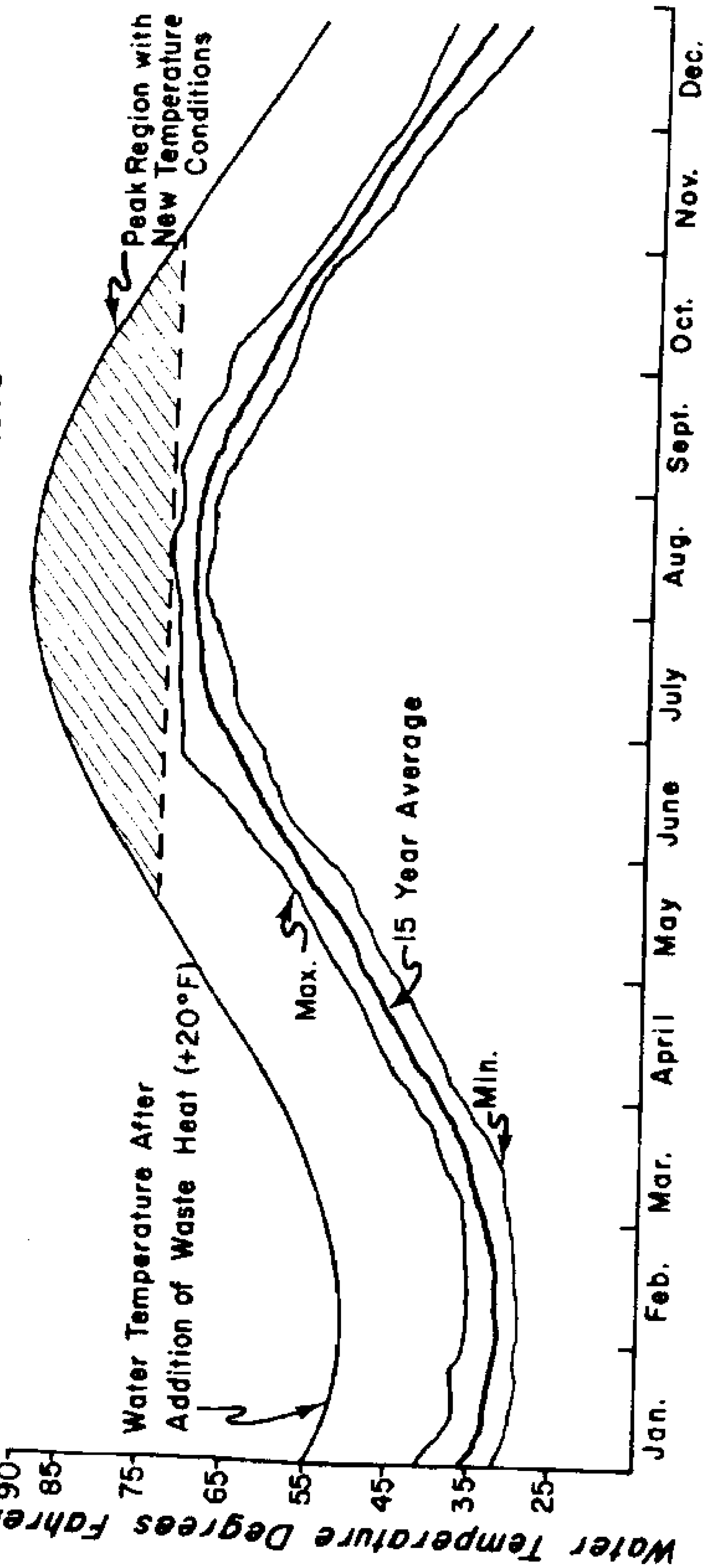
Even if cooling ponds and cooling towers are used and the fluids recirculated, there are still advantages in being near water to provide for water makeup and for occasional flushing of the cooling system. Thus, many of these plants will be located in our coastal regions.

The thermal effluents or cooling waters from power plants have been examined for a variety of potential uses (Mathur and Steward, 1970; Yarosh, 1972). However, the water temperature increases over ambient water temperatures are insufficient for most industrial purposes. It is, in general, even insufficient for home and factory heating. As an example, the winter water temperature may be 30°F which, with a rise of 20°F, is still only 50°F. For many potential uses, the costs of pumping, piping and distributing such large volumes of water over extended areas make these uses of the waste heat impractical.

2.1.2 Aquacultural Potential

Fortunately, thermal effluent water temperatures are in many ways ideally suited for use in the cultivation of aquatic organisms. The placing of many power plants adjacent to large bodies of water promises that pumping and piping costs from the plants to potential aquaculture sites may possibly be minimal. The general effect of using the heated effluents is dependent on the natural water temperature profiles. The example in Figure 2.1 is typical for estuarine areas in New England which exhibit a very large water temperature change from the winter low to the summer high relative to other coastal areas of the country. In the example, a hypothetical power plant with a coolant water temperature increase of 20°F, except for a period

Figure 2.1. Woods Hole Surface Water Temperatures 1956–1970



during the summer, has temperatures which do not exceed the range of natural water temperatures found at Woods Hole, Massachusetts. If the aquacultural operation has the option of using or not using the heated water, this peak region can be either reduced or eliminated. Thus, a greatly flattened curve will result with temperatures all year round having much smaller deviations from some average and hopefully optimum temperature. The net effect is to expand the season of rapid growth from perhaps only a few months to potentially the entire year. Experiments with salmon, flatfish, trout, oysters and lobsters have shown that, through such control of water temperatures, the growing period required (Mathur and Stewart, 1972; Yarosh, 1972) to reach market size can be significantly reduced under many circumstances by one-half or more. The greatest potential gain is in areas of the country that have large water temperature changes between winter and summer, and hence generally have short growing periods for many species of commercial interest. The advantages are dependent not only on the power plant heat addition and the natural water temperatures, but also on the ability to control the water temperatures in the cultures, and to provide the other prerequisites for growth. As an example, temperature control can reduce the eight years required for lobsters to reach market size in nature to less than two years (Hughes and Sullivan, 1972). In addition, genetically selecting individuals for growth in elevated water temperatures above those naturally experienced in some cases promises to shorten the required growing period even further. There currently is considerable activity in determining the practicality of using power plant waste heat in large-scale marine applications (see Table 2.1). Unfortunately, the results from many of these efforts have not been published.

2.1.3 Pioneering Projects

The Long Island Lighting Company's Norport Power Station on Long Island Sound is probably unique in having a commercially viable shellfish hatchery situated on its 2-1/2 acre discharge lagoon. The first experiments were conducted during the winter of 1967-68 and applied research involving oysters, clams, scallops and shrimp is still being conducted. The 14,000-square-foot, $300,000 hatchery is primarily used to spawn and rear oysters to stocking size when they are placed on thousands of acres of managed shellfish beds in Long Island Sound (Burns, 1969). This one operation, whose primary market is the New York half-shell restaurant trade, is estimated to be grossing $5 million/year and growing rapidly (N.Y. State Department of Commerce, 1971).

The heated power-plant effluents make it possible, due to the increased water temperature, for the baby oysters to feed and grow during the winter when other oysters are inactive. The increased temperature also provides increased growth at other times of the year, and doesn't appear to get high enough in the summer to be detrimental. During the period in the lagoon, the oysters are estimated to grow five times faster than those in nature, and accelerate the oysters' growth to market size by a full year (Vanderborgh in Yarosh, 1972).

Another program, at the Mason Station of the Central Maine Power Company in Wiscasset, Maine, was started by Frederick Towle with rainbow trout in the spring of 1972. While the rainfrom Power Plants

Plant Location	Type	Organisms of Interest
Hunterston, Scotland	Nuclear	plaice, sole, turbot
Wiscasset, Maine	Fossil fuel	rainbow and brook trout, coho salmon
Turkey Point, Florida	Fossil fuel and Nuclear	shrimp, blue crab, mangrove snapper, spiny lobster, pompano, sea trout
Northport, Long Island, New York	Fossil fuel	oysters, hard clams, scallops, shrimp
San Diego, California	Fossil fuel	American lobster, shrimp, abalone, crabs
Poole, England	Fossil fuel	hard clams
Millstone Point, Connecticut	Nuclear	oysters
Crystal River, Florida	Fossil fuel and Nuclear	shrimp
Galveston Bay, Texas	Fossil fuel	pompano, croaker, pinfish
Hinkley Point, Somerset, England	Fossil fuel	shrimp
At least seven different plants in Japan	Fossil fuel and Nuclear	Mostly shrimp and yellowtail

bows, harvested in October, did very well, Coho (silver) salmon, a Pacific fish, appear to be a more promising commercial species under the prevailing conditions. Thus, 800 Coho (four inches long and under one ounce each) acquired from a hatchery in Oregon were stocked in a 10 x 10 x 10-foot floating cage placed in the plant's thermal discharge (Caldwell, 1972). In late December, the remaining fish were harvested and averaged 11 to 12 inches long and just under one pound. The mortality was under 10 percent. Due to the abundance of natural food available, it took only two pounds of prepared trout pellets and ground waste shrimp to produce a pound of marketable fish. Plans are now in progress to carry out much larger-scale Coho salmon culturing activities.

The Turkey Point Power Plant, placed on a 12,000-acre tract owned by Florida Power and Light Co., has two conventional oil-fired units and two nuclear units. With the backing of the power company, Armour and Company, the United Fruit Company, and the National Science Foundation, the University of Miami started building in 1968 and now manages a marine aquaculture research facility at the power plant site. The primary research objectives have been to develop methods to rear shrimp from eggs to market size at a profit and develop methods to induce shrimp to breed in captivity. While early efforts concentrated on pink shrimp (Penaeus duorarum), effort has now shifted to a white shrimp from Central America (P. occidentalis) which grows faster and seems a better prospect for reliable controlled breeding.

The research facility is composed of a well-equipped hatchery-laboratory building, thirty-six 445-gallon concrete tanks, sixteen 5,000-gallon concrete tanks, four 1/4-acre ponds, two 1/2-acre ponds (Tabb et al., 1969; Caillonet and Tabb, 1972). The steep sides of the ponds are covered with a rubber lining; the bottom is composed of gray marl; the average water depth is five feet; and the ponds can be completely drained at low tide. The total complex is built between two man-made elongated channels, one with ambient temperature seawater and the other connected to the heated power-plant effluent. These two water sources can be combined to provide a temperature-controlled flow of seawater.

While the aquacultural potential of Turkey Point is significant, the future is not bright. There has been considerable controversy, both local and national, over the thermal pollution in Biscayne Bay from the addition of the two nuclear units. As a consequence, the power company is proceeding toward a closed cooling system using 168 miles of man-made canals. The recycling is expected to result in a slow buildup of various substances, including low-level radioactive materials in the cooling water, which will probably make the sale of animals grown in the system for food legally impossible.

2.1.4 Major Problems in the Use of Thermal Effluents

2.1.4.1 Technical Problems

While aquaculture may promise greatly increased benefits from the use of waste heat now rejected by power plants, it is unlikely that it alone can provide a near-term solution to the thermal effluent problem itself. The immense water volumes involved are but one difficulty. Most current efforts to use the heated water in aquaculture do not actually "consume" its heat content. Thus, the thermal pollution problem may be simply transferred downstream. In addition, during the summer peak when control over the thermal output is most needed, the aquaculturist is least likely to want the heated water. If aquaculture is to be carried out in large cooling ponds used by some power plants, the aquaculturist will probably have to either accept the peak summer temperatures or curtail operations during this period. However, even with partial utilization, aquaculture may assist in defraying the costs associated with the ponds and help in justifying their use.

It is further necessary, due to plant shutdowns both planned and unexpected, that the species selected for breeding can at least survive under the extremes of water temperature that may occur naturally. This could curtail the flexibility in species selection considerably and, after market constraints, those species that can still be considered as practical possibilities under any particular set of circumstances may be extremely limited.

The seawater quality in plants which recycle their cooling water may not be suitable for direct use in aquaculture. This is due to water property changes over time due to plant inputs. However, heat could still be extracted from even a closed power plant cooling system through a large heat exchanger, such as a long, thermally-conductive bulkhead.

Water temperature control may require a second independent high-flow-rate water supply system, to be provided by the aquaculturist, supplying ambient temperature water which can be blended in various proportions with the power-plant effluent. Unfortunately, mechanical pumping systems which provide the required high flows are a major cost item and could easily determine the economic viability of such projects. A possible way around this problem may be to use tidal pumping for this ambient temperature source. Another possibility is to tap into the large pumping systems of power plants and take some of the water before it is used for cooling. While this might affect a plant's cool-system and increase operating costs, mutually advantageous arrangements might still be made, especially if new plants were designed to consider such possibilities. There may be significant economies of scale by combining pumping requirements.

2.1.4.2 Biological and Chemical Problems

While the use of heated water may increase the average growth rate, it may also have other less desirable effects about which very little is currently known. Parasites, predators, and diseases that were formally either eliminated or suppressed by natural temperature extremes or the shortness of time at some desirable temperature may flourish. In addition, there is the risk of unintentionally bringing in some of these "undesirables" in the effluent water. Diseases pose a particularly serious threat. The increased metabolic rate, resulting from warmer temperatures and more intensive feeding, greatly increases the disease potential already existent due to the crowding together of many organisms. Diseases, once introduced into such a favorable environment, can sometimes produce a virtually instantaneous and complete loss of culture stocks. The warmer water also may degrade an organism's market value by changing the meat's firmness, texture, color or taste. Further, the lack of pronounced seasonal water temperature variations may alter the organism's natural life-cycle patterns with unknown long-range consequences.

Power plants tend to be already established in dense population areas where water resources are already polluted. Hence, the possibility of introducing disease to the aquaculture environment would require a priori water control.

A serious bacterial form of food poisoning comes from an organism called *Vibrio paraheniolyticus*, appearing primarily in the summer months, when it thrives in warm waters. It could pose a very serious problem in the uniformly warm waters of an aquaculture system. (See Appendix A for further details about this organism.)

Power plants also eject, usually infrequently and in very low concentrations, a wide variety of toxic and potentially dangerous substances. Some of these materials are reagents used in the power plant; others are leakage and runoff from equipment; and some may be injected to reduce corrosion or biological fouling in the plant's piping (see Figure 2.2). While legal and regulatory activities, such as the Clean Water Act of 1972, can be expected to steadily reduce the levels of these additions, they will remain for some time a factor to be considered by aquaculturists both for whatever quantities may still be released, as well as for the occasional "accidents." In addition, the corrosion and erosion of the plant's piping can significantly increase the concentrations in the cooling water of some metals such as copper, zinc, nickel and aluminum. (See Section 2.2.5.1 for description of metals pollution problems.) As an example,

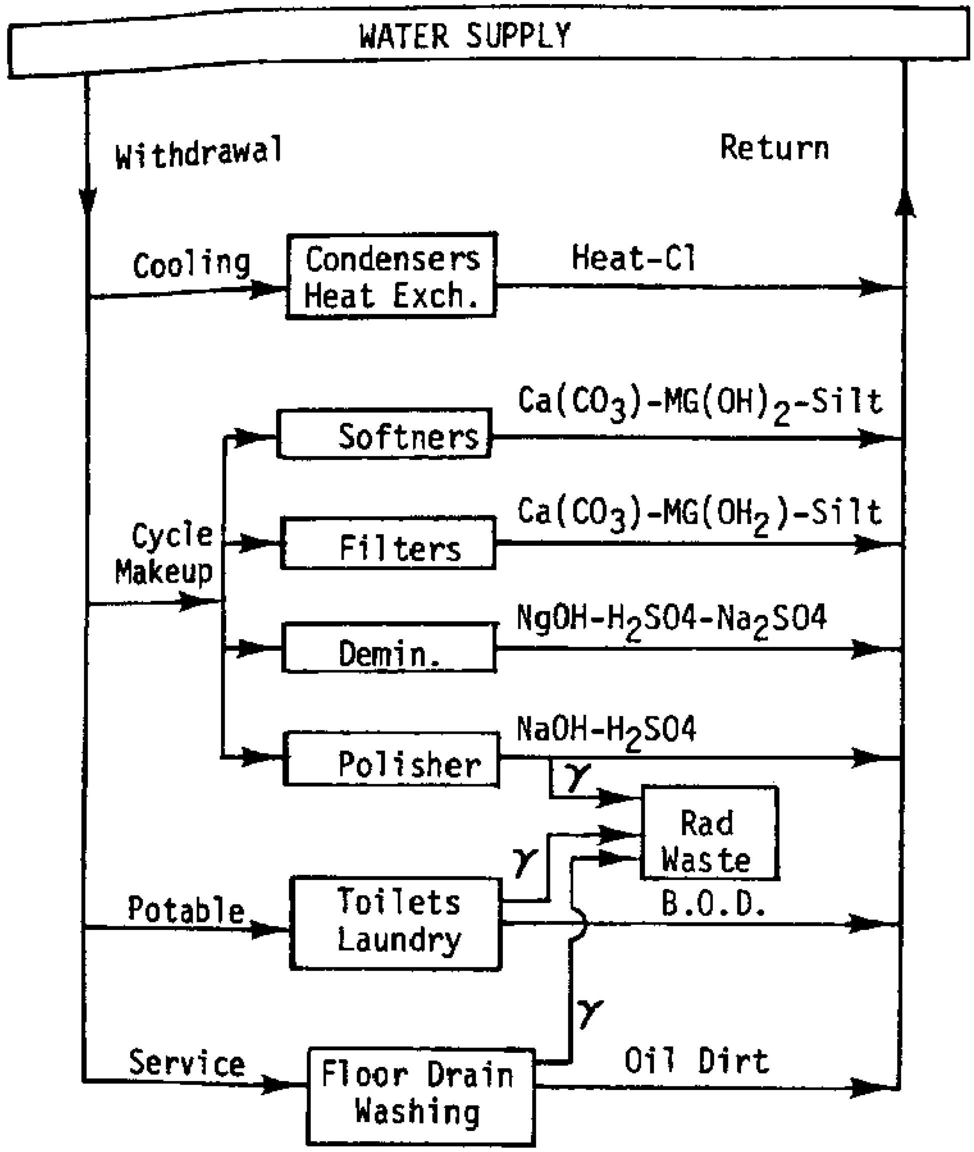


Figure 2.2. TYPICAL WATER USES AND DISCHARGES OF POWER PLANT

Source - Thermal Pollution - 1968, P-24
Hearings before the Subcommittee on
Air and Water Pollution, U.S. Senate

oysters grown in a power-plant effluent have been shown to accumulate enough copper to turn their meat green (Rooseburg, 1969). Except at high levels, the effects of these materials are generally unknown.

Many marine organisms can commonly concentrate hundreds and thousands of times the levels of materials in the water, and occasionally by a factor of as much as one million (Bryan, 1971). Very little is known about the mechanisms involved which limits our knowledge of pollution tolerance considerably. For nuclear power plants, the accumulation of released low-level radioactive materials by marine organisms may be an additional problem. Determining levels for each of these different pollutants individually and in combinations which are "safe" for human consumption currently poses an extremely difficult legal, political and scientific dilemma.

2.1.5 Summary

Aquaculture, in general, and thermal aquaculture, in particular, have a great many unknowns. There are very little data available on the equipment and techniques that can be successfully used in large-scale culturing. Scaling-up small laboratory techniques and results to larger sizes introduces major uncertainties and high risks. Since performance is so uncertain, it is often not clear whether large-scale culturing is technically or economically feasible. There is a need to "productionize" aquaculture systems for larger-scale operation, increased production efficiency, and economy.

The pilot plant experiments and demonstration projects are essential for providing the information required for realistic analysis of aquacultural systems. Unfortunately, much of the information which does exist is held by private firms and is of a proprietary nature and unavailable. In general, little is known about long-term effects of using heated water or how it may affect the concentration and transmittal of pollutants through the food chain which includes man. Clearly, a great deal of research still remains to be done.

2.2 The Use of Domestic Sewage in Marine Aquaculture

2.2.1 The Current Situation

When untreated domestic wastes are discharged into the sea they are quickly attacked by bacteria and decomposed to their inorganic constituents (carbon dioxide, ammonia, phosphate, etc.) using dissolved oxygen from the water in the process. When this occurs in confined estuaries and embayments that have restricted circulation and long flushing times, the accumulated sewage itself is unsightly, malodorous, and otherwise objectionable. In extreme cases, the oxygen demand of the added wastes may exceed that of the receiving waters; the area becomes anoxic; aquatic life perishes; and ecological disaster ensues.

To prevent these undesirable effects, it is customary to subject sewage, prior to its discharge into a confined area, to a secondary sewage treatment process that oxidizes and mineralizes most of the organic waste. This procedure improves upon, but does not necessarily correct, the ecological imbalance, for the mineralized wastes now serve as nutrients for the growth of unicellular algae (phytoplankton). This photosynthetically-produced new organic matter may be quantitatively as great as, or even greater than, that originally contained in the raw sewage.

As long as the nutrients and the resulting algal populations remain at or near the sea surface, the plants actively produce oxygen and pose no threat to the oxygen balance of the system. Even under these conditions, however, the dense algal "blooms" themselves are unsightly and undesirable from an esthetic or recreational point of view as they impart a distinct coloration and often an unpleasant odor to the water. The situation is perhaps best illustrated by the conditions commonly referred to as "eutrophication" now prevailing in Lake Erie and other heavily-polluted waters. Furthermore, if and when the algae settle out of the photosynthetic layer at the surface, the organic load and its oxygen demand may again create anoxic conditions with the accompanying drastic ecological effects.

Ironically, "eutrophic" environments (i.e., those of high biological productivity) are also normally the most valuable food-producing regions of the world. The few places in the ocean where natural processes of upwelling bring nutrient-rich deep water to the surface and, as a consequence, support dense phytoplankton blooms are also the locations of the world's most productive marine fisheries. For example, the small zone of upwelling off the coast of Peru, an area no larger than about 800 x 30 miles, produces annually nearly 20 percent by weight of all the fish caught in the world. Similar activities occur off the coasts of southwest Africa and the Arabian Sea. Despite their impressive yields of fish, these places have the undesirable attributes of eutrophication. At best, their waters are discolored and malodorous. At times, the systems become anoxic with accompanying mass mortalities of marine life.

Thus, in any consideration of pollution problems, the choice is not simply between "clean" and "dirty" water, but may also to a large extent involve the choice between high and low productivity of organisms, including those of direct use to man as food. There can be little question that the high yields of shellfish from such places as Chesapeake Bay, Long Island Sound, and other estuaries is due, at least in part, to the fertilization of these waters with human wastes (Ryther, 1971). The cleansing of these waters may therefore be accomplished at the expense of their fisheries.

2.2.2 Aquacultural Potential

If we assume that half of our nation's population lives close enough to the coasts that all their domestic sewage goes to the sea either directly or indirectly at a rate of 100 gal/person day, this results in about 3.6×10^{12} gallons of both treated and untreated sewage entering our coastal waters every year. The best way to gain some idea of the potential of this resource is to look at the total nitrogen contained in the sewage, since it has been shown to be the limiting nutrient in marine coastal waters (Ryther and Dunstan, 1971). If we assume an average concentration of 25 gm/m^3 in the sewage, this one m^3 is potentially capable of supporting the production of about 250 grams (dry weight) of algae or about 1.25 kg (wet weight)(Ryther et al., 1972). This amount of marine algae can support the production of about 125 grams (wet weight) of herbivores such as zooplankton clams, scallops, oysters, etc. Thus, the total resource could potentially stimulate the production of 1.7×10^{10} kg (wet weight) per year of algae, 1.7×10^{9} kg (wet weight)/year of herbivores, such as many shellfish, or 1.7×10^8 kg/year of carnivores, such as many kinds of fish. Since the total U.S. supply of fishery products, including U.S. fisheries and imports and both industrial uses and that going for human consumption, averages about 6×10^9 kg/year (U.S. Department of Commerce, 1971), the nutrient content of domestic sewage represents a sizable potential resource. In addition to the sewage from humans, there are the wastes from farm animals, mostly cattle, which produce wastes equivalent to two billion people (NIPCC, 1971). Some of these nutrients also undoubtedly wind up in our coastal waters at present, and must be contributing toward the productivity of the coastal fisheries. Much of the rest is probably used by marine organisms which are of no direct use to man.

2.2.3 Pioneering Projects

There is a considerable history of man's use of sewage to promote aquatic food production (Allen, 1970), and there have been many experiments along these lines (see Table 2.2). However, a relatively small percentage of the effort appears to have been directed at marine uses.

There are two different approaches currently being pursued in the United States for using secondarily-treated sewage in marine aquaculture. Both projects are supported in part by the Sea Grant Program. At California State University the emphasis is on raising salmon acquired from a hatchery to migrant size, at which time they are released to grow to maturity in the wild (Allen and O'Brien, 1967). These experiments are being continued in a new "pilot plant" facility attached to the oxidation pond

Table 2.2 AQUACULTURE EXPERIMENTS USING SEWAGE PRODUCTS

ORGANIZATION	LOCATION	SPECIES	REMARKS
Calif. State Univ.,Humbolt	Arcata, California	Chinook	Secondary Effluent and Seawater
Woods Hole Oceanographic Institution	Woods Hole, Massachusetts	wide variety	Secondary Effluent and Seawater
Six State and Federal Agencies	Santee, California	6 species	Secondary Effluent
Bavarian Biological Institute	Munich, Germany	Carp, Trout	Primary Effluent
Salmon, Unlimited	Illinois	Chinook, Rainbow	Primary Effluent
Michigan State University	East Lansing, Michigan	Catfish, Bluegill	Secondary Effluent
Trout Hatchery	Cottage Grove, Oregon	Goldfish, Trout	Food Pellets From Sewage Sludge

Common useage of Agricultural/Fishery processing wastes as food inputs in aquaculture.

of the City of Arcata Sewage Treatment Plant at Arcata, California (Allen, Conversano and Colwell, 1972). This process has several advantages. The sewage effluent effectively fertilizes the seawater supporting heavy algal growth upon which zooplankton feed which, in turn, are eaten by the young fish. Since the fish are not harvested directly, but only after an extended period in the sea, many of the potential health hazards, as well as any direct association with sewage, are nicely avoided. There is also no culturing cost involved with the fish during the extended time that they are at liberty. Since adult salmon will return to their source of origin, it is possible that this process could be economically viable, as well as provide an additional step in sewage treatment. This approach could operate for the benefit of either the existing commercial fisheries or for sportsmen, and as a tourist attraction. However, there can obviously be many problems in trying to control the distribution of benefits from a "crop" which is at liberty and may be accessible to a wide spectrum of people.

The second approach is being followed at the Woods Hole Oceanographic Institution under the direction of Dr. John H. Ryther. This program involves the use of a complete aquaculture system for the dual purpose of food production and a nutrient depleting tertiary sewage treatment process (Ryther et al., 1972). The program was stimulated by experiments in 1969 which compared secondarily-treated domestic sewage with prepared culture media, and determined that sewage is a very favorable fertilizer for the growth of marine phytoplankton, and does not exhibit any undesirable characteristics (Dunstan and Menzel, 1971). It is interesting to note that there is currently considerable national interest and research in a terrestrial equivalent, where treated sewage is used to promote agricultural crops (Kardos, 1970). The use of treated sewage to fertilize and promote the growth of microscopic plants at the base of the marine food chain can be exploited to give a wide variety of desirable outputs with only a small number of the possibilities having yet been explored. While most of the effort in this program has centered on a sewage-phytoplankton-shellfish food chain, a much more complex food web is involved (Figure 2.3). Research is being carried out with flounder, lobsters, abalone, shrimp, bait worms, and seaweed to evaluate their utility in such systems. While a lot of work remains to be done, from experience to date it is clear that such systems can be made to work and produce rapid growth and high survival of the culture organisms (Dunstan and Tenore, 1972; Tenore and Dunstan, 1973). Both indoor and outdoor research has been very promising (Ryther et al., 1973), and some of the early fears of heavy accumulations of pollutants appearing in the shellfish have not materialized. A new laboratory complex, which scales up the current systems by a factor of about 100 and will help to determine performance and optimal operating techniques for even larger units, is currently beginning operation (Huguenin and Ryther, 1974).

2.2.4 Major Problems in the Use of Domestic Sewage

2.2.4.1 Technical Problems

There are obviously many other factors to be considered before the nutrient potential of sewage can be translated into

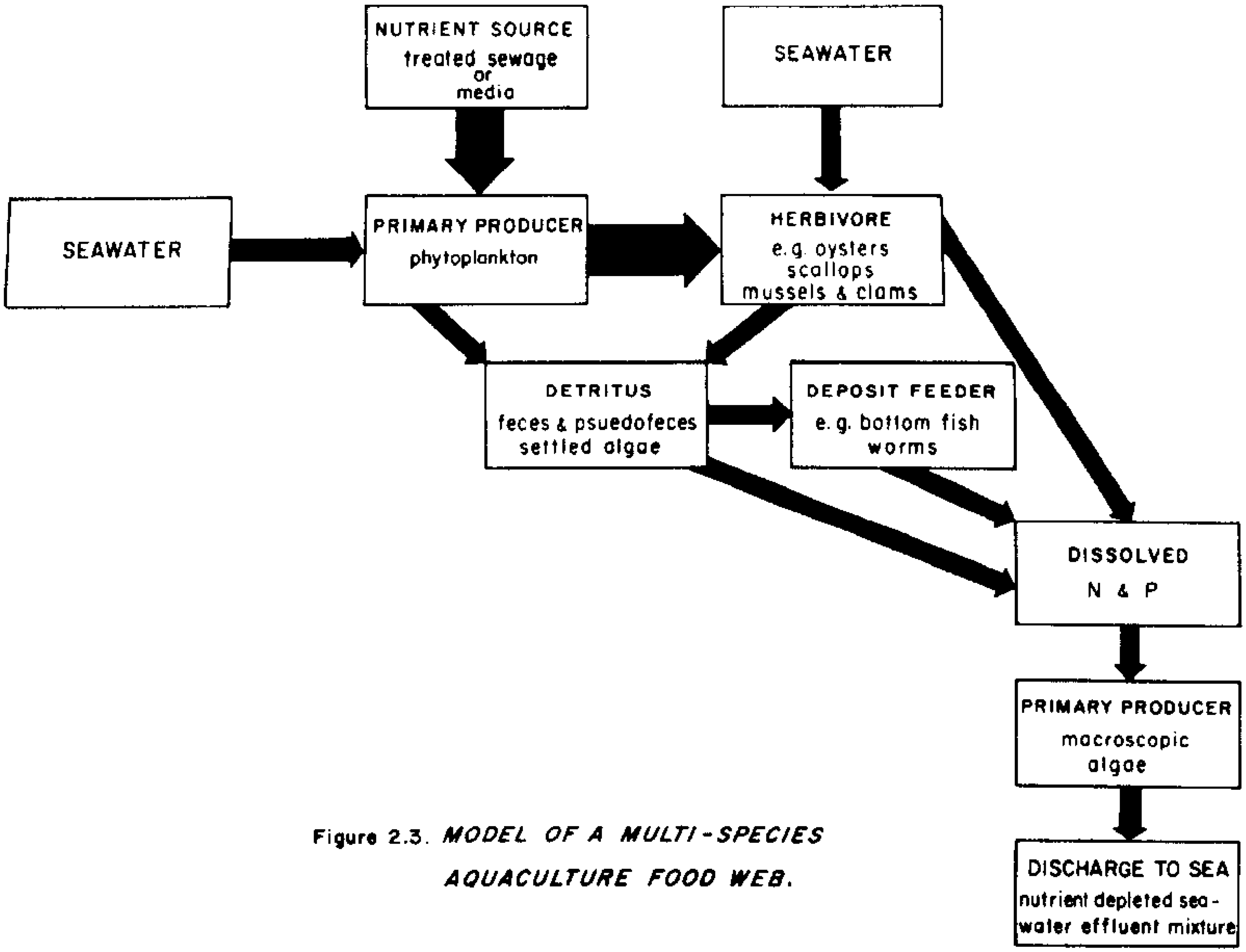


Figure 2.3. *MODEL OF A MULTI-SPECIES AQUACULTURE FOOD WEB.*

seafood production. Since sewage is basically fresh water, it must be diluted with seawater to provide a proper environment for the growth of marine organisms. For a large-scale application, this implies a high-capacity seawater system which can be costly unless the seawater can be provided by tidal pumping. Depending on the individual circumstances, there can be other factors that limit productivity, including inadequate light for photosynthesis due to cloud cover and/or northern latitudes, water temperatures that are too low, and some specific nutrient, mineral or vitamin, that is in short supply. There are also a whole host of water property changes and additives that can be very harmful and which require continuous attention. Many of these factors, including the sewage supply itself, are not consistent in their properties, but often exhibit relatively predictable cyclic variations. The actual waste properties are not well defined, and there exist both diurnal and seasonal patterns which can be critical and limiting.

2.2.4.2 Public Health Hazards from Sewage Use

The most serious drawbacks to the development of sewage waste-food recycling systems are public health hazards. This is clearly the area requiring the greatest amount of immediate research in order to clear the way for a large-scale industry to develop.

Bacteria. As mentioned among problems of thermal effluent systems, the organism *Vibrio parahemolyticus* has historically posed a serious problem to aquaculture systems (see Appendix A). Acceptable levels for this organism in shellfish or estuarine waters have not been established in the United States, but it has been the reported source of one outbreak of food poisoning already. It is a type of hazard which represents a great many unknowns.

The salmonella and shigella are the most important bacterial pathogens in any proposed mariculture system. Contamination of seawater by sewage organisms and their die-away ratios in a number of geographical locations are given by Orlob (1956). Greenberg (1956), in a review of the literature on survival of enteric organisms in seawater, concluded that they can create a significant health hazard in bays, estuaries, and on beaches. Berger et al. (1963) cite a number of cases of enteric disease including ten cases of typhoid fever.

Viruses. Standard water bioanalysis relies primarily on the presence or absence of certain sewage bacteria, notably *Escherichia coli*. The absence of viable bacteria is frequently taken to mean that the water is not contaminated with sewage. However, this may or may not be true. Therefore, water may contain sewage that is not detected. This could be of considerable concern because enteric viruses, such as polio virus and hepatitis virus, may be present in sewage or inadequately treated water. There have been many studies (Merrel et al., 1967; Ramas, 1970) on the isolation and frequency of recovery of enteric viruses from treatment plant effluent as well as raw sewage. Clark et al. (1962) estimated that the average enteric virus concentration in raw sewage is approximately 5×10^3 PFU (plaque-forming unit) per liter. The ratio of enteric virus to coliforms in human feces was said to be 15 virus particles for every million coliform organisms. Shuval et al. (1970) reported that enteroviruses were detected frequently in seawater samples collected at some distance from a sewage outfall. The average virus concentration of raw sewage was approximately 660 PFU per liter.

One of the major problems with regard to adequate quality control in mariculture is related principally to the unavailability of reliable and standard methods to concentrate, detect, and isolate low numbers of virus from very large volumes of water. Viruses do not replicate outside of living cells; therefore, the amount of virus of human and animal origin in water supplies is never likely to be large. Furthermore, many studies indicate that viruses may survive undetected under conditions eliminating coliform organisms (Metcalf et al., 1970; Metcalf et al., 1972; Berg, 1969). Infectious hepatitis is basically an enteric infection due to an unusually hardy virus transmitted via the intestinal-oral route, either directly by close personal contact, or indirectly by contamination of food or water. It presents special problems to the mariculture system for there is still no reliable method for detection or cultivation of the agent outside of its natural human host. (See Appendix B for a discussion of the hepatitis problem.)

Factors influencing virus survival in shellfish or sewage are shown in Figure 2.4. The presence of low numbers of virus in water is important if small numbers are capable of producing infection and disease. There is evidence that in cell cultures one virus can produce infection. However, this is unlikely in the complex animal host where such factors as acquired resistance have a definite effect. Little is known concerning the

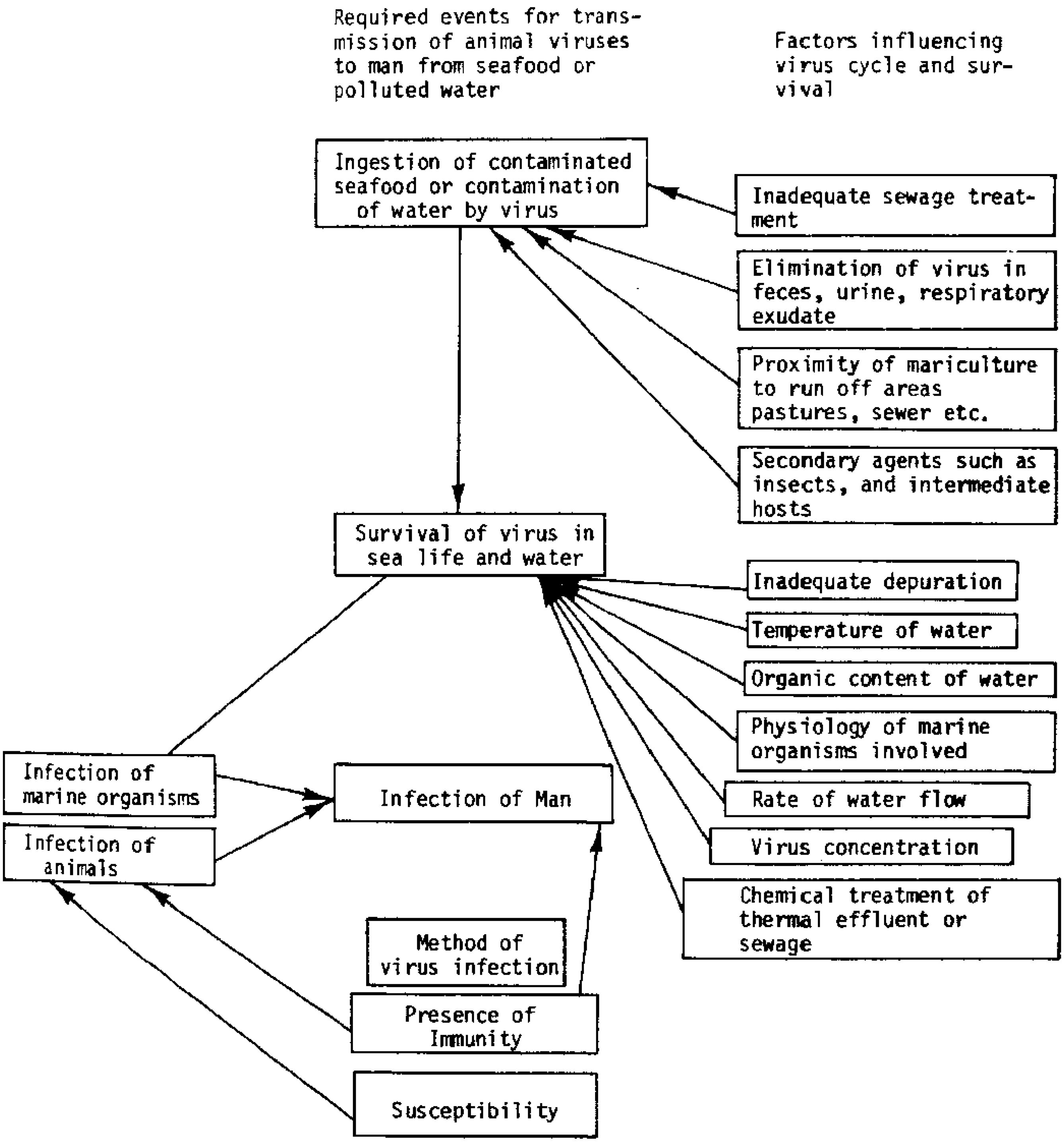


Figure 2.4 Factors effecting virus survival in marine organisms and water

minimal infective dose of viruses administered orally to man. There is a need for data which contribute to our knowledge of the effect of dosage on response.

Organic Chemicals. The organic chemicals can be divided into several major categories. The ones of concern to us are compounds whose abundant use makes them available as a potential contaminant. Three categories that meet this criterion are the hydrocarbons and their derivatives, the organic pesticides, and the halogenated hydrocarbons. These are characterized by relatively long half-lives in the environment, extensive use, and their potential harm to an aquaculture system or to the consumer.

The data voids are numerous in this area. Harmful levels for pesticides, PCBs and hydrocarbons are unknown for many species of fish and shellfish. The reactions to sublethal levels are an important parameter in the operation of an aquaculture system, and need much more study. Of particular importance are the synergistic effects, how the presence of one pollutant may adversely sensitize an organism to another stress. The flushing rates for various marine organisms are also needed--the rates at which they can dispose of or depurate a toxicant. This is a particularly important parameter in the case of substances that undergo bioconcentration. In general, the reactions, the pathways, and the residence times are unknown.

In addition to the direct effects of the marine organism, more information is needed on the human health hazards from ingestion of these organic chemicals at low levels. Although many guidelines have been established, the actual tolerance levels on the synergistic effects on man are largely undetermined.

Carcinogens. The carcinogen problem can be addressed in the context of organic chemicals, although many other classes of compounds have been shown to be carcinogenic (i.e., radionuclides and inorganics). The problem is not yet well understood. It is too broad, and the mechanisms are too complex to be defined with our present knowledge. The wide variety of compounds in the class make it difficult to know what to monitor. Shuval and Gruener (1973) give some indications of the more likely carcinogens to be found in waste water. The Delaney Clause* sets a zero tolerance level in food items for any addition of compounds that are shown to be carcinogenic, so the necessity for monitoring would seem to be indicated.

Aside from the direct sources of carcinogenic contamination that are possible in a marine-waste-food recycle system, there are other indirect sources that need examination. It has been shown that nitrosamines can be produced *in vivo* in the mammalian stomach under suitable conditions. With nitrogen compounds and amines made available through sewage, the possibility of nitrosamine and other carcinogen production within the aquaculture system should be studied.

It is not likely, however, that this would be a primary parameter in decisions concerning the marine-waste-food recycle system. The carcinogens are not a problem peculiar to this type of food production, with the possible exception being radionuclide contamination in systems using heated water from nuclear power plants. Many foods, such as bacon, sausages and hot dogs, are known to contain or produce nitrosamines upon cooking. With

*See pp. 84ff.

so little understood about them, monitoring for such a broad spectrum of compounds is out of the question at this time.

Some of the specific areas that need study are the presenc of known carcinogenic compounds in the marine-waste-food recycle system inputs, and comparison of the carcinogen levels in the crop in these systems with background levels in wild fish and shellfish. The accumulation rates and concentrating factors for carcinogenic compounds in fish are also generally unknown.

The hydrocarbons are generally regarded more as a nuisance than as a severe hazard to health. There are no guidelines set by the F.D.A., although areas have been closed to fishing becaus of gross oil contamination. Hydrocarbons characteristically give a foul smell and taste to fish. The components that cause this tainting, the low boiling fractions, are soon lost under clean water conditions. There is a possibility that the high boiling fractions, which are more persistent and not as readily detected, are carcinogenic.

The chlorinated pesticides are of the most concern among the pesticides. The herbicides and organophosphate pesticides are generally too short-lived to be transmitted through an aqua-culture system although, if present in high concentration, they may present a hazard to the health and success of the crop. The chlorinated pesticides (primarily DDT and its metabolites, plus endrin and dieldrin), as well as the halogenated hydrocarbons, are highly lipid-soluble and of limited solubility in water. This gives them a high partition coefficient into fats and oils in aquatic organisms. In a study of the Hudson River (Knelp, Howels and Wrenn, 1972), concentration factors for DDT metabolites and dieldrin in bivalves were found to be between 1,500 and 5,000, and in fish to be between 15,000 and 50,000. Butler (1967) found that clams and oysters can concentrate pesticides by as much as 70,000 times. Polychlorinated biphenyls (PC) are concentrated as much as 48,000 times in oysters (Vreeland, Morrill and Sheran, 1973).

In general, there is no known human health hazard for intake of residue or background quantities (less than 10 ppm) of these organic chemicals in food. But the high concentrating abilities of fish and shellfish enable them to exceed these limits even when ambient levels are low. The FDA has set guidelines of 5.0 ppm for PCBs and DDT and its metabolites as the maximum for marketed food. The guideline for dieldrin is 0.3 ppm.

2.2.4.3 Monitoring Requirements

Monitoring requirements by public health and marketing considerations are for a once-per-crop check at harvest. The concern is only for any contamination that may exist in the finished product. The sensitivity range required is on the order of 0.1 ppm and must be able to differentiate between different subgroups (as in different types of pesticides).

The operator is again concerned with toxic levels of chemicals that will affect his crop, particularly in the spawning and early developmental stages of his crop when resistance is particularly low. Ideally, he would like an on-line rapid-return system to monitor for organics, but this does not appear feasible at present. The next choice is frequent checks of the water quality. Some species are quite sensitive to certain organic compounds, so the levels to be monitored are low. PCBs at 1 ppb are lethal to shrimp (Hammond, 1972). Less than 0.1 ppm of dieldrin or endrin severely limits oyster growth (Mason and Rowe, 1969).

Monitoring Methods and Systems

The organic compounds are particularly difficult to monitor as a class because of the great variety of compounds and the corresponding variety in the responses to different methods of testing. The normal procedure is to go through a screening process to identify groups of compounds before running specific tests. These are generally simpler, shorter procedures, but do require some fairly sophisticated equipment. Some of the more common are extinction coefficient for ultra-violet light, ultraviolet fluorescence, total organic carbon, pH, oxidation reduction potential, and CNH analysis (Gafford, 1972). For further analysis, the methods become specific for the different groups.

With a general increase in awareness of the potential danger of many organic chemicals and a corresponding improvement in the controls and limitations on their use, there should be a decrease in the environmental levels of these compounds. Analytical methods for some trace level organic chemicals are approaching complete automation, and the technology to convert to an aquaculture system seems near at hand.

Hydrocarbons

There are two common methods for determining trace amounts of hydrocarbons. The carbonaceous analysis is an automated version of the total organic carbon process. It is not specific for just hydrocarbons, but is a good method for determining all organic carbon. The second, much more specific for the hydrocarbons, is the hydrogen-flame ionization detector linked with a gas-liquid chromatograph. The chromatograph partitions the hydrocarbons into its constituents and the ionization detector electrically senses ions formed when hydrocarbons enter a hydrogen flame. The difficulty with the method is that for seawater analysis the sample needs to be extracted and concentrated prior to performing the analysis.

Pesticides

The monitoring of chlorinated pesticide is very similar to the hydrocarbons, with the exception that chlorine is the important element rather than carbon. Again, there are two very common methods. An analysis for organic chlorine is not specific for just the chlorinated pesticides; it will include the chlorinated herbicides and other compounds. This could possibly be a very useful parameter, however. The sample is burned and the gas is trapped in an aqueous medium. The chloride ions are then measured with a standard silver-silver chloride electrode. Preconcentration and extraction would be required.

The other method is a gas-liquid chromatograph equipped with an electron capture detector. This type of equipment is already highly automated with 5 percent accuracy over twenty days of continuous operation.

PCB (Halogenated Hydrocarbons)

The PCBs are generally measured with a gas-liquid chromograph with an electron capture detector. The extraction and concentration are the critical parts of the process. Two methods for doing this are liquid-liquid extraction and resin absorption (Harvey, 1972).

2.2.5 Metal Contamination. The term metals covers most of the elements. In the context of this paper it will include any inorganic compound that may present a threat to an aquaculture system. Some of the metals are found abundantly in nature, but many are found only in trace quantities. Some are highly toxic to living organisms in small quantities, while others are necessary for life functions, although scarce in nature. In an aquaculture system where the chances of contamination or depletion are high, many aspects of monitoring will have to be considered.

Of primary concern in the contamination of fish products are the health effects on the consumer. Of the inorganic compounds, the most toxic are generally the heavy metals. In a list of potential inorganic marine pollutants by Dyrssen, Patterson, Weichart (1972), the most serious offenders are likely to be mercury, lead, cadmium, and arsenic, with zinc, selenium, cyanide, the acids (H^+), and others of less significance following. The ones most likely to be of immediate concern to public health authorities are mercury, cadmium, lead, arsenic, and selenium. There are presently guidelines for mercury content in food, and many of the others are now being looked at by the Food and Drug Administration.

As an example of one datum point for metal content in sewage, Dr. Francois Morel of California Institute of Technology gave the following values for Los Angeles sewage at an M.I.T. Water Resources and Hydrodynamics Seminar (March 14, 1973):

Metal	Mg/l (ppm)
Fe (Iron)	4300
Zn (Zinc)	1200
Cr (Chromium)	460
Cu (Copper)	410
Pb (Lead)	150
Ni (Nickel)	220
Mn (Manganese)	72
Cd (Cadmium)	16
Ag (Silver)	11
Co (Cobalt)	5
Hg (Mercury)	2

These values are for sewage that is approximately 30% industrial. The different metals average anywhere between 50% and 99% solids, with the rest in solution.

Much research has been done on the acute effects of metal poisoning and on the more pronounced and more immediate chronic effects. What is not known are the effects of long-term low dosages of these metals as could be expected from continuous contamination of cultured food. It is suspected that some of the effects may be of such long term or so subtle as to be not obvious for years, or even generations. Mercury has been reported to have possibly genetic and teratogenic effects (Ramel and Skerving, 1970). Cadmium may have long-term carcinogenic effects (Friberg, 1971). Lead is known to cause brain damage, but the lower threshold has not been determined.

2.2.5.1 Metals Pollution

Human mercury poisoning by ingestion of contaminated fish is well known. The most notorious such epidemic was in the Minimata River region in Japan (Wallace, 1971). Fish and shellfish had acquired heavy burdens of organic mercury from water into which methyl mercury had been discharged by a plastics factory. Among the hundreds of persons poisoned, 41 died and 19 malformed infants were born of affected mothers. Water was found to contain from 1 to 10 ppb mercury. In the open ocean, typical values for mercury are 0.13 to 0.15 ppb in young surface waters and 0.3 ppb in ancient deep waters (Dyrssen et al., 1972).

In contrast to its general tendencies, mercury in the organic forms can be stable within animals. A living organism usually has the capability of discharging metallic and inorganic mercury for itself, but only at slow rates. Organic mercury is mobile enough in an animal to pass through any normal isolation and excretion mechanisms. The organic mercury compounds concentrate in blood cells rather than plasma, and also in various other body tissues, principally brain, liver, and kidney.

A general summary of public health concerns is presented in Table 2.3, followed by a summary of state-of-the-art monitoring technology (Table 2.4) and a list of monitoring requirements (Table 2.5).

<u>Cadmium</u> does not have the well-known recent history as a pollutant that mercury does, but it does present very real problems. Cadmium is closely related chemically to zinc and can replace zinc in biological systems. It is found with zinc in most natural sources. The two main mechanisms of cadmium poisoning are through inhalation of cadmium oxide fumes and dust, and through ingestion of contaminated food. The inhalation of cadmium is primarily an industrial problem. In the case of ingestion, the primary response is in the kidneys. In long-term, low-concentration exposures, as much as one-third of the body

Table 2.3 Public Health Concerns

	Possible treatment	System response	Sampling mode	Sensitivity required	Sampling frequency	Degree of problem	Comments: Major unknowns and concerns
Inorganic chemicals (metals)	Depuration (slow) $T_{1/2}$ =months-year	Slow (weeks)	Product water/sewage	ppm ppb	1/harvest continuous (time average)	Minor	Bioconcentration
Organic chemicals HC PCB Pesticides	Depuration: (slow) $T_{1/2}$ = Weeks-years	Slow (weeks)	Product	ppm	1/harvest	Minor	Bioconcentration
Microorganisms Bacteria	Antibiotics Depuration: $T_{1/2}$ =days/weeks	Intermediate (days)	Water/sewage product	Coliform Index of ~2000/ 100 ml	Weekly	Major	Identify Coliform Unnatural stresses in aquaculture system that might be favorable to coliform growth and transmission
Virus	Depuration $T_{1/2}$ = 40-70 days (polio & ech.)	Very fast hours	Water/sewage product	Very sensitive 1 PFU/gal and/or good concentrator	Continuous (Time average)	Major	Identification of all problem virus. Need good general indicator virus.
Carcinogens	Unknown (Problem undefined)	Unknown (Problem undefined)	Product	Very sensitive (Presently zero tolerance by law)	1/Harvest	Possible Major. There is general lack of knowledge of the problem	Need Guidelines for tolerance limits. Need to study interactions of some water and fish with carcinogens.
Radionuclides	Depuration: (Will be <u>very</u> slow for some isotopes)	Generally slow Tritium?	Product		1/Harvest	Possible major for system operating with nuclear power plant.	Tritium

Table 2.4 Monitoring State-of-the-Art

	Speed	Sensitivity	Automation	Primary problems	Comments: Outlook for Solution
Inorganic chemicals (metals)	On line	ppb	Yes	Contamination	Good
Organic chemicals HC PCB Pesticides	Single sample Several hours	ppb	partial	Sample preparation expensive	On line gas chromatograph is foreseeable. Good for most of the organics for public health required monitoring
Microorganisms (bacteria)	~2 days for culture	Adequate	Partial	Speed of culture. Automation and data handling	Outlook is good for moderate speed increase
Virus	On line concentrator Several days for culture	Adequate with sufficient concentration	Partial	Speed of culture Need good indicator	Good in long run.
Carcinogens					Entire field still very much undefined. Specific carcinogens fall into one of other categories listed.
Radionuclides	On line	Adequate	Yes	Expensive	

Table 2.5 Aquacultural Monitoring Requirements

	Possible treatment	System response	Sampling mode	Sensitivity required	Sampling Frequency	Degree of problem to our health	Comments
Inorganic chemicals (metals)	Divert Inputs	Fast (Hours)	Water	Nominal	Continuous	Minor under normal conditions	Concern only for very high (lethal) doses
Organic chemicals HC PCB Pesticides	Divert inputs	Fast (Hours)	Water	Nominal	Continuous	Minor under normal conditions	"
Microorganisms Bacteria (Harmful to crop)	Isolation of diseased area	Days	Product	Crop condition is good indicator	Daily/ weekly	Small	High crop Densities complicate problem
Virus (Harmful to crop)	Isolation of diseased area	Days	Product	Crop condition is good indicator	Daily/ weekly	Negligible	"
Carcinogens	Operator is not generally concerned					Small ?	
Radionuclides	Operator is not generally concerned					Minor under normal circumstances	

burden can be concentrated in the kidneys. As the burden increases, kidney failure (renal tubular dysfunction) usually occurs. Other manifestations of more serious cases are anemia, liver dysfunction, and bone decalcification (osteomalacia).

A significant outbreak of severe cadmium poisoning occurred in Japan in the vicinity of the Jintsu River. The area is just downstream from a lead, zinc and cadmium mine. High concentrations of cadmium were found in the water, fish and rice. Clinical manifestations were pain from any pressure on the bone, bone deformation, and multiple fractures from trauma as mild as coughing. This form of cadmium poisoning became known as the "Itai-Itai" disease, which can be translated as the "Ouch-Ouch" disease (Friberg et al., 1971).

Chronic cadmium intoxication may result in kidney disease leading to renal failure. Long-term mutagenic, teratogenic and carcinogenic effects of low-level cadmium ingestion are not known for man. Much research is still needed in this area to define maximum safe levels of cadmium intake.

Lead is one of the most abundant and most used of the heavy metals. Through its use in motor fuels, paints, and in many industrial processes, it has the potential to contaminate almost any aspect of life on earth.

Lead within a human being acts primarily as an enzyme inhibitor. It affects the blood through a decrease in heme synthesis which leads to a decrease in the number, lifetime, and functionality of the red blood cells. The clinical picture includes anemia and stippled red blood cells. Other chronic effects of lead poisoning are kidney damage (chronic nephritis), brain and peripheral nerve damage. Although all of these effects generally begin at blood levels greater than 0.5 ppm (Ng/Gm), it is not known what the threshold might be for more subtle brain damage (i.e., learning deficits) and genetic or teratogenic effects.

Lead is not present in organic compounds in nature. In contrast to mercury, it does not move into biological systems as readily. Absorption through the intestinal tract is on the order of 10 percent. There is also a mechanism for excretion, so that the body burden does not dramatically increase with very small continuous exposure. Finally, the enzyme inhibition effect does seem to have a threshold, indicating that there is an enzyme reserve. This allows the body to accept some lead without producing any as-yet detectable symptoms. As was previously stated, more research is needed on more subtle or long-term effects (Chisolm, 1971).

2.2.5.2. Operator Monitoring Concerns

Aside from public health concerns, the next most important area of concern is the direct effect that contamination will have on the system. Possible effects range from massive crop kills to changes in the palatability of the product. Almost all of the inorganic compounds are toxic to the system in some degree if present in high enough concentrations. The ones of primary concern to a particular operator will depend on the presence of sources of contamination. A system downstream from a mining operation, a plating plant, or any chemical industry will need protection from the discharges of that industry. Although the biggest hazard would seem to be batches of contaminant that would cause crop kills, more subtle effects have just as profound an effect on the success of the crop. Copper in small concentrations, for example, can cause oysters to turn green. Aquamarine blotches develop on various parts of the oyster body, and its taste becomes bitter. Other chemical dumpings known to have produced serious effects on marine environments are cyanide, phosphorus, and arsenic (Dyrssen et al., 1972). The field, in general, is not well understood. Careful study is called for before starting an aquaculture operation in an area where potential polluters are present.

An additional monitoring concern of the operator is closely related to the primary reason for the magnitude of the public health problem. If the aquaculture system uses a closed-water cycle, there is the possibility of depletion of necessary trace elements. Certain elements that are vital in normal life processes are relatively scarce in nature. Biological organisms have developed the means to concentrate these elements against very strong concentration gradients. All elements are concentrated to some degree, with the exception of chlorine (which is rejected) and sodium (rejected weakly)(Pringle et al., 1968). It is because of this concentrating ability that marine animals require most elements in concentrations that fall within rather narrow limits. Copper, one of the most extreme cases, is necessary, and yet toxic to soft shell clams at concentrations greater than 20 ppb (Ng/Gm). Mercury, as described previously, is usually stable in organic systems, and hence will have a high concentration factor and a long retention time. Studies by Kerfoot (WHOI, personal communication) indicate that the half-life of cadmium in shellfish is greater than 200 days. The pickup of lead is linear with concentration and time of exposure (Pringle et al., 1968).

2.2.5.3. Monitoring Requirements

Public health monitoring requirements will be strongly dictated by future trends in governmental regulations of permissible levels for contaminants. If the trend follows its present path of leaning toward tighter and tighter limits, the prospects for sewage recycle systems look bleak.

Two approaches may be made toward public health monitoring: an analysis of the final product, or a continuous monitoring of the culturing environment. The ultimate concern is the quality of the final product, so testing in that area is assumed to be required. Monitoring of culturing conditions, on the other hand, is a way for the operator to assure that his product will pass final inspection by any regulatory agency, so it will also be considered under public health monitoring.

Mercury is the only metal presently having specified limits in foodstuffs. The limits in the United States are 0.5 ppm in food and 0.005 ppm in drinking water. In general, the monitoring requirements for product sampling are simplicity, speed, reproducibility, and a sensitivity in the 100 ppb range for biological samples. The process should be simple so as not to require a great deal of technical skill. Since the sample is optimally taken just before the product goes to market, speed of analysis is important to allow for regulatory action. Reproducibility is important because legal judgments may be based on the results. A sensitivity of 100 ppb covers present requirements with some allowance for future reductions in limits.

Although the trend in the last few decades has been toward tighter and tighter restrictions on permissible levels in all matters of contamination, it would seem that these will level off within an order of magnitude of the 100 ppb range. Below this, one is in the range of natural background levels for most substances. It seems illogical at this time that the limits for metals will ever be set to the "zero" tolerance level.

The operator's requirements are not as stringent as the public health requirements for accuracy, but are more so for speed and automation. The operator is primarily concerned with levels that pose an immediate threat to his crop. If detected upstream from his system in either the water or "waste" supply, he can divert the contaminant to a bypass system. The general requirements are continuous sampling, automation with feedback and signal capabilities, simplicity, reasonable cost, and reliability with a minimum of maintenance in a rugged environment. Sensitivity requirements are 50 ppb, but this is for water, which is much more easily handled than biological samples.

The aquaculturist needs a system that he can set and have run by itself. If levels surpass a predetermined threshold, the system has to actuate either an alarm or a servomechanism to direct flow. The equipment will be operating in or close to a salty, humid area with few accommodations for humidity or temperature control, so it will need to be rugged and inherently stable under a variety of conditions.

2.2.5.4. Available Systems

The methods and systems for metal analysis are many and varied. Those which appear applicable to the aquaculture system under consideration are as follows:

a) Dithizone Spectrophotometric (Colorimetric)

b) Atomic Absorption Analysis

c) Emission Spectroscopy

d) Neutron Activation Analysis

e) Anodic Stripping Voltammetry

The spectrophotometric methods use the characteristic energy bands of a molecular species to determine its presence. The absorption of specific wavelengths is measured. Metal ions are analyzed by first reacting them with one of various organic reagents. Most organic complexes have strong absorption bands, while most inorganic ions do not. Problems with this method may arise from interferences from other chemicals that may be present. They may prevent the complexing reaction from occurring, absorb the same wavelengths as the complex, or react with the complex to change its absorption characteristics. The chemical preparation in these cases requires a great deal of knowledge about the many possible reactions, and often simply a good deal of intuition (Maney, 1971).

Atomic absorption spectrophotometry (A.A.S.) is based on the same principle as molecular absorption spectrophotometry, but on an atomic rather than a molecular scale. Every element has its own discrete atomic energy levels, the collection of which is peculiar to that particular element. When an atom is struck by light of a particular wavelength (particular energy), it is excited if the energy of the light corresponds to the difference in two of its energy levels and the light is effectively absorbed. By measuring the wavelengths that are absorbed by a sample, the contents may be determined. The advantage of the A.A.S. is that it is rapid and cheap for routine analysis of specific metals, and still gives the sensitivity and accuracy required for trace element monitoring. It is also amenable to having the sample preparation automated. Its major disadvantage is that the instrument must be refitted with a new source, and readjusted for each different metal being analyzed.

Emission spectroscopy is closely related to A.A.S., but in this case the emitted light, rather than the absorbed light, is measured. The characteristic light spectra are much the same in either case. This method has been used for many trace metal analyses in water, but it is not sensitive enough to be used without prior concentration of the sample for many metals. Although it is not as sensitive as A.A.S., it is much faster and much more suited to large numbers of samples. One run for each sample suffices to determine many different compounds simultaneously (Grove, 1971).

Neutron activation analysis (N.A.A.) is one of the most sensitive and most accurate analyzing methods that are presently available. The general procedure involves irradiation of the sample with a neutron source, and the subsequent measurement of the radiation from the radioisotopes produced by the radiation. The method owes its accuracy and sensitivity to the large variations in cross section for neutrons of the various elements. Since the reactions are strictly nuclear in nature, atomic and molecular interactions have no effect on the results. Very little manipulation of the sample is required before irradiation, and anything done (or added) to the sample after irradiation will not affect the results since only the radioactive component is measured. This has the advantage of minimizing the chances of sample contamination. Neutron activation analysis does not measure relative amounts, but measures absolute quantities present in the sample. For metals such as mercury and cadmium, the limits of detection are 1-3 Ng (1-3 x 10^{-9} Gm). The problems associated with N.A.A. are cost and technical requirements. The best source for a high flux of neutrons is a reactor, which is not always readily available. The measuring equipment must be able to distinguish between various energy level gamma rays with high accuracy. The technical skill needed to run and interpret the tests is a very high cost item. An additional problem for use with salt water is the interference of some elements with the results. Sodium, for example, must be chemically removed before the measurements are made. In general, evaporation or crystallization is necessary for any wet samples.

Anodic stripping voltammetry (A.S.V.) is a form of polarography which measures metals in ionic form by means of their electric potentials. The metals are plated out of solution onto electrodes by controlled potential electrolysis. After plating, the metals are stripped off by reversing the polarity and sweeping the potential at a controlled rate. A plot of current versus voltage gives peaks at the voltages particular for each metal. A.S.V. technology has reached the level that the entire system is in a self-contained "black box." The system is easy to operate and requires a minimum of skill and training. Work is presently being done on automation with predictions of completion being on the order of two years (Wayne Matson, E.S.A., personal communication). The method is extremely fast, requiring a few minutes for a sample, and is sensitive to the sub-ppm range. Present systems use mercury or mercury-coated electrodes, so they are not effective in analyzing for mercury. New types of electrodes (gold film) have opened up the possibility of solving this problem.

These systems cover the aquaculture system needs fairly completely. The two most promising at this time are atomic absorption spectrophotometry and anodic stripping voltammetry. A.S.V. is currently a very active field. It appears to have the potential to be one of the simplest, most complete, and fastest methods of metal analysis available. A.A.S., on the other hand, is so well accepted at present that it may be considered to be the standard of the trade. The methods and equipment are readily available and are reliable. The major difficulty is with speed of analysis. Emission spectroscopy bypasses this problem, but, due to its relative lack of sensitivity, has lost popularity with the upsurgence of A.A.S. Neutron activation analysis is by far our most sensitive method of analysis, but is too slow and expensive for routine analysis.

2.2.6 Summary

As a rule, the aquaculturist is primarily concerned with the overall health of his crop. Unless there are direct threats of severe contamination by certain pollutants, he will probably only concern himself with monitoring the major physical parameters of the system. These are:

a) dissolved oxygen*

b) water temperature*

c) salinity

d) pH (alkalinity)

e) flow rates

f) biomass
   behavior (general health of crop)*

g) mortalities

h) weather*

These parameters can be used as indicators of anything that might be wrong with the system. Should anything go wrong, it would show on at least one of the above parameters. By carefully monitoring these, the operator can operate satisfactorily with the more sophisticated monitoring equipment on a standby or on-call basis.

Most of these physical parameters are closely interrelated, so all must be watched in order to determine the status of the system. Four of the most important are marked with an asterisk. Oxygen level and use depend on the temperature, the biomass, and especially on the weather, as well as on the activity of the crop. The weather plays a big role in analyzing many factors. The amount of sunlight greatly affects the oxygen levels when plant life is present.

One of the most critical parameters for the operator is determining the biomass (total crop weight) in the system. He needs this to determine the flow rates for maintenance of proper oxygen levels, to determine the feeding requirements, and to interpret the other parameters mentioned above. In systems such as those under consideration, it would be very possible to waste one's time feeding and caring for ponds and raceways unbeknowing that the crop has been depleted by disease or predators.

The danger of public health hazards in a sewage recycling aquaculture program is very real and is of foremost concern for further investigation. The Environmental Protection Agency's proposed rules for aquaculture projects (see Appendix C) reflect this concern. Guidelines for the application for a permit indicate the need to furnish detailed data on possible health effects on humans and aquatic life nearby, monitoring and control information, and bioconcentration data. Further demands will include information on how the aquaculture wastes will be disposed of and how the system would dispose of its cultured organisms in the case of their contamination and massive death.

A great deal of monitoring will have to be focused on the incoming sewage effluent as well as the culture itself and its discharge, as all of these parameters affect health concerns. It is reasonable to anticipate conservative interpretation and enforcement of regulations relating to these parameters, due to the climate of public opinion on these matters and the sensitivity of a sewage aquaculture system.

2.3 Advantages and Disadvantages of Both Thermal Effluent and Sewage Use

There is obviously some overlap in discussing comparative advantages and problems of thermal effluent use and sewage use in mariculture. It is important to highlight their differences in order to establish some basis for comparison and future decision-making. Several technical assets and problems are the same, however, and they are discussed as they pertain to both areas of endeavor.

2.3.1 Advantages of Management

Aquaculture, due to its management aspects and fixed site nature, possesses a distinct advantage in the degree of control that can be exercised over the quality of the products reaching the marketplace. These advantages stem from the aquaculturist's control over diets, culture conditions, possibly some of the environmental variables, and the capability to plan and schedule pre- and post-harvesting processing. In addition, the large scale of operations (compared to fishermen) enables relatively expensive monitoring and harvesting equipment to be used. The schedulable nature of the operations and the uniformity of the outputs will enable regulatory agencies to exercise a high degree of control over aquaculture systems as compared to fishermen. There is some threat of overregulation of aquaculture and under-control of fishery products from natural sources, and equal standards for the seafood itself from both sources may be the answer. The EPA proposed rules (Appendix C) do indicate an inclination to tolerate higher levels of "pollution" in the mari-culture environment. It is much more logical to state "accep-table" levels in terms of the marketed and consumed product than the water from which it came. Standards based on the end prod-ucts would leave the aquaculturist free to process his product, if it is feasible to do so, to bring it within "acceptable" limits. The depuration of shellfish to lower bacteria counts and the processing of animals to remove bones and organs, which concentrate specific materials, can very significantly reduce the levels of some pollutants. Transplanting the organisms from a power plant site, where rapid growth takes place, to an unpolluted site for a period of time before harvesting may, in some cases, achieve the same results. Processing the product is likely to be a much better approach than facing the even more difficult problems involved with processing the immense volumes of water needed in most forms of aquaculture. More work needs to be done not only in the technical areas to demonstrate repeatability, reliability, and practicality on a large scale, but also in the public health and public policy areas to assure the safety and acceptance of the products resulting from promising depuration approaches. The process of bioconcentration of pollutants is, as yet, poorly understood. For nuclear power plants, the accumulation of released low-level radioactive material may be a problem. Determining levels for each of these different pollutants, singly and in combination, which are safe for human consumption poses an extremely difficult dilemma. Yet, the possibility of managing an aquaculture environment is an excellent impetus to do the necessary research in this area.

2.3.2 Technical Problems

2.3.2.1 Water Requirements and Discharge Characteristics

Large flow rates are characteristic of aquaculture. If we consider the water requirements of Salmonids (salmon and trout) as being the standard (these fish are particularly sensitive to low water quality and quantity) for high-quality culturing, some interesting factors emerge (Liao, 1971). The carrying capacity of a gallon/min (GPM) flow rate is a function of fish size (varying by a factor of about 2-3) and, more important, water temperature (factor of about 10). A good number is about 10 pounds of fish per GPM, and is typical of limiting capacity at harvesting (while smaller animals need relatively more water, the total crop weight is significantly reduced; thus the constraint on the system is probably at harvesting) under ideal conditions. Using this number and considering the growing periods of many months to years required for the growth of most aquatic animals of interest, it is obvious the water used per pound of output is astronomical. This number may go as high as 100 tons of water per pound of output, completely dwarfing any industrial water uses.

The next question is obviously why the requirement for such high water flows. The flow does several things. It removes metabolic wastes; it provides dissolved oxygen; and it distributes food. Of these, the supply of oxygen is often the most limiting. The dissolved oxygen (DO) level must be high for health (input water is usually at saturation level), and can thus not be allowed to drop too much. Animals, plants (at night and on cloudy days), and decaying organic matter all require a great deal of DO. The exact respiration rates are a function of many variables, but probably most important is the water temperature. Plants, in particular, are troublesome since they present a highly variable and uncontrolled factor in the system producing DO during photosynthesis, and withdrawing it at other times. The DO can be increased artificially by aeration and by allowing the water to fall over spillways. This is usually done to some degree to decrease the water requirements. However, it is in general not practical, for economic reasons, in large cultures to continually provide most of the required oxygen, due to the quantities of water involved.

There are other system outputs in the water besides lowered DO levels. Dissolved metabolic wastes, if allowed to build up, can restrict growth in the system or create severe problems downstream. This is already a problem with fish hatcheries (Liao, 1970A; Henshaw, 1973). Generally, conventional waste-water treatment methods are applicable for hatchery waste control, although several times more expensive (Liao, 1970B). At lower levels, the wastes may promote plant growth (possibly undesirable growth). These wastes, in addition, use up DO. The water may also contain very low levels of specific secretions from the system's plants and/or animals which can significantly influence downstream organisms. As yet, there is little known about many of these phenomena. If the culture is very intensive, it is possible that the water effluent might have a small but noticeable smell. While this source of odor is by no means the worst source of odors in an overall aquaculture system, it may be very difficult to do anything about it. Another possible output in the water is increased turbidity due to suspended solids. This increase may be due to increased water velocity in the system, actions of animals, feed and feeding practices or cleaning, and maintenance operations. These suspended solids may settle out downstream and create some very unpleasant problems, both ecological and political. Another undesirable output carried by the water might be predators, parasites, and diseases that possibly breed and grow within the aquaculture system. If these organisms attack the "crop," they will obviously become evident and countermeasures will be taken, but what if these undesirables do not harm the crop directly, but are only harmful to downstream species, or even to man himself? Such a situation may not be obvious, and as such may go on for a long time without discovery.

If the water going into an aquaculture system already has some undesirable properties such as thermal effluents from a power plant, being processed through the system could increase the thermal waste problem. The addition of wastes and reduced DO may do more damage downstream due to a combination of stresses than would have resulted from the increased temperature alone. The problems thus may just have been increased and moved downstream. However, many power plants are now being required to provide a water-holding capacity (time) sufficient to reduce the temperature of their effluents, and this storage capacity would be equally valuable in allowing time for much of the settlable solids in the aquaculture effluents to settle out before discharge. However, some "pollutants" in the input water, such as the dissolved wastes of animals or people, could be beneficially removed by carefully designed aquaculture systems (Ryther et al., 1972).

It is important to realize that even an aquaculture system which is designed as a pollution control method with effluent properties in mind will alter the properties of water going through it, and at least some of these changes could be considered to be unbeneficial. The problems of discharge characteristics are growing rapidly in importance due to recent legislation which requires discharge permits for aquaculture operators (Cully, 1973). It is possible that stiff new requirements could easily be beyond the current state-of-the-art, and not only preclude the development of effluent-dependent aquaculture, but bankrupt already existing operations.

Another effluent problem which has arisen, but not yet in regard to aquaculture per se, is that of supersaturated levels of gases dissolved in the water. Nitrogen is the gas most commonly mentioned as causing problems, but there could be others. If saturated water is pressurized (as in a pump or falling over a spillway) in the presence of air, the level of dissolved gases may increase to approach the "new" but transient saturation level On removal of the pressure, the fluid is supersaturated. Another way to achieve supersaturation is to heat saturated water since saturation levels are temperature-dependent with greater solubility at lower temperatures. This might logically be a problem with power plant thermal effluents which are often supersaturated, and in one set of experiments it was suspected of being a critical factor (Marcello and Strawn, 1972). It has also been implicated as a basic cause of several fish kills at power plants. In both the pressure and thermally-induced cases, the supersaturated fluid will seek a new equilibrium, but this process is not instantaneous. If aquatic animals pass this supersaturated water through their gills, the levels in their blood may also become supersaturated. When this excess dissolved gas does return to a gaseous form, it may kill the animals. This is very analogous to the "bends" in divers.

2.3.2.2 Solid Wastes

A big aquaculture operation will probably have a large quantity of animals under culture at any particular time. These large quantities of animals generate huge problems. Animal solid wastes are already a national problem whose magnitude is not generally appreciated. The waste problem in an aquatic environment can only be worse (Liao, 1970). While aquatic organisms can under some circumstances consume more than their body weight in food per day, a better number would be in the order of 5-10 percent of body weight in wet food weight (or equivalent) per day. The over 600 State and Federal fish culture stations in the United States utilize yearly over 41 million pounds of fish food, with almost 23 million pounds being agricultural and fishery wastes, such as offal, meats, fish, and other organic materials, and the remaining 18 million pounds being commercially-prepared pellets or other dry feeds (Hinshaw, 1973). If something like 30 percent of the total feed weight becomes solid waste, a large culture over a period of time can accumulate a formidable amount of debris. While this settled organic waste can be handled in a more or less conventional manner, the ultimate disposal of the quantities involved will probably have some on-site processing of the aquacultural output. This processing will also generate a very large amount of solid wastes which may or may not be utilized.

2.3.2.3 <u>Physical Environmental Alterations</u>

The best sites for marine aquaculture are the marginal lands around coastal marshes, and around estuaries, bays, etc. These sites involve not only land that is being competed for by many other interests, but also almost inevitably would involve some degree of heavy construction at the land-sea interface.

Construction in or near the land-sea interface involves many complex legal aspects for which considerable precedents and information exist. It is probably best here to examine the physical changes which can lead to litigation. Construction such as piers, groins, bulkheads, breakwaters, diking, etc., can often change the local water circulation patterns and water quality parameters in an area. Since the amount of suspended solids a flow of water can carry is dependent on velocity, slowing the flow in an area may result in the deposition of sediment on the bottom, and a speeding-up may result in erosion and the carrying-away of solids. These changes not only change shoreline shapes, but also can significantly alter the biological resources of an area by killing feeding, spawning and breeding areas and shellfish beds through sedimentation or erosion. There are two major characteristics of these changes. One is that the effects of any specific construction project are very hard to predict with any confidence, and the other is that any type of remedial action after the effects are known are generally extremely expensive.

Another area of major physical change due to this type of construction is the possibility of altering the local flow of fresh water into a marine area. Ill effects can result from both the loss of water volume as well as the resulting salinity change. Since many types of important marine organisms breed or spawn in coastal marshes where the proper salinity is an important variable, this aspect is particularly likely to raise opposition. Perhaps the use of sewage, which is fresh water, could be used in certain cases not only to increase aquaculture output, but also specific downstream natural outputs.

There are many ways to achieve major disasters in aquacultural operations resulting from various failures of a mechanical nature or natural phenomena. The possible impact on contiguous ecosystems is quite great, which poses one other restraint on the economics and scale of an aquaculture system.

Table 2.6 <u>Sources of Disasters in Marine Aquaculture</u>

Dissolved Oxygen Depletion

Physical Storm Damage

Fresh Water Inflow

Diseases and Parasites

Mechanical Failures

Predators

Lack of Status Information

Upstream Inputs

A potential solution to some of the thermal water pollution problems is to adopt a closed form of aquaculture. With this approach the water used is processed after use and recycled, rather than being discharged, and heat can be transferred into the system through a heat exchanger. The inflow and outflow water volumes can thus be reduced by more than 90 percent. At least one fresh-water salmon hatchery has been built using this basic approach, with encouraging results (Burrows and Combs, 1968). Unfortunately, reuse systems are very expensive and have a host of disadvantages. In such systems, diseases are more readily transmitted; the aquatic chemistry must be very carefully monitored for buildups and depletion of various substances; feed and feeding practices become more critical; most therapeutic drugs cannot be used; the animal loading can only be changed slowly; and relating causes to effects becomes very difficult due to the many interacting factors operating. Thus, for reliable use in practical commercial operations, recycled water systems would require a great deal of ecological information and technological capability, much of which does not yet exist. At least for the near future, more conventional flow-through systems for raising animals to market size are technically more feasible, economical, and practical.

2.3.2.4 Use of Chemicals

A wide variety of chemicals are commonly used in aquaculture today (see Table 2.7)(Lennon, 1971). It is extremely unlikely that any viable aquaculture industry can develop without being dependent on the use of at least some chemicals, although their current use in small systems is still illegal. This is easily believable if one examines some of the mass culture methods currently being used in animal husbandry. The reasons that so many chemicals are used routinely and illegally in aquaculture are many. To date, successful aquaculturists have generally been well integrated with their rural power structure, usually conducted their business completely on private land, and operated semi-secretly on such a small scale that it has not yet become a focus for opposition; but the potential exists.

One problem that exists is that many of these chemicals may still have effects downstream, far removed in both time and distance from the original application. It doesn't require much imagination to conceive of the possible downstream consequences on a balanced and complex natural system from the introduction of antibiotics, fungicides, algaecides, and other killing agents. Very little is currently known about possible long-term effects,

Table 2.7

Chemicals Registered and Used*

Purpose	In use in 1967	Registered as of 1971
Fish anesthetics	7	0
Fish toxicants Rotenone and antimycin	8	2
Fish marking dyes Oxytetracycline for use in migrant salmon	3	1
Fish transport aids	7	0
External therapeutants	16	0
Internal therapeutants Dulfamerazine and terramycin	18	2
Controls for invertebrate and vertebrate pests	13	0
Herbicides Acrolein, ammonium sulfamate, copper sulfate, dichlobenil, dichlone, 2,4-D, 2,4-DP, diquat dibromide, diuron, endothal, monuron, petroleum solvents, silvex xylene, monosodium acid methane arsonate	23	15[1]

[1] The labels on the herbicides are restricted and good only until December 31, 1971. Many cannot be used in the presence of food and game fish.

* Lennon, 1971

and they are almost inevitably embroiled in scientific disagreement and uncertainty. The current controversies over the long-term effects of DDTs, PCB, and other chlorinated hydrocarbons are relevant since these substances are closely associated with many of the chemicals in question. The problems are greatly increased by the use of these chemicals in an aquatic rather than terrestrial application since water is so pervasive and such a good carrier. Warnings have already been made about the dangers inherent in current aquacultural practices (Hubbs, 1970; McLarney, 1970).

Another aspect of aquacultural use of chemicals is that there are currently no incentives for doing needed research. Many of the chemicals can be legally used in terrestrial application, and are thus variable. Since the aquacultural use of these chemicals is in insignificant quantities, the chemical companies have no incentive to carry out the research and development required to obtain approval for use in aquaculture. Even if individual aquaculture operations were to become quite large, it is doubtful that it would be rational for any aquaculturists to financially support a drug clearance program independently. In any case, the procedures for registration are very involved, time-consuming and expensive (Lennon, 1967; Meyer, 1973). In addition, chemicals must be cleared and registered for specific uses with specific species under precisely-defined circumstances by notice of the FDA Bureau of Veterinary Medicine (Lennon, 1967). This means that, if a drug is cleared for use with a specific species of trout, it cannot legally be used on another closely-related species, or even the same species for a different use, or under different conditions (fresh water to seawater). Each combination must be cleared through a separate test program.

The testing of promising drugs for use in aquaculture might be a good area for government funding and a means to promote and indirectly subsidize aquaculture. If aquaculture is to emulate the success of modern agriculture, it is reasonable to assume that favorable government actions are necessary. The development of agriculture has been heavily subsidized, both directly and indirectly, through such things as the Land Grant Act of 1862, the formation of the Department of Agriculture, and the existence of favorable tax and other statutes in nearly every state.

2.3.2.5 Nonindigenous Species

Using plants and animals to perform functions in aquaculture systems, generally done with chemicals, and the constraints imposed by market factors and available sites may require importing nonindigenous species. Transporting aquatic animals usually means also transporting some water which, along with the animals, contains diseases, parasites, competitors, predators, and hitchhikers (Lachner et al., 1970). Even transporting animals within the region of their natural distribution and over comparatively short distances can spread "undesirables" into regions where they are not presently. The problems of spreading trout diseases from one operation to another falls in this category (Hoffman, 1970). These nonintentional transplants can be reduced by the use of chemicals, but can usually not be completely eliminated. Even large animals, for a variety of reasons, very commonly often escape. Some of these releases may survive in the new environments, sometimes at the expense of indigenous species.

The problem of transplants, both planned and unintentional, is currently a hot controversy in fishery and aquaculture circles, and it appears as a matter of concern in the EPA proposed rules for aquaculture (see Appendix C). The issue may be especially severe for aquaculture which uses thermal effluents. Since the most interesting animals for such culture are those of commercial value which are at their northern distributional limits at the plant site, breeding or stocking animals may have to be brought in. In addition, the site may be well beyond the natural range of many of the organisms inadvertently also brought in. Unfortunately, a thermal aquaculture operation may enable these other organisms to "winter over" and, possibly more dangerous, slowly adapt to a colder climate. Thus, thermal aquaculture may well be an ideal environment for helping transplants, both planned and unintentional, to get established in a new area.

2.3.2.6 Protection from Predation and Vandalism

Predators can come from land, sea or air. Land and sea predators can often be discouraged by the use of screens, fences, traps, and other physical means. Chemicals also are used, but often have serious problems and limitations. This is not to imply that all land and sea predator problems have been solved; they have not. However, the solutions are unlikely to produce any large-scale visible effects.

Stopping predacious birds may be a problem. The control methods against birds may be rather obvious, and capable of generating opposition. Wading birds can be countered by steep embankments and water too deep for them to wade. This may work on a large scale if the depth can be achieved. Floating birds have been countered by vertical obstructions sufficiently close together to prohibit the birds the necessary flying room for getting in and out. This works for small cultures, but will probably be prohibitive for large ones. Other possible methods include broadcasting animal noises, poisons and guns. Obviously, any or all of these methods might generate opposition and, even if they don't, restricting birds from large areas where they previously roamed may be opposed with arguments based on aesthetics or conservation.

Further trouble can be anticipated from man himself; considerable effort and expense can go into the prevention of poaching. Also, policies need to be established around the questions of public access and recreational use.

2.4 Conclusion

Much of the research which is needed to develop a full-scale aquaculture industry utilizing wastes involved scaling up known data obtained in small pilot plant operations. Clearly, neither the economics nor the operations can be simply scaled up, and additional research will have to deal with the problem of scale.

Due to the increased scrutiny of food contents by consumers and regulatory agencies, the greatest concentration of research will have to be in the area of public health factors. Increasingly sophisticated agencies and consumers are going to force technology to demonstrate safety and will not tolerate high levels of uncertainty.

Chapter 3. Social, Legal, Political and Economic Factors in Marine Waste-Food Recycling Systems

3.1 Economic Planning

The mechanics of introducing a waste-produced food into the American market could be quite complicated, and it behooves the potential aquaculturist to attack the problem with sophisticated assessments of the true social costs and benefits of the system. (See Appendix D for a proposed economic model.)

An accurate estimation of true aggregate consumption costs and benefits will have to consider a multitude of factors. An account must be made of possible effects on externalities, e.g., costs and benefits to neighboring bodies of water and their uses. Regional needs are affected, e.g., incomes of present fishermen, related industries, possible effects of a system disaster, whose health is potentially affected, and the overall economics of the region. At the same time, the overall effects on national income must be assessed, including effects on balance of payments, other food sources, etc.

An extremely important economic parameter to consider is the relationship between the aquaculture industry and the source of the waste (i.e., power plant, sewage system, etc.). It is crucial to plan out economic choices and define the interrelationships due to the inevitability of having to make decisions to the advantage of the one over the other. During the summer heat peak, will the mariculture system shut down if it cannot accept the temperature, or will it be more economically practical to divert the thermal waste? At whose cost? Is there a sharing of costs involved in disposing of unused thermal waste? If there are other beneficial uses for the available wastes, this becomes another cost factor.

There will be considerable need to plan out these interrelationships; laws will no doubt evolve affecting them; and the success of the system will depend on them. Current accounting systems for most power companies will lack the sophisticated techniques to do accurate cost/benefit estimations which probably will leave the aquaculturists to introduce the management concepts.

3.2 The Participants

In the examination of the sociopolitical system involved in the implementation of an aquaculture system, it is necessary to look closely at who will be directly and indirectly affected by its introduction. How will the recipients of costs and benefits react? Logically, it can be expected that those receiving the benefits will not oppose the system and its products, although they might not necessarily support it overtly unless their gains are clearly identifiable and evoke a sense of need for the product. It is critical to examine who will stand to lose and how they might go about opposing its introduction.

The beneficiaries of this approach to aquaculture can be identified both on the producing and receiving side. On the producing side, the owners and operators of the system will benefit for obvious reasons. The manufacturers and designers of new equipment should benefit from new business, including their employees. In order for the system to be effectively operated, it must have an efficient system of monitoring to guarantee the product quality and related to risks. If looked at broadly enough, this system could be an impetus for developments in technology that could ultimately benefit the entire society in other areas where the same monitoring requirements are becoming increasingly necessary. Other beneficiaries of this system depend upon the business arrangements which are ultimately worked out to provide the necessary treated sewage and/or thermal effluents. Cities and power companies might make some added dollars by selling or leasing their waste products for this enterprise.

On the receiving side, the consumer will surely benefit from the added supply of seafood to the market. Whether the product is sold as a premium product or not, if it is safe to eat, it will mean greater amounts of fish on the market and probably lower prices as a result. They might also be exported and contribute to the U.S. balance of trade situation in a very positive way, while also helping to increase the protein production for the world. If the new systems allow the export of seafood products which have little value in the United States to other parts of the world, this too would benefit society.

Depending on the size of the market and what it will allow, and the cleverness of advertising, the general fisherman could easily be hurt by an aquaculture enterprise. If an aquaculture enterprise floods the market with too many of a certain species of fish, it may depress the price so much that no one can make enough money. The aquaculturist also has some strong advantages which could prove critical in the competition at the marketplace. The relatively higher levels of organization and mechanization could drive the traditional fisherman out, unless he is somehow incorporated into the new industry.

A second kind of opposition might come at the production level. There are many fishery and conservation laws which may or may not be applied to aquaculture. For example, minimum size limits placed on fish to assure against depletion of natural stocks do not make sense when applied to an aquaculturist who controls the reproductive and growth cycles of his own "flock." Exempting him from size limits might make enforcement of these laws difficult in the marketplace, i.e., how can a game warden determine whether an undersized oyster was raised in a commercial bed or caught in the wild? Any attempt to change the laws will surely generate opposition from the entrenched special interest group. Other similar laws regarding the water and other ingredients for such an enterprise must be changed and indications are that they will attempt to accommodate aquaculture needs. (See EPA Proposed Regulations, Appendix C.)

A third kind of opposition comes early in the preproduction stage during attempts to find a favorable site. Finding a large enough site with favorable physical conditions for aquaculture is very difficult, with most of the zoning for the coastal zone still in the hands of the local authorities. Convincing the local townspeople to use some of their valuable coastal area for aquaculture enterprises is not easy. If the aquaculture operation is being planned by "outsiders," it is doubly difficult. Here, the opposition is not from those directly affected by the activity, but those secondarily affected, either those who had other uses in mind for the same site, or those who fear possible smell or other detrimental aspects of the enterprise.

On the other hand, a clever operator of an aquaculture enterprise might try to turn the siting in a particular area into a plus for the community by assuring that some advantages accrue to the area, such as added income through taxes, employment, or in other ways. However, if local interests do not have a sense of involvement and a degree of control, the prospects for approval are bleak.

Another kind of opposition might come from consumer groups which, for one reason or another, don't want the product sold on the general market. There are a number of possibilities here. For example, there are always people who are opposed to any new product. Particularly if it is not possible to provide a 100 percent guarantee on all questions with resulting zero risk, these groups will insist that these products be conclusively proved safe before introduction. Groups such as these may serve a useful function if they can maintain their objectivity in encouraging that the proper research, development and monitoring is carried out to assure a quality product.

A second level of opposition and supporting groups could emerge around the secondary products which could potentially grow out of an aquaculture system. A great number of potential sources exist for secondary products with a comparable number of outlets (see Tables 3.1 and 3.2). Particularly the last four potential outlets listed could be strongly affected by a large production aquaculture industry that could severely influence the market structures.

3.3 Individuals and Institutions of Concern

It is also necessary to understand the political and social process which offers both constraints and opportunities. This system of people, institutions and resources will allow or disallow the successful entrance of a commercial operation of a marine waste-food recycle system into the marketplace.

Table 3.1. Sources of Secondary Products

Excess Hatchery Production
Harvest of Useful or Noninterfering Species
Captured Predators and Competitors
Usable Processing Wastes
Outputs from Waste of Water Treatment

Table 3.2. Potential Outlets for Secondary Products

For Human Food
For Pet/Animal Food
Bait for Commercial Fishermen
Bait for Sports Fishermen
Food for Aquarium Fish
For Extracts and/or Pharmaceuticals
For Research, Education, or Laboratory Use

3.3.1 Food and Drug Administration

The major work of the Food and Drug Administration relevant to mariculture programs concerns either adulteration or misbranding of the products, and its reach is confined to food in interstate commerce. While the agency has no direct statutory authority to ban a food, its actions clearly can have that effect. The FDA can seek to prohibit the introduction of food into interstate commerce by injunction,[1] seizure of the food,[2] and criminal penalties.[3]

3.3.1.1 Adulteration

The word "adulteration" has been held to mean to "corrupt," debase or make impure by the mixture of a foreign or a baser substance.[4] The Food, Drug and Cosmetic Act terms a food adulterated for several reasons,[5] including poisonous or deleterious natural constituents which would ordinarily prove injurious to health,[6] poisonous or deleterious added substances regardless of their tendency to injure,[7] and filth or decomposition.[8]

The provision expressly contemplates that deleterious substances naturally found in foods should not serve to disqualify the product unless they are in fact dangerous to health.[9] Accordingly, the presumption favors the acceptability of food. However, a food is prohibited if there is a possibility that its added substance could jeopardize the health of any potential consumer.[10] Thus, the FDA has a lighter burden in actions involving added substances since possibility of harm may support a charge of adulteration. The term "added substance" includes intentional and unintentional additions to food, but seems to require that the substance originate through the act of man.[11] This distinction between "added" and "not added" substances would indicate that mariculture is subject to the law as it deals with "added" substances. Thus, if any of the wastes used in the process also remain in the mariculture product and carry the possibility of harm to the consumer, the FDA may take action, armed with a significantly light burden of proof.[12] However, of most concern to mariculture is the provision which condemns as adulterated food that which "consists in whole or in part of any filthy, putrid, or decomposed substance, or if it is otherwise unfit for food." These words have been interpreted in their ordinary rather than their scientific meaning.[13] Courts have read the section "or if it is otherwise unfit for food" as coordinate and independent, rather than as a qualification of the antecedent clause.[14] The effect of this construction is to make it unnecessary for the FDA to prove that an article of food, which is shown to be filthy, putrid, or decomposed, is unfit for human consumption or harmful to health.[15]

Thus, in Salamonie Packing Co. v. United States,[16] the court affirmed a judgment ordering the destruction of the accused tomato juice as being "adulterated," when the government's evidence showed that the tomato juice contained mold and decomposed tomato material--even though there was no evidence that the juice was unfit for food. Some evidence even indicated that the food was not offensive to the sense of smell or taste, and that the mold and materials were not observable to the naked eye, but the court concluded that the status of the tomato juice as "fit for food" could not be made an issue in a case of this type.[17]

Similarly, in United States v. Lazere,[18] it was held not necessary to show that the defendant's bakery products were injurious to health in order that the products fall within the condemnation of the statute as adulterated food.[19] The court found irrelevant the medical testimony offered by the defendant which stated that, because of the high heat under which bread was baked, the presence of parts of rodents and bugs in the bread would not injure the health of the consumer.[20]

Fish has been held to be adulterated when consisting in part of a "filthy" substance. For example, in 230 Boxes, etc., v. United States,[21] certain shipments of fish, admitted to the United States from Canada, were reexamined by inspectors from the FDA who found them to be adulterated, based on the fact that the fish consisted of a filthy substance--parasitic worms. Of particular relevance to mariculture employing "wastes" is the phrase "otherwise unfit for food." As noted, this phrase does not qualify the earlier part of the provision, and offers the FDA and the courts a way to suppress certain foods which do not contain filthy, putrid, or decomposed substances. The clause has allowed a wide range of reasons for condemning a food since there is no standard of fitness suggested.

Although few cases have arisen directly under this provision, it is an available alternative for banning food which does not specifically violate other regulations, but violates the sensitivities. Thus, the court in United States v. 24 Cases of Canned Herring[22] denied a motion to dismiss a libel which alleged that the canned herring in question was unfit for food within the meaning of the statute, in that it was of a "tough, rubbery consistency." The court noted that a food product could conceivably be unfit for food due to its excessively tough or rubbery state and, if so, should be condemned for the protection of the consumer; and that the standard to be applied is whether the average, normal person, under ordinary conditions, would think the product unfit.[23]

A food is also adulterated if it is prepared, packed or held "under insanitary conditions whereby it may have been rendered injurious to health."[24] This provision protects consumers against products which were produced under conditions considered to be highly unsanitary, yet which conceal the filth in the final product. Thus, where there was evidence that a macaroni plant and its equipment contained live or dead moths, live larvae, insect webbing, and pupae, the court in Golden Grain Macaroni Co. v. United States[25] held the food to have been prepared under insanitary conditions, and therefore adulterated.[26] In cases of this type, it is not necessary that the final product be injurious or filthy, but only that "manufacturing" conditions be such as may reasonably result in contamination.[27]

Discussion of the imprecise adulteration provision of the Food, Drug and Cosmetic Act indicates a critical issue for the future of mariculture systems which employ "wastes." Courts have emphasized that the purpose of this section is to protect the aesthetic feelings and sensibilities of the consumer so that allegations and evidence of possible danger to health are unnecessary.[28] Since there is a strong possibility that some consumers or consumer advocates will exhibit negative attitudes of repugnance and disgust for a waste-grown product,[29] this could lead the FDA to condemn the mariculture products as adulterated. Proponents of FPC, which consists of dried, processed, whole fish--without removal of heads, fins, tails, viscera or intestinal contents--have already met considerable opposition. Although this "fish flour" was seen as a major new source of protein and of income to the fishing industry,[30] the FDA has considered the product unacceptable--"filthy"--because of essentially aesthetic considerations (Coffin, 1971).

The use of "waste" or "trash" fish in Fish Protein Concentrate gives some interesting parallels with potential waste-food recycle systems. While there appeared to be no health danger, aesthetic qualities became the issue. The FDA's interpretation of the situation posed a difficult philosophical problem. It could rule that, if people knew what they were eating, they wouldn't buy it, and so they should protect the public by not allowing it to be marketed as an additive, or they could require that the product be adequately labeled and allow its sale, leaving the ultimate decision to the consumer. While the original intent of the 1906 Food and Drug Act is thought to have been to protect the public from deception, it was thought that the citizen should be permitted to choose what he wanted. At first the Food and Drug Act was strictly enforced, based on aesthetics as well as health. Then it became more flexible and the courts' rulings became less rigid. As test cases showed impurities necessary for processing certain foods, the FDA rulings became more flexible.

While the FDA is supposed to be an objective agency bereft of political pressures, in the case of FPCs it was accused of using the media and bowing to political pressures. The decision, which essentially precluded the commercial production of FPCs in the United States, is one that has caused some to reconsider the role of the FDA. The fact that Congress did not intend to limit the citizen's choice by passing the Food and Drug Act, but rather to prevent deception, is one that should be considered. The fact that Congress did not intend to impede progress in food technology, but rather to encourage it, should also be considered. However, the FPC case may have had exactly that result. Of considerable significance for mariculture is the recent decision of the FDA approving the use of fish protein concentrate, provided that any foods containing the concentrate as an additive declare this fact on the label.[31]

Under a literal interpretation of the adulteration provision, almost every food could be prosecuted.[32] This would be undesirable and judicial common sense has led to a recognition that the presence of a minimal amount of filth may not be sufficient for condemnation. Thus, in United States v. 558 Cases of Iona Tomatoes,[33] the court found that the product in question contained an infinitesimal and inconsequential amount of filth which could not be eliminated even under the most advanced processes, and concluded that the tomatoes were not adulterated since the public must inevitably eat some filth.[34]

The FDA often promulgates information standards in regard to the application of this provision.[35] These standards are established and maintained in secrecy[36] because of the governmental interest in the confidentiality of agency standards for food condemnation, thereby providing a means of dealing with the problem caused by unavoidable, harmless impurities and the public's need for food. The secrecy is maintained to ensure that producers will attempt to approach as closely as possible the desired goal in that, if the standard were published, some producers may treat it, rather than zero impurities, as their goal.[37] However, some courts have gone so far as to determine reasonable standards for impurities by themselves in cases in which the FDA has set no standard.[38] The FDA may also establish published guidelines either on its own (e.g., for mercury, a 0.5 ppm in raw edible portions of fish), or as part of an interagency task force (e.g., for PCBs, several levels for different foodstuffs).

Significant problems therefore face mariculture. Informal standards and guidelines cannot be challenged prior to enforcement, and have legal effects only to the extent that individual suits are won in court.[39] Thus, it would be extremely difficult to determine beforehand whether or not a mariculture product would come safely within the boundaries of an FDA informal standard. In addition, there are not informal standards or guidelines for every type of impurity,[40] and the cases in which the court determines its own reasonable standard are still in the distinct minority so that there remains the possibility that the adulteration provision will be strictly enforced against waste-produced food.

3.3.1.2 The Delaney Amendment

Another issue critical to the future of mariculture is the Delaney Amendment to the Food, Drug and Cosmetic Act.[41] The amendment provides that no additive[42] shall be deemed to be safe[43] if it is found to induce cancer in man.[44] This provision was adopted because under the present state of scientific knowledge a safe tolerance for man of a carcinogenic substance is difficult to establish.[45] Based on this premise, the provision has recently been literally enforced.

Therefore, in Bell v. Goddard,[46] the court dismissed petitioner's contention that the additive in question, diethystilbestrol (DES), was present in the poultry to which it had been added in such miniscule amounts as to enable it to be found not hazardous to health by the simple statement that DES is a carcinogen, and thus banned by the Delaney Amendment. Any definite connection between DES and cancer was deemed sufficient to trigger the prohibition, regardless of the absence of extensive scientific knowledge concerning the additive and its effect. Similarly, the artificial sweetener cyclamate was banned from sale in the United States by the Secretary of Health, Education, and Welfare, relying upon an application of the Delaney Amendment, due to the growing concern about the cancer-causing possibilities of the substance (Turner, 1971). In 1959, the FDA seized millions of pounds of cranberries which had been sprayed with a weed-killing pesticide which had been found to cause cancer in experimental animals, based on the fact that cancer experts did not know how much, or how little, of the carcinogenic substance would trigger the growth of cancer in a susceptible individual.[47]

However, there has been growing opposition to the inflexible quality of the provision. Modern analytical methods can detect and measure increasingly small quantities which escaped earlier methods of detection, so that a "zero tolerance" standard may have to be reevaluated (Oser, 1965). Many scientists believe that there is no justification for banning a useful substance, even though carcinogenic, if the amount used is safe (Janssen, 1964).

Thus, there is authority for an attempt to "read between the lines" of the amendment so as to make it realistically workable.[48] It has even been noted that the view of the FDA may be leaning in the direction of "informal standards," as discussed above in the adulteration section, since that would still force producers to attempt achievement of a zero impurities level, while allowing the agency a needed flexibility in the interpretation and application of the amendment.

Indeed, it is even possible that mariculture products may escape application of the Delaney Amendment. The provision includes a stipulation that the prohibition shall not apply with respect to the use of a substance as an ingredient of feed for animals which are raised for food production, if it is found that the additive will adversely affect the animals for which such feed is intended, and that no residue of the additive will be found in any edible portion of such animal after slaughter.[49] In Bell v. Goddard,[50] small amounts of DES residue remained in the chicken to be eaten by humans. Thus, argument may be made that the use of "wastes" in mariculture is a food ingredient coming within this exception, so long as it can be shown that no traces of carcinogenic substances are found in the finished product. This could be accomplished by a strict monitoring system at the mariculture facility, but may also necessitate clearance and treatment of the thermal and sewage treatment "wastes" to be used.

3.3.1.3 Misbranded Food

The FDA has jurisdiction over "labels," defined as matter affixed to the package, and "labeling," defined as material "accompanying" the product.[51] Both Kordel v. United States[52] and United States v. Urbutert[53] have given the latter phrase a liberal construction. The test employed in these cases focused on the functional similarities between the alleged labeling and the label on the immediate container of the article so that, if material supplements a label even though it reaches the consumer apart from the product, it is labeling.

A product is misbranded "if its labeling is false or misleading in any particular."[54] This standard holds the defendant to a high level of honesty. In that it establishes no requirement of materiality, the FDA can correct even de minimis misrepresentations. The clause applies to deception through omission even if it leaves no impression at all concerning a material fact.[55] For example, substantial and respectable authority in opposition to a statement made on the label is a material fact which must be revealed even though an even more substantial body of authority holds the opinion stated on the label.[56] Thus, it is necessary to spell out all information necessary to safeguard consumers.

Indirect deception, which is possible by the use of a statement technically correct, but misleading in total impression, is also prohibited as misbranding.[57] Even though a label contains no false statement, its effect, taken as a whole, may be misleading by implication or because of improper emphasis.[58] If the labeling is ambiguous, the existence of a deceptive interpretation is enough to trigger the application of the statute.[59] Thus, the label is generally construed against its composer since the validity of a label is usually judged by the probable inference the consumer will draw from it.[60] It is what the public concludes from a label, rather than what the label states, which is the determinative factor.[61]

The FDA may also establish standards of identity defining the contents of specific foods in order to "promote honesty and fair dealing in the interest of consumers."[62] A product which does not conform to this standard may not be marketed as the defined food without FDA permission,[63] which may be conditioned on explanation on the label of the deviation. Thus, it appears that another critical issue for mariculture products will be their labels, indicating in some manner that they were grown with "wastes," since this fact is surely one which would be deemed necessary to the consumer, and should therefore not be omitted.[64] It may be wise to request an advisory letter on the legality of any proposed labeling.

It would be overly optimistic to assume that clear labeling of waste-grown seafood products will not be required by the FDA. It could, however, happen, especially with respect to power plants, but is more unlikely if sewage products are used. All such statements are, at the present time, extremely speculative. Considerations include not only the specific circumstances, decisions of advocates, societal pressures, and FDA attitudes, but also the advances in related technologies, and the degree of opposition which is encountered. The exact conditions of any requirements that might be imposed by the FDA could well be critical. The FDA may approve the label or recommend changes with the warning that action under the statute may otherwise be taken. Since the breadth of the provision makes successful defense in the courts unlikely, it is best to comply with the FDA's advisory letter.

3.3.2 Federal Trade Commission (FTC)

The Federal Trade Commission has specific control over the advertising of products in interstate commerce. It prohibits any false advertising for the purpose of inducing the purchase of a product[65] which is misleading in a material respect.[66] This includes not only positive representations, but also the failure to reveal facts which are material in the light of such representations.[67]

Thus, the FTC standard seems less stringent than the FDA misbranding standard in that it establishes a requirement of materiality. The FTC has more relaxed criteria,[68] less demanding enforcement procedures,[69] and basically serves to protect the businessman from unfair competition, whereas the FDA is concerned primarily with the consumer.

Particularly in the requirements of affirmative disclosure are the FDA's standards more stringent than those of the FTC. The FTC may only proscribe an omission if it leaves an impression concerning a material fact. It has been held that the FTC may not exercise any "affirmative function of requiring or encouraging additional interesting and perhaps useful information"[70] Yet undisclosed truth may at times be as misleading as a false statement, and the FTC has in certain circumstances imposed requirements of affirmative disclosure based on assumptions about consumer behavior.[71] It is only necessary to show that the advertisement tends to deceive and not that anyone was in fact deceived.[72] Thus, advertising falls within the prohibition of this section not only when there is proof of actual deception, but also when the representations made have a capacity or tendency to deceive--that is, when there is a likelihood of fair probability that the reader will be misled.[73] In addition, the fact that the defendant made his representations in good or bad faith is not determinative of whether such statements are deceptive.[74] Thus, significant omission or nondisclosure is guarded against.

As to who must be misled, courts find the material proscribed if it would deceive those to whom it appeals,[75] thus protecting those who are most likely to be harmed. Therefore, the important criterion in determining whether a product is falsely advertised, according to the court in Charles of the Ritz Distributors Corp. v. FTC,[76] is the net impression which the advertisement is likely to make upon the general public.

In evaluating the tendency of advertising to deceive, the FTC is bound to protect the public in general--the unsuspecting as well as the skeptical.[77] Thus, the agency can prevent use of an advertisement which, while not beguiling the average individual, would deceive a small, gullible group. The advertising need not be literally false in order to fall within the prohibition of this statute.[78] Accordingly, a true statement may be employed in advertising which falls within the false advertising category if the statement is half truth, where nondisclosure of the context in which the statement was used renders it misleading or where the statement in context has two or more commonly understood meanings, one of which is deceptive.[79] Of particular relevance to waste-grown food advertising is the possible ruling against euphemisms as deceptive. Such words as "recycled" may be construed as misleading. It is difficult to anticipate how the FTC will construe any wording or overall communication, and choices of language would be of extreme importance. However, it must always be remembered that the advertiser has a wide latitude for "puffing," which is the dealer's opinion about the product and which the consumer is assumed to disregard.

There will probably have to be strong advertising for the new mariculture products. Few problems are foreseen with regard to the FTC regulations, but significant problems are foreseen with the FDA regulations, due to the different primary concerns of the agencies. It may be advisable to request an FTC advisory opinion. However, although the FTC does render these to potential advertisers, it is mostly in the context of trade regulation laws, as opposed to dealing with consumers.

3.3.3 Coastal Jurisdiction

Current coastal zone legislation (Public Law 92-583) has placed authority for coastal zone planning at the state level. Depending on state structures, much of that authority may lie with local coastal towns. Once a state management program is approved by the Federal Government, the ultimate authority over the use of the coastal zone resides with the state unless some activity is viewed by the Federal Government as detrimental to the national interest. Thus, the entrepreneur probably must get the local zoning in line and persuade the local townspeople to lease or sell him the property he desires. Then he must apply for a number of permits from many agencies at the local, state, regional and federal levels. Sometimes this process can extend to as many as 36 agencies. During this process, any number of possible opposition groups may emerge, or just single-agency opposition. In addition, the Environmental Protection Agency will be attempting to ensure that the surrounding environs will not be polluted, and the Federal Trade Commission might initiate a review of the proposed industry at the request of a competitor.

3.3.4 Private Opposition

A commercial fishing group might initiate such an FTC review, or others who have aquaculture enterprises which don't use the "waste" inputs, and try to make an argument that their product is safer. The review is usually done to assure that the marketing of the product complies with federal regulations, and that no deceptive or other unethical practices are used. Here an interesting problem can arise. If the potential initiator of a review is a fisherman or other aquaculturist, the entrepreneur for the marine waste-recycle system has some recourse which might stop them before they begin. For example, if the entrepreneur decides to sell his product as if it were exactly the same as those from nature, and is called upon to fully label the product as grown on sewage, the facts can be brought forward to demonstrate that, in all probability, the waters in which the "wild" fish were caught contained some sewage, chemicals, etc., since most coastal waters have some amount of pollution. It is likely that potential opposition groups might be reluctant to expose those facts about their own products.

The controversy over fish protein concentrate is a case in point. Two of the strongest opponents to this substance were the wheat industry and the dairy industry. These two groups feared market competition for a protein substitute. This fight almost pitted the agriculture states, dependent on dairy and wheat sales, against the coastal fishing states. The advocates of FPCs found an interesting basis for compromise. First, they offered to sell their products to each of those industries for additives to increase the protein amounts. Secondly, they threatened to counter opposition complaints with the exposure of the fact that the FDA is authorized to allow permissible tolerance levels for things they recognized as necessary for production of a product, but which was not injurious to health. For example, they had devised unpublished tolerances for filth: rodent urine in grain and manure in milk (Singal, 1963). Interestingly, another opposition group developed when it looked as if the grain industry and the FPC people were about to resolve their dispute. The AFL-CIO wrote that it would oppose any move which would add bulk to bread and thereby raise the price for its workers.

The potential for commercial opposition of this type comes not only from other fishing interests, but also from secondary industries, consumer groups, environmental groups, health organizations, and groups we cannot even forecast from this juncture.

3.4 Consumer Acceptance of Waste-Grown Seafoods

3.4.1 Consumer Attitudes Toward Wastes

An extensive review of the relevant literature has failed to bring forward research evidence or reports of commercial attempts to market products similar to marine waste foods. The precedents are of a preprocessed product (Fish Protein Concentrate) or involve a mediating process before human consumption (such as "Milorganite" which is simply processed sewage sludge and is marketed to the turf trade and to garden lovers, but is reported also used to fertilize kitchen gardens). The closest to a direct precedent for the use of sewage products in the United States is the Santee Recreation Project where fish are caught for human consumption from lakes fed water directly from a sewage plant (Merrell et al., 1967). "Public response to the fishing program has been good from the beginning" (page 20) for this well-monitored and controlled project. In addition, at least some of the food outputs from small-scale experimental cultures using power-plant thermal effluents have been consumed.

Generally, new product marketing concerns itself with what is new for the consumer, rather than newness of the production processes, or other aspects of the product that do not have a direct impact on the consumer and his use patterns. In this sense, it appears that the food outputs of maricultural waste-recycling systems are not new to the consumer. It is essential that the products are not differentiated by color, texture, smell, taste, or any other obvious way from similar products from other managed aquaculture sources not using these wastes. This fact appears to be true for the use of power-plant effluent and some organic processing wastes, but for others it remains to be verified. Nevertheless, it is useful to conceptualize the product in the framework of new product design and development since we believe that the consumer may be influenced directly in his purchase decision by knowing the inputs into the maricultural system.

The average American has been acculturated to have a repugnance for wastes, especially human, and shows this distaste as a concern both for modesty and cleanliness. The cleanliness issue is of particular relevance to our study. To what extent does the consumer associate his repugnance for human waste to a food product grown on these wastes? If the Santee Project (see 3.4.2) is any indication, this associative link either may not exist or can be nullified, even where the physical facts are made clearly known. The common use of waste products in agriculture may be another example. Unfortunately, there is no research available which bears upon this question. A useful research strategy could be to supply enough information to the consumer to permit the formation of an attitude, and then to analyze the attitudes over samples of consumers.

In summary, we can anticipate the existence of negative attitudes when human or other wastes are used in the production of food. These are most likely to represent disgust and a fear that the product is unclean or impure as well as potentially disease-causing. On the positive side, the fact that the system is ecologically attractive, and that health problems are potentially solvable may produce strongly favorable responses.

3.4.2 Consumer Attitudes Toward Reclaimed Water

Dr. William Bruvold of the School of Public Health at the University of California, Berkeley, has studied some interesting aspects of public attitudes toward water reclaimed from municipal sewage. This research is reported in several places (see

Bruvold and Ward, 1970, 1972; Bruvold, 1971, 1972 a,b). The concepts of water reclamation and waste-recycling appear to be related insofar as they are potentially evocative of similar responses by consumers.

The study focused on ten communities in California, five of which had some exposure to an actual water reclamation project The other five communities served as "controls" and had had no such exposure. The data were gathered from personal interviews with nearly 100 respondents from each community using structured questionnaires as well as unstructured nondirective probes during the interview. While the study was designed to investigate several aspects of opinions about water resources in addition to the attitudes summarized below, we will present only those findings related to the issue of waste-grown fish.

A total of 972 respondents was presented with 25 potential uses of reclaimed water and asked to indicate whether they would or would not oppose such use. The highest opposition rates were for use as drinking water (56.4%), food preparation in restaurants (56.0%), cooking in the home (54.5%), and the preparation of canned vegetables (54.1%). The next highest opposition rates were 38.7% for the use of reclaimed water for bathing at home, and 23.7% for swimming. Only 0.8% opposed the use of reclaimed water for road construction, which was the lowest rate of opposition encountered. Bruvold (1972c) concludes that the "opposition to use of reclaimed water correlates well with likelihood or extent of personal contact" (p. 21). He further concludes (Bruvold and Ward, 1972) that, while many low-contact uses appear acceptable, "public opinion in California will not yet tolerate direct reuse" (p. 1695).

The important question for our purposes may be less related to the percent of respondents opposing high-contact uses than to the activism of the opponents. To elaborate, we may restate the above as 43.6% of the respondents would not oppose using reclaimed water as drinking water, 44.0% would not oppose its use in the preparation of food in restaurants, etc. These figures represent a large market segment not opposing these uses, but give no idea of the segment that would actively support such uses. Indeed, a small but vocal minority can often sway public opinion in either direction. The fluoridation decisions in cities and towns repeatedly show the occurrence of this phenomenon (see Sapolsky, 1968).

The Berkeley study then indicates that at least 40% of the respondents would not oppose high-contact use of reclaimed water. For our purpose, if extrapolation is at all meaningful, this potentially represents a very large market segment which is unopposed to waste-grown fish. Furthermore, a consumer always has the option not to buy the aquacultural product, but respondents in the Berkeley study could have construed that some of the uses of reclaimed water as presenting no such option. For instance, if the city supplies reclaimed water on tap, one does not have the option of not drinking it. This greater latitude or freedom of choice may represent a situation wherein waste-grown fish may not be opposed by a hostile public. Nevertheless, interest groups are likely to see a powerful threat to their vested interests and generate confusion in the minds of consumers by publicizing conflicting opinions about the product. The safest course for the consumer then is the decision not to buy.

The Berkeley study further investigated reasons for opposition to uses of reclaimed water. Responses were elicited in open ended manner by asking "Would you please tell me why you checked <u>opposed</u> for item(s)...?" Responses were then coded into broad categories. The percent indicating various reasons were as follows:

Reason	Percent Stating Reason (N = 972)
1. Psychologically repugnant	29.2
2. Lack of purity	21.5
3. Can cause disease	9.8
4. Bodily contact undesirable	8.0
5. Undesirable chemicals added	5.1
6. Taste and odor problems	3.9
7. Cost of treatment unreasonable	0.8

[Adapted from Bruvold, 1972c, Table 12, page 23.]

Since the categorization was not free from overlap because differences existed between the coders, and because multiple answers were possible, we can only consider these figures to be broadly indicative of the respondents' primary concern.

It is clear that the affective responses "repugnant" and "impure" are vastly stronger than the other more specific responses. A sampling of 500 people in an unrelated study (Kelly, 1972) showed a correlation between a general concern about water pollution and changes in fish consumption. We can definitely state that emotional responses are likely to dominate public acceptance or nonacceptance of the concept of waste-grown fish. Unfortunately, these are also the most difficult to surmount since the communication of scientific evidence or reasoned, logical arguments are unlikely to overcome a "gut-level," or visceral, distaste.

The Gallup Organization reports that a survey was conducted for the American Water Works Association, a nonprofit scientific and educational society, in mid-March 1973 on public response to drinking reclaimed water (The Gallup Poll release, Wednesday, May 16, 1973). Personal interviews were conducted with a representative national sample of 1,648 persons 18 years of age and over.

One of the key questions asked along with the results is reported below.

Q: "Suppose health authorities in your community determined that it was safe to drink recycled sewage--that is, water that has been purified and treated for taste, appearance, and so on. Would you have any objection to drinking this water, or not?"

Yes, would	55%
No, would not	38%
No opinion	7%

Again, about 40 percent of respondents do not indicate any opposition to the concept of drinking reclaimed water. Note that the question refers directly, and without euphemistic statement, to "recycled sewage." Also note that the question assumes that local health authorities have cleared the water on purity and safety for human consumption. Further, while the Berkeley study was restricted to 10 communities in California, five of which had some prior exposure to the used of reclaimed water, the Gallup survey is purportedly based on a <u>representative national sample</u>.

3.4.3 Consumer Attitudes to the Concept of Waste-Grown Fish

A pilot study was carried out to investigate the kinds of comments consumers made when confronted with the concept of buying waste-grown fish. (The details of the pilot study are presented in Appendix E.) Three questions were submitted to 45 housewives, designed to gather opinions about waste-grown versus natural fish, fair prices, and the reasons why opinions were given. It appears from the attitude statements that the broad areas of psychological repugnance, lack of purity, and the possibility of disease are dominant negative responses. Equally, as expected, the positive aspects that appeal to respondents were the ecological balance of the proposed system, the possibility of adequate food supplies and the generally positive reactions that recycling ideas evoke today. The percentage of people favoring the idea to those opposing it was found to be consistent with the literature on attitudes towards water reuse. The number of respondents making favorable comments was about one-half of the total number who made responses to the attitude question.

The pricing question is perhaps better phrased as a quasi-experiment in its present form since no one was willing to pay higher prices, or admit they would, in response to the kind of question used in this pilot survey.

3.5 Marketing Strategies

3.5.1 Product Design Issues

Product design is of crucial importance, as is evidenced by the very high failure rate for new products. The general strategy for maximizing the probability of success for a new product has been to map the perceptual and preference space for the product class, and then to position the new offering in such a way that predetermined objectives are met. Its importance appears only at the stage of consumer marketability. Given the flexibility of the production process and its general adaptability, it does not appear that questions such as what kind of fish (e.g., shellfish versus finfish), or what important esthetic attributes (size, color, consistency, texture) are desired, are major production questions. However, there is some evidence (Kelley, 1972) that the consumption of different product forms (i.e., fresh, frozen, canned) are not equally impacted by negative attitudes about pollution. This study also indicates that this reduced consumption may lead to a substitution effect among the different product types, with the specifics dependent on the consumer's profile.

What does the consumer look for in fish? While a general answer is not possible, some of the work done by Dr. Harold Webber and his colleagues at Groton Bio-Industries has direct bearing on the question. In investigating consumer preferences for seafood in general, and oysters in particular, this group of researchers found that perceptions of seafood did not appear to differ across consumers from different parts of the country. However, preferences were markedly different across regions, and evaluations of specific kinds of seafood (identified by species and area caught) were based on variations in taste.

The design implications of this kind of research are substantial. The finding that perceptual dimensions are invariant across the country would imply that a large study in one area of the country is generalizable to other areas insofar as consumers perceptions of the aquacultural product are concerned. Thus, only preference judgments on the same perceptual dimensions need be investigated in the different regions.

Returning to the attitudes elicited in this study, consumers generally agreed that they would be willing to try the product, but that repeat purchase would be based on usage experience. This suggests immediately that taste-tests are a very necessary part of the test-marketing and product-design phases of marketing. Furthermore, such tactics as couponing (cents-off a purchase of the product) and sampling (giving out free samples of the product to a large section of the consuming population) would be useful, at least in the test-market stages. (It must be added that an unacceptable product will only be hurt by the offering of samples. Such actions are only warranted after extensive testing on small groups of consumers.)

Some points stand out as being of special importance to the marketing of these types of aquacultural products. First, it is necessary to define the market in terms of patterns of substitution and competition across products. Thus, fish may not really compete with beef in any general way, but (for example a salmon steak may compete with a beef steak. In any case, the aquacultural product has other possibly inhibitory/attractive content that may distinguish it from naturally-occurring fish. Second, through analysis of small samples of consumers' judgments, the "why" of similarities and differences among products is determined. These can be correlated with actual purchasing behavior through using panel data (if available) or through large-scale preference studies. We may add that Market Facts, Inc., and the "Chicago Tribune" maintain large consumer panels that are available for a fee. The next step involves the measurement of preference for new product descriptions, and the determination of the description that a sizable segment of the consuming population finds acceptable, and which could fulfill management objectives for the product. Finally, a new product is developed around the product description. Supporting advertising and promotional material is also developed in such a way that brand name (if any), package design and advertising messages match the physical product.

3.5.2 Pricing Issues

A second important issue is that of pricing, since a premium price for the cultured product may be necessary to insure economic viability, at least initially. Although the pilot survey did contain a question on price, it is likely that responses were biased on account of the wording. At present, given the escalation in food prices, it is not likely that respondents who would actually be willing to pay more for the cultured product would indicate this in their response. Nonetheless, 10 of 41 respondents felt that the aquacultural product should be priced higher than current fishery products, and the same number felt that it should be priced lower. It should be noted that aquacultured products almost universally command a premium price over similar products from natural sources. The basic question is if the use of wastes will alter this established pattern.

Most of the responses to the question about consumers' opinion are indicative of an acceptance based on the idea of a "purer" or "safer" fish because of the control exercised. This indicates the possibility of commanding a premium price even for waste-grown seafood. However, at this stage it is not possible to make a definitive statement. We suggest instead a method of exploring the issue further at each stage of a proposed consumer-research study. While we have included a quasi-experimental approach to pricing questions, it must be stressed that the question is still tentative since attitudes toward higher prices are likely to be very different during times when price levels are generally rising. The time span to expected commercial availability is too large to forecast trends in price levels at this time.

3.5.3 Distribution Issues

There appear to be two major decisions about the system of distribution to be adopted, assuming that the decision to produce commercially has been made. The first, will distributors already in the business agree to handle the aquacultured product, relates to the second: should existing channels be used or should a new network, perhaps owned and operated by the management of the aquacultural enterprise, be created? If the existing network is unwilling to handle the product, it becomes mandatory to create an alternative route to the consumer.

Questions related to the target market also arise at this stage. Is the consumer the sole decision-maker as to the acceptability of the waste-grown product? Of what size is the restaurant trade? What are the decision-variables in the restaurant business? How do distributors and retailers react to the product concept?

There are no clear answers available at the present time to such qestions, and the matter of distributor acceptance is an empirical issue. It is suggested that interviews with potentially interested distributors tap the question, but this is unlikely to be meaningful until (a) the product is commercially viable and samples are available, and (b) additional research on consumer acceptance has indicated that they will react favorably to the concept.

Kotler (1972) concludes that the evidence suggests "to the seller who is trying to get a new product into retail distribution that he stands the best chance when he can report strong test-market evidence indicating consumer acceptance, a well-designed and extensive introductory advertising and promotions plan, and deals (primarily margin and allowances) to incentivize the retailer" (page 157).

3.5.4 Communication Issues

As a basis for a communication strategy, we believe that three factors will be found to account for most of the variability of consumer response. One will account for such ideas as ecology, pollution, and recycling. The second involves psychological repugnance. The last will account for such attitudes as the lack of purity (or the greater purity) of the product, the possibilities of disease transmission, and the like.

The question most likely to arise at this stage is: how do we play the theme of waste-grown? The literature on advertising, as well as the result of laboratory research on communication, is not very helpful in answering this question. The most direct answers come from Volney Stefflre, whose work is reported by Silk (1969). Stefflre's view of advertising is that it should contribute toward:

1) Bringing the favorable dimensions of the product into greater focus;
2) State as euphemistically as possible the undesirable features of the product that cannot be avoided;
3) Attempt to move the product along those dimensions where advertising is adequate to place the product in an advantageous position;
4) Ensure that there is a match between the advertising for the product and the consumer's image of the product.

Basically there are two broad ways to advertise: a supportive technique in which the advertiser extols the virtues of his product, and a refutational technique, in which the advertiser states the opposition's viewpoint briefly, and then sets out to refute it in detail. The research results indicate the strong superiority of the refutational method when the subjects were exposed to counterpropaganda after they had seen the refutational communication. It appears that the stating of the opposing view and then its refutation "inoculates" the subject against the opposing view. We may safely expect that the aspect that will be picked for counter-advertising by interest groups is the fact that the seafoods were grown on waste. Given that the emotions evoked in consumers are repugnance, we have the alternative of facing the situation squarely and refuting the idea that the fish are impure or unclean, or the option of stating the facts "euphemistically." The section on governmental regulation adds some caveats to euphemistic phraseology. Perhaps one way out of this bind is to state the truth euphemistically, and then refute the claims that it results in an unclean product.

Perhaps the best strategy for product development is to research every step of the way carefully, and to obtain consumer opinions and attitudes at each stage. While the cost of such a systematic research program, coupled with the design issues, is high, we feel that the cost of failure would be even higher. The risks are considerable, and the best that can be done at this stage is to stress the need for more research. The other way is of ignoring the pitfalls, and expecting that changes in societal or market conditions will force public acceptance of the product. This path has been chosen often, and the results are well-echoed in the failure rate of new products. Particularly in a product where considerable consumer nonacceptance is expected, this path is fraught with hazards. It is the purpose of future research to clarify some of these risks and indicate which positioning of the products is most likely to be acceptable to the consumer, and therefore to succeed commercially.

3.6 Summary

In the final analysis, mariculture programs must face up to possible difficulties with the adulteration and misbranding sections of the Food, Drug and Cosmetic Act. In order to resolve the adulteration issue, strict monitoring systems should be developed to control the quality of the final product,[80] and "good manufacturing practice regulations" should be developed to assure that mariculture will develop in full recognition of human health factors.[81]

In order to comply with possible strict labeling requirements of the FDA, yet not lose consumers who would be disturbed by the use of wastes in the mariculture process, a broad consumer education program must be outlined and implemented. Consumers are now believed to be adequately informed by the label "whole fish protein concentrate," and presumably will not react with disgust to manufactured foods with FPC additives.[82] A similarly neutral yet informative label may be devised for mariculture products grown on wastes, and public education may lead to acceptance of the labeled mariculture products. Recent action has been taken by the National Marine Fisheries Service of the National Oceanic and Atmospheric Administration to standardize the nomenclature of fish and shellfish products.[83] The purpose of this action, now being initiated, is to deal with "problems related to nomenclature (which) constitute an obstacle to the development of underutilized fishery resources,...thereby limiting opportunities for alleviating shortages in fishery products associated with traditional fisheries." Although designed to deal with "nutritious species with aesthetically objectionable common names that severely limit their marketability (e.g., ratfish...cancer crab...)," the program could be extended to devise appropriate nomenclature for mariculture products grown on wastes.

Hence, monitoring and pretreatment of wastes, quality control of mariculture production to diminish risks, public education as to the benefits of the products, appropriate disclosure of the products' cultivation using wastes and a carefully planned advertising program, will all prove to be the necessary condition for the acceptance and commercial viability of mariculture systems employing power plant and sewage treatment wastes.

The advocates of past new products have made errors and exhibited a lack of understanding of the political and social processes. Perhaps aquaculturists can learn from past experience. With the interest and possible entry of large corporate interests into aquaculture comes a wealth of professional expertise. With industries such as Union Carbide, Dow Chemical, General Tire and Rubber, and Ralston Purina in advocacy position, the law and political processes should not be the awesome problem they have seemed before. If the operators of the marine waste-food-recycle system are able to keep their costs down and the price of their products competitive with natural aquaculture systems, the obstacles can probably be overcome with some efforts.

In the next five to ten years there may be increasing food shortages in the United States as well as in foreign countries. As need is demonstrated for any product, particularly if it is food, tolerance levels grow and definitions of law are expanded to allow things which, under different circumstances, would not have been permitted. As in the case of air pollution laws, when there was abundant energy, there were stringent laws. When energy sources appeared in short supply, pollution standards fell to increase energy supply. Thus, with food and drug protection. If there is a promising system to provide additional food products to a society that finds its foodstuffs in short supply, although there remain some unknowns and associated risks, and if the need is great enough, the law will be interpreted more broadly to allow food products from this new source.

Finally, there are two paths which an aquaculturist might follow. He can try to gather all the right advocates behind him and attempt to change the necessary laws to produce a more favorable legal environment. This approach minimizes the legal-political risk to the enterprise, but at best is very time-consuming and, depending on the circumstances, may not even be a realistic option.

Alternatively, the entrepreneur can enter the market withou all the laws and processes in place, but with a strong, quality product, and try to achieve credibility before he is questioned. Here the risk is much greater for, if challenged and found to be in violation of some laws, the consequences to the enterprise could easily be disastrous. However, if he makes it and proves through actual use his product safe for market, then the laws could conceivably come into line with the operation.

Footnotes to Chapter 3

1. 21 U.S.C. 332 (1973)

2. 21 U.S.C. 334 (1973).

3. 21 U.S.C. 333(a) (1973).

4. United States v. St. Louis Coffee & Spice Mills, 189 F. 191 (1909).

5. The adulteration section must be interpreted liberally in order to effectuate congressional purpose. United States v. 935 Cases, More or Less, Each Containing 6 No. 10 Cans of Tomato Puree, 65 F. Supp. 503 (1946).

6. 21 U.S.C. 342(a)(I)(1973)(second clause).

7. 21 U.S.C. 342(a)(I)(1973)(first clause).

8. 21 U.S.C. 342(a)(3)(1973).

9. In United States v. 1232 Cases of American Beauty Brand Oysters, 43 F. Supp. 749(w.l). Mo. (1942), the court held that cans of oysters containing shell fragments were not adulterated, noting that by the use of the most modern means, shell fragments could not be entirely separated from an oyster food product.

10. United States v. Lexington Mill & Elevator Co., 232 U.S. 399, 411 (1914).

11. See United States v. 1232 Cases American Beauty Brand Oysters, 43 F. Supp. 749 (w.d. Mo. 1942); Note Health Regulations of Naturally Hazardous Foods: The FDA Ban on Swordfish, 85 Harvard L. Rev. 1025, 1030 (1972).

12. Re: Swordfish article & Goodman Case.

13. United States v. 44 Cases, etc., Viviano Spaghetti with Cheese, 101 F. Supp. 658 (1951): United States v. Swift & Co., 53 F. Supp. 1018 (1943). See also United States v. Roma Macaroni Factory, 75 F. Supp. 663 (1947); United States v. Lazere 56 F. Supp. 730 (1944).

14. United States v. 449 Cases, Containing "Tomato Paste," 212 F. 2d 567 (1954); Bruce's Juices, Inc. v. United States, 194 F. 2d 935 (5th Cir. 1952); United States v. 1851 Cartons of Frosted Fish, 146 F. 2d 760, 761 (10th Cir., 1945)(The added clause "is in the disfunctive and does not condition, qualify, or obscure the plain meaning of the whole sentence when considered in its context.") United States v. 935 Cases of Tomato Puree, 65 F. Supp. 503 (N.D. Ohio 1946); United States v. 184 Barrels of Dried Whole Eggs, 53 F. Supp. 652 (D. Wis. 1944).

15. United States v. 484 Bags, More or Less, 423 F. 2d 839 (1970); United States v. Two Hundred Cases, etc., 289 F. 157 (1923); United States v. 233 Tins, More or Less, Strawberries, 175 F. Supp. 694 (D. Ark. 1959); United States v. 184 Barrels Dried Whole Eggs, 53 F. Supp. 652 (D. Wis. 1943).

16. 165 F. 2d 205 (8th Cir. 1948), cert. denied 333 U.S. 863.

17. See United States v. 716 Cases, More or Less, etc., Del Comida Brand Tomatoes, 179 F. 2d 174 (1950), United States v. Two Hundred Cases of Adulterated Tomato Catsup, 211 F. 780 (1914): United States v. 133 Cases of Tomato Paste, 22 F. Supp. 515 (D. Pa. 1938)(A tomato paste which contained about 85 fragments of corn ear worm in each 200 cubic centimeters was subject to confiscation on grounds that it was adulterated, notwithstanding that the tomato paste was not injurious to health or that the worm fragments could not be detected by the consumer either by sight or taste).

18. 56 F. Supp. 730 (D. Iowa 1944).

19. See United States v. 1,200 Cases Pasteurized Whole Eggs by Frigid Food Products, Inc., 339 F. Supp. 131 (D. Ga. 1972); United States v. Bodine Produce Co., 206 F. Supp. 201 Co. Ariz. 1962); United States v. 599 Cases, more or less, Ritter Tomato Catsup, 204 F. Supp. 104 (D. Pa. 1962).

20. See United States v. 935 Cases of Tomato Puree, 65 F. Supp. 503 (N.D. Ohio 1946). In this case, the court held that the government had sustained the burden of proof upon showing that the tomato puree contained rat fragments, fly eggs and fly maggots. It was further noted that the fact that a product could not be prepared and shipped in interstate commerce except in an "adulterated" state could not justify permitting it to be free from application of the statute. See also Triangle Candy Co. v. United States, 144 F. 2d 195 (9th Cir. 1944); United States v. 44 Case, etc., 101 F. Supp. 658 (D. Ill. 9951). Also, see United States v. O.F. Bayer & Co., 188 F. 2d 555 (2d Cir. 1951), in which bags of green coffee were condemned as adulterated because they contained extraneous filthy matter in the nature of dirt, wood splinters, matted fiber and other debris. The court rejected the contention that the foreign matter would be eliminated by the roasting process to which the beans would later be subjected, stating that food which was adulterated might be condemned even though it was intended to have the adulteration eliminated by a future process. See also United States v. Capital City Food, Inc., 345 F. Supp. 277 (D.N.D. 1972); United States v. 1,200 Cans Pasteurized Whole Eggs by Frigid Food Products, Inc., 339 F. Supp. 131 (D. Ga. 1972)(Impossibility of compliance with adulteration provision or evidence that the defendant is doing the best he can under the circumstances is not valid defense).

21. 168 F. 2d 361 (6th Cir. 1948). See also United States v. Sprague, 208 F. 419 (19B), in which oysters, although shipped unopened as taken from the water, contained bacteria by reason of the condition of the waters in which they were grown, were deemed to come within the prohibition against filthy, putrid, or decomposed food, and were therefore adulterated.

22. 87 F. Supp. 826 (D. Me. 1949).

23. The court suggested that to accept any other standard would make it a matter of personal taste, since a fussy individual might throw out a certain product as unfit, while another individual, who "brags he can eat anything," might eat and enjoy the same food.

24. 21 U.S.C. 342(a(4)(1973).

25. 209 F. 2d 166 (9th Cir. 1953).

26. Cf. United States v. Roma Macaroni Factory, 75 F. Supp. 663 (D. Calif. 1947).

27. See Berger v. United States, 200 F. 2d 818 (8th Cir. 1952); United States v. 1,200 Cans Pasteurized Whole Eggs by Frigid Food Products, Inc., 339 F. Supp. 131 (D. Ga. 1972).

28. United States v. 935 Cases of Tomato Puree, 65 F. Supp. 503 (N.D. Ohio 1946); United States v. 1,500 Cases More or Less, Tomato Pack, 236 F. 2d 208 (1956).

29. Cf. Edminster, Application of Sewage Sludge to Agricultural Land in Minnesota, Draft Environmental Statement, U.S. Dep't of Agriculture 6 (March 22, 1973), at 1, 8, in which the author notes a general public reluctance to permit sludge spreading on agricultural land because of possible danger to aesthetics. See also Sewage Sludge Incorporation in Experimental Field Plots to Evaluate Hazards and Benefits, and Develop Techniques for Optimizing Benefits, and Minimizing Hazards, Environmental Impact Statement, U.S. Dep't of Agriculture (July 31, 1972); Chaiken, Poloncsik, Wilson, Muskegon Sprays Sewage Effluents on Land, 43 Civil Engineering--ASCE 49 (May, 1973); Proposed Ingredient and Labeling Requirements for Frankfurters and Certain Other Cooked Sausage Products, 37 Fed. Reg. 28430 (1972)(public response indicates that by-products are unattractive to a large segment of consumers).

30. Fish Flour: FDA Approval Likely on Improved Product, 52 Science 738 (May, 1966).

31. 38 Fed. Reg. 19815 (1973).

32. See Beacham, The Food Law Is Reasonable, 6 Food Drug Cosm. L.J. 282, 284 (1951).

33. 2 CCH Food D.C. Law Rep. (2d ed.) 7260 (N.D. Ill. 1953).

34. See United States v. Gerber Products Co., Unreported (D. Mich. 1944), in Developments in the Law, Supra note 5, at 645, the court stated that Congress could not have intended to make criminal the presence of a negligible amount of filth unavoidable with the highest care.

35. In addition, the Food, Drug and Cosmetic Act authorizes the establishment of official tolerances for several specifically defined types of added substances.

"Food additives" render a food adulterated unless the quantity of the substance is within a safety tolerance established through formal procedures by the Secretary of Health, Education, and Welfare. 21 U.S.C. 348 (1973). Another section of the Act provides for the setting of official tolerances for added substances "required in the production of a food or which cannot be avoided by good manufacturing practice." 21 U.S.C. 346 (1973). However, it has been held that the FDA is under no obligation to set up any formal standards, but is left to exercise its discretion in the matter. United States v. 1,500 Cases More or Less, Tomato Paste, 236 F. 2d 208 (7th Cir. 1956). See also United States v. Goodman, 5 ERC 1969 (7th Cir. 1973).

36. There are no regularly published reports of internal FDA deliberations on these matters. United States v. 27 Jars, etc., F. D. Cosm. L. Rep. 60,063 (D Wyo. 1963).

37. United States v. 1,500 Cases More or Less, Tomato Paste, 236 F. 2d 208 (7th Cir. 1956).

38. E.g., Id.; Cf. United States v. Two Hundred Cases of Adulterated Tomato Catsup, 211 F. 780 (1914).

39. Developments in the Law, Supra note 5, at 1035-36.

40. Cf. United States v. 27 Jars, etc., F.D. Cosm. L. Rep. 60,063 (D. Wyo. 1963).

41. Delaney Amendment, 21 U.S.C., 348 C(3)(A), 1973.

42. 21 U.S.C. 321(s)(1973) defines "food additive" to mean any substance the intended use of which results in its becoming a component or otherwise affecting the characteristics of any food, which is not generally recognized among scientific experts to be safe under the conditions of its intended use. See United States v. 41 Cases, More or Less, 420 F. 2d 1126 (1970).

43. A food additive needs to be classified as "safe" so as to escape condemnation as adulterated under clause (2)(C) of 21 U.S.C. 342(a), which states that a food is adulterated if it contains a food additive which is unsafe within the meaning of 21 U.S.C. 348.

44. 21 U.S.C. 348(c)(3)(A)(1973).

45. National Institutes of Health & National Cancer Institute, Evaluation of Environmental Carcinogens 15 (Apr. 22, 1970); Ringuette, Medicated Animal Feeds Under the Food-Additives Amendment of 1958: A Case Study, 15 Food Drug Cosm. L.J. 320, 327-37 (1960).

46. 366 F. 2d 177 (7th Cir. 1966).

47. 24 Fed. Reg. 9543 (1959).

48. Letter from Elliot L. Richardson, Ass't Sec. of HEW, to Rep. Oren Harris, Chairman of House Comm. on Interstate and Foreign Commerce, 104 Cong. Rec. 17515 (1958).

49. 21 U.S.C. 348(c)(3)(A)(1973).

50. 366 F. 2d 177 (7th Cir. 1966).

51. 21 U.S.C. 321(k)$_{1}$(m)(1973).

52. 335 U.S. 355 (1948). <u>See</u> United States v. 8 Cartons of Molasses, 103 F. Supp. 626 (W.D.N.Y. 1952).

53. 335 U.S. 355 (1948). Thus, it is the textual relationship, not physical attachment, which is significant. United States v. Diapulse Mfg. Corp. of America, 389 F. 2d 612 (1968), <u>cert. denied</u>, 392 U.S. 907.

54. 21 U.S.C. 343(a)(1973). This provision has been strictly construed. United States v. Article of Food Consisting of 432 Cartons...Lollipops, 292 F. Supp. 839 (D.N.Y. 1968); United States v. 30 Cases...Fruit Spread, 93F. Supp. 1950 (D. Iowa 1950). Thus, Congress intended to prohibit interstate shipment of even nondeleterious substances, if a food is misbranded. Libby, McNeill & Libby v. United States, 148 F. 2d 71 (1945).

55. 21 U.S.C. 321(n)(1973), states that a product may be misbranded if its label fails to reveal material facts. <u>See</u> Midwest Game Co. v. M.F.A. Mill Co., 320 S.W. 2d 547 (Mo. 1959).

56. <u>Cf.</u> Research Labs, Inc. v. United States, 167 F. 2d 410, 422 (9th Cir.), <u>cert denied</u>, 335 U.S. 843 (1948). This result was clearly intended by Congress. H.R. Rep. No. 2139, 75th Cong., 3d session 7-8 (1938).

57. United States v. 95 Barrels of Apple Cider Vinegar, 265 U.S. 438, 445 (1924); Research Laboratories, Inc. v. United States, 167 F 2d 410, 422 (9th Cir.), cert. denied, 335 U.S. 843 (1948); United States v. 6 Dozen Bottles of Dr. Peter's Kurko, 158 F. 2d 667, 669 (7th Cir. 1947).

58. V. E. Irons, Inc. v. United States, 244 F. 2d (1st Cir.), cert. denied, 382 U.S. 918.

59. V. E. Irons, Inc. v. United States, 244 F. 2d 34 (1st Cir.), cert. denied, 354 U.S. 923 (1957). Thus, this section envisions that there might be a misleading label without its being false. Van Lieu v. United States, 321 F. 2d 664 (1963).

60. United States v. Articles of Drug, etc., 263 F. Supp. 212 (D. Neb. 1967) (False or misleading character of label is measured by its significance as read by those to whom it appeals). In addition, the words of the label are to be construed in their ordinary and customary meaning so far as they have one. United States v. One Hundred & Fifty Cases of Fruit Pudding, 211 F. 360 (D. Mass. 1914); Libby, McNeill & Libby v. United States, 210 F. 148 (D. Va. 19B); United States v. Seventy-Five Boxes of Alleged Pepper, 198 F. 934 (1912).

61. United States v. 11 1/4 Dozen Packages, etc., 40 F. Supp. 208 (W.D.N.Y. 1941).

62. 21 U.S.C. 341 (1973).

63. 21 U.S.C. 343(c), (g) (1973).

64. See Whole Fish Protein Concentrate, 38 Fed. Reg. 19815 (1973), which provides that the labeling of foods manufactured with this additive must bear the words "whole fish protein concentrate," this being sufficient because the additive name has become adequately established as the common or usual name and would be sufficiently informative to consumers.

65. 15 U.S.C. 52(a) (1973).

66. 15 U.S.C. 55(a) (1) (1973).

67. Id.

68. See, e.g., Carlay Co. v. FIC, 153 F. 2d 493, 496 (7th Cir. 1945).

69. See Handler, The Control of False Advertising Under the Wheeler-Lea Act, 6 Law & Contemp. Prob. 91 (1939); Vernon, Labyrinthine Ways: The Handling of Food, Drug, Device, and Cosmetic Cases by the Federal Trade Commission Since 1938, 8 Food Drug Cosm. L.J. 367 (1953).

70. Alberty v. FTC, 182 F. 2d 36, 39 (D.C. Cir.), cert. denied, 340 U.S. 818 (1950).

71. See Developments in the Law - Deceptive Advertising, 80 Harv. L. Rev. 1005, 1048-51 (1967).

72. Charles of the Ritz Distributors Corp. v. FTC, 143 F. 2d 676 (2d Cir. 1944).

73. FTC v. Sterling Drug, Inc., 317 F 2d 669 (1963).

74. Doherty, Clifford, Steers & Shenfield, Inc. v. FTC 392 F. 2d 921 (6th Cir. 1968).

75. Aronberg v. FTC, 132 F. 2d 165 (1943); FTC v. National Health Aids, 108 F. Supp. 340 (D. Md. 1952).

76. 143 F. 2d 676 (2d Cir. 1944). In FTC v. Sterling Drug, Inc., 317 F. 2d 669 (1963), the court found that the major factor in determining whether advertising is in violation of this statute is the probable effect which the advertisement will have upon the "eye and mind of the reader."

77. Doherty, Clifford, Steers & Shenfield V. FTC, 392 F. 2d 921 (6th Cir. 1968).

78. FTC v. Sterling Drug, Inc., 317 F. 2d 669 (1963).

79. Rhodes Pharmacal Co. v. FTC, 208 F. 2d 382 (7th Cir. 1954), modified on other grounds, 348 U.S. 940. Cf. J. B. Williams Co. v. FTC, 381 F. 2d 884 (6th Cir. 1967).

80. Another suggested means is to have a collective group of specialists, including members appointed by the federal government, inspect the facilities. See Colorado River Wildlife Council, Resolution of the Colorado River Wildlife Council Pertaining to Fish Disease Control on the Colorado River Drainage System.

81. See Proposed Current Good Manufacturing Practice Regulations for Oysters, Clams, etc., 21 C.F.R. Part 128g, developed by FDA; Shellfish Sanitation Branch, for an example of the role that can be taken by the FDA to assure quality control in the shellfishing industry.

82. See 38 Fed. Register 19815 (1973).

83. See 38 Fed. Register 34682 (1973).

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APPENDIX A. Biohazards of Vibrio parahemolyticus

Vibrio parahemolyticus is a gram-negative helophilic organism known in Japan as a cause of the offd-poisoning syndrome associated with the consumption of raw fish and shellfish (Staley and Colwell, 1973). The food poisoning due to this organism is thought to be of an infectious type resembling salmonellosis. The enteropathogenicity of the organism has been established by several human volunteer tests; positive results have been obtained only by administering living cultures. As yet, no enterotoxin-like substance has been demonstrated in culture filtrates.

Kaneko and Colwell (1973) have recently reported that more than 70 percent of the cases of food poisoning in Japan are caused by ingestion of seafood (fish and shellfish) contaminated with V. parahemolyticus. In Japan, food poisoning by this organism is restricted to the summer months, presumably because of the sensitivity of the organism to low temperatures. V. parahemolyticus was implicated in only one reported outbreak of food poisoning associated with the ingestion of infected crabmeat occurred in Maryland during the summer of 1971 (Kaneko and Colwell, 1973). The natural habitat of V. parahemolyticus is not fully known despite extensive studies of the distribution of this organism in the marine environment. In fact, it is not known whether this organism is truly of marine origin. However, it is generally accepted that its prevalence is highest in estuarine or coastal areas of the world's ocean. It has been suggested that V. parahemolyticus can survive the winter in sediment, in scavenger fish and shellfish, but the number of organisms isolated has been small.

The disease occurs mainly during the warm summer months. The incubation period ranges from six to 24 hours (average 14-20). The disease usually begins with violent epigastric pain accompanied by nausea, vomiting and diarrhea. In severe cases, mucus and blood are observed in the feces. Fever ranging up to 39°C (102°F) is observed in most cases. Because of these symptoms, the illness is often erroneously diagnosed as dysentery (Zen-Yosi et al., 1965). Epidemiological and etiological evidence suggests that only biotype 1 is enteropathogenic. The second biotype, V. alignolyticus, may also cause food poisoning, but is less prevalent.

Acceptable levels of V. parahemolyticus in shellfish or estuarine waters have not been determined in the United States. However, Oshiro (1971) reported 10 to 20 V. parahemolyticus per milliliter in a heavily polluted area in the Seto Inland Sea of Japan. Shellfish obtained from this area were responsible for a number of food-poisoning incidents.

Positive identification of V. parahemolyticus requires 72 to 96 hours. This time period is quite acceptable in a quality control system for mariculture. The commercial availability of multiple fermentation tubes and rapid enzyme tests will alleviate many of the man-hours and expense necessary to monitor for its presence. There is still a void of information regarding the geographical distribution of V. parahemolyticus in the coastal waters of the United States and factors affecting its survival.

APPENDIX B. Hepatitis

The best available data pertaining to quantitative assessment of the infectivity of hepatitis for man are those of Krugman and Ward (1960). They demonstrated that 0.1 g of feces from a patient with infectious hepatitis produced infection, whereas 0.001 g did not. Since the authors used jaundice as evidence of infection, and because their subjects were children in whom this disease most often runs an icteric course, their calculated ID_{50} of 1 to 2 g of stool is probably high.

Physicians have long recognized that its symptoms--inflammation of the liver accompanied by fever, weakness, loss of appetite, jaundice, malaise, headache, and muscle pains may arise from two distinct types of virus. Hepatitis A, also called infectious hepatitis, is generally transmitted by fecal contamination of food and water, and is responsible for some 90 percent of the more than 74,000 cases reported in the United States every year (Mough, 1972). Hepatitis B, also called serum hepatitis, is most frequently transmitted by infusions of blood from infected individuals. However, it is hepatitis A which constitutes the greatest potential danger to aquaculture.

The absence of clinical symptoms in the majority of the animals has necessitated the use of relatively new, highly sensitive techniques for confirmation of infection. Among the most important of these are radioimmunoprecipitation (RIP) which tests for HBHb (hepatitis B antibody), and radioimmunoassay (RIA) which tests for HBAb (hepatitis B antigen). It is conceivable that these techniques may eventually be adapted to the detection of hepatitis A also. RIP is reported to be 2,000 to 500,000 times more sensitive for detecting HBAb than previous methods, such as complement fixation. In RIP, radiolabeled HBAb is incubated with the serum being tested. Antigen-antibody complex, if present, is then precipitated and centrifuged. Radioactivity in the sedimented pellet then indicates the presence of HBAb in the serum. The use of a radiolabel makes the technique expensive, but the expense is justified by the increased sensitivity.

RIA is a solid-phase technique for detecting antigen and is of approximately the same sensitivity as RIP. In RIA, the serum or other sample (e.g., seawater) to be tested for antigen is incubated in a plastic tube whose inner surface is coated with antibody. The tube is then washed, radiolabeled antibody is added, and the new mix incubated. After a final washing, residual radioactivity in the tube then indicates the presence of specific antigen in the original sample.

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ENVIRONMENTAL PROTECTION AGENCY

■

AQUACULTURE PROJECTS

Requirements for Approval of Discharges

ENVIRONMENTAL PROTECTION AGENCY

[40 CFR Part 115]

AQUACULTURE PROJECTS

Proposed Requirements for Approval of Discharges

The Environmental Protection Agency hereby proposes to implement section 318 of the Federal Water Pollution Control Act, as amended; 33 U.S.C. 1251, 1328 (the Act). Section 318(a) authorizes the Administrator to permit, after public hearings and under controlled conditions, discharges of pollutants which are associated with an approved aquaculture project that is under Federal or State supervision. Section 318(b) requires the Administrator to promulgate regulations establishing procedures and guidelines necessary to carry out section 318.

The following features of the proposed regulations should be noted:

1. In view of the extremely broad definition of "pollutant" in section 502(6) of the Act, it would be virtually impossible to add any material to the navigable waters in connection with an approved aquaculture project than would not be also subject to provisions of the Act other than section 318. The regulations proposed today contemplate that discharges occurring within the designated project area of an aquaculture project may well exceed effluent guidelines that may be established under other provisions of the Act for discharges into navigable waters. At the same time, the legislative history of section 318 makes it clear that Congress intended that authorized discharges under section 318 should not contribute to water pollution outside the designated project area. In order to harmonize such expressions of Congressional intent with the manifest intent to permit agriculture projects under controlled conditions, the regulations proposed today provided in effect, that discharges of pollutants inside the designated project area may exceed other standards or limitations in the project area, but such discharges must not give rise to the addition of pollutants to the navigable waters outside the designated project area in quantities that would violate other provisions of the Act if the designated project area were itself a "point source" as defined in section 502 (14) of the Act.

2. Section 318 authorizes the Administrator to permit discharges of pollutants "associated with an approved aquaculture project under Federal or State supervision." The regulations proposed today provide that an aquaculture project is "approved" within the meaning of section 318 if EPA issues the operator of the project and the supplier of the pollutant a permit to utilize a discharge to the project pursuant to the procedures established in the regulations. The regulations assume that an aquaculture project is "subject to Federal or State supervision" within the meaning of section 318 where it receives a permit pursuant to the regulations since Regional Administrators would, under the proposed regulations, have the authority to revoke such a permit, thereby effectively subjecting the owner or operator of that project to supervision. There may, of course, be aquaculture projects that are subjected to other types of supervision under State law, but such projects would stand on no different footing than would acquaculture projects subject only to EPA supervision under the proposed regulations.

3. The Administrator's authority to permit discharges under section 318 is subject to a requirement for public hearings. The Agency believes that the requirement of a public hearing will be satisfied if an opportunity for public hearing is provided by the regulations. Thus, no public hearing would be required if no member of the public were to request one. Furthermore, it is EPA's position that a public hearing is a necessary prerequisite to the grant of a permit under section 318 only if a member of the public alleges facts which, if true, would be relevant to the decision of the Regional Administrator in accordance with the regulations. At the same time, the Regional Administrators would have discretion to call a public hearing without a request if there is substantial interest in, or objection to, the grant of a permit.

4. Section 401 of the Act requires that, prior to the time any Federal agency issues a license or permit to conduct an activity which may result in a discharge into the navigable waters, it must give an opportunity to the State in which the discharge originates to certify that any such discharge will comply with applicable provisions of sections 301, 302, 306, and 307 of the Act. With respect to discharges into the designated project area, they may well exceed effluent guidelines established under the provisions of the Act referenced in section 401, so that in many instances no State would be able to certify as required by section 401 if it were read literally. Accordingly, the proposed regulations assume that section 401 is not, strictly speaking, applicable to permits issued under section 318. However, they also provide that the State certifying agency under section 401 will be asked to certify that additions of pollutants to navigable waters outside the designated project area will not exceed the effluent guidelines established under sections 301, 302, 306, and 307 that would be applicable if the designated project area were itself a "point source."

Interested members of the public are invited to comment on the regulations proposed today by written submissions to the U.S. Environmental Protection Agency, 401 M Street, SW., Washington, D.C. 20460; Director, Water Quality and Non-Point Source Division. Prior to promulgation of the regulations in final form, all comments received on or before July 15, 1974, will be carefully considered. In addition, interested members of the public may inspect copies of all comments received at the above location during normal working hours.

In consideration of the forego[ing], [it] is proposed to amend Chapter I of [Title] 40 of the Code of Federal Regulation[s] [by] adding a new Part 115 as set fo[rth] below.

Dated: June 7, 1974.

JOHN QUARLES,
Acting Administrator.

PART 115—AQUACULTURE

Subpart A—General

AUTHORITY: Sec. 318, 501 of the Fe[deral] Water Pollution Control Act, as amended [(33] U.S.C. 1328, 1361).

Subpart A—General

§ 115.1 Definitions.

(a) All terms used in this part but [not] defined herein shall have the mea[ning] given them in section 502 of the Act.

(b) The term "Act" means the F[ed]eral Water Pollution Control Act, a[s] amended (33 U.S.C. 1251, et seq.).

(c) The term "discharge of pollut[ants] associated with an aquaculture pro[ject]" means the addition or discharge of a s[pe]cific pollutant(s) in a controlled ma[nner] from a point source to an aquacult[ure] project to enhance the growth or pro[pa]gation of the species under culture.

(d) The term "aquaculture pro[ject]" means a defined water area which [is] managed and uses discharges of a p[ol]lutant(s) into the designated pro[ject] area for the maintenance, propagation and or production of harvestable fre[sh]water, estuarine, or marine plant or a[ni]mal species.

(e) The term "designated project ar[ea]" means those portions of the navi[gable] waters within which the applicant [for a] permit pursuant to this part propose[s to] confine the cultivated species, util[izing] a method or plan of operation (includ[ing] but not limited to, physical confinement) which on the basis of reliable scient[ific] evidence is expected to insure that s[pe]cific individual organisms comprising [the] aquaculture crop will enjoy growth [at]tributable to the discharge of pollut[ants] mitted under this part, and suffer har-ting within a defined geographic area.

(f) The term "Administrator" means Administrator of the U.S. Environ-ental Protection Agency.

(g) The term "Regional Administra-r" means one of the ten Regional Ad-inistrators of the U.S. Environmental rotection Agency.

(h) The term "applicant" means an pplicant for a permit for a discharge of llutants to an aquaculture project.

(i) The term "permit" means any per-it or equivalent document or require-ent issued to regulate the discharge of llutants to an aquaculture project.

§ 115.2 Purpose and scope.

(a) The regulations in this part estab-lh the procedures and guidelines for pproval of an aquaculture project and r approval of any discharge of pollut-nts associated with an aquaculture roject.

(b) The regulations are intended to uthorize, on a selective basis, controlled scharges which would otherwise be un-awful under the Act in order to deter-ine, in a carefully controlled manner, e existing and potential feasibility of ilizing pollutants to grow aquatic or-anisms which can be harvested and used eneficially, and to encourage such proj-cts, while at the same time protecting her beneficial uses of the waters.

(c) The regulations in this part do not pply to those aquaculture facilities such s fish hatcheries, fish farms and similar rojects which do not utilize discharges f wastes from a separate industrial or unicipal point source for the mainte-ance, propagation and/or production of arvestable freshwater, marine or estu-rine organisms. Such projects are regu-ated under Title IV of the Act.

§ 115.3 Approval of discharges to aqua-culture projects.

(a) The Regional Administrator shall rant a permit authorizing a discharge f he determines that:

(1) Such discharge is associated with n aquaculture project, and

(2) The discharge and the aquaculture roject meet the requirements of the Act nd of this part.

(b) The granting of a permit for a ischarge pursuant to this part will mean hat the aquaculture project with which he discharge is associated is an approved quaculture project within the meaning f section 318(a) of the Act.

(c) All discharges of pollutants or ombinations of pollutants from all oint sources into the navigable waters, he waters of the contiguous zone or the cean are unlawful and subject to the enalties provided by the Act, unless the ischarger has a permit issued pursuant o this part, Part 125 of this chapter, or y a State which has an approved Na-onal Pollution Discharge Elimination ystem program pursuant to Part 124 f this chapter, or is specifically relieved y law or regulation from the obligation f obtaining a permit.

§ 115.4 Delegation of authority.

(a) The authority to issue and condi-tion permits or to deny applications for permits or to revoke permits for dis-charge pursuant to this part and section 318 of the Act is hereby delegated to each of the Regional Administrators for the area which he administers.

(b) The authority granted to the Ad-ministrator by sections 308 (a) and (b) of the Act is hereby delegated to each of the Regional Administrators for the area which he administers. Any action taken pursuant to section 308(b) shall be in conformance with the provisions of § 125.35 of this chapter.

Subpart B—Processing of Permits

§ 115.5 General provisions.

(a) The decision whether or on what conditions a permit authorizing a dis-charge will be issued shall be based upon an evaluation as to how such discharge will meet applicable requirements under the Act and this part.

(b) The expected impact of a proposed discharge or the present impact of an existing discharge in connection with an aquaculture project on the quality and uses of the receiving body of water also shall be considered. The objections of any State or interstate agency whose waters may be affected by the discharge shall be duly considered when making any permit decision.

§ 115.6 Application for a permit.

(a) An applicant for a permit may secure the required application form(s) from the Regional Administrator. Ap-plication form(s) must be filed with the Regional Administrator of the EPA Re-gion which includes the State in which the aquaculture project is operating or will operate.

(b) An application submitted by a cor-poration must be signed by a principal executive officer of at least the level of vice president, or his duly authorized representative, if such representative is responsible for the overall operation of the facility from which the discharge de-scribed in the application form orig-inate. In the case of a partnership or a sole proprietorship, the application must be signed by a general partner or the proprietor respectively. In the case of a municipality, State, Federal or other public entity, the application must be signed by either a principal executive officer, ranking elected official, or other duly authorized employee.

(c) Application for a permit or re-newal of a permit shall be accompanied by a payment of $1,000.00 to cover the cost of processing the application and project surveillance.

(1) Checks and money orders shall be payable to the Environmental Protection Agency.

(2) Agencies or instrumentalities of Federal, State or local governments will not be required to pay the fee provided for in this paragraph.

(d) The application for approval of a discharge to an aquaculture project shall be made jointly by both the supplier of the pollutant and by the operator. The supplier and the operator may be one person. Any permit issued shall be issued jointly.

(e) Applications for discharges to aquaculture projects presently in exist-ence shall be made within 180 days after the date of promulgation of these reg-ulations.

(f) Any person who plans to begin a discharge to an aquaculture project or plans to establish an aquaculture proj-ect shall apply for a permit no later than 180 days in advance of the date on which the discharge or the project is to be com-menced unless permission for a later application date has been granted by the Regional Administrator.

(g) An application for a permit shall include, at a minimum:

(1) Identification of the kind and quantity of pollutant(s) to be used in the aquaculture project.

(2) Available information on:

(i) The conversion efficiency of the pollutant to harvestable product,

(ii) The potential increased yield of the species being cultured, and

(iii) Any identifiable new product to be produced, including anticipated quan-tity of harvestable product.

(3) Identification of the species of or-ganisms to be cultured.

(4) Identification of the water quality parameters required for growth and propagation of the cultured species in-cluding, but not limited to, dissolved oxy-gen, salinity, temperature and nutrients, such as nitrogen, nitrates, nitrites, am-monia, total phosphorus and total or-ganic carbon.

(5) Identification of possible health effects of the proposed aquaculture proj-ect including:

(i) Diseases or parasites associated with the crop which could affect aquatic life outside of the designated project area and which could become established in the designated project area and/or in the species under cultivation;

(ii) The potential effects on human health;

(iii) Available measures for control of potential disease producing organisms associated with the aquaculture project;

(iv) Bioconcentrations in the crop in-cluding, but not limited to, radionuclides, heavy metals, and pathogenic organisms associated with the pollutant used; and

(v) Potential for escape of non-indigenous species from the designated project area.

(6) Identification of pollutants pro-duced by the species under culture, especially those which may be channeled into waste effluent such as ammonia, hydrogen sulfide, organic residues, phos-phates and nitrates.

(7) Identification of the disposal method to be used should there be a necessity for intentional destruction or a massive natural death of the organisms under culture.

(8) A map locating the site of the pro-posed aquaculture project, engineering

drawings indicating the general features of the project, and maps which locate man-made and natural geographic features in the area of the proposed aquaculture project.

(9) A completed Standard Form A—Municipal, or a Standard Form C—Manufacturing and Commercial, or their equivalents, as established in Part 125 of this chapter for the pollutant(s) to be discharged to the aquaculture project.

§ 115.7 Access to facilities and further information during evaluation of the application.

Permit application forms are designed to fit the normal situation for most aquaculture projects in the United States. In many cases, however, further information and site visits may be necessary in order to evaluate the project completely and accurately. When the Regional Administrator determines that either further information or a site visit is necessary in order for the Environmental Protection Agency to evaluate the aquaculture project, he shall so notify the applicant and in addition provide a date no later than 60 days hence by which time arrangements will have been made for receipt of the requested information and/or scheduling of the site visit. In the event that a satisfactory response is not received, the permit may be issued or denied and the applicant so notified.

§ 115.8 Distribution of application and permit.

(a) When an application for a permit is received, the Regional Administrator shall determine if the applicant has provided all of the information required by the application form and by this part.

(b) In order to insure that the Secretary of the Army, acting through the Chief of Engineers, has adequate time to evaluate the impact of the proposed discharge on anchorage and navigation, the Regional Administrator will forward to the District Engineer in the appropriate district one copy of the application form immediately upon its receipt in the regional office in completed form. Accompanying the application will be notice that the District Engineer has a stated number of days to evaluate the impact of granting such permit upon anchorage and navigation and to advise the Regional Administrator of his evaluation. District Engineers of the Corps of Engineers will normally be given 30 days for such evaluation. Where the Regional Administrator finds that less time should be allowed, he shall so advise the District Engineer of such lesser period of time and specify his reasons. Granting of this permit will not be substantially impaired by failure of the District Engineers to answer within the allotted period of time. Where the District Engineer advises the Regional Administrator that anchorage and navigation of any of the navigable waters would be substantially impaired by the granting of a permit, such permit will be denied and the applicant shall be so notified. Where the District Engineer advises the Regional Administrator that the imposition of specified conditions upon the permit is necessary to avoid any substantial impairment of any of the navigable waters, the Regional Administrator shall include in the permit the conditions so specified by the District Engineer. Where the District Engineer notifies the Regional Administrator that additional time is needed for his evaluation, such additional time shall be granted where the Regional Administrator determines that the public interest warrants the extension of time to comment.

(c) Complete copies of all applications for discharge of pollutants in association with an aquaculture project filed with the Environmental Protection Agency subsequent to final promulgation of these regulations shall be furnished to the Department of the Interior and Department of Commerce for comment, provided that these Departments may waive their right to receive any such applications. The Regional Administrator shall meet with appropriate officials of the Department of Interior and Department of Commerce in order to reach agreement as to which existing application forms those Departments are to receive. When an application is transmitted to these departments, the Regional Administrator shall notify the Departments that they have a stated number of days in which to evaluate the impact of granting such permit upon the fish, shellfish, and wildlife resources of the State in which the discharge will occur, and to advise the Regional Administrator of such evaluations. The normal period of time for such evaluation will be 30 days. Failure of such Departments to advise the Regional Administrator of their evaluation within the allotted period of time will be deemed to be a statement that the Departments do not choose to comment on the application. Where the Departments advise the Regional Administrator that the imposition of specified conditions upon the permit is necessary to avoid substantial impairment of fish, shellfish, or wildlife resources, the Regional Administrator may include in the permit the conditions specified by the departments. Where such departments request additional time for evaluation, such additional time will be granted where the Regional Administrator determines that the public interest warrants the extension of time to comment.

(d) Upon receipt of an application from a Federal Agency or instrumentality, the Regional Administrator shall make one copy of the application form available to the State water pollution control agency for the State in which the aquaculture project will operate. The State may comment on whether a permit for such aquaculture project should be granted or if any conditions should be applied to any permit that might be issued. The State should indicate conditions it believes are necessary in order that the aquaculture project will comply with sections 301, 302, 306 and 307 of the Act. Such comments shall be received within 30 days from receipt of the application form unless the Regional Administrator allows additional time.

(e) The Regional Administrator [illegible] applicants for permits in [illegible] coordinating the requirements of the Act and this part with those of appropriate public health agencies.

(f) If a permit is issued, a copy of the permit and, if not previously transmitted, a copy of the application form shall be transmitted to the State in which the discharge is located. Copies of these documents shall be available for inspection and reproduction by the public in the regional office.

§ 115.9 State certification.

(a) No permit shall be granted until a State certification has been obtained or has been waived, that discharges from the designated project area would meet the requirements of section 401 of the Act if the designated project area were a point source. A waiver occurs when the certifying agency fails or refuses to act on a request for certification within a reasonable period of time (which shall not exceed 1 year) after receipt of such request. Three months shall generally be considered to be a reasonable period of time. If, however, special circumstances require that action on a permit application be taken within a more limited period of time, the Regional Administrator shall determine a reasonable lesser period of time. He shall then advise the certifying agency of the need for action by a particular date, and that if certification is not received by the date established, it will be considered that the requirement for certification has been waived. Similarly, if it appears that circumstances may reasonably require a period of time longer than 3 months, the Regional Administrator may afford the certifying agency up to 1 year to provide the required certification before determining that a waiver has occurred. Where such extension of time is made at the request of the certifying agency, the request must be in writing and must include the reasons for the request.

(b) Upon receipt of an application which does not include a State certification, the Regional Administrator will make available one copy of the application form to the State water pollution control agency for the State in which the aquaculture project operates or will operate. The Regional Administrator shall advise the State agency that the State must:

(1) Certify that the aquaculture project will comply with the applicable provisions of sections 301, 302, 306, and 307; or

(2) Certify that there are no applicable limitations under sections 301, 302, 306 and 307; or

(3) Deny such certification; or

(4) Waive its right to certify or deny such certification.

The Regional Administrator shall specify a reasonable period of time within which such certification or denial must be received or a waiver will be deemed to have occurred.

(c) Discharges by agencies or instrumentalities of the Federal Government, as provided in section 401(a)(6) of the

Act, do not require certification pursuant to section 401.

(d) An application shall also be accompanied by statement from the State Fish and Wildlife Agency as to whether the project will be in compliance with State regulations on wildlife.

Subpart C—Criteria, Terms and Conditions of Permits

§ 115.10 Criteria for issuance of permits.

(a) No permit shall be issued unless:

(1) The Regional Administrator determines that the aquaculture project (i) is intended by the project operator to produce a crop which has commercial value (or is intended to be operated for research into possible production of such a crop); and (ii) does not occupy a designated project area which is larger than can be economically operated for the crop under cultivation.

(2) The applicant has demonstrated to the satisfaction of the Regional Administrator that the use of the pollutant to be discharged to the aquaculture project will result in an increased harvest of the organisms under culture over what would naturally occur in the area.

(3) The applicant has demonstrated to the satisfaction of the Regional Administrator that, if the species to be cultivated in the aquaculture project is not indigenous to the designated project area, there will be minimal deleterious effects on the flora and fauna which are indigenous to the area, that the total commercial value of the introduced species is at least equal to that of the displaced or affected indigenous species (or is intended to research into possible production of such a crop), and that there is minimal probability that the introduced species will serve as a carrier or vector of disease to man or to indigenous flora or fauna.

(4)(i) The Regional Administrator determines that effluents to water outside the designated project area of all pollutants from the aquaculture project will not violate water quality standards or violate effluent limitations applicable to the supplier of the pollutant established pursuant to sections 301, 302, 306, and 307 of the Act as if the designated project area were itself a point source. The approval of an aquaculture project shall not result in the enlargement of a pre-existing mixing zone area beyond that which had been designed by the State for the original discharge.

(b) No permit shall be issued if, in the judgment of the Secretary of the Army, acting through the Chief of the Corps of Engineers, anchorage and navigation of any of the navigable waters would be substantially impaired by the aquaculture project.

(c) No permit shall be issued for any aquaculture project in conflict with a plan or an amendment to a plan approved pursuant to section 208(b) of the Act.

(d) No permit shall be issued for any aquaculture project located in the territorial sea, the waters of the contiguous zone, or the oceans, except in conformity with guidelines issued under section 403(c) of the Act.

(e) Designated project areas shall in no event include a portion of a body of water such that a substantial portion of the biota indigenous thereto will be exposed to the conditions obtained within the designated project area. For example, the designated project area shall not include the entire width of a watercourse, since all organisms indigenous to that watercourse may thus be subjected to discharges of pollutants that would, except for the provisions of section 318 of the Act, violate section 301 of the Act.

(f) Any modifications caused by the construction or creation of a reef, barrier or containment structure shall not alter the tidal regimen of an estuary or interfere with migration of unconfined aquatic species.

(g) Any pollutants not required by or beneficial to the aquaculture crop shall not exceed effluent limitations established for such pollutants pursuant to the Act when entering the designated project area.

§ 115.11 Terms and conditions of permits.

(a) The Regional Administrator shall insure that the terms and conditions of the permit provide for and insure the following:

(1) That following notice and opportunity for a public hearing, the permit may be modified, suspended, or revoked in whole or in part during its term for cause including, but not limited to, the following:

(i) Violation of any terms of conditions or the permit;

(ii) Obtaining a permit by misrepresentation or failure to disclose fully all relevant facts; and,

(iii) A change in any condition that requires either a temporary or permanent reduction or elimination of the permit discharge.

(2) That the permittee shall allow the Regional Administrator or his authorized representative, and/or the authorized representative of the State water pollution control agency in the case of non-Federal facilities, upon presentation of his credentials:

(i) To enter upon the permittee's premises where an aquaculture project is located or where any records are required to be kept under terms and conditions of the permit;

(ii) To have access to and copy, at any reasonable time, records required to be kept under terms and conditions of the permit;

(iii) To inspect, at reasonable times, any monitoring equipment or method required in the permit; and

(iv) To sample, at reasonable times, any discharge of pollutants.

(3) That the permittee shall at all times maintain in good working order and operate as efficiently as possible any facilities or systems of control installed or utilized by the permittee to achieve compliance with the terms and conditions of the permit.

(4) That the issuance of a permit does not convey any property rights either in real estate or material, or any exclusive privileges, nor does it authorize any injury to private property or invasion of rights, nor any infringement of Federal, State, or local laws or regulations; nor does it obviate the necessity of obtaining State or local assent required by law for the discharge authorized.

(5) That if a toxic effluent standard or prohibition (including any schedule of compliance specified in such effluent standard or prohibition) is established under section 307(a) of the Act for a toxic pollutant which is present in the permittee's discharge and such standard or prohibition is more stringent than any limitation upon such pollutant in the permit, the Regional Administrator shall revise or modify the permit in accordance with the toxic effluent standard or prohibition and so notify the permittee.

(6) The Regional Administrator may suspend the permit on grounds of imminent and substantial danger to public health or to aquatic life outside the designated project area.

(b) A permit shall include such special conditions as are necessary to assure compliance with applicable effluent limitations or other water quality requirements including schedules of compliance, treatment standards, and such other conditions as the Regional Administrator considers necessary or appropriate to carry out the provisions of the Act. The permit shall also contain such other conditions as the District Engineer of the Corps of Engineers considers to be necessary to insure that navigation and anchorage will not be substantially impaired. Conditions recommended by State water pollution control officials, Federal and State fish, shellfish, and wildlife resources officials, or other governmental officials may be added to the permit if the Regional Administrator believes such recommended conditions will aid in carrying out the purposes of the Act.

(c) Permits are subject to periodic review and if not in compliance with these regulations may be suspended. Permits will be valid for five years, after which renewal application may be made.

(d) The issuance of a permit to discharge pollutants in association with an aquaculture project shall not relieve the permittee from public or private liability associated with the aquaculture project.

§ 115.12 Effluent limitations in permits.

In the application of effluent standards and limitations, water quality standards, and other applicable requirements, the Regional Administrator shall specify for each permit average and maximum daily quantitative limitations for the level of pollutants in the authorized discharge in terms of weight, or in the case of pH, temperature, radiation, and any other pollutants not appropriately expressed by weight, by an appropriate unit of measure based upon usual scientific practice.

§ 115.13 Monitoring, recording, and reporting.

(a) Any permit shall be subject to such monitoring requirements as may be reasonably required by the Regional Administrator, including the installation, use, and maintenance of monitoring equipment or methods (including, where appropriate, biological monitoring methods).

(b) Any discharge which the Regional Administrator requires to be monitored or contains toxic pollutants for which an effluent standard has been established by the Administrator pursuant to section 307(a) of the Act shall be monitored by the permittee for at least the following:

(1) Flow (in gallons per day); and

(2) All of the following pollutants:

(i) Pollutants (measured either directly or indirectly through the use of accepted correlation coefficients or equivalent measurements) which are subject to reduction or elimination under the terms and conditions of the permit;

(ii) Pollutants which the Regional Administrator finds, on the basis of information available to him, could have a significant impact on water quality;

(iii) Pollutants specified by the Regional Administrator, in regulations issued pursuant to the Act, as subject to monitoring.

(c) Each effluent flow or pollutant from the aquaculture project required to be monitored pursuant to paragraph (b) of this section shall be monitored at intervals sufficiently frequent to yield data which reasonably characterizes the nature of the discharge from the aquaculture project of the monitored effluent flow or pollutant and as approved by the Regional Administrator. Variable effluent flows and pollutant levels shall be monitored at more frequent intervals than relatively constant effluent flow and pollutant levels.

(d) The Regional Administrator shall specify recording requirements for any permit which require monitoring of the authorized discharge consistent with the following requirements:

(1) The permittee shall maintain records of all information resulting from any monitoring activities required of him in his permit;

(2) Any records of monitoring activities and results shall include, for all samples:

(i) The date, exact place, and time of sampling;

(ii) The dates analyses were performed;

(iii) Who performed the analyses;

(iv) The analytical techniques/methods used; and

(v) The result of such analyses.

(e) The permittee shall be required to retain for a minimum of 5 years any records of monitoring activities and results including all original strip chart recordings for continuous monitoring instrumentation and calibration and maintenance records. This period of retention shall be extended during the course of any unresolved litigation regarding the discharge of pollutants by the permittee or when requested by the Regional Administrator.

(f) The Regional Administrator shall require periodic reporting (at a frequency of not less than once per year) of monitoring results obtained by a permittee pursuant to monitoring requirements in a permit. Such reporting periods, the length of which shall be determined by the Regional Administrator, shall end on the last day of March, June, September, and or December.

Subpart D—Notice and Public Participation

§ 115.14 Formulation of tentative determinations and draft permits.

(a) The Regional Administrator shall formulate and prepare tentative determinations with respect to a permit in advance of public notice of the proposed issuance or denial of the permit. Such tentative determinations shall include at least the following:

(1) A proposed determination to issue or deny a permit for the discharge to and from the aquaculture project described in the application; and.

(2) If the determination proposed in paragraph (a)(1) of this section is to issue the permit, the following additional tentative determinations should be included:

(i) Proposed effluent limitations for those pollutants to be utilized, and

(ii) A brief description of any other proposed special conditions which will have a significant impact upon the discharge from the aquaculture project described in the application.

(b) The Regional Administrator shall organize the tentative determinations prepared pursuant to paragraph (a) of this section into a draft permit.

§ 115.15 Public notice.

(a) Public notice of every complete application for a permit shall be circulated in a manner designed to inform interested and potentially interested persons of the aquaculture project and of the proposed determination to issue or to deny a permit. Public notice of hearings shall be circulated in a manner designed to inform interested and potentially interested persons of the aquaculture project and of the intention to hold a hearing on the matter. Procedures for the circulation of public notice shall include at least the following:

(1) Notice shall be circulated within the geographical area of the proposed aquaculture project. Such circulation shall include any one of the following:

(i) Posting in the post office and public places of the municipality nearest the premises of the applicant in which the aquaculture project is located; or

(ii) Posting near the entrance to the applicant's premises and in nearby places; or

(iii) Publishing in local newspapers and periodicals, or, if appropriate, in a daily newspaper of general circulation; except that public notice of hearings shall be published in at least one newspaper of general circulation within geographical area of the discharge in cases.

(2) Notice shall be mailed to the applicant and to any person or group upon request; and

(3) The Regional Administrator shall add the name of any person or group upon request to a mailing list to receive copies of notices for all applications within the State or within a certain geographical area.

(4) The Regional Administrator shall notify Federal and State fish, shellfish, and wildlife resource agencies and other appropriate government agencies of each completed application for a permit and of hearings and shall provide such agencies an opportunity to submit their written views and recommendations on each completed application.

(b) (1) Where notice is being given of an application for a permit, the Regional Administrator shall provide a period of not less than 30 days following the date of the public notice during which time interested persons may submit their written views concerning the tentative determinations or request that a hearing be held. All written comments submitted during the 30 day comment period shall be retained by the Regional Administrator for a period of 3 years and considered in the formulation of his final determinations with respect to the application. Extensions of time for the receipt of comments following the end of the comment period may be granted by the Regional Administrator when the public interest warrants.

(2) Where notice is being given of a hearing, the Regional Administrator shall provide a period of not less than 30 days following the date of the public notice during which time interested persons may prepare themselves for the hearing.

(c) The contents of public notice of an application shall include at least the following:

(1) Name, address, and phone number of the regional office issuing the public notice;

(2) Name and address of each applicant;

(3) A brief description of each applicant's activities or operations which utilize the discharge described in the application including a statement of whether the application will result in a violation of water quality standard outside of the project area;

(4) Name of waterway in which the aquaculture project is to be constructed;

(5) A brief description of the procedures for the formulation of final determinations, including the 30 day comment period required by paragraph (b) of this section and any other means by which interested persons may influence or comment upon those determinations; and

(6) A statement of the tentative determination made pursuant to § 115.14;

(d) The contents of public notice of any hearing shall include at least the following:

(1) Name, address, and phone number onal office holding the hearing;

() Name and address of each appli- whose application will be considered he hearing;

() Name of the waterway and a short iption of the location where the culture project is or will be located;

() A brief reference to the public e issued for each application, includ- identification number and date of ance;

(5) Information regarding the time location for the hearing;

() The purpose of the hearing;

(7) Address and phone number of mises at which interested persons y obtain further information, request copy of each draft permit prepared rsuant to § 115.14, and inspect and y forms and related documents; and

() Where applicable, a statement that nfidential information has been re- ved that may be used to determine e of the conditions for the permit.

(e) The Regional Administrator, in his cretion, may include in any notice of plication for a permit under para- aph (c) of this section a notice of hear- g in accordance with paragraph (d) of s section, whether or not any request such hearing shall have been submit- d to him.

(f) If individual States, in connection with applications for certification required by § 115.9 wish to enter into agreements for joint Federal-State public notice concerning permits, the Regional Administrator may, after consulting with the headquarters of the Environmental Protection Agency approve mutually satisfactory agreements consistent with this section.

§ 115.16 Public hearings.

(a) Any applicable effected party may, within 30 days of compliance by the Regional Administrator with the provisions of § 115.15, object to the issuance of the permit described in the public notice, and may request a public hearing.

(b) Within 10 days of receipt of any request for a public hearing under paragraph (a) of this section by any person who alleges facts which, if true, would be relevant to the decision to grant or deny the permit, the Regional Administrator shall call a public hearing, to be held as near as may be practicable to the location of the proposed aquaculture project. Notice of any such hearing shall be given under § 115.15 and shall be given not less than 10 working days prior to the time scheduled for the hearing. The Regional Administrator may convene a public hearing in any other case in which he determines there is substantial public interest in, or opposition to, the proposed permit, including any case in which his tentative determination is to deny the permit.

(c) Hearings convened pursuant to paragraph (b) of this section shall be conducted before a presiding officer to be designated by the Regional Administrator. The presiding officer shall have the authority to limit the introduction of irrelevant or repetitious evidence, and to limit cross-examination. Following the conclusion of the hearing, the presiding officer shall, within 15 working days, submit written findings and recommendations as to whether the tentative determination of the Regional Administrator should be adhered to, or modified in any respect.

§ 115.17 Public access to information.

Certifications issued pursuant to § 115.9, the comments of all governmental agencies on a permit application, and all information and data provided by an applicant or permittee identifying the nature of the aquaculture project shall be available to the public in accordance with the requirements of section 308(b) of the Act.

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APPENDIX D. A Model for Social Cost/Benefit Considerations in Decision-Making for a Marine Waste-Food Recycling System

D.1 Multiobjective Decision-Making

Where objectives are agreed upon, and where the contributions of projects and programs such as waste-food systems to objectives are clear, and where there are no conflicts among objectives, then social decisions are straightforward. However, in the usual case, it appears that there tend to be conflicts among the various social objectives that new programs affect, and so a way must be found to present the important conflicts among objectives to decision-makers. Multiobjective decision-making provides a suitable means for presenting these choices.

We can suppose, without loss of generality, that we are considering the implementation of waste-food systems in a particular area, say, New England, and even a particular urban area where the necessary waste products and/or thermal enrichment are present. What are the objectives of such a system? We wish to consider all relevant and important social objectives that might be affected by such a system, but at the same time to avoid clouding the basic issues or use scarce planning resources in the analysis of effects that are not important. A useful criterion is to analyze the effects of a project on those objectives which are both socially important (perhaps only to certain groups), and which also can be expected to be substantially affected by the project.

For the sake of illustrating the methods, we can assume that the objectives of a waste-food system in a particular New England city are to increase the economic well-being through the production of desired goods (in this case, food products) and to improve health, or at least to avoid serious effects on health due to the use of waste-grown organisms. An actual system would almost certainly have a much more extensive and complicated set of objectives.

The selected economic objective is referred to by economists as the "national income" or "aggregate consumption" objective. There are rules that are well defined theoretically for the estimation of the national income effects of a project, and these rules have long been implemented, at least in part, in water resources projects in the United States and in many types of projects supported by, for example, the World Bank. Descriptions of the rules can be found in Marglin, 1967, and UNIDO, 1972. Thus, in principle we can estimate the positive and negative impacts of a waste-food system on the national income.

Estimating the effects of such a system on health is less common in planning than the estimation of national income effects but we can conceptualize the problem in much the same way. We wish to relate different designs of a waste-food system to the levels of health related to them. To do this, we can, in the simplest case, have a count of incidence of disease per 1,000 population, say, where only one disease is involved; or, where several diseases or dimensions of health are involved, we have to have an index of health (or we could make the analysis multidimensional). Developing such an index is conceptually the same as developing an index of, say, environmental quality (Leopold, 1969). Needless to say that in the absence of good quantitative data, which seems to be the current case with waste-food systems, such an index can have a high subjective content. With health effects, just as with national income effects, we wish to measure the "with and without" effects of a particular waste-food system. This means that, even if the products of the system have to some extent a deleterious effect on health, the implementation of the system could actually improve the overall health of a population because the food that the waste-grown food would replace might in fact be worse for health. Thus, the net effects on health of a waste-food system might be either positive or negative.

For the particular city or area under consideration, there will be a variety of investment/management measures possible that can produce different types of waste-food systems. We wish to display the effects of each possible alternative on our two objectives. To do this, we can consider Figure D.1. In this figure, effects on the national income objective are displayed on the vertical axis, and effects on the health objective are displayed on the horizontal axis.

In such a display, we focus on the net effects of a particular technical alternative on the objectives. (In a more complex presentation, where budget constraints are relevant, cost can be treated as an additional objective parameter and similarly traded off.) Moreover, we are interested in being able to aggregate net impacts toward a particular objective over time. To do this, we find an appropriate interest rate for that objective, and discount the impacts to the present time (or other base year, as convenient). This is normally done in economic analysis. On the other hand, the idea of aggregating impacts over time for an objective like health is a relatively new one in project analysis (see Marglin, 1967).

If this is too difficult for decision makers to deal with effectively, we can simply display all of the effects labeled with the time of their occurrence, and allow choices of time-preference to be implicit in the choice of one or another version of our waste-food system. (For this type of "bottom-up" decision-making, see UNIDO, 1972.)

In the figure, increases in national income are shown above the origin, and decreases are shown below. In terms of traditional benefit-cost analysis, then, a project with a benefit-cost ratio of less than one on the income account is a project represented by some point lying below the horizontal axis in the graph. On the horizontal axis, the net improvements in the health of the population resulting from the implementation of a waste-food system are represented by points to the right of the origin, and net decreases in health are represented by points to the left.

Now, in the two-dimensional space shown there will be a point representing each possible investment/management alternative in the development of a waste-food system. The relationship between a particular type of project and net-benefit space has to be estimated by technical personnel, probably representing many disciplines since it depends on social, economic, physical, and biological factors. The set of points in objective or net-benefit space that it is possible to achieve through all technically possible waste-food systems is called the feasible set. (Note that, because we plot net benefits or impacts, we cannot read gross costs, for example, from the graph; we have to go to planning documents to get these.) The feasible set will of course have some boundary. If it is supposed that certain waste-food systems will increase net disease in the population, we will have some points to the left of the vertical axis. Whether the maximum point of economic benefit on a net basis is to the left or right of the vertical axis depends on the actual case. In Figure D.1 it is shown for convenience as lying to the right of the axis, which is to say the optimal system from the standpoint of the national income also decreases net disease to some extent. This is only illustrative, of course; it is not even a hypothesis. (We should note here that the strictly national income effects of diseases are <u>included</u> in the national income axis; the choice of health as an objective shows that we are concerned with this objective for reasons beyond the national income effects of health.)

We can illustrate the effects of new marketing and health developments on our situation by considering a system in which there is consumer resistance to waste-grown food items. Suppose that this resistance is not soundly based on scientific fact, and can be overcome by an educational campaign. Then, if we have a relatively cheap educational campaign, with relatively good results, we have the situation in which the boundary of the feasible set shifts upward (not necessarily symmetrically) toward higher national income effects (given certain provisos discussed in Section D.4).

If we discover some new system management technique or process that results in a reduction of the disease potential of the system, then we might be able to reduce the negative health effects resulting from our systems, and so shift the boundary of the feasible set toward the right, toward options with better health effects.

This estimation of the feasible set is an important responsibility of technical personnel; and, to the extent that waste-grown food items face increasingly sophisticated regulatory agencies and consumer groups will have to be done. If this cannot effectively be done, due to lack of basic data resulting in large uncertainties, research effort will have to be applied to develop the technical information required for design-making. The estimation of the feasible set represents what might be called the technical side of multiobjective decision-making.

The value side can be represented in Figure D.1 by a family of social welfare curves, labeled W1, W2, etc. Each such curve represents a locus of points of equal social welfare. On the general supposition that more benefits toward each objective are better than fewer, the social welfare curves increase in value as we move to the northeast (as we have defined our axes in the graph). Each curve is better than all the curves lying to the southwest of it. While it is true that in the general case we cannot assume that a reasonably-shaped group of curves can be developed from a political process (this is the famous point proved by Arrow, 1963), nonetheless there are many situations where we suppose that reasonable choices can be formulated on the basis of social preferences. In any case, we must confront social preferences in dealing with waste-food systems. In the most general case, we suppose that we look toward a detailed legislative process for the development of social preferences

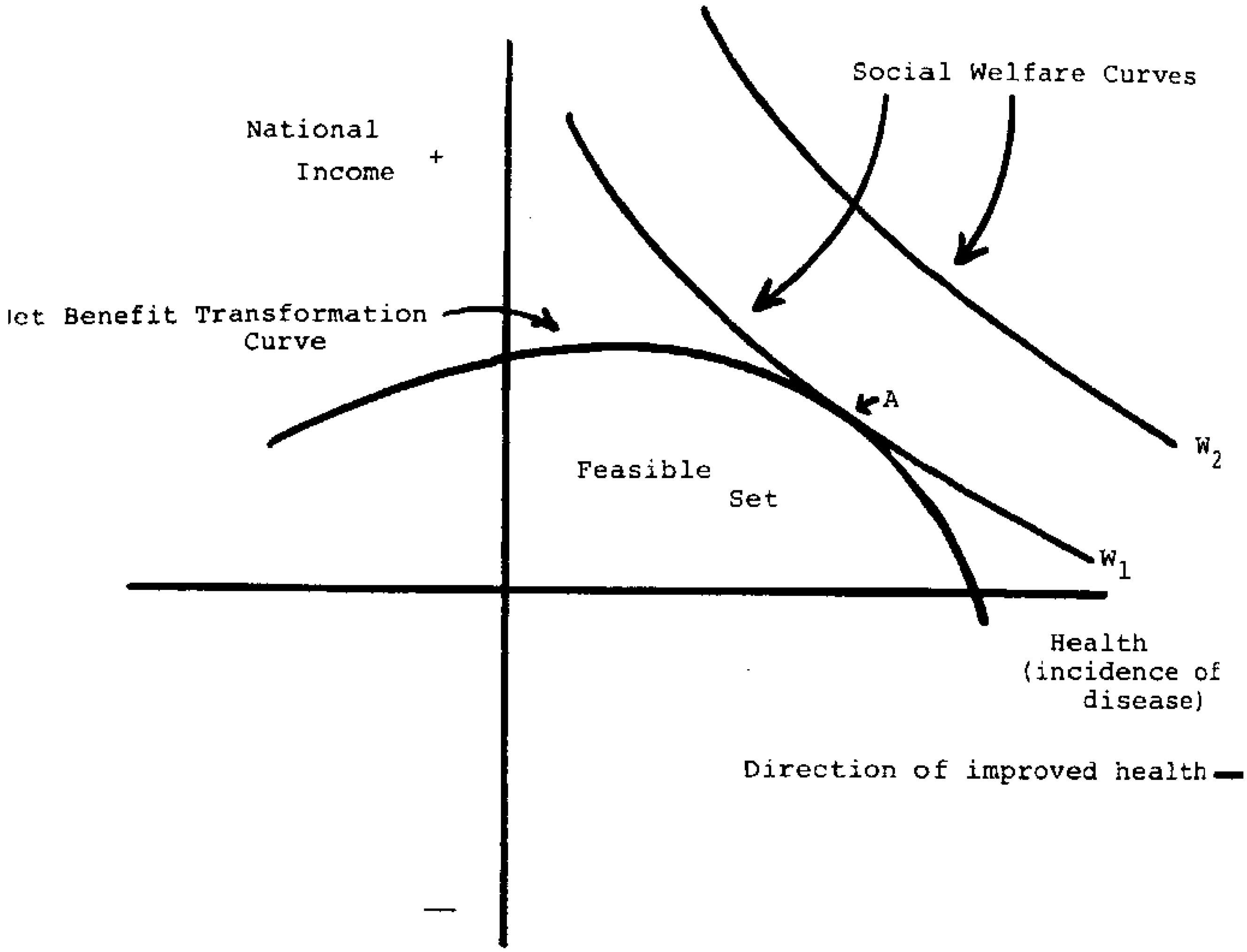

Figure D.1

Multiobjective Analysis of Waste-Food Systems

(Maass et al., 1962, Ch. 15), but, in our particular case, we might simply wish to assume that social preferences are expressed by the relevant regulatory agencies, and, perhaps, by consumer groups.

Now, it is obvious that the best system design must be represented by the net benefit combination at the point of tangency of the feasible set to the highest attainable social welfare curve. In Figure D.1 this point is at A. This shows that in the example the socially most desirable point is not the one that is economically most desirable; rather, the regulatory agencies would be willing, if their preferences are as shown on the graph, to give up some economic benefit from waste-food systems to achieve higher levels of health.

D.2 Applications of this Analysis to the Waste-Food Problem

Evidently there are three things to be done in applying this analysis. Objectives must be chosen; the transformation curve must be developed; and there must be interaction between the preferences of decision-makers and the technical possibilities shown in the transformation curve. All of these things have been applied to some extent in the area in which these techniques have been most highly developed, i.e., water resources. For example, transformation curves for multiobjective systems have been developed by mathematical programming (Cohon and Marks, 1973). While these methods have not been applied so far as is known for problems of mariculture systems, there is no reason why, at a minimum, information on these systems cannot be organized in these forms even if mathematical modeling techniques are not utilized. However, the problem of setting objectives, defining feasible sets, and interacting with decision-makers is at best a very difficult problem and is abounding in pitfalls. This is counterbalanced by the fact that this method provides a rational way of organizing and structuring difficult many-faceted decisions, and has already been applied in analyzing related water resource problems.

D.3 Other Objectives in Waste-Food Systems

The two objectives used for illustration will no doubt be important in many waste-food system problems. However, other objectives must also be included. Thinking of a particular New England city or area, one can suppose that accounting for regional economic effects will be important in many real cases, as will accounting for effects relating to environmental quality objectives. The regional income objective, like the national income objective, is the subject of well-defined accounting rules; environmental quality objectives are rather like health objectives in that they are multidimensional and can be represented by indices of various types. In addition to these objectives, there will also be possible distributional objectives, for example, the effects of a system on the health of persons in different income or social classes. For some countries, although not necessarily the United States, balance of payment objectives will be important. We can also note here that the probability distributions of some effects--as, for example, the probability of a disaster event in the area of public health that might result from a failure in a waste-food system--should also be objects of social preferences.

D.4 Estimation of True National Income of "Aggregate Consumption" Benefits from Waste-Food Systems

D.4.1 Major Considerations

This section relates to the assumption that during the next five or ten years when it is possible or probable that waste-food systems will begin substantial production the regulatory agencies and consumer groups will require increasingly sophisticated assessments of true social costs and benefits if these systems, assuming their social worth, are to be accepted. In the foregoing sections we presented a method of displaying and analyzing the basic distinction in the assessment of the "economic" effects of these systems.

This distinction is the distinction between commercial profitability and increases in national income or "aggregate consumption." Commercial profitability is the difference between cash inflows to the firm and its cash expenditures, gains which will in general not be the same as commercial profitability in real market situations. The differences arise because, in the actual working of an economic system, the structure of the system is different from the assumptions of the purely competitive system from which the market derives much of its normative significance; so we cannot necessarily impute true economic benefits to systems that appear to be economically feasible in the commercial profitability sense.

An excellent discussion of this distinction can be found in UNIDO, 1972, pages 18-26. The basic notion of a market economy that gives it a normative significance is that in the marketplace each individual is paying exactly as much as he wishes to pay out of his income for each type of good or service, and is offering as much as he desires of the factors of production at his command (his labor, for example) in the market. At the same time, it is assumed that the costs of production of every good and service reflect accurately the true costs to society of the use of the factors of production employed in the production of that good or service (the rule or price = marginal cost). In other words, the market is functioning on a perfectly competitive, decentralized basis with appropriate prices.

Under these circumstances (precise definitions can be found in, for example, Henderson and Quandt, 1958), a normative significance can be imputed to the market; in project evaluation, we can assume that the commercial cash flows that are produced in such markets are proper reflections of the benefits and costs of a system on the national income account. The great benefit of such a situation would be, of course, that it would simplify the problem of estimating the economic worthwhileness of alternative proposed projects, such as waste-food systems. (Neverthless, the question of prediction of the appropriate costs and benefits would remain always a difficult question.). We could simply assess all inputs and outputs at market prices, confident that these represented appropriate social values.

However, in actual market situations the conditions required for the equality of commercial cash flows and social gains and losses in consumption do not hold. When they do not hold, then the problem of assessing the true contributions of a project to aggregate consumption are made more difficult. In fact, in the general case, it would be impossible to correct for all market distortions, and so, in practice, we can never really measure true gains and losses on the national income account. What has been done in benefit-cost analysis is to elaborate the reasons why distortions in market might occur, and then to work from these insofar as possible to make corrections for a particular project.

In this section, we provide several examples of types of market distortions that might be of relevance for the evaluation of waste-food systems. These should serve as a kind of checklist for the assessment of various waste-food project alternatives.

D.4.2 Inadequate Pricing Schemes

An inadequate pricing scheme can result in inappropriate calculation of the gains and losses to aggregate consumption from a waste-food system. This possibility is especially likely in the context of systems such as those dealt with in this report since these systems are related to public systems for which pricing schemes are frequently inadequately developed or not developed at all. For example, one input to the systems discussed here is sewage effluent. If this effluent has alternative profitable uses, such as in spray irrigation, then there should be a charge for its use in the waste-food system that reflects its value in the alternative use of spray effluent. If in fact the sewage is received free by the waste-food plant, then the waste-food plant will not be accounting for all of the true costs of the process in its commercial-profitability accounting.

Another example that is likely to arise in the waste-food systems discussed here deals with interaction in the production functions of the three main systems involved (sewage, power, and waste-food). (For a discussion of the idea of a production function, see Henderson and Quandt, 1958, or Maass et al., 1962, Chapter 3.) Suppose, for example, that from time to time (as emergency conditions occur, the need for more heat effluent in winter) the sewage plant or the power plant are operated not in terms of optimization of their contributions to social consumption alone, but rather partly in terms of the needs of the waste-food plant. Such a change in operation, assuming that the plants had previously been operated in an optimal manner, would imply that, for the sake of maintaining operations in the waste-food system, aggregate comsumption benefits are given up in the power or sewage plants. This reduction in benefits must be accounted as a charge to the waste-food plant. However, it is not at all certain at the present time that systems such as sewage systems and power systems are set up with appropriately sophisticated accounting systems to provide this information on a routine basis. Nevertheless, it must be estimated if the true social consumption benefits of the waste-food system are to be accounted for. To complicate the matter further, it might well be that the electricity plant and the sewage plant, being (generally) regulated monopolies, do not themselves produce the correct amounts of their respective services (sewage treatment and electric energy) from the aggregate consumption point of view. In such a case, which might be the general case, one would have to assess not only the paper loss in net benefits to the other plants if the operating policies were altered to accommodate the waste-food plant, but also the true economic changes incumbent upon such changes in operating policy.

D.4.3 Externalities

A broad class of effects that must be taken into account in economic assessment of waste-food systems is the well-known type of effect called an externality. Here, the activity of one production process affects the activities of another outside of the market process. For example, an upstream factory might pollute the stream on which it is located, raising costs of production (due to purification requirements) for a factory downstream. There is no general way in which such a cost, which is imposed on society by the upstream factory, can be shifted onto that factory in the marketplace. Hence, the costs of the upstream factory in dollar terms understate social costs, and the costs of the downstream factory in dollar terms overstate social costs. Some nonmarket mechanism, such as a taxing or regulation scheme, is required to correct the situation. Waste-food production processes, being located presumably in urban areas near the sources of sewage and thermal enrichment, might well cause externalities; these might be both positive and negative. A positive externality might be that the waste-food installation provided for a quieter harbor for pleasure craft than otherwise might exist because of breakwaters, etc., that are constructed together with the waste-food system. In this case, the benefits accruing to the owners of the pleasure craft should be attributed to the aggregate consumption account of the waste-food system. A negative externality might result from the generation of certain waste products from the operation of the waste-food system. These might affect other consumption or production activities in the immediate area in a negative way and, if so, these debits would have to be incorporated into the aggregate consumption account of the waste-food system. (Note that there might also be positive externalities from the reduction of certain other types of waste that are used in the production process in the waste-food system.)

There are also negative and positive externalities in consumption. These arise when the welfare or utility of one person is affected not only by his own consumption, but by the consumption or lack of consumption of others. (Remember that the arguments of the indifference curves for the consumer in traditional economics are only his own levels of consumption of goods and services.) When these externalities exist, the market pricing mechanism does not give us a clear picture of the total consumption values arising from a system; it reflects only the utilities of the buyers of the product. That such effects might exist in the waste-food industry is illustrated by the existence of our own project. If there are negative feelings about eating waste-grown products, these feelings might well apply to others' use of these products as well as our own. Such effects are rarely taken into account in economic assessments, although they might be partially taken into account in the market in our case, since restaurants might not demand our products if they are required to identify them as waste-grown because of the negative effects they might have on those of their customers who do not choose to eat the products themselves, but, nonetheless, are unpleasantly affected by their existence in the same restaurant as the one in which they are eating. However, there is no guarantee whatever that, in fact, these effects will be completely and correctly taken into account in the marketplace. Positive effects are also possible; perhaps some persons would be positively affected by the fact that others are consuming the products of ecologically useful systems. In such a case, the aggregate consumption benefits of our products would be understated if only the cash flows from consumers' purchases were counted.

D.4.4 Unemployed Resources

A further effect that must be taken into account in assessing true aggregate consumption contributions from a waste-food system arises from the possible use in such a production process of resources that are otherwise unemployed or underemployed. Where resources (say, labor utilized in the production process for waste-food systems) are unemployed, their cost to the nation on the aggregate consumption account is zero, but, in fact, the employer must pay some positive wage--in fact, probably one set by law or custom in the area and industry. Hence, although the cash expenditures of the system are positive, the true cost on the aggregate consumption account is zero, and this must be taken into account in the evaluation of the system.

D.4.5 Taxes and Subsidies

From the aggregate consumption point of view, taxes and subsidies are simply transfers (at least in the first order effects) and therefore must be taken out of the calculations when estimating the true aggregate consumption benefits of the waste-food system. Insofar as the system must be taxed, for example, the cash profitability account of the system will understate the true economic profitability of the system. Subsidies to the system must be taken into account in a reverse way. While taxes and subsidies are pervasive throughout the economy so that it is hopeless to attempt to correct for their effects on an overall basis, still it is probably useful to attempt to make the appropriate adjustments for the taxes and subsidies which immediately affect the waste-food system.

All of these--and some more complicated problems--are well elaborated in the references given above, as, for example, Henderson and Quandt, 1958; UNIDO, 1972; and Maass et al., 1962. It should be emphasized here that for commercial profitability to measure contributions of a waste-food system to aggregate economic consumption, all private costs must exactly equal social costs; there must be no taxes or subsidies and no externalities in consumption. Obviously, all of these conditions do not hold, and so in general we must try to estimate the deviations of commercial profitability from aggregate consumption. The points made in this section--and in more detail in the references cited--can be used as a kind of checklist to see that such corrections are made when waste-food systems are presented for consideration to regulatory agencies and consumer groups. Such a checklist appears to be particularly useful because in much of the literature to date on waste-food systems commercial profitability is the focus of discussion (for example, J. R. Davidson); and commercial profitability, while it might guarantee the operation of the systems if these are to be in the private sector, nevertheless does not guarantee an accurate representation of aggregate consumption benefits.

APPENDIX E. Pilot Study on Consumer Attitudes Toward Waste-Grown Fish

Three concept statements were generated, which included the attributes of the cultured product which distinguish it from naturally-occurring fish. It was intended to design three concepts in decreasing order of favorability towards the product; one was designed to be "neutral," and one each to be biased favorably to the concept and unfavorably. The results of presenting the concept-statements, one each to a small number of respondents, would indicate the differences in response arising through small differences in the wording of the statements. Thus, if a statement elicited responses which showed great sensitivity to the wording of the statement, we would have an idea of the amount of variability inherent in this method of generating responses.

The statements generated are as shown in Section E.1. Each was roughly 200 words in length and was kept as simple as possible in order not to tax the respondents' capacities too much. The M.I.T. seal on top of the statements was intended to add a degree of authenticity to both the survey itself and the idea of the technological innovation being presented. As noted above, the objective of the pilot study itself was to generate a list of attitude statements in response to the concept, and to study the variation in preferences due to the wording of the concept statements.

Four respondents ranked the three concept statements in terms of their degrees of favorability towards the concepts presented. They were asked to indicate which was most positive or favorable, and which least positive or favorable. All four respondents rank-ordered Stimuli numbers 3, 1 and 2 in terms of decreasing favorability. The probability of this occurrence, given independence among the respondents and a random order of presentation on concept statements, is less than 0.001. Since this was not a major part of the entire research effort, it was considered an adequate test of differences among the three presentations.

Forty-three housewives were selected at the author's convenience. These represented a fairly wide cross section of the population ranging from lower-middle-class, conservative housewives to very sophisticated upper-middle-class, liberal, highly-educated academicians. (Some had Ph.D.'s in nutrition and biology, and were doing research at M.I.T.) However, no claim is made as to lack of bias in sampling. All respondents were women who agreed to participate at first contact, and ate fish at least every fortnight. Housewives were contacted by telephone and those agreeing to participate were mailed one concept statement each and a copy of the questionnaire (see Section E.1), provided they consumed fish at least once every two weeks.

The intent of Question 1 was to determine how the cultured product would be perceived if the respondent's favorite fish were available at the same place and time in both its cultured and normally-grown forms. Since price is often a crucial issue in determining the economic viability of new products, the second question was designed to elicit an opinion on what could be considered a "fair" relative price for waste-grown cultured fish. The third question was the most important, and used an open-ended format to acquire reasons for responses to the other two questions

Since the questionnaires were mailed, and returned also through the mail, some respondents did not return the concept statement. No control could be exercised over this since the eventuality had not been foreseen. Such respondents are grouped below under the head Stimulus #?.

Section E.1 gives a summary of the results obtained. Only 2 of 43 respondents failed to answer the first two questions, but the nonresponse to the open-ended attitude questions was 8 of 43 respondents. This is only to be expected because of the open-ended nature of this question.

In total, 49 comments were made. These are shown in Section E.1 along with the Stimuli that elicited them.

Responses to Questions 1 and 2 were subjected to a chi-square analysis to test the hypothesis of no difference in response means for the Stimuli statements. Responses to both questions indicated that no statistically significant differences could be detected.[1]

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1. $X^2_{15} = 21.4449$, $p = 0.1287$ for Question #2. $X^2_{15} = 17.3985$, $p = 0.296$ for Question #1. Due to the small sample sizes, the expected value criterion may not have been met. Collapsing the categories for "Stimulus #?" and the "No response" class did not lead to statistically significant differences.

E.1 Questionnaire Data

a) Stimulus #1: A Novel Concept in Fish Farming

b) Stimulus #2: A New Concept in Fish Farming

c) Stimulus #3: A Novel Way to Grow Fish

d) The Questionnaire Used in the Pilot Study

e) Table E.1: A Classification of Responses Obtained from the Preliminary Questionnaire

f) Table E.2: A 2-Way Classification of Responses to the Purchase Intention and Fair Price Questions, by Stimulus Number

g) Lists of the Attitudes Elicited by Each Stimulus

A NOVEL WAY TO GROW FISH

A new and exciting way to grow fish in ponds is underway. Domestic and industrial sewage will be dissolved in water, and solid impurities removed. The water will be further purified, and then used to grow simple organisms known as "algae." The algae are the usual food eaten by fish, and they will be fed to fish in controlled ponds, which will be located near power plants on the coast-line. The ponds must be kept at selected temperatures, and this will be done by using the waste heat from the power plants during winter. The ponds will be quite small, and will put out fresh water for recreational and other uses. Thus sewage disposal, fresh water and fish production will be simultaneously achieved.

The fish itself will be of the highest quality--their color, smell, size, taste and texture will be as good as, or better than, those of the fish we eat today. Since all factors will be controlled, and their freshness is assured by "harvesting" them at the right time, and they will be available all year round. Since scientists know exactly what goes into the system, the dangers of chemicals, bacteria and viruses will be less than for ocean-grown fish. Safety for human consumption will be assured by obtaining the permission of the Food & Drug Administration before selling any cultured fish. It is believed that all kinds of fish can be grown in these ponds.

A NEW CONCEPT IN FISH FARMING

A novel idea is being intensively developed to use domestic and industrial sewage, as well as waste heat from power plants, to grow fish for human consumption. The process involves treating the sewage to remove solids, and then further purifying the water. This water is a very good medium for growing "algae," which are simple organisms that fish feed upon. The entire process is controlled by trained personnel, and the algae are then fed to fish in special ponds. The ponds are kept at certain temperatures, using the waste heat from the power plants during the winter. Portions of the coast-line near power plants are to be converted to ponds to breed these "cultured" fish.

Scientists working in this area believe that cultured fish can safely be eaten, since the presence of bacteria, viruses and chemicals can be controlled to very low levels--possibly much lower than in the fish we eat today. The fish will be really fresh, since they do not have to sit on large fishing boats for a long time, and can be "harvested" as and when desired. The scientists claim that the color, taste, smell, size and texture of these fish will be as good as, or better than, those of the fish commercially available today. The permission of the Food & Drug Administration will be sought before these fish are sold in the market. It is believed that all kinds of fish can be grown using this process.

QUESTIONNAIRE.

After you have finished carefully reading the accompanying concept, please answer the following questions.

1. Would you consider buying the cultured product if your favorite kind of fish were locally available, along with the cultured variety? Please circle the appropriate number.

   5. Definitely
   4. Perhaps
   3. Undecided
   2. Unlikely
   1. Definitely not

2. Given the availability of both the cultured and the normal variety of your favorite fish, what price would you consider appropriate for the cultured kind relative to the price of the normal kind?

   5. Significantly higher for the cultured product
   4. Moderately higher for the cultured product
   3. About the same for both
   2. Moderately higher for the normally grown product
   1. Significantly higher for the normally grown product

3. We would like you to give as many of the reasons that come to mind for how you responded to the questions above. Please be as definite as possible; preferably, comment on reasons for accepting/rejecting the cultured product.

   1. ______________________________

   2. ______________________________

   3. ______________________________

   4. ______________________________

   5. ______________________________

THANK YOU FOR YOUR COOPERATION.

Table E.1

Classification of Responses Obtained From Preliminary Questionnaire

Respondent #	Stimulus #	Purchase Intention	Fair Price	Comments Made?
01	01	3	–	no
02	01	4	4	no
03	01	2	3	yes-negative
04	01	5	3	yes-positive
05	01	5	3	yes-positive
06	01	4	2	no
07	01	5	2	no
08	01	5	4	no
09	01	4	4	yes-dubious
01	02	4	3	yes-dubious
02	02	4	3	yes
03	02	4	4	no
04	02	–	–	no
05	02	5	2	yes
06	02	4	1	yes-dubious
07	02	5	1	yes-positive
08	02	–	1	yes
09	02	5	2	yes-positive
01	03	4	3	no
02	03	5	4	yes-positive
03	03	5	4	yes-positive
04	03	3	3	yes
05	03	2	4	yes-negative
06	03	5	3	yes
07	03	5	4	yes-positive
08	03	5	3	yes-positive
09	03	4	3	yes-positive
10	03	4	3	yes
11	03	4	1	yes
12	03	5	4	yes-positive
13	03	5	3	yes-positive
01	?	5	3	yes-positive
02	?	5	2	yes-positive
03	?	1	3	yes-negative
04	?	4	4	yes-dubious
05	?	2	3	yes-dubious
06	?	2	3	yes-dubious
07	?	4	2	yes-negative
08	?	4	2	yes-negative
09	?	4	3	yes-indifferent
10	?	4	2	yes-negative
11	?	4	3	yes-positive
12	?	4	3	yes

Table E.2

N=43	$n_1=9$	$n_2=9$	$n_3=13$	$n_7=12$
Purchase Intention	Stimulus 1	Stimulus 2	Stimulus 3	Stimulus 7
5-Definitely	4	3	7	2
4-Perhaps	3	4	4	7
3-Undecided	1	0	1	0
2-Unlikely	1	0	1	2
1-Definitely not	0	0	0	1
0-No response	0	2	0	0
	$n_1=9$	$n_2=9$	$n_3=13$	$n_7=12$

Fair Price	Stimulus 1	Stimulus 2	Stimulus 3	Stimulus 7
5-Sig. higher	0	0	0	0
4-Mod. higher	3	1	5	1
3-Same	3	1	7	7
2-Mod. lower	2	3	0	4
1-Sig. lower	0	3	1	0
0-No response	1	1	0	0
	$n_1=9$	$n_2=9$	$n_3=13$	$n_7=12$

List of Attitude Statements Generated Using Stimulus #1

01. I don't think I could ever prefer artificially grown fish over natural.

02. I wouldn't want to pay more for this type of product.

03. The idea of eating a "garbage" fish may be unappealing to many people, but with pollution and world population as it is now, there may not be any other alternative.

04. I seriously doubt that this program will go into production until it has been tested by the FDA many, many times and been proven safe for human consumption.

05. I think it would be well worth the effort if the danger of pollution is controlled.

06. I would buy the new cultured product if it were cleaner or less contaminated than normal.

List of Attitude Statements Generated by Stimulus #2

01. I would not buy the cultured product until I had substantial evidence that they could safely be eaten.

02. The cultured product should be, after purification, very similar to the normally grown product.

03. I must be positive that it won't hurt me.

04. I believe that, under carefully controlled conditions, the quality should be good, and the product safe.

05. The idea is ecologically encouraging since it uses recycling concepts.

06. This method of production should relieve some pressure from the normally grown product.

07. The whole concept represents great progress to me.

08. It appears to be a safer product to eat.

09. It seems like a good solution to the growing need to replenish the ocean.

10. The thought that the fish are grown on sewage is uppermost in my mind.

11. The purifying aspects are uppermost in my mind.

List of Attitude Statements Generated by Stimulus #3

01. I definitely consider the fish to be of as good quality as the kind I buy today.

02. I expect the cost to be moderately higher because of the care put into growing it.

03. The cultured fish should be more edible since most rivers and lakes today contain unfit materials.

04. I expect to pay more for the cultured kind because of the reduced danger of food poisoning.

05. If both kinds are available together, no one would consider a higher price for either.

06. I would definitely try the cultured fish.

07. I would continue to eat the cultured kind only if I were satisfied with my first purchase.

08. The entire concept appears to be infeasible.

09. I question the controls that will be used.

10. My prejudiced mind will not accept sewage-grown algae.

11. I feel this project should help defray the cost of sewage treatment.

12. I think it's a great idea if it is practical.

13. I like the concept because it sounds like a purer fish.

14. I would be willing to try the cultured fish without prejudice

15. I have no reason to object to a cultured product if it is as good as natural fish products.

16. I would reject the fish if the process of growing it is played up.

17. I would buy only if the price were lower and quality the same.
18. I would buy if everything were the same as for natural fish, because of the ecological benefits.
19. Today's fish are not always pure because of pollution.
20. Eventually more cultured products have to be developed to feed the population.

List of Attitude Statements Generated by Stimulus #2

01. Fish grow on algae anyway and, if the waste and water are treated, it makes no difference to me whether the fish are natural or cultured.

02. I have absolutely no qualms about buying cultured fish if they are of good quality.

03. I would reject the cultured product because I fear that the bacteria from the sewage would be harmful.

04. I would worry about the toxic nature of various chemicals that could be present, but people would not think to check for.

05. I would fear the presence of undetected contaminants from industrial wastes.

06. I would fear the radiation from power plants.

07. This method seems to be a good way to start the growth of fish which would then be turned out into the ocean to grow.

08. I would suspect that the fish grown in controlled environments would lack some of the nutrients present in normally grown fish.

09. I would fear the danger of the processing system breaking down

10. I would need a lot of reassurance on the safety of eating cultured fish before I agreed to eat it.

11. I find the idea of eating anything that starts from sewage rather repulsive.

12. I would strongly favor the culturing of fish since the ocean's supply diminishes constantly.

13. I have a strong belief that at this stage in the development of technology, the cultured product is probably better in quality.