ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF ENFORCEMENT

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# DEVELOPMENT DOCUMENT FOR PROPOSED EFFLUENT LIMITATIONS GUIDELINES AND NEW SOURCE PERFORMANCE STANDARDS FOR THE

# FISH HATCHERIES AND FARMS

## POINT SOURCE CATEGORY

NATIONAL FIELD INVESTIGATIONS CENTER-DENVER
DENVER, COLORADO

APRIL 1974

## NOTICE

The attached document is a DRAFT REPORT. It includes technical information and recommendations submitted by the United States Environmental Protection Agency ("EPA") regarding the subject industry. It is being distributed for review and comment only.

The report, including the recommendations, will be undergoing extensive review by EPA, Federal and State agencies, public interest organizations and other interested groups and persons during the coming weeks. The report, and in particular, the recommended effluent limitation guidelines and standards of performance are subject to change in any and all respects.

The regulations to be published by EPA under Section 304(b) and 306 of the Federal Water Pollution Control Act, as Amended, will be based to a large extent on the report and the comments received on it. However, pursuant to Sections 304(b) and 306 of the Act, EPA will also consider additional pertinent technical and economic information which is developed in the course of review of this report by the public and within EPA. EPA is currently performing an economic impact analysis regarding the subject industry, which will be taken into account as part of the review of the final report. Upon completion of the review process, and prior to final promulgation of regulations, an EPA report will be issued setting forth EPA's conclusions concerning the subject industry, effluent limitation guidelines, and standards of performance applicable to such industry. Judgments necessary to promulgation of regulations under Sections 304(b) and 306 of the Act, of course, remain the responsibility of EPA. Subject to these limitations, EPA is making this Draft Report available in order to encourage the widest possible participation of interested persons in the decision making process at the earliest possible time. Persons desiring to make comments on this document should do so by May 17, 1974. Written comments should be submitted to Robert Schneider of the EPA National Field Investigations Center, Box 25227, Denver Federal Center, Denver, Colorado, 80225 (303/234-2481).

U. S. Environmental Protection Agency
Office of Air and Water Programs
Effluent Guidelines Division
Washington, D. C. 20460

# DEVELOPMENT DOCUMENT FOR

# PROPOSED EFFLUENT LIMITATIONS GUIDELINES

# AND STANDARDS OF PERFORMANCE

# FOR THE

# FISH HATCHERIES AND FARMS

# POINT SOURCE CATEGORY

Prepared for the
United States Environmental Protection Agency
Office of Air and Water Programs
Effluent Guidelines Division
Washington, D. C.
April 1974

Project Officer - Robert F. Schneider

Prepared by the
Environmental Protection Agency
Office of Enforcement
National Field Investigations Center-Denver
Denver, Colorado

# REVIEW NOTICE

This document presents conclusions and recommendations of a study conducted for the Effluent Guidelines Division, United States Environmental Protection Agency, in support of proposed regulations providing effluent limitations guidelines and new source standards for the fish hatcheries and farms point source category.

The conclusions and recommendations of this document may be subject to subsequent revisions during the document review process, and as a result, the proposed guidelines for effluent limitations as contained within this document may be superseded by revisions prior to final promulgation of the regulations in the Federal Register as required by the Federal Water Pollution Control Act Amendments of 1972 (P.L. 92-500).

## ABSTRACT

This document presents the findings of a study of the fish hatcheries and farms industry for the purpose of developing effluent limitations guidelines, Federal standards of performance, and pretreatment standards for the industry, to implement Sections 304(b) and 306 of the Federal Water Pollution Control Act Amendments of 1972 (the "Act").

Effluent limitations guidelines are set forth for the degree of effluent reduction attainable through the application of the "Best Practicable Control Technology Currently Available," and the "Best Available Technology Economically Achievable," which must be achieved by existing point sources by July 1, 1977, and July 1, 1983, respectively. The "Standards of Performance for New Sources" set forth the degree of effluent reduction which is achievable through the application of the best available demonstrated control technology, processes, operating methods, or other alternatives. The proposed regulations require that the native fish flow-thru culturing systems segment of the industry provide by July 1, 1977, vacuum cleaning of culturing units or sedimentation of their cleaning waste flow with sludge removal before discharge to navigable waters. For the native fish pond culturing systems segment of the industry, the 1977 requirements are settleable solids reduction through controlled discharge of pond draining water. The non-native fish culturing systems segment of the industry is required to achieve no discharge of wastewater pollutants with land disposal by July 1, 1977. By July 1, 1983, the native fish flow-thru culturing systems will be required to achieve greater reductions in pollutants discharged by the sedimentation of their entire waste flow with sludge removal. The 1983 requirements for the other two segments of the industry are the same as for 1977. New source performance standards for all three segments of the industry are the same as the 1983 requirements.

Supportive data and rationale for development of the proposed effluent limitations guidelines and standards of performance are contained in this report.

<u>NOTICE:</u> THESE ARE TENTATIVE RECOMMENDATIONS BASED UPON INFORMATION IN THIS REPORT AND ARE SUBJECT TO CHANGE BASED UPON COMMENTS RECEIVED AND FURTHER INTERNAL REVIEW BY EPA.

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## SECTION I.

## CONCLUSIONS

For the purposes of establishing effluent limitation guidelines and standards of performance, the fish culturing industry has been divided into three subcategories, based on product and culturing process. Other factors, including wastes generated, treatability of wastewater, facility size and age, geographic location and raw materials were considered but do not justify further subcategorization. The subcategories are:

1. Native Fish -- Flow-thru Culturing Systems
2. Native Fish -- Pond Culturing Systems
3. Non-Native Fish Culturing Systems

Data were summarized to arrive at waste characteristics for each subcategory. Waste characteristics for the native fish subcategories are shown in Table I-1.

Non-native fish are cultured in pond systems. Therefore, with the exception of biological pollutants, waste characteristics are the same as for native fish pond culturing systems.

The current standard of practice in the native fish culturing industry is no treatment of wastewater discharges. An estimated 12 percent of the flow-thru systems and one percent of the pond culturing

TABLE I-1

WASTE CHARACTERISTICS - NATIVE FISH CULTURING SYSTEMS

| Waste Constituent | Flow-thru Culturing System (kg/100 kg fish on hand/day) | Pond Culturing System[a/] (mg/l) |
|---|---|---|
| BOD | 1.3 | 5.1 |
| COD | 5.5 | 31 |
| Suspended Solids | 2.6 | 157 |
| Settleable Solids[b/] | 0.8 | 5.5 |
| $NH_3$-N | 0.09 | 0.39 |
| TKN | 0.38 | 0.78 |
| $NO_3$-N | 0.06 | 0.41 |
| Total $PO_4$-P | 0.03 | 0.13 |
| Fecal Coliform[c/] | 28 | >200 |

a/ Characteristics are for draining discharges only because flow-thru ponds are considered flow-thru culturing systems.
b/ Reported as ml/l.
c/ Reported as number of bacteria per 100 ml of water.

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systems provide treatment. In non-native fish culturing, an estimated 60 percent of the operations discharge to municipal sewage treatment facilities, an estimated 33 percent discharge to surface waters without treatment, and an estimated 7 percent use land disposal to achieve no discharge of wastewaters to surface waters.

Technology is available to improve the quality of discharges from fish culturing facilities. In-plant control measures can be incorporated to reduce the level of pollutants discharged. Eight treatment methods, providing different levels of pollutant reduction, have been identified for flow-thru systems culturing native fish. Three control and treatment methods have been identified for native fish pond culturing systems, and three have been identified for non-native fish culturing. Cost estimates for alternatives in each subcategory have been made and are summarized in Table VIII-13.

It is concluded that the Best Practicable Control Technology Currently Available (BPCTCA) for the Native Fish -- Flow-Thru Culturing Systems subcategory is treatment of the cleaning flow by sedimentation or vacuum cleaning. This technology will eliminate slug discharges of pollutants associated with cleaning wastes and in terms of total pollutant load will remove 15 percent of the BOD and suspended solids. The Best Available Technology Economically Achievable (BATEA) is sedimentation of the entire flow with sludge removal. This treatment method will remove 35 percent of the BOD and 50 percent of the suspended solids.

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Both BPCTCA and BATEA for the Native Fish-Pond Culturing Systems subcategory are shown to be in-plant control of draining discharges consisting of: (a) draining at a controlled rate; (b) draining through another rearing pond or settling pond; or (c) harvesting without draining. Each of these measures can remove at least 40 percent of the settleable solids.

It is also concluded that BPCTCA and BATEA for the Non-Native Fish Culturing Systems subcategory is no discharge with land disposal. This will eliminate the discharge of pollutants.

Furthermore, BPCTCA and BATEA can be implemented by the fish culturing industry by July 1, 1977, and July 1, 1983, respectively.

# SECTION II.

## RECOMMENDATIONS

Presented herein are the recommended effluent limitations guidelines for the fish culturing industry. Limitations written in terms of daily or thirty-day values will be monitored for compliance with 24-hour composite sampling. Limitations written in terms of instantaneous values should be monitored for compliance with grab sampling. Maximum one-day values are 1.3 times the thirty-day value. The value of 1.3 was chosen on the basis that the treatment systems recommended accomplish pollutant removals through entirely physical means and thus are considered stable processes.

It is recommended that the Best Practicable Control Technology Currently Available be implemented by the fish culturing industry on or before July 1, 1977. It is further recommended that the effluent limitations indicated in Table II-1 be adopted as Level I technology achievable through the implementation of BPCTCA.

It is recommended that the Best Available Technology Economically Achievable be implemented by the fish culturing industry on or before July 1, 1983. It is further recommended that the effluent limitations indicated in Table II-2 be adopted as Level II technology achievable

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TABLE II-1

LEVEL I EFFLUENT LIMITATIONS[a] - JULY 1, 1977

| Parameter | kg/100 kg fish on hand/day Max. Daily | Avg. Daily | Maximum Instantaneous (mg/l) |
|---|---|---|---|
| | **NATIVE FISH -- FLOW-THRU CULTURING SYSTEMS** | | |
| Suspended Solids | 2.9 | 2.2 | -- |
| Settleable Solids[b] | -- | -- | 0.2 |
| $NH_3$-N | 0.12 | 0.09 | -- |
| Fecal Coliform[c] | -- | -- | 200 organisms/100 ml |
| | **NATIVE FISH -- POND CULTURING SYSTEMS** | | |
| Settleable Solids[b] | -- | -- | 3.3 |
| Fecal Coliform[c] | -- | -- | 200 organisms/100 ml |

NON-NATIVE FISH CULTURING SYSTEMS

No discharge of process wastewater pollutants

a/ Effluent limitations are net values.
b/ Reported as ml/l. Limitation applies to cleaning culturing units containing fish or cleaning after fish have been removed.
c/ Salmonid operations are excluded from this effluent limitation.

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TABLE II-2

LEVEL II EFFLUENT LIMITATIONS[a/] - JULY 1, 1983
and
LEVEL III EFFLUENT LIMITATIONS[a/] - NEW SOURCES

| Parameter | kg/100 kg fish on hand/day Max. Daily | kg/100 kg fish on hand/day Avg. Daily | Maximum Instantaneous (mg/l) |
|---|---|---|---|
| NATIVE FISH -- FLOW-THRU CULTURING SYSTEMS | | | |
| Suspended Solids | 1.7 | 1.3 | -- |
| Settleable Solids[b/] | -- | < 0.1 | 0.2 |
| $NH_3$-N | 0.12 | 0.09 | -- |
| Fecal Coliform[c/] | -- | -- | 200 organisms/100 ml |
| NATIVE FISH -- POND CULTURING SYSTEMS | | | |
| Settleable Solids[b/] | -- | -- | 3.3 |
| Fecal Coliform[c/] | -- | -- | 200 organisms/100 ml |

NON-NATIVE FISH CULTURING SYSTEMS

No discharge of process wastewater pollutants

a/ Effluent limitations are net values.
b/ Reported as ml/l. Limitation applies to cleaning culturing units containing fish or cleaning after fish have been removed.
c/ Salmonid operations are excluded from this effluent limitation.

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through the implementation of BATEA. The effluent limitations presented in Table II-2 are also recommended as New Source Performance Standards or Level III technology.

# SECTION III.

# INTRODUCTION

## PURPOSE AND AUTHORITY

### Legal Authority

Existing Point Sources -- Section 301(b) of the Act requires the achievement by not later than July 1, 1977, of effluent limitations for point sources, other than publicly-owned treatment works, which require the application of the best practicable control technology currently available as defined by the Administrator pursuant to section 304(b) of the Act. Section 301(b) also requires the achievement by not later than July 1, 1983, of effluent limitations for point sources, other than publicly-owned treatment works, which require the application of the best available technology economically achievable which will result in reasonable further progress toward the national goal of eliminating the discharge of all pollutants, as determined in accordance with regulations issued by the Administrator pursuant to section 304(b) of the Act.

Section 304(b) of the Act requires the Administrator to publish regulations providing guidelines for effluent limitations setting forth the degree of effluent reduction attainable through the application of the best practicable control technology currently available and the degree of effluent reduction attainable through the application of the best control measures and practices achievable including treatment techniques, process and procedure innovations, operating methods and other alternatives. The regulations proposed herein set forth effluent limitations guidelines, pursuant to section 304(b) of the Act, for the fish culturing facilities source category. As such, it covers only facilities in the United States that culture or hold native or non-native species. It does not address fish piers, fish outs, fishing preserves, frog farms, oyster beds, mariculture, or aquaculture facilities as covered by Section 318.

New Sources -- Section 306 of the Act requires the achievement by new sources of a Federal standard of performance providing for the control of the discharge of pollutants which reflects the greatest degree of effluent reduction which the Administrator determines to be achievable through application of the best available demonstrated control technology, processes, operating methods, or other alternatives, including, where practicable, a standard permitting no discharge of pollutants.

Section 307(c) of the Act requires the Administrator to promulgate pretreatment standards for new sources at the same time that standards of performance for new sources are promulgated pursuant to section 306.

Section 304(c) of the Act requires the Administrator to issue to the States and appropriate water pollution control agencies information on the processes, procedures or operating methods which result in the elimination or reduction of the discharge of pollutants to implement standards of performance under section 306 of the Act. This Development Document provides, pursuant to section 304(c) of the Act, information on such processes, procedures or operating methods.

Summary and Basis of Proposed Effluent Limitations Guidelines for Existing Sources and Standards of Performance and Pretreatment Standards for New Sources.

General Methodology -- The effluent limitations guidelines and standards of performance proposed herein were developed in the following manner. The point source category was first studied for the purpose of determining whether separate limitations and standards are appropriate for different segments within the category. This analysis included a determination of whether differences in raw material used, product produced, manufacturing process employed, age, size, wastewater constituents and other factors require development of separate limitations and standards for different segments of the point source category. The raw waste characteristics for each such segment were then identified. This included an analysis of (1) the source, flow and volume of water used in the process employed and the sources of waste and wastewaters in the operation, and (2) the constituents of all wastewaters. The constituents of the wastewaters which should be subject to effluent limitations guidelines and standards of performance were identified.

The control and treatment technologies existing within each segment were identified. This included an identification of each distinct control and treatment technology, including both in-plant and end-of-process technologies, which are existent or capable of being designed for each segment. It also included an identification, in terms of the amount of constituents and the chemical, physical and biological characteristics of pollutants, of the effluent level resulting from the application of each of the technologies. The problems, limitations and reliability of each treatment and control technology were also identified. In addition, the non-water quality environmental impacts, such as the effects of the application of such technologies upon other pollution problems, including air, solid waste, noise and radiation, were identified. The energy requirements of each control and treatment technology were determined as well as the cost of the application of such technologies.

The information, as outlined above, was then evaluated in order to determine what levels of technology constitute the "best practicable control technology currently available", the "best available technology economically achievable" and the "best available demonstrated control technology, processes, operating methods, or other alternatives." In identifying such technologies, various factors were considered. These included the total cost of application of technology in relation to the effluent reduction benefits to be achieved from such application, the age of equipment and facilities involved, the process employed, the engineering aspects of the application of various types of control techniques, process changes, non-water quality environmental impact (including energy requirements) and other factors.

The basis for development of the effluent limitations presented in this document consists of review and evaluation of available literature; EPA research information; Bureau of Sport Fisheries and Wildlife information; monitoring data from State Fish and Game Departments; consultant reports on fish hatchery design; water pollution studies by government agencies; interviews with recognized experts and trade associations; and analysis and evaluation of permit application data provided by the industry under the Permit Programs of the Rivers and Harbors Act of 1899 (Refuse Act).

The pretreatment standards for new sources proposed herein are intended to be complementary to the pretreatment standards proposed for existing sources under 40 CFR Part 128. The bases for such standards are set forth in the Federal Register of July 19, 1973, 38 FR 19236. The provisions of Part 128 are equally applicable to sources which would constitute "new sources" under section 306 if they were to discharge pollutants directly to navigable waters, except for §128.133. That section provides a pretreatment standard for "incompatible pollutants" which requires application of the "best practicable control technology currently available," subject to an adjustment for amounts of pollutants removed by the publicly-owned treatment works. For the pretreatment standards applicable to new sources, §128.133 is amended to require application of the standard of performance for new sources rather than the "best practicable" standard applicable to existing sources under sections 301 and 304(b) of the Act.

This effluent guidance document is intended to satisfy all the requirements of the Act as it pertains to the previously described fish culturing source category. Fundamental differences in the methods of obtaining, holding, culturing and distributing of species necessitates separate discussion for native and non-native fish.

## NATIVE FISH* - GENERAL DESCRIPTION OF THE INDUSTRY

### Industry Growth

The development of native fish-culturing activities in the United States since the turn of the century has been phenomenal. In 1900 the Federal Government operated 34 fish hatcheries and fish-collecting stations and it was estimated that there were about the same number of state hatcheries (242). In subsequent years the number of government owned and operated hatcheries increased rapidly. By 1948 nearly 500 more state hatcheries were in operation and the federal units had increased to 97. During the past 25 years, many of the smaller and less efficient hatcheries have been replaced by larger modern facilities (244). In 1970, according to data compiled by the Bureau of Sport Fisheries and Wildlife, there were 579 fish-culturing facilities operated by governmental agencies. Of this total, 482 were state and 97 were federal fish hatcheries. It has been estimated that government facilities produce more than 9070 metric tons (20 million pounds) of salmonid fish (salmon and trout) and 680 metric tons (1.5 million pounds) of other native species, such as catfish and sunfish, annually (244,260).

Similar development has occurred in privately-owned fish production facilities, often referred to as fish farms. Private fish

*Native species of fish are defined in "Special Publication No. 6" of the American Fisheries Society entitled, "A List of Common and Scientific Names of Fishes from the U.S. and Canada." Although common carp, goldfish and brown trout are categorized as non-native fish in the American Fisheries Society List, they are considered native species in this document. The rationale for this inclusion is based upon the fact that these fish have a widespread distribution and relatively long residence time in the waters of the United States (82).

farming began in the United States during the 1930's and by the mid-1950's the industry was fairly well developed and widespread (31). The principal type of fish cultured at farms in the western and northern sections of the United States was trout (59) while in the central and southern areas the major efforts were directed at culturing buffalo fish usually in combination with catfish, crappie and bass (96).

About 1963 there was a change in the central and southern fish-farming activities. Nearly 80 percent of the land under pond cultivation for raising buffalo fish was converted to the raising of catfish and minnows (31).

During the 10 years that followed (1963 to 1973), fish farm production continued to experience significant growth. Unfortunately many private farmers guard their production information resulting in only fragmentary data on the fish-farming industry. Nevertheless, the importance of private enterprise in producing marketable fish can be illustrated. For example, private fish farms in Idaho annually produce about the same poundage of trout as all the federal fish hatcheries in the United States combined (135). It has been estimated that these private hatcheries produced 6,800 metric tons (15 million pounds) of trout each year primarily for consumption (268), and reportedly have potential for additional development (23). Fish farms raising catfish have shown similar growth. In the southern United States privately-owned catfish farms produced 12,250 metric tons (27 million pounds) in 1968 and projections indicate that these farms have a potential of producing more than 50,800 metric tons (112 million pounds) by 1975 (122).

In a cooperative study with the 50 states, the Bureau of Sport Fisheries and Wildlife, U. S. Department of the Interior, published information on the potential growth of the native fish-culturing industry in the United States (244). This national survey concluded that during 1965, federal and state hatcheries produced nearly 250 million trout, from fry to catchables, weighing almost 8,165 metric tons (18 million pounds). By the year 2000, it is estimated that trout production in government-owned and operated hatcheries will more than double to 505 million fish per year weighing nearly 17,240 metric tons (38 million pounds) [Table III-1]. This 9,070 metric tons (20 million pound) increase would mean an average annual production rate of 30 to 45 metric tons (65,000 to 100,000 pounds) of fish per hatchery. However 300 additional hatcheries will have to be constructed to meet this estimate.

The potential hatchery production of warm-water fish was also estimated in the cooperative national survey. In 1965 the annual production of warm-water fish by state and federal hatcheries was about 1.2 billion and by the year 2000 the annual production is estimated to approach 2 billion [Table III-2].

As part of the national survey, an effort was made by the Fish and Wildlife Service, USDI, to obtain present and future production capabilities of private hatcheries and fish farms. Only 97 operations supplied information and the data are not presented in this document because of their incompleteness.

TABLE III-1

TROUT PRODUCTION AT FEDERAL AND STATE HATCHERIES
PROJECTED THROUGH THE YEAR 2000
(FROM REFERENCE 244)

| State | Production (Thousands of Fish) | | | |
|---|---|---|---|---|
| | 1965 | 1973 | 1980 | 2000 |
| Alabama | 6 | 15 | 19 | 23 |
| Alaska | 2,100 | 4,000 | 6,900 | 9,500 |
| Arizona | 6,555 | 7,310 | 7,800 | 9,330 |
| Arkansas | 882 | 1,353 | 1,495 | 2,093 |
| California | 28,933 | 51,713 | 57,898 | 58,000 |
| Colorado | 18,473 | 34,963 | 36,484 | 40,678 |
| Connecticut | 709 | 953 | 972 | 1,443 |
| Delaware | 15 | 35 | 39 | 55 |
| Florida | 3 | 3 | 3 | 4 |
| Georgia | 803 | 1,276 | 1,378 | 1,809 |
| Hawaii | 100 | 150 | 300 | 400 |
| Idaho | 27,663 | 36,021 | 37,021 | 39,021 |
| Illinois | 31 | 20 | 22 | 31 |
| Indiana | 66 | 107 | 112 | 131 |
| Iowa | 282 | 349 | 408 | 493 |
| Kansas | - | - | - | - |
| Kentucky | 79 | 616 | 681 | 954 |
| Louisiana | - | - | - | - |
| Maine | 2,004 | 2,651 | 2,466 | 2,732 |
| Maryland | 339 | 867 | 899 | 1,039 |
| Massachusetts | 1,648 | 2,187 | 2,338 | 2,753 |
| Michigan | 5,317 | 17,203 | 23,038 | 31,133 |
| Minnesota | 4,019 | 4,935 | 5,532 | 4,505 |
| Mississippi | - | - | - | - |
| Missouri | 2,880 | 3,211 | 3,383 | 3,990 |
| Montana | 7,916 | 9,500 | 14,288 | 14,613 |
| Nebraska | 795 | 1,017 | 1,155 | 1,497 |
| Nevada | 3,770 | 5,150 | 5,685 | 7,310 |
| New Hampshire | 2,825 | 2,320 | 2,470 | 2,985 |
| New Jersey | 650 | 914 | 1,031 | 1,451 |
| New Mexico | 8,780 | 12,859 | 14,607 | 17,150 |
| New York | 5,769 | 5,463 | 5,503 | 5,675 |
| North Carolina | 1,525 | 1,335 | 1,397 | 1,661 |
| North Dakota | 1,238 | 1,220 | 1,348 | 1,887 |
| Ohio | 23 | 90 | 96 | 120 |
| Oklahoma | 66 | 144 | 160 | 224 |
| Oregon | 26,932 | 38,348 | 47,801 | 73,621 |
| Pennyslvania | 4,028 | 6,519 | 9,179 | 12,350 |
| Rhode Island | 515 | 401 | 414 | 447 |
| South Carolina | 166 | 126 | 139 | 195 |

TABLE III-1 (Cont.)

TROUT PRODUCTION AT FEDERAL AND STATE HATCHERIES
PROJECTED THROUGH THE YEAR 2000
(FROM REFERENCE 244)

| State | Production (Thousands of Fish) | | | |
|---|---|---|---|---|
| | 1965 | 1973 | 1980 | 2000 |
| South Dakota | 1,440 | 2,178 | 2,313 | 2,749 |
| Tennessee | 1,515 | 2,999 | 3,314 | 4,564 |
| Texas | - | - | - | - |
| Utah | 19,773 | 23,980 | 25,714 | 46,800 |
| Vermont | 2,485 | 2,716 | 2,778 | 3,017 |
| Virginia | 1,194 | 2,061 | 2,451 | 3,432 |
| Washington | 37,334 | 42,477 | 48,069 | 63,985 |
| West Virginia | 1,528 | 1,557 | 2,194 | 2,960 |
| Wisconsin | 3,013 | 3,580 | 3,564 | 4,062 |
| Wyoming | 13,566 | 18,628 | 20,205 | 22,588 |
| District of Columbia | 2 | 5 | 6 | 8 |
| Total | 249,755 | 355,525 | 405,069 | 505,468 |

TABLE III-2

WARM-WATER FISH PRODUCTION AT FEDERAL AND STATE HATCHERIES
PROJECTED THROUGH THE YEAR 2000
(FROM REFERENCE 244)

| State | Production (Thousands of Fish) 1965 | 1973 | 1980 | 2000 |
|---|---|---|---|---|
| Alabama | 5,218 | 8,903 | 9,445 | 11,736 |
| Alaska [a/] | - | - | - | - |
| Arizona | 516 | 950 | 1,500 | 2,500 |
| Arkansas | 11,210 | 15,034 | 18,337 | 21,151 |
| California | 27 | 130 | 535 | (535) |
| Colorado | 10,775 | 12,637 | 15,807 | 26,290 |
| Connecticut | 14 | 16 | 17 | 20 |
| Delaware | 118 | 242 | 246 | 264 |
| Florida | 5,041 | 9,378 | 10,325 | 12,922 |
| Georgia | 16,209 | 23,114 | 25,039 | 31,534 |
| Hawaii | 50 | 75 | 100 | 150 |
| Idaho | 10 | 50 | 50 | 50 |
| Illinois | 2,124 | 2,451 | 2,598 | 3,216 |
| Indiana | 2,873 | 3,813 | 4,242 | 5,864 |
| Iowa | 114,679 | 141,089 | 165,209 | 208,953 |
| Kansas | 13,185 | 41,600 | 46,531 | 52,843 |
| Kentucky | 2,465 | 8,495 | 11,376 | 14,726 |
| Louisiana | 10,213 | 18,864 | 23,624 | 30,724 |
| Maine | 34 | 50 | 55 | 77 |
| Maryland | 168 | 12,249 | 25,277 | 15,387 |
| Massachusetts | 214 | 338 | 388 | 535 |
| Michigan | 3,701 | 4,925 | 5,022 | 5,431 |
| Minnesota | 194,718 | 304,437 | 304,903 | 306,864 |
| Mississippi | 9,380 | 17,071 | 18,863 | 26,409 |
| Missouri | 4,194 | 20,949 | 81,326 | 103,461 |
| Montana | 2,052 | 2,100 | 2,102 | 2,615 |
| Nebraska | 18,622 | 15,592 | 16,158 | 16,591 |
| Nevada | 116 | 110 | 110 | 112 |
| New Hampshire | 1 | 5 | 6 | 8 |
| New Jersey | 290 | 390 | 430 | 597 |
| New Mexico | 4,500 | 7,265 | 8,029 | 11,240 |
| New York | 348,469 | 450,478 | 450,515 | 450,669 |
| North Carolina | 5,878 | 10,029 | 10,860 | 14,356 |
| North Dakota | 46,505 | 46,924 | 49,752 | 61,653 |
| Ohio | 48,009 | 52,698 | 58,827 | 71,919 |
| Oklahoma | 26,381 | 31,956 | 46,530 | 61,902 |
| Oregon | 502 | 2,502 | 3,002 | 3,502 |
| Pennsylvania | 17,462 | 21,250 | 31,775 | 42,385 |
| Rhode Island | 3 | 26 | 48 | 88 |
| South Carolina | 57,605 | 8,698 | 9,450 | 12,391 |

TABLE III-2 (Cont.)

WARM-WATER FISH PRODUCTION AT FEDERAL AND STATE HATCHERIES
PROJECTED THROUGH THE YEAR 2000
(FROM REFERENCE 244)

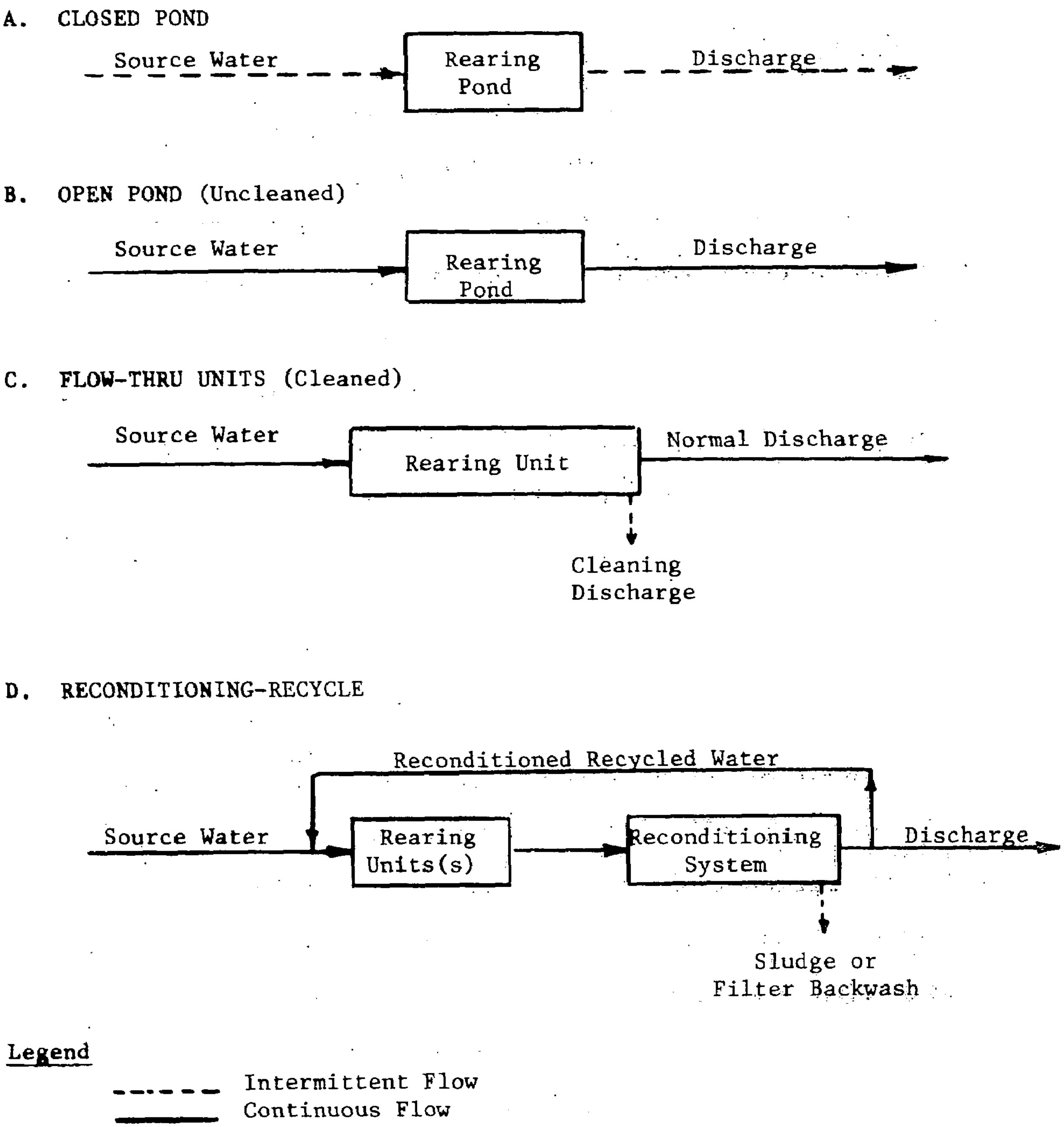
| State | Production (Thousands of Fish) | | | |
|---|---|---|---|---|
| | 1965 | 1973 | 1980 | 2000 |
| South Dakota | 48,450 | 71,226 | 73,034 | 101,646 |
| Tennessee | 6,389 | 4,076 | 4,249 | 5,979 |
| Texas | 17,278 | 13,996 | 14,417 | 16,192 |
| Utah | 3,045 | 10,059 | 10,065 | 10,091 |
| Vermont | 1 | 4 | 5 | 7 |
| Virginia | 6,004 | 11,350 | 15,729 | 21,236 |
| Washington | 76 | 100 | 100 | 200 |
| West Virginia | 579 | 679 | 810 | 979 |
| Wisconsin | 112,468 | 169,675 | 170,785 | 185,618 |
| Wyoming | 10,013 | 10,025 | 10,028 | 10,039 |
| District of Columbia | 7 | 13 | 14 | 20 |
| Total | 1,187,841 | 1,578,104 | 1,747,645 | 1,973,677 |

a/ No warm-water fish culturing operations.

Types of Facilities

Perhaps the most striking difference in native fish-rearing facilities is related to water-flow patterns. Fish can be reared in closed ponds which typically discharge less than 30 days per year or only during periods of excess runoff. Another operation, the open pond, usually has a continuous overflow. A third type of operation, the flow-thru system, consists of a single or series of rearing units. The fish are concentrated in the culturing unit through which a continuous flow of water passes. Uneaten food and fish excreta are routinely removed from most types of flow-thru rearing units by various types of cleaning practices.

A fourth type of rearing process relies upon reconditioned and recycled water. Surveys (34) have revealed that reconditioning is becoming more attractive because: (a) many water supplies are too cold and must be heated, thus on a once-through basis all the heat remaining is wasted; and (b) many areas do not have sufficient water supplies to rear a full capacity of fish during dry months. In addition, reconditioning is attractive in operations where source water must be disinfected to control diseases. Figure III-1 diagrammatically shows the four systems described. Many operations do not limit their activities to the use of just one of these confinement methods for their fish-culturing processes. For example, typical cold-water or salmonid fish hatcheries have propagation facilities that include holding ponds,




**Note:** B and C operate as single-pass systems with single units or multiple units in series.

Figure III-1. Types of Water-Flow Systems Used in Fish Culturing rearing tanks and raceways (139). Even the warm-water fish culturing operations such as catfish farms are beginning to expand their facilities beyond the strictly pond-type system of rearing. They are beginning to construct and stock raceways because this production process offers ease in harvesting fish, greater carrying capacity and other distinct advantages over the pond systems (205). The blending of production processes is even more evident in hatcheries or farms that have multiple water sources allowing them to rear warm-water and cold-water fish.

## Location of Facilities

Hatcheries specializing in the rearing of salmonid fish are concentrated in the northwest region of the United States (176) where the volume of cool water (about 10°C or 50°F) for culturing is abundant and inexpensive. However, cold-water hatcheries are not limited to the west. Considerable numbers of salmonid hatcheries are located in the Great Lakes area, along the northeast Atlantic states, and in the mountains of the mid-coastal and southeastern states [Table III-3]. On the other hand, warm-water fish culturing operations are concentrated in, but not limited to, the central-southern section of the United States where climate, water temperatures and other physical conditions are conducive to the rearing of such types of fish as minnows, sunfish and catfish (31,87,121,223).

Fish farms and hatcheries are generally located in rural areas. Some occupy several hundred acres while others may be contained within a single building or even a portable shed with an incubator and a water

TABLE III-3

GEOGRAPHIC DISTRIBUTION OF STATE, FEDERAL AND PRIVATE FISH-CULTURING FACILITIES IN THE UNITED STATES THAT REAR NATIVE FISH[a/]

| State | Cold Water | | | Warm Water | | | Mixed[b/] | | |
|---|---|---|---|---|---|---|---|---|---|
| | Federal | State | Private | Federal | State | Private | Federal | State | Private[c/] |
| Alabama | | | 1 | 2 | 2 | 9 | | | |
| Alaska | | 4 | | | | | | | |
| Arizona | 2 | 2 | 1 | | | 1 | | 1 | |
| Arkansas | 2 | | 8 | 2 | 3 | 30 | | | |
| California | 2 | 20 | 66 | | 2 | 118 | | | 32 |
| Colorado | 2 | 19 | 12 | | 2 | 1 | | | 2 |
| Connecticut | | 3 | 9 | | | 18 | | | 5 |
| Delaware | | | | | | | | | |
| Florida | | | | 1 | 2 | 1 | | | |
| Georgia | 1 | | 2 | 3 | 7 | 19 | | 2 | |
| Hawaii | | | | | | | | | |
| Idaho | 3 | 17 | 34 | | | | | | 2 |
| Illinois | | | 5 | | 2 | 13 | | | |
| Indiana | | 1 | | | 6 | 4 | | | |
| Iowa | 1 | 2 | | 1 | 26 | 10 | | 4 | |
| Kansas | | | | 2 | 2 | 55 | | | |
| Kentucky | | | | 1 | 1 | 2 | | | |
| Louisiana | | | | 1 | 3 | 18 | | | |
| Maine | 1 | 17 | 12 | | 1 | 5 | 1 | | 1 |
| Maryland | | 3 | | | 2 | 4 | | 1 | |
| Massachusetts | 2 | 6 | 9 | | 2 | 5 | 1 | | 1 |
| Michigan | 3 | 8 | 111 | | | 10 | | 1 | 10 |
| Minnesota | | 3 | 1 | | 34 | 86 | 1 | 2 | 19 |
| Mississippi | | | | 2 | | 35 | | | |
| Missouri | | 5 | 10 | | 6 | 62 | 1 | | 3 |
| Montana | 3 | 8 | 35 | | | | 1 | | 1 |
| Nebraska | | 1 | 5 | | 1 | 10 | 1 | 3 | |
| Nevada | 1 | 5 | 1 | | | | | | |
| New Hampshire | 2 | 8 | 2 | | | 2 | | | |
| New Jersey | | 1 | | | | 3 | | 1 | 1 |
| New Mexico | 1 | 6 | 2 | 1 | | 2 | | | |
| New York | 1 | 13 | 38 | | 3 | 4 | | 2 | 1 |
| North Carolina | 1 | 4 | 18 | 2 | 3 | 2 | | | |
| North Dakota | | | 1 | 2 | 6 | | 1 | | |
| Ohio | | 1 | 3 | 2 | 3 | 46 | | 3 | 23 |
| Oklahoma | | | | | 4 | 83 | 1 | | 8 |
| Oregon | 1 | 31 | 25 | | 1 | | | | 1 |
| Pennsylvania | | 3 | 50 | | 1 | 33 | 1 | 7 | 6 |

TABLE III-3 (Cont.)

GEOGRAPHIC DISTRIBUTION OF STATE, FEDERAL AND PRIVATE FISH-CULTURING FACILITIES IN THE UNITED STATES THAT REAR NATIVE FISH[a]

| State | Cold Water | | | Warm Water | | | Mixed[b] | | |
|---|---|---|---|---|---|---|---|---|---|
| | Federal | State | Private | Federal | State | Private | Federal | State | Private[c] |
| Rhode Island | | 2 | | | | | | | 1 |
| South Carolina | 1 | | | 2 | 6 | | | | |
| South Dakota | 2 | 1 | 3 | | 3 | | 1 | | |
| Tennessee | 2 | 2 | 7 | | 4 | 21 | | 1 | 3 |
| Texas | | | | 3 | 11 | 54 | | | |
| Utah | 1 | 11 | 7 | | | | | 2 | |
| Vermont | 1 | 6 | 2 | | | | | | |
| Virginia | 1 | 3 | 4 | 2 | 3 | 6 | | | |
| Washington | 10 | 59 | 33 | | | | | | |
| West Virginia | | 4 | 5 | | 1 | 3 | 3 | 1 | 2 |
| Wisconsin | | 7 | 17 | | 3 | 8 | 2 | 5 | 28 |
| Wyoming | 2 | 10 | 1 | | | | | 1 | |
| Total | 49 | 296 | 540 | 29 | 156 | 783 | 15 | 37 | 150 |

a/ Data based on information contained in Supplement B.
b/ Operations with both cold- and warm-water fish.
c/ Census incomplete.

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supply. A warm-water hatchery often appears to be much larger than a trout or salmon hatchery. This is because of the larger acreage of ponds utilized for natural spawning and rearing of warm-water fishes. At federal facilities the average cold-water fish hatchery includes about 60 hectares (150 acres) of land while the average warm-water hatchery is 8 hectares (20 acres) larger (244).

If wastewater treatment is deemed necessary at these facilities, there is generally sufficient acreage to permit the installation of adequate treatment systems. Those with spatial limitations either have other land available they can purchase or are reasonably well suited (from a physical but not necessarily an economical standpoint) for operating a water-recycling system. Most hatcheries are built on flat to moderately rolling terrain. In many localities the most economical and desirable site cannot be used because the land is subject to flooding. In other localities the type of soil may present a major problem in site selection for earthen raceways, ponds or impoundments. A potential farm or hatchery location may be rejected if soils allow excessive seepage or adversely affect water quality and subsequently interfere with the fish-rearing process.

## Fish Cultured

A review of available literature [Section XIII] produced a list of 83 species of native fish cultured in the United States. For the sake of simplicity, these species were placed into two major groups, cold-water and warm-water fish. Because of similarities in production and for convenience, cool-water fish such as pike and walleye were included in the warm-water fish group (Table III-4).

TABLE III-4

NATIVE FISHES CULTURED IN THE UNITED STATES

| Common Name | Scientific Name | Reference |
|---|---|---|
| | COLD-WATER FISH | |
| 1. Pink salmon | Oncorhynchus gorbuscha (Walbaum) | (248) |
| 2. Chum salmon | Oncorhynchus keta (Walbaum) | (250) |
| 3. Coho salmon | Oncorhynchus kisutch (Walbaum) | (250) |
| 4. Sockeye salmon | Oncorhynchus nerka (Walbaum) | (250) |
| 5. Chinook salmon | Oncorhynchus tshawytscha (Walbaum) | (250) |
| 6. Apache trout[a/] | Salmo apache (Miller) | (271) |
| 7. Golden trout | Salmo aguabonita (Jordan) | (271) |
| 8. Cutthroat trout | Salmo clarki (Richardson) | (250) |
| 9. Rainbow trout | Salmo gairdneri (Richardson) | (250) |
| 10. Gila trout | Salmo gilae (Miller) | (271) |
| 11. Atlantic salmon | Salmo salar (Linnaeus) | (250) |
| 12. Brown trout | Salmo trutta (Linnaeus) | (250) |
| 13. Brook trout | Salvelinus fontinalis (Mitchill) | (250) |

TABLE III-4 (Cont.)

NATIVE FISHES CULTURED IN THE UNITED STATES

| Common Name | Scientific Name | Reference |
|---|---|---|
| **COLD-WATER FISH (Cont.)** | | |
| 14. Dolly Varden | Salvelinus malma (Walbaum) | (250) |
| 15. Lake trout | Salvelinus namaycush (Walbaum) | (250) |
| 16. Arctic grayling | Thymallus arcticus (Pallas) | (248) |
| 17. Inconnu | Stenodus leucichthys (Güldenstadt) | (248) |
| **WARM-WATER FISH** | | |
| 1. Gizzard shad | Dorosoma cepedianum (Lesueur) | (31) |
| 2. Shovelnose sturgeon | Scaphirhychus platorynchus (Rafinesque) | (250) |
| 3. Paddlefish | Polyodon spathula (Walbaum) | (32) |
| 4. Bowfin | Amia calva (Linnaeus) | (250) |
| 5. Central mudminnow | Umbra limi (Kirtland) | (18) |
| 6. Gars | Lepisosteus sp. | (249) |
| 7. Northern pike | Esox lucius (Linnaeus) | (250) |
| 8. Muskellunge | Esox masquinongy (Mitchill) | (250) |

TABLE III-4 (Cont.)

NATIVE FISHES CULTURED IN THE UNITED STATES

| Common Name | Scientific Name | Reference |
|---|---|---|
| | WARM-WATER FISH (Cont.) | |
| 9. Chain pickerel | *Esox niger* (Lesueur) | (65) |
| 10. Stoneroller | *Campostoma anomalum* (Rafinesque) | (18) |
| 11. Goldfish | *Carassius auratus* (Linnaeus) | (250) |
| 12. Carp | *Cyprinus carpio* (Linnaeus) | (250) |
| 13. Silveryminnow | *Hybognathus nuchalis* (Agassiz) | (126) |
| 14. Hornyhead chub | *Nocomis biguttatus* (Kirtland) | (18) |
| 15. River chub | *Nocomis micropogon* (Cope) | (18) |
| 16. Golden shiner | *Notemigonus crysoleucas* (Mitchill) | (18) |
| 17. Plains minnow | *Hybognathus placitus* (Girard) | (126) |
| 18. Brassy minnow | *Hybognathus hankinsoni* (Hubbs) | (18) |
| 19. Lake chub | *Couesius plumbeus* (Agassiz) | (126) |
| 20. Utah chub | *Gila atraria* (Girard) | (126) |
| 21. Leatherside chub | *Gila copei* (Jordan and Gilbert) | (126) |
| 22. Emerald shiner | *Notropis atherinoides* (Rafinesque) | (18) |

TABLE III-4 (Cont.)

NATIVE FISHES CULTURED IN THE UNITED STATES

| Common Name | Scientific Name | Reference |
|---|---|---|
| | WARM-WATER FISH (Cont.) | |
| 23. Common shiner | *Notropis cornutus* (Mitchill) | (18) |
| 24. Red shiner | *Notropis lutrensis* (Bard & Girard) | (156) |
| 25. Sand shiner | *Notropis stramineus* (Cope) | (126) |
| 26. Northern redbelly dace | *Phoxinus eos* (Cope) | (18) |
| 27. Southern redbelly dace | *Phoxinus erythrogaster* (Rafinesque) | (18) |
| 28. Bluntnose minnow | *Pimephales notatus* (Rafinesque) | (18) |
| 29. Fathead minnow | *Pimephales promelas* (Rafinesque) | (25) |
| 30. Finescale dace | *Phoxinus neogaeus* (Cope) | (18) |
| 31. Blacknose dace | *Rhinichthys atratulus* (Herman) | (18) |
| 32. Speckled dace | *Rhinichthys osculus* (Girard) | (126) |
| 33. Redside shiner | *Richardsonius baleatus* (Richardson) | (126) |
| 34. Creek chub | *Semotilus atromaculatus* (Mitchill) | (18) |
| 35. Utah sucker | *Catostomus ardens* (Jordan and Gilbert) | (126) |
| 36. White sucker | *Catostomus commersoni* (Lacépède) | (126) |

TABLE III-4 (Cont.)

NATIVE FISHES CULTURED IN THE UNITED STATES

| Common Name | Scientific Name | Reference |
|---|---|---|
| | WARM-WATER FISH (Cont.) | |
| 37. Smallmouth buffalo | Ictiobus bubalus (Rafinesque) | (249) |
| 38. Bigmouth buffalo | Ictiobus cyprinellus (Valenciennes) | (249) |
| 39. Blue catfish | Ictalurus furcatus (Lesueur) | (250) |
| 40. Bigmouth x Black buffalo | Ictiobus cyprinellus (Valenciennes) x Ictiobus niger (Rafinesque) | (156) |
| 41. Black bullhead | Ictalurus melas (Rafinesque) | (249) |
| 42. Yellow bullhead | Ictalurus natalis (Lesueur) | (156) |
| 43. Brown bullhead | Ictalurus nebulosus (Lesueur) | (249) |
| 44. Channel catfish | Ictalurus punctatus (Rafinesque) | (250) |
| 45. Spotted bullhead | Ictalurus serracanthus (Yerger & Relyea) | (156) |
| 46. White catfish | Ictalurus catus (Linnaeus) | (250) |
| 47. Flathead catfish | Pylodictis olivaris (Rafinesque) | (250) |
| 48. Mosquitofish | Gambusia affinis (Bard & Girard) | (250) |
| 49. Guppy | Poecilia reticulata (Peters) | (156) |

TABLE III-4 (Cont.)

NATIVE FISHES CULTURED IN THE UNITED STATES

| Common Name | Scientific Name | Reference |
|---|---|---|
| | WARM-WATER FISH (Cont.) | |
| 50. White bass | *Morone chrysops* (Rafinesque) | (250) |
| 51. Striped bass | *Morone saxatilis* (Walbaum) | (250) |
| 52. Green sunfish | *Lepomis cyanellus* (Rafinesque) | (250) |
| 53. Warmouth | *Lepomis gulosus* (Cuvier) | (250) |
| 54. Bluegill | *Lepomis macrochirus* (Rafinesque) | (250) |
| 55. Redear sunfish | *Lepomis microlophus* (Günther) | (250) |
| 56. Smallmouth bass | *Micropterus dolomieui* (Lacépède) | (250) |
| 57. Spotted bass | *Micropterus punctulatus* (Rafinesque) | (250) |
| 58. Largemouth bass | *Micropterus salmoides* (Lacépède) | (250) |
| 59. White crappie | *Pomoxis annularis* (Rafinesque) | (250) |
| 60. Black crappie | *Pomoxis nigromaculatus* (Lesueur) | (250) |
| 61. Brook stickleback | *Culaea inconstans* (Kirtland) | (250) |
| 62. Yellow perch | *Perca flavescens* (Mitchill) | (250) |

TABLE III-4 (Cont.)

NATIVE FISHES CULTURED IN THE UNITED STATES

| Common Name | Scientific Name | Reference |
|---|---|---|
| | WARM-WATER FISH (Cont.) | |
| 63. Sauger | Stizostedion canadense (Smith) | (250) |
| 64. Walleye | Stizostedion vitreum vitreum (Mitchill) | (250) |
| 65. Blue pike | Stizostedion vitreum glaucum (Hubbs) | (250) |
| 66. Freshwater drum | Aplodinotus grunniens (Rafinesque) | (250) |

a/ Recently described native species, not listed in American Fisheries Society list of common and scientific names of fish (15).

## Raw Materials

A basic raw material required by all fish-production facilities is water. The source of water used in fish farms or hatcheries may be from streams, ponds, springs, wells or impoundments that store surface runoff. Regardless of which source is used, the supply must be available in sufficient quantity to maintain a minimum design flow and to periodically or continuously flush out organic wastes.

Because water is the medium in which the fish are cultured, the successful operation of a fish farm or hatchery is dependent upon the quality as well as the quantity. Preferably, the water should be moderately hard, have a pH of 7 to 8, and be suitable in temperature to promote rapid fish growth. It should be clear, with a high oxygen content and free from noxious gasses, chemicals, pesticides or other materials that may be toxic to fish (39,59,141).

Except for temperature, water quality requirements for the propagation of warm-water fish are much the same as for trout and salmon. For a discussion of optimum temperatures for cold- and warm-water cultures, the reader is directed to such publications as Inland Fisheries Management (41), Culture and Diseases of Game Fishes (59) and Textbook of Fish Culture (115).

Another raw material required for some fish-culturing activities is prepared feed. Operations engaged in intensive culturing hold and rear fish at densities that require routine feeding with prepared food. Other operations rear fish at densities more similar to those enjoyed by wild fish. These non-intensive culturing operations typically rely on natural foods existing in earthen ponds (59).

Feeding prepared foods was once considered a simple task and was usually assigned to the least-experienced fish culturist. The chore consisted of merely feeding all that the fish would consume, and then a little more to assure an abundant supply (186). Economics, pollution and other factors have caused revolutionary changes in feeding.

In many fish hatcheries, diets have progressed from all-meat mixtures, to bound mixtures of meats and dry meals, to pelletized diets fed with periodic meat allowances, and recently to exclusive feeding of moist or dry pelletized feed (27,46,114,138,143,146,158,178,186, 187,188,215,216,259). Currently, the 579 state and federal fish hatcheries operating in the United States use an average of 44 percent prepared pellets or other dry feeds; the remaining 56 percent is primarily fish or meat offal (109). No statistics are available on feeding practices for the private sector of the industry.

The quantity of feed per fish is also an important variable in maintaining a hatchery or farm. The amount of feed required is a function of the fish size, activity, and water temperature (185,186). In salmonid hatcheries, it is generally less than 5 percent of the body weight per day for any individual fish and averages between 1.0 and 2.5 percent in a typical hatchery (139). In catfish hatcheries and other warm-water facilities that require feeding, it is usually 5 percent of the body weight per day for any individual fish under two months old and 3 percent for older fish (45).

In fish-culturing facilities that use commercially prepared feed, young fish are fed dry mash which floats, while older fish and adults in ponds or raceways are fed pelleted food (186). Feeding may be manual or mechanical (99) and varies in frequency from daily for salmonid broodfish to twice daily for catfish (45) to hourly feedings for fry (40,81,103,186).

A third raw material required for some fish-culturing operations is fertilizer. As previously stated, some warm-water hatcheries and farms rely upon natural foods existing in earthen ponds. These fish foods are often produced by artificial fertilization of ponds. The fertilizer is dissolved in the pond water and the nutrients from the fertilizer stimulate a growth of algae. These tiny plants may be eaten by protozoans, which, along with the algae, are eaten by water fleas and other invertebrates. The invertebrates are eaten by the young of game fishes or by forage fishes which, in turn, become the prey of larger fish (59). Thus, the nutrient-rich material introduced into the pond during artificial fertilization is subsequently converted into kilograms of fish.

In addition to stimulating the growth of fish-food organisms and thus increasing fish production, pond fertilization has two other desirable effects. First, it makes possible a standard maximum rate of stocking fish. Second, it stimulates the growth of phytoplankton, reducing light penetration, thus preventing the growth of submerged water weeds. Davis (59) and Huet (115) have published detailed descriptions on the techniques and results of proper fish-pond fertilization.

A fourth raw material used by most fish culturing operations is treatment chemicals. These chemicals are used specifically for water treatment or for disease control. The list of chemicals used in fish culturing operations and the typical dosage used in fish propagation activities are shown in Table III-5.

Production Process

Typical fish-hatchery operations are done in 8 to 9 basic steps, consistent with the species, size and growth of the fish. In some hatcheries broodfish are harvested from the brood ponds and stripped of eggs and milt. The eggs and milt are mixed in pans to induce egg fertilization. Then the eggs are incubated in a nursery basin in the controlled environment of an enclosed hatchery building. From the nursery basin, fry are placed in rearing troughs. Fingerlings are transferred to raceways, or in some cases, into flow-thru ponds for fingerling rearing. Young fish are then moved to the main rearing units and raised to marketable or releasable size (59).

In other fish hatcheries or fish farms, culturing techniques are often quite different because the basic unit is a pond rather than a flow-thru unit (29,42,64,95,160,162,180,183,193,214,222,239,255). Instead of harvesting broodfish and stripping eggs and milt by hand, the fish are usually allowed to spawn naturally. In some operations the young are reared in ponds under much the same conditions as those enjoyed by wild fish (59,160). Still other fish-culturing facilities limit their activities to the pond rearing of young fish to maturity for release or sale. Hatchery and farm methods or designs may vary, but the basic facilities and rearing methods have been universally adopted [Figure III-2].

TABLE III-5

CHEMICALS USED FOR CONTROL OF INFECTIOUS DISEASES OF FISHES AND FOR OTHER FISH PRODUCTION RELATED REASONS[a/]

| | |
|---|---|
| Acetic acid, glacial | Diluted in water:<br>1:500 for 30-60 seconds (dip)<br>1:2000 (500 ppm) as bath for 30 minutes |
| Acriflavine (Trypaflavine) | 5-10 ppm added to water every few hours to several days |
| Betadine® (Iodophore containing 1.0% of iodine in organic solvent) | 100 to 200 ppm in water on basis of iodine content by weight for 15 minutes for fish egg disinfection. |
| Bromex® (Dibrom, Naled; a pesticide) | 0.12 ppm added to (pond) water for indefinite time. |
| Calcium cyanamide | Distributed on the bottom and banks of drained-but-wet ponds at a rate of 200 g per $m^2$. |
| Calcium oxide (quicklime) | Distributed on the bottom and banks of drained-but-wet ponds at a rate of 200 g per $m^2$. |
| Carbarsone oxide | Mixed with food at a rate of 0.2%. Feeding for 3 days. |
| Chloramphenicol (Chloromycetin)® | 1. Orally with food 50-75 mg/kg body weight/day for 5-10 days.<br>2. Single intraperitoneal injection of soluble form 10-30 mg/kg.<br>3. Added to water 10-50 ppm for indefinite time as needed. |
| Chlortetracycline (Aureomycin)® | 10-20 ppm in water |
| Copper sulphate (Blue stone)<br>$CuSO_4$, anhydrous<br>$CuSO_4 \cdot 5H_2O$, crystalline | For 1 minute dip: 1:2000 (500 ppm) in hard water. Add 1 ml glacial acetic acid per liter.<br>0.25 to 2 ppm to ponds. Quantity depends on hardness of water. Hard water requires more. |

TABLE III-5 (Cont.)

CHEMICALS USED FOR CONTROL OF INFECTIOUS DISEASES OF FISHES AND FOR OTHER FISH PRODUCTION RELATED REASONS[a]

| | |
|---|---|
| Cyzine® (Enheptin-A) | 20 ppm in feed for 3 days |
| Diquat® (Patented herbicide, Ortho Co. contains 35.3% of active compound) | 1-2 ppm of Diquat cation, or 8.4 ppm as purchased added to water. Treatment for 30-60 minutes. Activity much reduced in turbid water. |
| Dylox® (Dipterex, Neguron, Chlorophos, Trichlorofon Foschlor) | 0.25 ppm to water in aquaria and 0.25 to 1.0 ppm in ponds for indefinite period. |
| Formalin (37% by weight of formaldehyde in water. Usually contains also 12-15% methanol) | 1:500 for 15 minute dip<br>1:4000-1:6000 for one hour<br>15-20 ppm to pond or aquarium water for indefinite period. |
| Formalin with Malachite green | Formalin, 25 ppm<br>Malachite green, 0.05 ppm. For 6 hours in aquaria; may be repeated as needed. For indefinite period in ponds. |
| Furazolidone (Furoxone N.F. 180 N.F. 180 Hess & Clark) Commerical products contain Furazolidone mixed with inert materials. | On the basis of pure drug activity; 25-30 mg/kg body weight/day up to 20 days orally with food. |
| Other Nitrofurans (Japanese) | |
| Furanace (P-7138) Made in Japan | Added to water with fish to be treated at 1 ppm for several hours. Toxicity to different fishes varies from 0.5 to 4.0 ppm (Experimental drug). |
| Hyamine 1622® (Rohm & Haas Co., Quarternary ammonium germicide available as crystals or as 50% solution) | 1.0-2.0 ppm in water for one hour. |

TABLE III-5 (Cont.)

CHEMICALS USED FOR CONTROL OF INFECTIOUS DISEASES OF FISHES AND FOR OTHER FISH PRODUCTION RELATED REASONS[a/]

| | |
|---|---|
| Hyamine 3500® (As above) | As above |
| Iodophores | (See under Betadine and Wescodyne) |
| Kamala | Mixed with diet at a rate of 2%. Feeding to starved fish for 3 days. |
| Malachite green | 1:15,000 in water as a dip for 10-30 seconds. 1-5 ppm in water for 1 hour (most often used as 5 ppm). 0.1 ppm in ponds or aquaria for indefinite time. |
| Methiolate | 10-20 ppm to suppress bacterial growth. |
| Methylene blue | 1.0-3.0 ppm in water for 3-5 days. |
| Neguvon® (See Dylox) | |
| Oxytetracycline® (Terramycin) | 50-75 mg/kg body weight/day for 10 days with food. (Law requires that it must be discontinued for 21 days before fish are killed for human consumption.) |
| Potassium permanganate $KMnO_4$ | 1:1000 (1000 ppm) for a 10-40 seconds dip. 10 ppm up to 30 minutes. 3-5 ppm added to aquarium or pond water for indefinite time. |
| Quinine hydrochloride or Quinine sulfate | 10-15 ppm in water for indefinite time. |
| Roccal® (Benzalkonium chloride, Quarternary ammonia germicide - see also Hyamine 3500. Sold as 10-50% solution) | 1-2 ppm in water for 1 hour. Toxic in very soft water; less effective in hard water. |

TABLE III-5 (Cont.)

CHEMICALS USED FOR CONTROL OF INFECTIOUS DISEASES OF FISHES AND FOR OTHER FISH PRODUCTION RELATED REASONS[a/]

| | |
|---|---|
| Sodium chloride (table salt, iodized or not) | 1-3% in water from 30 minutes to 2 hours only for freshwater fishes. |
| Sulfamerazine | 200 mg/kg body weight/day with food for 14 days. (Law requires that treatment must be stopped for 21 days before fishes are killed for human consumption.) |
| Sulfamethazine | 100-200 mg/kg body weight/day depending on the type of food with which it is mixed. For prophylaxis reduce the quantity to 2 g per kg/day. Length of treatment as recommended. |
| Sulfisoxazole (Gantrisin)® | 200 mg/kg body weight/day with food. |
| Terramycin® (See Oxytetracycline) | |
| Tin oxide, di-n-butyl | 25 mg/kg body weight/day with food for 3 days. |
| Wescodyne® Iodophore containing 1.6% of iodine in organic solvent | 100-200 ppm in water on basis of iodine content by weight for 15 minutes for fish egg disinfection. |

a/ This list of chemicals is from Reference 212.

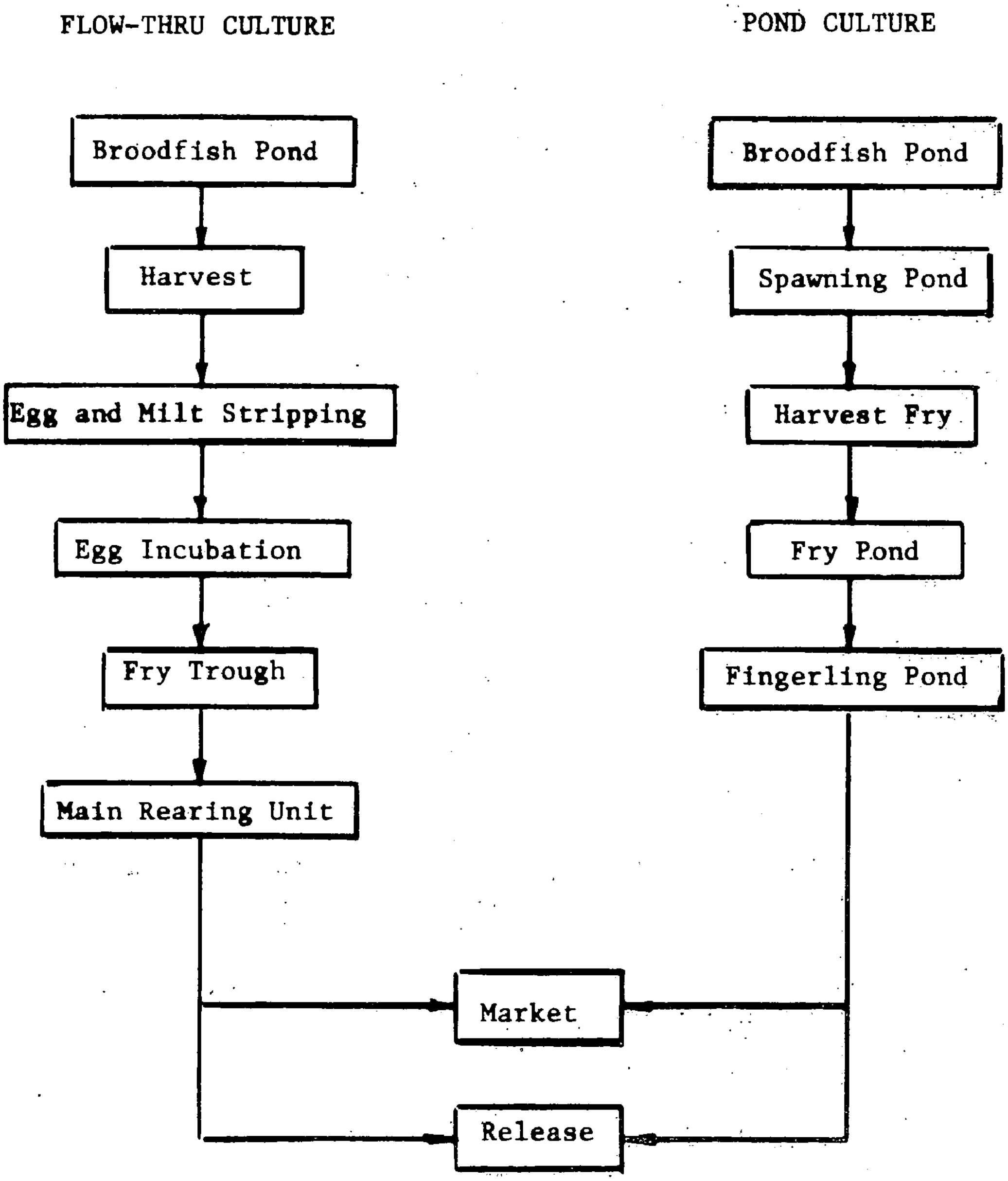


**Figure** III-2. Typical Native Fish-Culturing Process Diagram

## NON-NATIVE FISH - GENERAL DESCRIPTION OF THE INDUSTRY

### Industry Growth

The non-native fish industry in the United States began in Florida in 1929 and has experienced tremendous growth since World War II (56). The annual growth of the number of family-owned ornamental fish, for example, in the years 1969 to 1972 has varied between 15 and 23 percent (25).

It has been estimated that between the years 1968 and 1974, the total population of family-owned pet fish will increase from 130 million to 340 million (206), ornamental fish sales will rise from 150 million dollars to 300 million dollars (206), combined sales of ornamental fish and accessories will increase from 350 million dollars to 750 million dollars (206), and total live fish imported may rise from 64.3 million fish to more than 137 million fish (196).

It has been estimated that more than 1,000 species of ornamental fish are imported into the United States each year (133, 195). For the single month of October 1971, it was reported that 582 species, representing 100 families, were imported (197). Of these, 365 were freshwater species and 217 were marine species. Fifteen species were imported in quantities exceeding 100,000 individuals. Because the list of ornamental fishes imported and cultured is constantly changing, it is not included in this report. The product of ornamental non-native fish culturing facilities is usually pet fish, although a few species used for scientific experimentation are produced (56).

The growth potential of the non-native fish industry involved with food, sport, and biological control species is more difficult to predict.

There are reasons for thinking the industry will grow and other, perhaps more compelling reasons for thinking it will decline. Reasons for believing the industry will grow include the fact that several large companies are interested in culturing and selling grass carp to control the growth of nuisance aquatic plants and a similar interest in silver carp is expected to follow (54). Furthermore, a recent book on aquaculture (17) may stimulate United States fish culturists to attempt rearing many species of exotic fishes as food fishes (52).

Conversely, reasons exist for believing the industry will decline. For example, interest in *Tilapia* farming in Florida is growing slowly, perhaps in part due to State restrictions on culture and possession of all species of this genus (54). For similar reasons, *Tilapia* farming interest is not growing in Louisiana (9). If problems of over-production of stunted populations, lack of consumer demand as food, and deleterious competition with valuable native sport fish become widely known, interest in *Tilapia* farming will probably decline.

The American Fisheries Society has officially adopted a position opposed to the introduction of all non-native fish species prior to careful experimental research and approval by an international, national, or regional agency having jurisdiction over all the water bodies which might be affected (4).

In a similar vein, the Sport Fishing Institute officially adopted a resolution urging the U. S. Department of the Interior to prohibit the importation into the United States, except for well-controlled scientific study purposes, of all exotic fishes other than those that can be proven to lack harmful ecological effects upon the natural aquatic environments of the United States and the native flora and fauna found therein (231).

Both these organizations have a substantial amount of influence on fisheries biologists nationwide and have helped alert state officials to the dangers of introducing harmful species, particularly those related to the carp. Due to the growing awareness of problems associated with non-native species and the growing number of state and federal laws prohibiting various species, enthusiasm for culturing non-native species of sport, food, and biological control fishes may decline.

Types of Facilities

There are essentially three types of ornamental fish production facilities: importers, ornamental fish farmers, and facilities which both import and cultivate ornamental fish.

Facilities which are strictly importers typically unpack the fish, acclimate them for 3 to 21 days, and sometimes treat them with dilute formalin or other chemicals before reshipping them (191).

Ornamental fish farmers ordinarily do not import fish from outside the country but rely primarily on stocks already established in Florida and are usually relatively small operators. A recent report (25) divides small ornamental fish farms into two groups:

Group I includes ornamental fish farmers that have 25 to 40 acres of land, 8 to 12 employees, and produce about 60 species of fish. Some farmers in this group do import fish (219), but the percentage imported is relatively small (25).

Group II includes ornamental fish farmers that have less than 25 acres, employ 1 to 3 people, and produce 20 to 25 species of fish. It is estimated that there are about 120 small farmers in these groups in Florida (25).

The same report states that large ornamental fish farmers typically import fish to increase the volume and variety of their product. The largest farms typically import from 25 to 50 percent of their product and purchase considerable quantities of fish from the smaller farmers. For example, there are 27 operations in the Tampa area alone that do not ship fish themselves, but sell all of their product to other fish farmers (10).

The types of facilities producing non-native carp-related species (grass carp, silver carp, bighead carp, and black carp) and Tilapia are similar in general characteristics to those of pond-cultured native fish.

Location of Facilities

Breeding and culturing of ornamental fish on a commercial basis is worldwide, but the largest single breeding center is Florida (10). It was estimated that 90 percent of the production of ornamental fish in the United States in 1970 was in Florida (25), the location of about 150 facilities (217). In 1972, 150 million ornamental fish (53 million imported, 97 million bred in the state), weighing 10,200 metric tons (11.25 million pounds), were shipped from Florida (25).

Indoor production of non-native ornamental fish by small facilities and even advanced hobbyists occurs throughout the country but most of the outdoor production is in Florida. There is at least one ornamental fish farmer utilizing outdoor production ponds in Louisiana (63), and there are some small outdoor operations in Texas which utilize warm-water springs occurring along a limestone fault line which extends from Austin through San Antonio, Texas (7). Some former outdoor production facilities in Baton Rouge, Louisiana (179), and various parts of California (123,191) have reportedly ceased production.

Production of non-native sport fishes has not been widespread, although the common carp was originally brought to this country in 1877 based partially on claims that it would be a good sport fish (136). Just as these claims later proved to be false, early claims that *Tilapia* would be a good sport fish in Florida (55) and Puerto Rico (77) proved to be exaggerated.

The farming of various species of *Tilapia* as food fish is widespread around the world (100). There is evidence that *Tilapia* was cultured in Egypt as early as 2500 B.C. (148), and some species are still considered to be promising food fish for underdeveloped nations (100). *Tilapia* are being cultured in the United States in Texas (49, 199), California (149,229), Louisiana (100), North Carolina (53), Nebraska (106), and Alabama (100); but production is often experimental or on a small scale. In spite of state restrictions, fear of introductions, disenchantment with sportfish qualities, and over population of stunted fish, dealers in Arizona, Mississippi, and Texas continue to be listed as suppliers of *Tilapia* (79).

The production of non-native relatives of the common carp currently appears to be centered in Arkansas and Missouri, with interest in polyculture of native channel catfish with non-native cyprinids (the grass carp, Ctenopharyngodon idella; silver carp, Hypophthalmichthys molitrix; bighead carp, Aristichthys nobilis; and black carp Mylopharyngodon piceus) increasing only in Arkansas (229). Grass carp, and more recently, silver carp, are for sale by culturists in Arkansas, Minnesota, and Virginia (54). Arkansas has stocked the grass carp widely in the state, including in several large lakes (14). They are for sale from dealers in Missouri and Ohio (79), and experiments with this species continue in Louisiana (9), Arkansas (153), and Florida (53), even though 40 states have now banned them (53).

Silver carp, although not good as food, are being cultured in Arkansas in experiments to determine if they are good "biological filters" for use in sewage treatment (153). A private fish farmer in Arkansas recently imported 100,000 silver carp (147).

The bighead carp is cultured in the Sacramento, California area and sold live in Chinatown, San Francisco, as food fish (147); and at least one private fish farm in Arkansas has had a stock of bighead carp under culture for three years (153). Another Asian carp, the black carp, has been cultured by at least two private fish farmers in Arkansas (153,229).

Raw Materials

The basic raw materials used to produce non-native ornamental fish are high quality water similar to that described for native fish culture except that high water temperatures (ideally 22 to 24°C or 72 to 76°F) are required, fish food, pond fertilizer, and various water treatment chemicals (10).

Ornamental fish food used includes mash, frozen food, live food and dry food (222). Dry food is composed of fish meal, shrimp meal, crab meal, blood meal, salmon-egg meal, pablum, clam meal, beef meal, Daphnia, and fish roe (10). Some fish food used in outdoor ponds consists of about one part fish meal mixed with two parts oatmeal in addition to meat scrap and cotton-seed oil (222). Some pet fish farms utilize commercial pelletized food similar to that used in food fish culture, and others use bulk fish flakes from Germany (137). Many large ornamental fish farms make a wet mash for indoor feeding, using various mixtures of lean ground beef heart, a more expensive fish meal, cooked spinach, and cooked liver (222). Other ingredients used in some wet mashes include oatmeal, shrimp, and egg yolk. Cooked foods utilized include chicken, turkey, fish, beef liver, muscle meats, fish roe, minced clam, boiled shrimp, lobster, and crab (10). Live organisms used as pet fish food include brine shrimp, Daphnia, water boatman, midge larvae, glass worms, Gammarus, microworms, fairy shrimp, snails, meal worms, infusoria, and earthworms (10). Ornamental fishes cultured in Hong Kong and other parts of the orient are fed tubificids and other worms grown in human sewage (93).

As in some other types of warm-water fish culture, fertilizer is sometimes added to ornamental fish ponds to encourage the natural production of planktonic fish food. Sheep manure (a possible source of fecal bacteria) and cottonseed meal are listed as common fertilizers (212). Chemicals used as raw materials for water treatment and disease control in fish culture were previously listed in Table III-5. Raw materials used in the production of non-native food, sport, and biological control fish are similar to those listed for native species.

## Production Process

There are two basic types of ornamental fish production processes, that used for outdoor breeders, primarily live-bearers, and that used for indoor breeders, primarily egg-layers (192, 221). Different species of fish require slightly different culturing techniques, but the basic non-native fish production process follows the flow diagram outlined in Figure III-3.

Outdoor breeding is possible with most live-bearers and with some egg laying species. In the major production areas in Central Florida, dirt ponds are prepared for a new crop by being pumped dry and treated with hydrated lime. The ponds refill in a few days through infiltration (221). Ponds are then fertilized with substances such as cottonseed meal and sheep manure and allowed to remain dormant, except for the addition of live <u>Daphnia</u>, for about three weeks (10). The pond is then full of planktonic fish food and ready to be stocked with fish. One strain of fish is introduced and 5 to 12 months later the fish are ready to be harvested (10, 221). In some cases, the strain remains productive and repeated spawning allows the pond to stay in production without drainage for up to 5 years (221).

While the fish are in ponds, weed control is accomplished with chemicals (10). In the past, dangerous chemicals such as arsenic compounds have been used (10); wide-spread recognition of the dangers

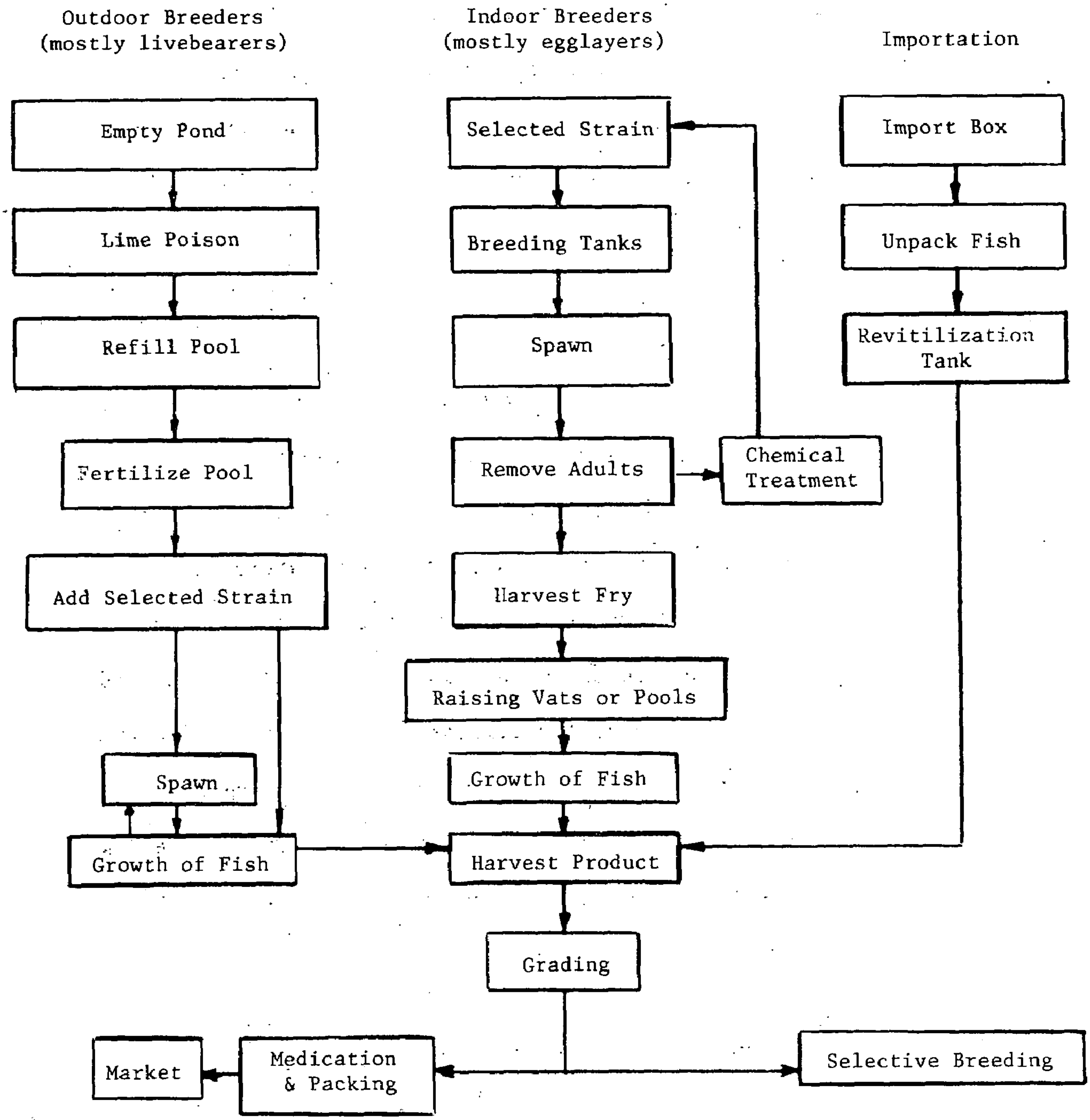


Figure III-3. Non-Native Fish Culturing Process Diagram of such chemicals has hopefully eliminated their use. Some fish are brought inside during the cold periods, while relatively warm well water is sometimes routed through outdoor ponds to help regulate the temperature. The fish are harvested by trapping and brought inside for preshipment holding. During this time they are sometimes medicated with dilute chlorine or various commercial chemicals (192) prior to packing and shipment.

Indoor breeding is done in tanks where after spawning the adults of many species are separated from the eggs (10). The fry may then be cultured in vats or outside in ponds. Many of the egg-layers are sold prior to November to avoid problems of low temperatures, while others are more tolerant and can be retained outside until spring (221).

The process used in the culturing of non-native food, sport, and biological control fish are generally similar to those listed for the pond culture of native fish. However, grass and silver carp are produced in the United States by artificial spawning methods, whereas _Tilapia_ production is from natural spawning in ponds (54).

# SECTION IV.

# INDUSTRY CATEGORIZATION

In developing effluent limitations guidelines and standards of performance for a particular industry, a judgement must be made by the Environmental Protection Agency as to whether effluent limitations and standards are appropriate for different segments or subcategories within the industry.

To determine whether subcategorization was necessary, the following factors or variables were considered.

1. Product
2. Wastes Generated
3. Treatability of Wastewater
4. Production Process
5. Facility Size and Age
6. Geographic Location
7. Raw materials

## FACTORS OR VARIABLES CONSIDERED

### Product

The products of the fish-culturing industry are native and non-native fish. Native fish are cultured in fish farms or hatcheries throughout the United States to be subsequently marketed (sold for consumption or bait) or released (fish stocking). Non-native fish are imported into the United States to be used principally by the aquarium industry.

The principal product of native fish-culturing activities in the United States is mature fish. State and Federal hatcheries rear fish for release to public waterways. Most privately-owned hatcheries or farms rear fish for commercial distribution, primarily for consumption. Although mature fish themselves are the major hatchery product, fish eggs or fingerlings may also be sold to others for rearing. Other operations include rearing broodfish for breeding and marketing and selling fish eggs for consumption or bait.

The product of non-native fish culturing is also mature fish. Instead of being released to public waterways or sold for consumption or bait, non-native species are principally imported by the aquarium industry for sale as ornamental fish.

Therefore, the fish-culturing industry can be subcategorized into native and non-native fish on the basis of fish-type and ultimate use.

Wastes Generated

Native Fish Culturing -- The principal type of waste generated by fish hatcheries or farms is organic material. Through the process of decomposition, these wastes reduce dissolved oxygen levels and increase biochemical oxygen demand, chemical oxygen demand, nitrogen and phosphorus levels. Particles of waste not dissolved within the hatcheries increase the levels of suspended and settleable solids in the effluent while the portion entering solution will elevate the total dissolved solids level (109).

Wastes generated from fish hatcheries or farms are often intermittent and directly related to housekeeping. Rearing ponds and raceways are cleaned typically at intervals varying from daily to monthly or longer. When the facilities are being cleaned, the effluent can contain fecal wastes, unconsumed food, weeds, algae, silt, detritus, chemicals and drugs and can produce a major pollution problem (28,139). Conversely, these same hatcheries or farms may discharge low amounts of wastes during normal operations.

While these operational differences require that special attention should be given to evaluating the increase in wastes generated during cleaning operations, it does not appear that sufficient variability exists to subcategorize the industry on the basis of the type of wastes generated.

Non-Native Fish Culturing -- The wastes generated by non-native fish culturing are similar to those generated by native fish culturing. All non-native fish have the potential for introducing harmful biological pollutants into native ecosystems (55,133,233) so further subcategorization based upon specific biological pollutants is not necessary.

## Treatability of Wastewater

Native Fish Culturing -- Conventional waste treatment methods are capable of reducing the levels of pollutants in fish-farm and hatchery wastewaters. Plant scale sedimentation systems have been operated at several hatcheries and have proven effective in removing that portion of the pollutant load associated with the settleable solids (113,235). Treatability studies have been conducted to determine the pollutant removal efficiency of sedimentation (113,140,251,258), aeration and settling (130,131), stabilization ponds (140), and reconditioning-recycle systems employing several methods of secondary waste treatment (159). Findings indicate that technology is available to accomplish a wide range of efficiencies in removing BOD and suspended solids from fish-culture wastewaters.

Although slug organic loadings do occur in facilities where intermittent cleaning is practiced, study results show that treatment efficiency is not impaired and in some cases increases during cleaning (113,130,131,235). Shock hydraulic loadings occur at some hatcheries during cleaning and should be carefully considered in the design of treatment facilities. In view of the fact that fish-farm and hatchery effluents are amenable to treatment, it does not appear that further division of the native fish-culturing industry is warranted on the basis of treatability of wastewater.

Non-Native Fish Culturing -- The rationale given above for native fish culturing is applicable to non-native fish culturing. The additional treatment technologies used in non-native fish culture, including dry wells, holding reservoirs, ultraviolet disinfection, and chlorination, are alternatives applicable to effluents for any non-native fish production facility and thus further subcategorization is not justified.

## Production Process

Native Fish Culturing -- Basically, fish hatcheries and farms are designed to control the spawning, hatching and/or rearing of confined fish. However, fundamental differences exist in the methods employed in the artificial propagation of cold- and warm-water fishes. Typically cold-water fish are cultured in raceways through which large volumes of water flow, while warm-water fish are pond cultured. Because the production process and resulting waste loads discharged from flow-thru and pond fish-rearing facilities may be substantially different, the need for subcategorization is indicated.

Non-Native Fish Culturing -- Raceway or other continuous flow facilities are not necessary for non-native fish species being cultured at present. Production is typically in static outdoor ponds or indoor tanks [Figure III-3], giving no reason to subcategorize based on slight differences in production processes.

Facility Size and Age

Native Fish Culturing -- The size of fish-culturing operations in the United States varies from facilities capable of producing a few kilograms of fish per year to facilities that produce several hundred thousand kilograms. Both small and large fish-culturing operations may, at certain times and under specific conditions, discharge poor quality water into receiving streams, thus the pollution potential of the industry is not strictly size dependent (232).

During the past 25 years many of the smaller and less efficient fish-culturing operations have been replaced by larger, modern facilities (244). This general practice of modernizing rearing units, coupled with similarities of waste characteristics from fish-culturing facilities of varying sizes, indicates that subcategorization of the native fish-culturing industry on the basis of facility size or age would not be meaningful.

Non-Native Fish Culturing -- The rationale above is also true for non-native fish production. The basic non-native ornamental fish production unit is a tank or a relatively small outdoor pond for large as well as small facilities. Production facilities for non-native sport, food, and biological control species are usually small, primarily due to regulations and fear of introducing harmful biological pollutants.

There are no substantial differences in facilities based on age because non-native fish culturing is a new industry that had its beginning in 1929 (56).

Geographic Location

Native Fish Culturing -- Cold-water fish hatcheries are concentrated in, but not limited to, the northwest region of the United States. Warm-water fish culturing facilities are primarily located in the central-southern and southeastern section of the country.

The specific location of these fish farms and hatcheries is determined by such factors as availability of water, climatic conditions, terrain, and soil types. Geographical location of a fish-culturing operation may determine the degree of success in rearing certain species of fish, or it may influence the selection of waste-treatment equipment, but it does not substantially alter the character of the wastewater or its treatability. Therefore, subcategorization according to location is not indicated.

Non-Native Fish Culturing -- The rationale given above for native fish production is also true for non-native fish. Because indoor producers typically do not discharge into navigable waters and because outdoor producers occur primarily in the South, there is no need for further subcategorization on the basis of geographic location.

Raw Materials

Native Fish Culturing -- Raw materials used for fish propagation operations include water, feed, fertilizer and treatment chemicals. The quantity of these materials used is generally dependent upon such factors as water temperature, fish size, rearing process, species and facility-carrying capacity (176).

Although variations in the amount and type of raw material used may change the strength of the waste discharged from the culturing facility, there are too many dependent variables to develop realistic subcategories. Therefore, it does not appear practical to subcategorize the native fish-culturing industry on the basis of raw materials used.

Non-Native Fish Culturing -- Raw materials listed above for native fish are used also in the cultivation of non-native fish. In addition, chemicals mentioned specifically for use in disease control in ornamental fish culturing include mercurochrome, epsom salts, and tetracycline hydrochloride (10).

## Subcategorization

On the basis of fundamental differences in holding, culturing, harvesting, cleaning and other factors, and rationale discussed herein, the United States fish-culturing industry was subcategorized for the purpose of designing adequate treatment systems and for developing recommended effluent standards and guidelines. These subcategories are:

Native Fish -- Flow-thru Culturing Systems

Native Fish -- Pond Culturing Systems

Non-Native Fish Culturing Systems

# SECTION V.

## WASTE CHARACTERISTICS

Wastewaters from fish culturing activities may contain metabolic waste products, residual food, algae, detritus, pathogenic bacteria, parasites, chemicals and drugs (28,109,139). Major consideration is given to metabolic and uneaten food wastes because these organic pollutants are characteristic of most fish culturing waste discharges while the other substances named above are often discharged sporadically (23, 109,139). The rate and concentration of organic waste discharged from a fish culturing facility are dependent upon such factors as feeding, fish size, loading densities and water supply (26,103,139,140,170,207). Because of the numerous combinations of these variables, typical waste characteristics were computed from the results of several independent studies. Values cited in this section were determined for sampling that ranged from single grab samples to 24-hour composite samples consisting of portions collected at hourly intervals. These values reflect the daily waste production for the fish culturing industry.

Organic wastes usually cause such water quality changes as reduction in the dissolved oxygen concentration and increase in the level of oxygen demanding materials, solids and nutrients (109,159). These and other waste characteristics are discussed below for native and non-native fish culturing activities.

## NATIVE FISH

### Oxygen and Oxygen-Demanding Constituents

Aside from the presence of waste products, the most important single factor affecting the number of fish that can be held in the restricted space of a pond, raceway or other culturing facility is the concentration of dissolved oxygen (DO) in the water (59). It is generally agreed that for good growth and the general well-being of cold- and warm-water fish, the DO concentration should not be less than 6 and 5 mg/l, respectively (245). Under extreme conditions, the DO may be lower for short periods provided the water quality is favorable in all other respects; however, it should never be less than 4 mg/l at any time (245). To reach or maintain these oxygen levels, some fish hatcheries and farms must rely upon artificial aeration devices.

As water passes through a fish rearing unit, the DO may be reduced (105). The change in DO concentration is mainly due to direct fish uptake and partly due to atmospheric losses and benthal oxygen demand (105,139).

Gigger and Speece (86) reported that small fish excrete more oxygen demanding wastes and directly use more oxygen per kilogram of fish than large fish do. Liao (139) graphically expressed this relationship for salmonid fishes by showing that as fish size increases from 16.5 to 21.6 cm (6.5 to 8.5 inches), the biochemical oxygen demand (BOD) production and oxygen uptake per kilogram both decrease [Figure V-1].

In terms of a daily oxygen reduction rate per kg of fish being cultured, the decrease in water passing through a typical fish hatchery

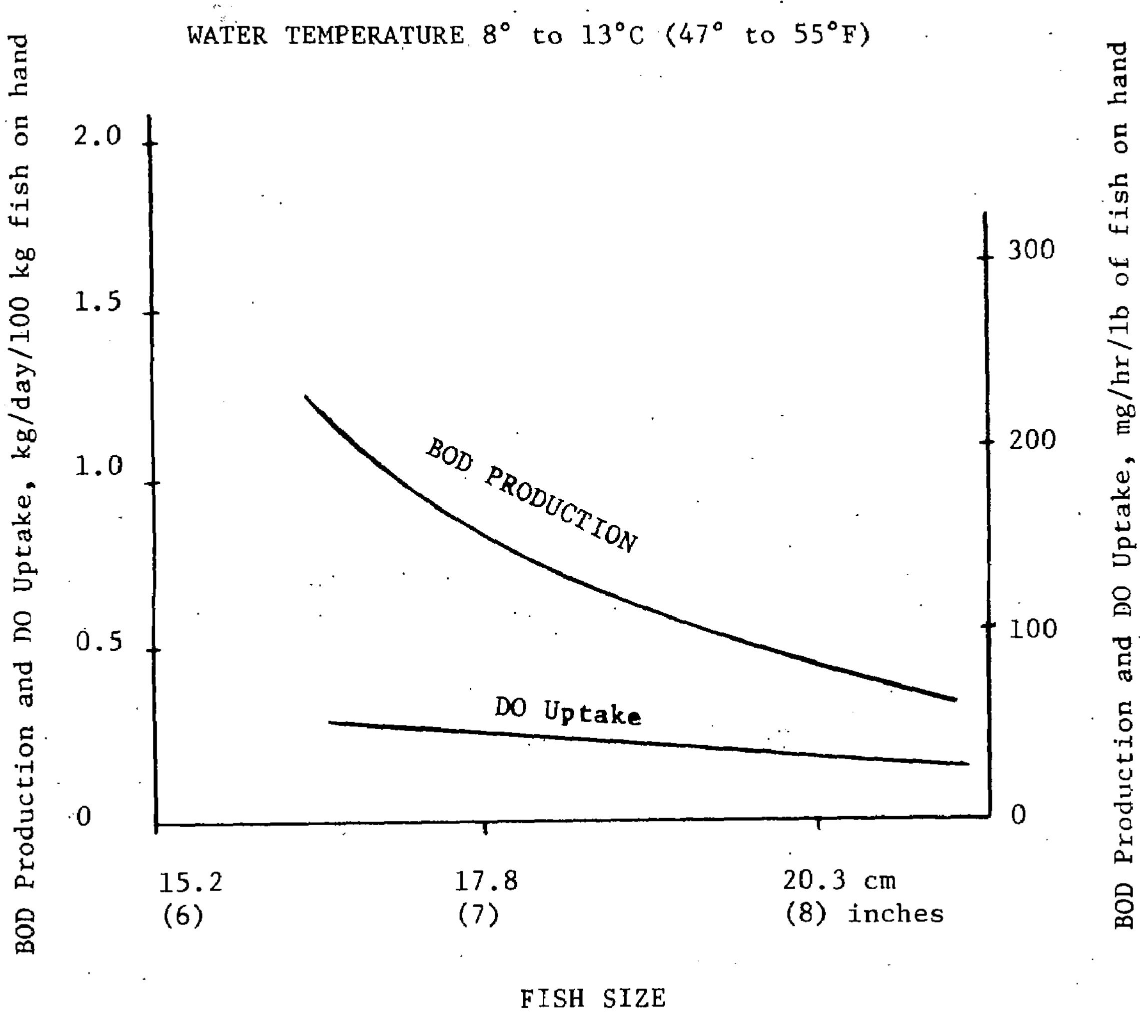


Figure V-1. BOD Production and DO Uptake Rates Versus Fish Size (139).

ranges from 0.2 to 1.7 kg with an average of 0.7 kg of oxygen used for each 100 kg of fish (139).

Accumulation and decomposition of waste feed, fish excreta or other organic matter in a culturing facility may reduce the amount of oxygen available to the fish. Usually this loss of oxygen is expressed in terms of concentrations or exertion rates of biochemical oxygen demand (BOD) or chemical oxygen demand (COD). The oxygen demanding materials in certain types of warm- and cold-water fish culturing facilities were compared in Table V-1. Findings showed that flow-thru systems culturing either warm- or cold-water fishes produce an average net increase in BOD of 3 to 4 mg/l during normal operations. The corresponding net increase in COD for these flow-thru culturing facilities averages 16 to 25 mg/l.

During cleaning operations there is a marked increase in the concentration of oxygen demanding materials discharged. Liao (139) reported that the average BOD concentration increased from 5.4 to 33.6 mg/l during cleaning activities at salmonid fish hatcheries. Other studies by Dydek (69) have shown similar results. Dydek reported that the average BOD concentration increased from 6.4 to 28.6 mg/l during raceway cleaning at the four federal fish hatcheries he evaluated. Results shown in Table V-1 reflect this trend for cold-water fish cultures.

Although survey data are not available to specifically evaluate cleaning wastes from warm-water fish culturing facilities, some reasonable assumptions can be made. During normal operations, flow-thru ponds and raceway systems used exclusively for rearing warm-water fish have BOD and COD characteristics quite similar to those reported in wastewaters

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TABLE V-1

OXYGEN-DEMANDING CHARACTERISTICS OF EFFLUENTS FROM FLOW-THRU FACILITIES CULTURING NATIVE FISH[a/]

| | Normal Operation | | Cleaning Operation | | |
|---|---|---|---|---|---|
| | Effluent (mg/l) | Net Change (mg/l) | Effluent (mg/l) | Net Change (mg/l) | Waste Load (kg/100 kg fish on hand/day) |
| **COLD-WATER FISH CULTURE** | | | | | |
| BOD | | | | | |
| Average | 5.0 | 4.0 | 27.3 | 21.2 | 1.3 |
| Range | 0.2-12 | 1.0-6.2 | 7.3-56 | -- | 0.5-2.5 |
| No. of Samples | 639 | 636 | 9[b/] | 9[b/] | 157 |
| COD | | | | | |
| Average | 30 | 25 | 97 | 48 | 6 |
| Range | 2-460 | 0-96 | 83-110 | -- | 0.6-22 |
| No. of Samples | 107 | 97 | 9[b/] | 9[b/] | 12 |
| **WARM-WATER FISH CULTURE** | | | | | |
| BOD | | | | | |
| Average | 8.2 | 3.1 | -- | -- | 1.4 |
| Range | 0.6-21 | 0.5-12 | -- | -- | 0.2-5.0 |
| No. of Samples | 300 | 150 | -- | -- | 17 |
| COD | | | | | |
| Average | 34 | 16 | -- | -- | 5 |
| Range | 2-120 | 4-24 | -- | -- | 0.7-17.8 |
| No. of Samples | 12 | 5 | -- | -- | 13 |

a/ Summarized from the data presented in Supplement B.

b/ Based upon selected data collected during cleaning activities at 9 fish hatcheries (References 69,75,76,139).

from cold-water fish culturing facilities. Therefore, one might expect raceway or flow-thru pond cleaning in warm-water facilities to produce about the same amount of oxygen demanding pollutants as reported for cold-water operations. This assumption becomes more acceptable when waste loads from flow-thru facilities culturing cold- and warm-water fish are compared. An extensive literature search and available field data indicate that flow-thru culturing facilities produce a daily average of 1.3 and 1.4 kg of BOD and 6 and 5 kg of COD per 100 kg of cold and warm-water fish respectively [Table V-1].

Typically, warm-water fish are cultured in earthen ponds (68). Cleaning is not routinely practiced for various reasons including practicality, manpower, time and need. If done at all, pond cleaning operations are usually accomplished in conjunction with fish harvesting. Therefore, waste characteristics shown in Table V-2 reflect conditions that exist when ponds are being drained to aid in fish harvesting.

Generally, pond-reared fish are harvested during the fall, following a spring and summer rearing period. In practice, the water level is drawn down to a suitable depth for wading. This activity is usually referred to as pre-harvest draining. The fish are then harvested with nets and in many operations the pond is then drained completely. The latter activity is termed post-harvest draining.

From a literature search supplemented with field studies by the Environmental Protection Agency (74), typical pond wastewaters from facilities culturing native fish have been characterized [Table V-2]. These studies show that wastewaters discharged during draining activities

TABLE V-2

OXYGEN-DEMANDING CHARACTERISTICS OF EFFLUENTS FROM CULTURING PONDS BEING DRAINED DURING FISH HARVESTING ACTIVITIES[a]

| | Effluent (mg/l) | Waste Load (kg/100 kg fish on hand) |
|---|---|---|
| BOD | | |
| Average | 5.1 | 2.2 |
| Range | 0.8-21 | 0.2-5.9 |
| No. of Samples | 135 | 40 |
| COD | | |
| Average | 31 | 6.2 |
| Range | 0-130 | 0.7-17.8 |
| No. of Samples | 33 | 30 |

a/ Summarized from the data presented in Supplement B.

had average BOD and COD concentration of 5.1 and 31 mg/l, respectively. In terms of waste loads, the draining wastewaters had 2.2 kg of BOD and 6.2 kg of COD for each 100 kg of fish being cultured.

Solids

Several sources contribute to the increase in the concentration of solids as water flows through a fish culturing facility. The unnaturally high density of fish confined in the facility leads to rapid accumulation of metabolic by-products and the buildup of particulate fecal matter (28). Speece (226) and Liao (139) cited this as a major contributor to the accumulation of solids in some fish culturing facilities. They showed that there is a correlation between the amount of solids produced by hatcheries and the amount of food fed; for every 0.45 kg (1.0 pound) of feed consumed, 0.14 kg (0.3 pound) of suspended solids are excreted by the fish. When feed is not completely consumed, it is not only wasteful and costly, but also contributes to the effluent BOD and suspended solids concentrations (139). In addition, the cleaning of algae, silt and detritus from ponds and raceways produces periodic discharges of additional solids.

Table V-3 shows that under normal operating conditions flow-thru systems culturing warm- or cold-water fish produce similar quantities of solids. The net increase in suspended solids in cold-water fish facilities is 3.7 mg/l while in warm-water fish facilities the increase is greater at 9.7 mg/l. Results also show that the settleable solids are very low averaging 0.6 ml/l and 0.2 ml/l in effluents from cold- and warm-water fish culturing facilities, respectively. Settleable solids are defined as the volume of solids that settle within one hour under quiescent conditions in an Imhoff Cone (234). Dissolved solids in cold-water hatcheries showed a net change (effluent minus influent) ranging from minus (-) 183 to 116 mg/l with an average value of 12 mg/l. The minus value is assumed to reflect the decrease in dissolved solids caused by biological uptake. Dissolved solids in warm-water fish facilities showed a net average increase of 22 mg/l, nearly twice the increase reported for cold-water fish operations. In part, this may be due to the fact that accumulated waste solids are intermittently flushed from cold-water fish rearing facilities during cleaning while in warm-water facilities waste solids are left to digest and solubilize.

During cleaning operations in cold-water fish facilities, the accumulation of waste, feed, fish feces, algae and other detritus is removed from the culturing facility. Table V-3 shows that the average suspended solids concentration increases more than 16 times, from a net change of 3.7 to 61.9 mg/l, during cleaning activities. The net change in settleable solids increased more than four times from 0.5 to 2.2 ml/l. Based upon data reported by Liao (139), there is no net change in the dissolved solids concentration when comparing normal operation effluent characteristics with cleaning-water characteristics.

Effluent characteristics reported by Dydek (69) and Liao (139) demonstrate that the previously discussed increases in solids and the data shown in Table V-3 are typical. Dydek reported that average suspended solids concentrations increased from 22 to 74 mg/l during raceway cleaning activities at three Federal fish hatcheries. Liao (139) reported suspended

TABLE V-3

SOLIDS CHARACTERISTICS OF EFFLUENTS FROM FLOW-THRU FACILITIES CULTURING NATIVE FISH[a/]

| | Normal Operation | | Cleaning Operation | | |
|---|---|---|---|---|---|
| | Effluent (mg/l) | Net Change (mg/l) | Effluent (mg/l) | Net Change (mg/l) | Waste Load (kg/100 kg fish on hand/day) |
| **COLD-WATER FISH CULTURE** | | | | | |
| Suspended Solids | | | | | |
| Average | 9.5 | 3.7 | 73.5 | 61.9 | 2.6 |
| Range | 0-220 | (-)13-40 | 0.1-122 | 3.6-120 | (-)19.8-23.8 |
| No. of Samples | 398 | 354 | 133 | 130 | 105 |
| Dissolved Solids | | | | | |
| Average | 326 | 12 | 78[b/] | 0[b/] | 22 |
| Range | 5-520 | (-)183-116 | -- | -- | (-)11.4-164 |
| No. of Samples | 238 | 238 | 75 | 75 | 88 |
| Settleable Solids[c/] | | | | | |
| Average | 0.6 | 0.5 | 2.2 | 2.2 | -- |
| Range | <0.1-12 | 0-10 | 0.5-3.5 | 0.5-3.5 | -- |
| No. of Samples | 168 | 168 | 5 | 5 | -- |
| **WARM-WATER FISH CULTURE** | | | | | |
| Suspended Solids | | | | | |
| Average | 38.2 | 9.7 | -- | -- | 3.1 |
| Range | 0.5-470 | 4-464 | -- | -- | 0.19-3.5 |
| No. of Samples | 91 | 83 | -- | -- | 9 |
| Dissolved Solids | | | | | |
| Average | 136 | 22 | -- | -- | 13 |
| Range | -- | -- | -- | -- | 0.37-49 |
| No. of Samples | 8 | 8 | -- | -- | 14 |
| Settleable Solids[c/] | | | | | |
| Average | 0.2 | <0.1 | -- | -- | -- |
| Range | <0.1-0.7 | 0-0.7 | -- | -- | -- |
| No. of Samples | 7 | 7 | -- | -- | -- |

a/ Summarized from the data presented in Supplement B.
b/ Data are from Reference 139.
c/ Reported as ml/l

solids ranged from 0 to 55 mg/l during normal operations and ranged from 85 to 104 mg/l during cleaning activities. This was an average net increase of 89 mg/l of suspended solids during cleaning. Liao addressed the pollution potential of solids by pointing out that his studies showed nearly 90 percent of the suspended solids removed from raceways during cleaning operations become settleable under optimum conditions. He concluded that ". . . most of the [suspended] solids contained in the cleaning water will immediately deposit on the stream bottom below the hatchery."

Although data are not available to evaluate the solids characteristics in cleaning wastes from warm-water fish cultures, it is expected that they do not differ appreciably from cold-water operation cleaning wastes. The daily waste loads for solids reported in the literature and obtained during field studies tend to substantiate this similarity. In terms of weight, Table V-3 shows that cold-water fish culturing units discharge an average of 2.6 kg of suspended solids per 100 kg of fish on hand per day. Warm-water fish cultures that are operated as flow-thru systems discharge slightly greater solids loads averaging 3.1 kg of suspended solids per 100 kg of fish on hand per day.

Solids are also discharged directly into receiving streams when earthen ponds are drained to harvest fish. To evaluate the pollution potential of these wastewaters several studies were reviewed and additional sampling was conducted (74). The data were compiled and are summarized in Table V-4. Findings showed that during harvest draining, ponds contributed from 4 to 470 mg/l of suspended solids. The variation

TABLE V-4

SOLIDS CHARACTERISTICS OF EFFLUENTS FROM CULTURING PONDS BEING DRAINED DURING FISH HARVESTING ACTIVITIES[a/]

| | Effluent (mg/l) | Waste Load (kg/100 kg fish on hand) |
|---|---|---|
| Suspended Solids | | |
| Average | 157 | 23.5 |
| Range | 4-470 | 3.5-43.7 |
| No. of Samples | 30 | 30 |
| Settleable Solids[b/] | | |
| Average | 5.5 | -- |
| Range | <0.1-39 | -- |
| No. of Samples | 46 | -- |

a/ Summarized from the data presented in Supplement B.
b/ Reported as ml/l

was caused by the fact that solids are strongly influenced by such factors as sediment type and algae. On the average, draining wastewater contained 157 mg/l of suspended solids of which 5.5 ml/l were settleable. In terms of waste loads, the draining wastewater produced 23.5 kg of suspended solids per 100 kg of fish cultured.

Nutrients

In fish culturing facilities uneaten feed and fish excreta accumulating in the raceways and ponds are rich sources of nutrient pollutants. The nitrogen content, for example, of dried feces has been measured as 5.8 percent for carp and 7.3 percent for sunfish (86). As this fecal matter decomposes in the water system, organic nitrogen may be changed into ammonia by bacteria (124). In an open or flow-thru system there is usually sufficient water flow to dilute toxic levels of ammonia to harmless concentrations [<0.3 mg/l according to Smith (210), Burrows (35) and Brockway (28)]. However, in some open and many closed systems, such as a recycle facility, ammonia accumulation is often a major problem (144,145). It has been demonstrated that fish exposed to ammonia concentrations of 1.6 mg/l for six months have reduced stamina, reduced growth, suffer extensive degenerative changes to gill and liver tissue and are more susceptable to bacterial gill disease (210). The literature shows that the ammonia concentration in fish hatchery wastewaters is erratic but on an average ranges from 0.2 to 0.5 mg/l (36,113,139,247).

Given sufficient time and proper conditions organic nitrogen and phosphorus in waste feed and fish excreta will be oxidized to nitrate and phosphate. Table V-5 shows that under normal operating conditions, flow-thru systems culturing either warm or cold-water fish produce similar concentrations of nutrients. On the average there is a net increase in ammonia-nitrogen ($NH_3$-N) of 0.35 mg/l, and in total phosphate ($PO_4$-P) of 0.05 to 0.09 mg/l. On the other hand the nitrate-nitrogen ($NO_3$-N) concentration decreases on the average of 0.17 to 0.22 mg/l as water flows through the fish culturing facility. This net loss of nitrate is assumed to be caused primarily by biological uptake in phytoplankton and periphyton growths that commonly occur in raceway and ponds through which the nutrient-rich waters flow.

During cleaning operations there is a change in the concentrations of certain forms of nutrients in the fish culturing facility wastewater. The net change in ammonia-nitrogen was reported to be an increase from 0.35 to 0.52 mg/l, nitrate-nitrogen increased from (-) 0.17 to 0.64 mg/l, total kjeldahl nitrogen (TKN), which includes ammonia and organic nitrogen, increased from 0.74 to 1.15 mg/l and total phosphate increased from 0.09 to 0.38 mg/l. Although no data are available for characterizing the nutrient levels in cleaning wastewaters from warm-water (flow-thru) systems, there is little reason to believe that the characteristics differ from those reported for cold-water fish facilities. A comparison of the nutrient waste loads produced in either cold- or warm-water fish culture discharges shows the similarity in nutrient characteristics [Table V-5]. An average range of 0.06 and 0.07 kg of nitrate-nitrogen per 100 kg of fish on hand per day are discharged by cold- and warm-water fish culturing facilities, respectively. Further similarity in nutrient characteristic of wastewaters is shown by the fact that both flow-thru facilities produce 0.03 kg of phosphate per 100 kg of fish on hand per day.

TABLE V-5

NUTRIENT CHARACTERISTICS OF EFFLUENTS FROM FLOW-THRU FACILITIES CULTURING NATIVE FISH

| | Normal Operation | | Cleaning Operation | | |
|---|---|---|---|---|---|
| | Effluent (mg/l) | Net Change (mg/l) | Effluent (mg/l) | Net Change (mg/l) | Waste Load (kg/100 kg fish on hand/day) |
| **COLD-WATER FISH CULTURE** | | | | | |
| $NH_3$-N | | | | | |
| Average | 0.52 | 0.35 | 0.59 | 0.52 | 0.09 |
| Range | 0.0-3.60 | 0.02-2.18 | 0.06-2.40 | -- | 0.02-0.40 |
| No. of Samples | 654 | 644 | 7[a/] | 7[a/] | 116 |
| TKN | | | | | |
| Average | 1.20 | 0.74 | 2.05 | 1.15 | 0.20 |
| Range | 0.01-12.80 | 0.05-1.53 | 0.61-5.95 | -- | -- |
| No. of Samples | 251 | 248 | 7[a/] | 7[a/] | 1 |
| $NO_3$-N | | | | | |
| Average | 1.73 | (-)0.17 | 1.27 | 0.64 | 0.06 |
| Range | 0.0-8.2 | (-)3.6-1.1 | 0.13-4.50 | -- | (-)0.38-1.50 |
| No. of Samples | 685 | 619 | 7[a/] | 7[a/] | 143 |
| Total $PO_4$-P | | | | | |
| Average | 0.16 | 0.09 | 0.59 | 0.38 | 0.03 |
| Range | 0-0.57 | (-)0.09-0.94 | 0.17-1.63 | -- | 0.0-0.44 |
| No. of Samples | 375 | 372 | 7[a/] | 7[a/] | 85 |
| **WARM-WATER FISH CULTURE** | | | | | |
| $NH_3$-N | | | | | |
| Average | 0.41 | 0.36 | -- | -- | 0.09 |
| Range | 0.10-1.63 | 0.10-0.56 | -- | -- | 0.01-0.65 |
| No. of Samples | 137 | 126 | -- | -- | 18 |
| TKN | | | | | |
| Average | 0.63 | 0.55 | -- | -- | 0.41 |
| Range | 0.30-2.40 | 0.20-1.87 | -- | -- | 0.04-1.00 |
| No. of Samples | 16 | 7 | -- | -- | 7 |
| $NO_3$-N | | | | | |
| Average | 0.98 | (-)0.22 | -- | -- | 0.07 |
| Range | 0.05-4.00 | (-)0.31-0.10 | -- | -- | 0.02-0.29 |
| No. of Samples | 236 | 3 | -- | -- | 12 |
| Total $PO_4$-P | | | | | |
| Average | 0.28 | 0.05 | -- | -- | 0.03 |
| Range | 0.01-0.90 | (-)0.02-0.17 | -- | -- | (-)0.003-0.39 |
| No. of Samples | 17 | 17 | -- | -- | 18 |

a/ Based upon data collected during cleaning activities at 7 fish hatcheries (References 69,75,76).

DRAFT

A review of available data from various State agencies, the Bureau of Sport Fisheries and Wildlife and the Environmental Protection Agency shows that when earthen ponds are drained to harvest fish, nutrients are discharged into receiving waters. The ponds studied were in Oklahoma, Missouri, Georgia, Alabama, California, Ohio, Minnesota, Kansas and Arkansas. A summary of the results are presented in Table V-6. These studies show that, during draining, wastewaters contained an average of 0.39 mg/l ammonia-nitrogen, 0.78 mg/l of total kjeldahl nitrogen, 0.41 mg/l of nitrate-nitrogen and 0.13 mg/l of total phosphate. In terms of waste loads, the harvest wastewaters contained 0.04 kg of both nitrate and phosphate and 0.25 kg of ammonia per 100 kg of fish on hand.

Although nutrient levels in fish culturing wastewaters may occasionally be sufficient to stimulate algal growths, this condition is likely to occur only when the hatchery discharge constitute the major portion of the receiving water flow.

Bacteria

The Bureau of Sport Fisheries and Wildlife, U. S. Department of the Interior, established a water quality monitoring program in 1971 at 23 of its Federal fish hatcheries including 3 warm-water fish hatcheries (Senecaville, Ohio; New London, Minnesota and Tishomingo, Oklahoma). The monitoring studies were conducted over a period of one calendar year with sampling usually done on a monthly basis. These studies include the evaluation of coliform bacterial densities in the inflow or source water and the outflow water of the hatcheries. From these data, net changes in the bacterial densities were calculated (outflow

TABLE V-6

NUTRIENT CHARACTERISTICS OF EFFLUENTS FROM CULTURING PONDS BEING DRAINED DURING FISH HARVESTING ACTIVITIES[a/]

| | Effluent (mg/1) | Waste Load (kg/100 kg fish on hand) |
|---|---|---|
| $NH_3$-N | | |
| Average | 0.39 | 0.25 |
| Range | 0.07-3.00 | 0.06-0.36 |
| No. of Samples | 228 | 22 |
| TKN | | |
| Average | 0.78 | -- |
| Range | 0.10-5.25 | -- |
| No. of Samples | 54 | -- |
| $NO_3$-N | | |
| Average | 0.41 | 0.04 |
| Range | 0.0-1.39 | 0.02-0.05 |
| No. of Samples | 107 | 17 |
| Total $PO_4$-P | | |
| Average | 0.13 | 0.04 |
| Range | 0.01-0.45 | 0.01-0.12 |
| No. of Samples | 61 | 22 |

a/ Summarized from the data presented in Supplement B.

values minus inflow or source water values). The data showed that cold-water fish hatcheries had a mean net increase in total coliform of 170 per 100 ml of water and a mean net increase in fecal coliform of 28 per 100 ml of water. Studies at the warm-water fish culturing facilities in Tishomingo, Oklahoma showed a mean net increase of 58,000 and 4,800 per 100 ml of water for total coliform and fecal coliform bacteria, respectively.

A special study was done in conjunction with the preparation of this document to determine if coliform bacteria are harbored in the intestinal tract of fish and to determine the source of the coliform bacteria contamination [Table V-7]. Findings showed that large densities of non-fecal coliform bacteria are present in the gut of trout being cultured in a fish hatchery. The average (log mean) density of total coliform bacteria found in the gut of 15 rainbow trout examined was >2.5 million per 100 gm of fecal matter. No fecal coliform bacteria were isolated (value expressed as <20 in Table V-7). Examination of fish feed (commercially prepared pellets) and intake or hatchery source water showed total coliform bacterial densities (log mean) of 9,000 per 100 grams and 52 per 100 ml of water, respectively. No fecal coliform were isolated from the feed samples while the hatchery intake water contained a range of <2 to 11 fecal coliforms per 100 ml of water. Examination of the hatchery effluent revealed that wastewaters contained a log mean of 4,100 total coliform bacteria and 6 fecal coliform bacteria per 100 ml of water. It was concluded from this study that fecal coliform bacteria originated from the hatchery source water

## TABLE V-7

## SOURCES OF COLIFORM BACTERIA IN A COLORADO TROUT HATCHERY

### COLIFORM DENSITIES PER 100 GRAMS IN INTESTINAL CONTENTS OF RAINBOW TROUT[a] (OCTOBER 15-19, 1973)

| Fish Species | Water Temperature °F | Water Temperature °C | No. of Samples | Total Coliforms Log Mean | Total Coliforms Range | Fecal Coliforms Log Mean | Fecal Coliforms Range |
|---|---|---|---|---|---|---|---|
| Rainbow trout | 52 | 11 | 5 | >2,500,000 | 33,000->24,000,000 | <20 | <20 |

a/ Three fish were collected for each analysis.

### COLIFORM DENSITIES PER 100 GRAMS IN PELLETIZED FISH FEED

| No. of Samples | Total Coliform Log Mean | Total Coliform Range | Fecal Coliforms Log Mean | Fecal Coliforms Range |
|---|---|---|---|---|
| 5 | 9,000 | 2,300-17,000 | <20 | <20 |

### COLIFORM DENSITIES PER 100 ml IN TROUT-CULTURING WATER

| Station Location | Temperature °F | Temperature °C | Total Coliforms Log Mean | Total Coliforms Range | Fecal Coliforms Log Mean | Fecal Coliforms Range |
|---|---|---|---|---|---|---|
| Intake Water from Watson Lake | 52 | 11 | 52 | 22-330 | <3 | <2-11 |
| Raceway Water at Midpoint | 52 | 11 | 690 | 220-2,800 | <2 | <2-4 |
| Discharge from Combined Raceways | 52 | 11 | 4,100 | 1,300-28,000 | 6 | 5-8 |

(a river) and that other coliform bacteria are commonly present in the feed or source water; furthermore, these non-fecal bacteria accumulate in the intestinal tract of cold-water fish.

In the past, the literature indicated that fish rarely harbor bacteria normally found in the mammalian digestive tract (6,78,83,84, 85,88,98,107,116,118,120,154,201,237,253). However, other coliform bacteria normally associated with decaying vegetation, or soil have been found in accumulated uneaten feed and fish fecal material in fish hatchery raceways. Furthermore, examples are cited where the source water or feed contained high levels of coliform bacteria and consequently the fish hatchery wastewater contained high bacterial levels.

## NON-NATIVE FISH

### Oxygen Demanding Constituents, Solids, Nutrients, and Flow

There appears to be little data in the literature which relate strictly to these effluent characteristics from non-native fish culturing facilities. This may be partly because tropical fish culturing tanks and ponds are relatively small (most have a water volume of less than 50 cu m or 18,000 cu ft) when compared to native fish ponds and are sometimes drained less than once per year. Even large non-native fish culturing facilities do not usually drain more than two ponds per day. A typical maximum flow rate for draining two fish ponds (6 x 25 x 60 ft) per day is about 6.3 liters per second (100 gpm) (179), whereas winter flow-thru rates for one facility with 80 ponds was reported as 10.7 liters per second (170 gpm) (63). Non-native sport, food, and biological control species may be cultured in larger ponds, but to date their production has been primarily experimental and thus the volume of water discharged nationwide has been much smaller than the volume of water discharged from native fish culturing facilities. It has been estimated that only three million gallons of wastewater accompanies fish imports each year (56).

In the absence of other data, it seems reasonable to assume that the concentrations of oxygen demanding constituents, solids, and nutrients discharged from non-native fish culturing facilities are not unlike concentrations discharged from warm-water native fish culturing facilities. This assumption is based on the fact that the production processes involved are either very similar (in the case of non-native sport, food, and biological control species) or similar but scaled down (in the case of the ornamental fish) to processes utilized in some types of native fish culturing operations.

Biological Pollutants

A concern that severe environmental degradation might be the result of discharges of bacteria, parasites or other harmful organisms contained in the effluents of non-native fish production facilities has been voiced by many authorities (3,16,19,51,57,92,165,177,194,195,198,208,233,238). Aquatic environments in the United States are already stressed by pollution and physical alteration by man. Additions of foreign parasites, pathogens, predators, or species which might compete more favorably than native species for habitat or food represent a serious additional threat to the native aquatic environment (57). Experts on the subject have suggested that the introduction of any harmful non-native organism into the environment should be considered a form of pollution and that these organisms should be referred to as biological pollutants (55,133,198).

This approach is born out by past history of problems brought about by the introduction of undesirable species. In addition to the well publicized harmful effect of some fish introductions, many fish and shellfish parasites have been introduced from continent to continent and have caused economic losses, especially in stocks of game fish and shellfish (56,209).

Any introduced host, including those passing a quasi-quarantine by being held in facilities for a period of time, often retains the ability to introduce parasites into new localities (57). Various chemical and physical treatments are not always successful (57). Increased parasitism of local fish has occurred following the introduction of a non-native fish in at least one American river (60).

Concentrations of various biological pollutants discharged vary greatly depending on the individual pond and method of operation. In some cases, the entire pond and all its contents, including fish, have been discharged directly into navigable waters (55). In other cases the fish are kept in the pond but the water, containing bacteria and possibly other biological pollutants, is discharged into navigable waters. Because their concentrations in fish culturing effluents is so variable, most of the biological pollutants are discussed here qualitatively rather than quantatively.

The discussion of probable or possible as well as confirmed biological contaminents in discharges from non-native fish culturing facilities is appropriate for the following reasons:

1) There is some evidence that non-native fish may serve as carriers of human pathogens [Table V-8]. The relatively small number of previous reports referring to biological contaminents in non-native fish culturing effluents per se is probably a reflection of the relatively small amount of attention which has been given to that source.

2) Inspections of shipments of fish by the United States Public Health Service are visual (202), and not always done (227).

3) There is a serious threat to the environment and human health in the United States by some of the probable or possible constituents.

4) From a sanitary point of view, the safest approach is to consider water from contaminated areas as contaminated until proven otherwise (212).

5) At present, non-native fish and import water come from countries where sanitary conditions are known to be poor (3), and the fish are often fed food grown on human sewage (93). These facts greatly increase the probability of contamination.

Bacteria--Fish arriving from overseas often arrive in unhealthy condition (33,240). Some individuals will sell poor quality, sick fish at reduced rates (24); one of the largest American dealers has reported to the United States Congress that about 60 percent of all

TABLE V-8

SALMONELLA ISOLATIONS FROM A
FLORIDA TROPICAL FISH FARM
(NOVEMBER 12-16, 1973)

| Sample Source | Sertotype(s) Isolated |
|---|---|
| Aquarium water at point immediately before disinfection. | Salmonella enteritidis ser Typhimurium<br>S. enteritidis ser Typhimurium variant Copenhagen |
| Final discharge from indoor facilities. | Salmonella enteritidis ser Worthington<br>S. enteritidis ser Typhimurium var Copenhagen<br>S. enteritidis ser Anatum<br>S. enteritidis ser Tennessee |
| Fish food used in indoor facilities. | Salmonella enteritidis ser Typhimurium var Copenhagen |
| Foreign imported shipment, water sample, Hong Kong, China. | Salmonella enteritidis bioser Java |

imported tropical fish die within 30 days and that most have parasitic ichthyophthiriasis (ICH) or fungus infections (236). Although aquarium fish in good condition can live compatibly in a large water system containing, a high bacterial density (108), fish stressed by infections and crowded conditions in shipment have less resistence to bacteria and thus are more likely to become vectors of bacterial diseases. In addition to being carried into navigable waters by the effluent water itself, bacteria may be carried to the outside environment in fish intestines (155,209), body slime (155,166), and in uneaten fish food (227,241).

1. Aeromonas--Bacteria of this genus are almost universally present in any body of water containing organic material (213), and they have been found in tropical fish and import water from Hong Kong (94). Low levels of bacteria of this genus are not uncommon in healthy fish (94), but high levels are pathogenic to both fish and man (118,166). Aeromonas hydrophila is a common fish pathogen and is the cause of a variety of clinical diseases in man (118). A number of other members of the genus are closely related to human pathogens and may be responsible for eye, ear, nose, and throat infections more frequently than is presently realized (118). High levels in water are sometimes the result of contamination with aerated human sewage, a medium in which Aeromonas thrives (213).

2. Clostridium--Clostridium perfingens, the most important cause of gangrene in man, has been isolated from commercial diets of tropical aquarium fish (241). This fact takes special importance because it has

been shown that fish can act as carriers of bacteria of this genus, including the species which cause tetanus and botulism in man (200).

3. Chondrococcus--Members of this genus cause columnaris disease, a fish disease common in the United States and capable of causing great losses among important commercial species such as trout and salmon (211). It is fairly common in tropical freshwater fish, especially cichlids (129) and thus non-native fish culturing facilities have the potential for discharging bacteria of this genus in their effluents.

4. Escherichia--Members of this genus were found in the water with a shipment of tropical fish from Singapore, and in tropical fish imported from Hong Kong (94). It has been reported that some strains of E. coli bacteria can be carried by fish, cause no harm to the fish, yet remain pathogenic to man (200,209). Enteropathogenic strains have been retained in fish intestines for at least 21 days (132).

5. Erysipelothrix--Bacteria of this genus, reported from native and non-native fish, cause swine erysipelas ("fish rose") skin disease in humans that handle fish (118,200).

6. Leptospira--A member of this genus is carried in fish slime and causes infectious jaundice in humans handling fish (118,166,20).

7. Listeria--The genus includes bacteria that are pathogenic to man and that have been observed in fish (200).

8. Mycobacterium--Members of this genus are causes of tuberculosis, including fish tuberculosis in freshwater and marine fish (181,211). Tropical fish tanks provide ideal growth conditions for M. marium (1). This species has caused serious skin diseases among persons cleaning

ornamental fish tanks (1). No effective cure has been found for treating the fish (211) or humans (1) infected. Another member of the genus which has been isolated from both fish and human infections is M. fortuitum (118,200). It is possible that snails may be one of the vectors of the mycobacteria pathogenic to man and fish (211) and that the bacteria may be carried in an effluent in this manner.

The leprosy bacillus, Mycobacterium leprae, has been reported in fish by Russian workers (118).

9. Nocardia--Species of this genus have been isolated from fish and are known from human wound infections (200).

10. Paracolon--Members of this genus cause gastroenteritus in humans and were found in water with a shipment of South American reef fish (132).

11. Pasteurella--Members of this genus cause plague and tularemia (rabbit fever) in man and at least one species, P. tularensis, has been found in freshwater fish (118). It has been suggested that fish pathogens such as P. piscidida, closely related to the bubonic plague pathogen, might develop strains virulent to man (118).

12. Salmonella, Coliforms, and Fecal Streptococci--A bacteriological study done at a large tropical fish farm near Tampa, Florida, in conjunction with the preparation of this report revealed pathogenic Salmonella bacteria in the aquarium water, the final discharge from indoor facilities, the fish food used in indoor facilities, and the import water in a shipment of fish from Hong Kong (Tables V-8 and V-9).

TABLE V-9

BACTERIAL DENSITIES
FLORIDA TROPICAL FISH FARM
(NOVEMBER 12-16, 1973)

| Sample Source | No. of Samples | Total Coliforms Range | Total Coliforms Log Mean | Fecal Coliforms Range | Fecal Coliforms Log Mean | Fecal Streptococci Range | Fecal Streptococci Log Mean |
|---|---|---|---|---|---|---|---|
| Outdoor Rearing Ponds | | | | | | | |
| Water, MPN/100 ml | 4 | 1,300-3,900 | 2,500 | 4-79 | 13 | 11-490 | 59 |
| Fish, MPN/100 grams | 4 (Giant Sailfin Mollys-1) (Species Unknown-3) | 13,000-1,600,000 | 250,000 | 50-3,300 | 350 | 50-28,000 | 2,500 |
| Fish food used in outdoor rearing ponds, MPN/100 grams | 5 | 170,000-920,000 | 480,000 | 50-13,000 | 1,400 | 1,400-7,000 | 2,700 |
| Indoor Aquariums | | | | | | | |
| Water, live bearer room, MPN/100 ml | 5 | 2,800-35,000 | 13,000 | <2-700 | <12 a/ | 21-1,300 | 98 |
| Fish, live bearer room, MPN/100 grams | 6 (Kissing Gourami-2) (Blue Gourami-2) (Opaline Gourami-2) | 920,000-5,400,000 | 2,200,000 | 40-49,000 | 790 | 2,200-79,000 | 7,100 |
| Aquarium water at point immediately before disinfection, live-bearer room, MPN/100 ml | 4 | 14,000-49,000 | 26,000 | <20-49 | <28 | 22-110 | 56 |
| Water, import rooms, MPN/100 ml | 3 | 24,000-≥240,000 b/ | ≥110,000 | 27-490 | 150 | 79-2,200 | 310 |
| Fish, import rooms, MPN/100 grams | 4 (Walking Catfish-1) (Jack Dempseys-1) (Moonlight Fish-1) (Rainbow Shark-1) | 2,200-≥2,400,000 | ≥420,000 | <20-94,000 | <1,300 | 220-130,000 | 7,100 |
| Fish Food used in indoor facilities, MPN/100 grams | 5 | 170,000-≥2,400,000 | ≥690,000 | 80-49,000 | 9,800 | 35,000-920,000 | 130,000 |
| Final discharge from indoor facilities, MPN/100 ml | 5 | 11,000-≥2,400,000 | ≥75,000 | 500-18,000 | 2,600 | 1,100-92,000 | 9,800 |

| Sample Source | No. of Samples | Common Name | Total Coliforms | Fecal Coliforms | Fecal Streptococci |
|---|---|---|---|---|---|
| Foreign Imported Shipments | | | | | |
| Water. Hong Kong, China, MPN/100 ml | 1 | Blue Gourami | 240,000 | 13,000 | 280 |
| Guyana, South America | 1 | Hatchet Fish | ≥240,000 | ≥240,000 | 22 |
| Fish. Hong Kong, China, MPN/100 grams | 1 | Blue Gourami | 220,000 | 70,000 | 4,900 |
| Guyana, South America | 1 | Hatchet Fish | ≥2,400,000 | 28,000 | 1,700 |

a/ < = less than value
b/ ≥ = greater than or equal to value

Total (TC) and fecal coliform (FC) bacteria and fecal streptococci (FS) analyses were performed on random samples collected daily over a 5-day period. Sampling locations consisted of the following: a) water and fish from the outdoor rearing ponds and the fish food used in these ponds; b) water, fish and food from the indoor facility, including samples collected both before and after disinfection within the closed system; c) the final discharge from the indoor facility; and d) water and fish collected from foreign imported shipments. The results are summarized in Table V-9.

Water samples collected from the outdoor rearing ponds at the fish farm contained high total coliform densities; however, the water contained low fecal-coliform and fecal streptococci densities. Fish collected from these ponds reflected greater numbers of the three bacteriological parameters measured.

Aquarium water, fish and the fish food used in the indoor facility showed a pattern of pollution indicator densities very similar to those found in the outdoor pond; however, results show the densities were higher than in the ponds. The fish collected from the live-bearer room contained fecal coliform log mean densities of 790/100 gm. Fish taken from the import room contained fecal coliform log mean densities of <1,300/100 gm. Fish from both the live-bearer room and the import room contained fecal streptococci densities of 7,100/100 gm. The fish food used in the indoor facility is the most significant source of contamination (FC = 9,800/100 gm, FS = 130,000/100 gm). The presence of the pathogenic Salmonella substantiates the fecal coliform data in that the pathogens are only found in materials contaminated with feces from warm-blooded animals.

It should be noted that whole fish were homogenized before analyses. It is likely that if only the intestinal contents, rather than whole fish, were tested, they would contain bacterial densities in numbers similar to the levels found in the food.

The final wastewater discharge contained high densities of fecal coliforms and fecal streptococci (FC = 2,600/100 ml, FS = 9,800/100 ml), and high numbers of bacteria were found in both fish and water samples collected from foreign imported shipments.

In addition to the EPA study, there are several pertinent references to Salmonella in the literature. Five of 35 samples of a dry fish diet from a Canadian fish hatchery contained Salmonella, including S. monteuidea, S. livingston, and S. anatum, (240). The author of that report noted that the presence of Salmonella in fish rations may present a hazard to fish handlers as well as human and animal populations downstream from the discharge. Fish from polluted waters have been found to contain a number of species of Salmonella (118,157). Salmonella can survive at least two weeks in brackish water from Chesapeake Bay (118) and at least 29 days in fish intestines (157). Salmonella typhosa, the cause of typhoid fever in man, has been reported from the gut of a number of species of fish (118) and might be present in the water of shipments containing imported fish (13).

13. Shigella--A shipment of South American reef fish were found to contain species of this genus which cause gastroenteritus in man

(132). This genus had previously been reported in fish coming from polluted waters (200).

14. Staphylococcus--Fish from contaminated waters contained S. aureus, a human pathogen (200).

15. Vibrio--It has been reported that in many parts of the world fish are important vectors of the vibrio causing cholera (118). Russian workers claim that cholera vibrios grow actively in the gastrointestinal tract of fish and thus are transported up and down rivers (118). Vibrio parahaemolytirus, a bacterium which causes frequent cases of food poisoning in Japan, was only recently found to be the cause of such outbreaks in this country (80,167). Although it is not known how virulent strains reached this country, it is known that fish can serve as carriers (80).

Protozoan Parasites--One of the protozoan parasites commonly found on grass carp, Ctenepharyngodon idella, the ciliate Hemiophrys, was recently reported in Missouri (154) and may have the potential to parasitize native fish. Myxosoma cerebralis was brought to the U.S. with shipments of fish from Europe and is now the agent of whirling disease, a devastating rainbow trout disease now established in the U.S. (110).

Helminthic Diseases and Snail Hosts--The helminthic diseases of man which are carried by fish include those caused by three types of parasitic worms: flukes (trematodes), tapeworms (cestodes), and roundworms (nematodes).

These diseases are not established in a body of water unless the proper combination of the parasitic worms, intermediate snail and fish hosts, and final host (such as dogs, cats, birds, or humans) are all present.

Introductions of undesirable molluscs, including snails which can serve as intermediate hosts for helminthic diseases, have been a world wide problem (56). Such snails can and do accompany fish as "hitch-hikers" in shipments to the United States (56) and some of the dangerous snails have been widely sold by the tropical fish industry (208).

Immature snails and eggs are quite small and might easily accompany a shipment of fishes from Puerto Rico or other infected areas without notice (152). In this manner non-native snails which are carriers of disease might be introduced into fish ponds in the U.S. and gain access to navigable waters through the effluent (152).

The snails Melanoides tuberculatus and Tarebia granifera, carriers of many important helminthic diseases, have been sold widely along with tropical fish (173). These and other snails are often produced and held by the same facilities which produce and hold fish. It is known that a Tampa tropical fish dealer was responsible for contaminating Lithia Springs, Florida, with T. granifera (173).

Melanoides tuberculatus is now rapidly being spread around the country (163) and has been reported from Texas (67), Arizona (67), California (60), and Nevada (164). It is thought that most introductions are the direct or indirect result of its presence in the tropical fish trade (58,173).

Discharges from non-native fish culturing facilities would contain biological pollutants which might result in the spread of helminthic diseases if they contained any of the following:

1. free swimming cercariae of the parasite;
2. fish infected by the parasite;

3. snails carrying the parasite;

4. other intermediate hosts carrying the parasite.

The parasites could then infect man directly or could gain establishment in other final hosts such as dogs, cats, or birds. The latter could serve as "reservoir" carriers in establishing the disease and man could be infected at a later date. There is at least one case recorded in the literature where the total life cycle has been established in an American stream (172).

The helminthic disease organisms and associated snails are both probable components of unregulated discharges from non-native fish culturing facilities. For this reason a discussion of the types of helminthic parasites which would likely characterize wastewaters from some of these facilities is given below.

1. Clonorchis sinensis - The Chinese Liver Fluke--There is a probability that this parasite of man will be brought into this country because the Asian fish considered to be the most important vector and the most frequently infected is the grass carp, a species being promoted for introduction into the U.S. at present (262). The appropriate (173) snail intermediate host Melanoides tuberculatus, is available and cats and dogs can serve as the "reservoir" final hosts.

2. Fasciola hepatica - The Sheep Liver Fluke--Already causing millions of dollars of loss each year in the cattle and sheep industry in the United States, this parasite could become more wide spread if new intermediate hosts, such as Melanoides tuberculatus are introduced

in new areas through discharges from non-native fish farms. The new snail host may be more successful and contaminate new habitats where the native snail does not now occur.

3. Gyrodactylus--Members of this parasitic genus of trematodes were found on the skin and fins of non-native fish from Singapore (94). This suggests they may be occasional constituents in the effluents of culturing facilities, either in the water or on the fish. Although members of the genus are established in North America, further dissemination by new and successful hosts would be detrimental to the native aquatic environment (267). It has been reported that one species was probably introduced to this country with shipments of carp from overseas (110).

4. Paragonimus westermani - The Oriental Lung Fluke--This serious parasite of man is also carried by two snails introduced into this country, Melanoides tuberculatus and Tarebia granifera (173). A widespread native fluke which infects mink, pigs, bobcats, racoons, dogs, and crayfish is caused by a closely related species, Paragonimus kellicotti, and carried by a native snail which has a rather spotty distribution in the U.S. (224). Further introductions of Melanoides tuberculatus or Tarebia granifera could result in the following:

a) An introduction of a new human disease caused by P. westermani;

b) A spreading of both P. westermani and P. kellicotti through one or all of the three snail hosts, the native one, M. tuberculatus and T. granifera (224).

5. Philophthalmus megalurus--This fluke became established in San Antonio, Texas, after appropriate fish hosts and snail intermediate hosts (Melanoides tuberculatus) were introduced (172,173). It was possible that the infected snails were introduced into the water by discharges related to the local aquaria trade (173). The final hosts utilized in the initial establishment of the parasite were water fowl, but there are three records of flukes of this genus parasitizing humans in Asia (172,174).

6. Schistosoma sp. - The Blood Flukes--The members of this genus cause schistosomiasis (bilharzia), a usually fatal disease afflicting about 150 million people in foreign countries (136). Tilapia fish production ponds in Puerto Rico and Africa have provided an ideal habitat for the disease and increased its incidence. Because Tilapia are being imported to this country it is possible that the disease might be present in the import water (13,56).

Although the free swimming cerarial forms live only about 24 hours, it is possible that import waters from infected areas might be dumped into American waters as soon as 6 to 8 hours after leaving Puerto Rico (56). The cerariae might then borrow into the skin and infect humans in contact with the water. It is more probable that nutria, mice, racoons or other small mammals would act as the initial reservoir hosts to start the cycle in native waters (20). Humans wading, swimming, or having any other water contact could then be infected.

Imported snails which carry the disease represent a long term hazard, since they continue to shed infective cercariae for the rest of their life (20). Due to the seriousness of the disease and the probability that it could be come established in the United States, the presence of such snails in fish farm effluents would represent an especially serious threat to the environment (165).

Native snails representing one colony of Biomphalaria obstructa in Louisiana were able to carry the disease, and other such colonies, though not yet discovered, may exist in the South (152).

7. Other Trematodes--A number of mongenetic trematodes which parasitize fish have been transferred to the United States with shipments of non-native fish (110). These include three species of Anacanthorus transferred on the gills of piranhas from South America, Cichlidogyrus transferred on the gills of Tilapia from Africa, three species of Cleidodiscus on gills of piranhas from South America, Dactylogyrus on mixed species from Asia and Europe, and Urocleidus on piranhas from South America (110).

8. Nematodes - Round Worms--Parasitic roundworms carried by fish, especially the genera Porrocaecum, Ganthostoma, Angiostrongylurus, Eustoma, and Contracaecum, have caused various human health problems such as anisakiasis, other types of ulcerative enteritus, and eosinophilic meningitus, in foreign countries. It is known that a serious fish parasite, Philometra carassi became established in this country after being introduced with a shipment of fishes from Japan (110). Some of the foreign species of these genera might be brought in with shipments of non-native fish, and eventually gain access to navigable waters through fish farm effluents (224).

Molluscs--In addition to acting as carriers of helminthic diseases, snails and other molluscs discharged with non-native farm effluents may be classified as biological pollutants if they harm the native ecosystem by causing the eradication of desirable native species of molluscs or fishes through predation or competion (117,134,163,164). About 10 percent of the species of molluscs in this country are considered "endangered" (by extinction) species, and further dispersal of non-native molluscs will probably cause further damage (117).

The mollusc pests most likely to be associated with non-native fish farming (and therefore the most likely constituents in the wastewater) include the following:

1. Marisa--In the aquarium industry, snails of this genus have been widely sold as one of the large "mystery snails" (225). It is thought that its release into navigable waters of Florida was caused by individuals culturing non-native fish (133,203). It has proved to be a problem due to its threatened eradication of native species of birds in Everglades National Park (203,225).

2. Corbicula -- This Asian clam, which has become a destructive, expensive pest in the last few years, may have been introduced by the aquarium trade (133). Spreading widely in the U.S., it poses a threat to the Delaware and other rivers by crowding out other forms of life (8). It has no known predators or enemies and can cover the bottom 1 m (3 ft) deep, occuring in densities to 50,000 clams/sq m (5,000 clams/sq ft) (8).

3. Melanoides tuberculatus--In addition to carrying helminthic diseases, this snail has caused damage to some ecosystems by eradicating

native snail species (164,172) and eating eggs of endangered species of fish (163,164). Its very high reproduction rate has made it an especially serious competitor of native species of snails (174).

Copepods--It is known that harmful parasitic copepods were introduced to the west coast along with imports of seed oysters from Japan (209), and there is evidence that fish may also act as carriers (261). Learnea infestations were not recorded in the fish of Moapa River, Nevada, prior to 1941. Since that time these parasites have been introduced with fish non-native to the area and a native species of fish, Gila, has been afflicted with a high incidence of parasitism (261). The introduction of a non-native fish, Poecilia mexicana, into the Moapa River Water District spring was followed by heavy infestations of Learnea on another native species of fish (261).

Fish--Non-native fish are released from fish farms in the following ways (55):

1. Through unscreened effluent pipes
2. Pumping out "contaminated" (with mixed species) ponds.
3. Floods
4. Purposeful discharge of stocks which have been overproduced in relation to demand.
5. Dumping of illegal stocks.

A consideration of some species of fish as biological pollutants is warranted by the fact that fish introductions have often turned out to be harmful to the environment (30,56,133,175). The walking catfish, Clarias tatrarchus (50,55) and the common carp (136) present well known examples of the deleterious effect that undesirable fish species can have in American aquatic habitats.

Due to their low value as sport fish, competition with valuable species, and destruction of necessary as well as nuisance plants, several authorities have suggested the grass carp, *Ctenopharyngodon idella*, (56,133) and species of *Tilapia* (55,56) could also become biological pests of large magnitude.

# SECTION VI.

# SELECTION OF POLLUTANT PARAMETERS

## WASTEWATER PARAMETERS OF POLLUTIONAL SIGNIFICANCE

### Selected Parameters

The unnaturally high density of confined fish in culturing facilities leads to changes in the chemical, physical and biological properties of the process wastewaters. Major wastewater parameters of pollutional significance for the fish culturing industry include:

- Solids
  - Suspended Solids
  - Settleable Solids
- Nutrients
  - Ammonia Nitrogen
- Bacteria
  - Fecal Coliform
- Flow

In addition, biological pollutants (as described in the previous section) are considered to be of pollutional significance in non-native fish culturing operations.

On the basis of an extensive literature search, review and evaluation of Refuse Act Permit Application data, EPA data, industry data, personal communications and visits or studies at various fish-culturing facilities it was determined that other than ammonia nitrogen no purely hazardous or toxic pollutants (e.g., heavy metals, pesticides) exist in the wastes discharged from a fish-culturing facility. The pH, temperature and dissolved oxygen were not considered significant parameters in fish-culturing wastewaters because they must remain at levels found in high-quality water for successful fish rearing.

With the exception of ammonia, nutrients are not included in the present effluent limitation guidelines because the extent to which nutrients are removed by treatment processes remains to be evaluated. Furthermore, the need for advanced treatment technology specifically designed for nutrient removal has not been demonstrated at this time.

A brief discussion of biochemical oxygen demand (BOD) appears necessary because it is a commonly reported pollution parameter.

Because of the dilute nature of fish culturing wastes, dissolved oxygen (DO) problems seldom occur in receiving streams. With the exception of cleaning wastes, a typical salmonid hatchery discharge has a BOD of 5.0 mg/l (Table V-1). The potential effect of this concentration on DO is best illustrated by oxygen sag analysis using the Streeter-Phelps equation (270).

Assuming the most critical condition to be the case where the hatchery discharge makes up the entire flow of the receiving stream, an estimate of the minimum DO concentration may be calculated. With DO saturation equal to 10 mg/l, initial DO deficit $D_a$ equal to 2 mg/l, rate of self purification $f = 3.0$, initial BOD $L_a = 5$ mg/l and rate of deoxygenation $k = 0.2$, the critical DO deficit $D_c$ is determined by first calculating the time $t_c$ at which $D_c$ occurs.

$$t_c = \frac{1}{k(f-1)} \log_e \{F[1-(f-1)\frac{D_a}{L_a}]\}$$ (270) p. 844

$t_c = 1.28$ days

$$D_c = L_a e^{-kt_c}/f$$ (270) p. 844

$D_c = 1.3$ mg/l

The critical deficit $D_c$ is less than the initial deficit $D_a$. This indicates that the equations are not valid for a waste with an initial BOD $L_a$ of 5 mg/l. Apparently the rate of self purification or reoxygenation is greater than the rate of deoxygenation. Thus a true oxygen sag does not occur and the DO concentration immediately begins to increase downstream from the hatchery. For a hatchery discharging an initial BOD $L_a$ of 5 mg/l with the conditions previously described, the minimum DO occurs at the hatchery outfall and is 10 mg/l minus 2 mg/l = 8 mg/l.

Performing the same calculation for $L_a$ = 10 mg/l yields $D_c$ = 2.5 mg/l indicating that a true oxygen sag does occur. The minimum DO then equals 10 mg/l minus 2.5 mg/l = 7.5 mg/l. This oxygen sag analysis shows a negligible environmental impact.

Studies done by the EPA during the development of this document showed that the BOD was closely correlated to accumulated particulate matter in the fish-culturing facility. Therefore, if discharges of suspended and settleable solids are controlled, there will be a concomitant reduction reduction in the BOD.

For these reasons, BOD was not considered a major or meaningful pollutant parameter for evaluating fish-culturing wastewaters.

Rationale

The justification for the selection of the wastewater parameters for the fish-culturing industry is given below. Additionally, there is a brief discussion on suggested analytical methods for many of these parameters.

Solids--Two types of analyses for determining the concentrations of solids are significant in the fish-culturing industry. They are suspended and settleable solids.

1. Suspended Solids--This parameter measures the suspended material that can be removed from the wastewaters by laboratory filtration but does not include coarse or floating matter than can be screened or settled out readily (234). Suspended solids are a vital and easily determined measure of pollution. In the wastes from fish-culturing facilities the suspended particules correlate well with BOD and COD (70). Suspended solids are the primary parameter for measuring the effectiveness of solids removal processes such as screening and sedimentation (142).

Suspended solids may kill fish and shellfish by causing abrasive injuries, by clogging the gills and respirating passages of various aquatic fauna; and by blanketing the stream bottom, killing eggs, young and food organisms, and destroying spawning beds (151). Indirectly, suspended solids are detrimental to aquatic life because they screen out light and because, by carrying down and trapping bacteria and decomposing organic wastes on the bottom, they promote and maintain the development of noxious conditions and oxygen depletion, killing fish, shellfish and fish food organisms, and reducing the recreational value of the water (257).

2. Settleable Solids--The settleable solids test (234) involves the quiescent settling of a liter of wastewater in an Imhoff cone for one hour, with appropriate handling (scraping of the sides, etc.). The method is simply a measurement of the amount of material one might expect to settle under quiescent conditions. It is especially applicable to the analysis of wastewaters being treated by such methods as screening and sedimentation for it not only defines the efficiency of the systems, in terms of settleable material, but provides a reasonable estimate of the amount of deposition that might take place under quiescent conditions in the receiving water after discharge of the effluent (139,142).

Ammonia Nitrogen--Ammonia is a major pollutant in fish-culturing facilities. It may occur in high concentrations in cleaning wastewaters [Section V; Table V-5]. As such it should be measured separately by accepted techniques (73).

The lethal effects of ammonia in concentrations greater than 0.7 mg/1 are well documented (66,71,72,161,245,264). However, the effects of even very low un-ionized ammonia nitrogen levels are equally important in the fish-culturing industry (35,59,124). As ammonia concentrations in fish-rearing tanks and ponds increase, the fish lose their ability to utilize oxygen. When the ammonia concentration of the water reaches 0.3 mg/1, there is a measurable decrease in the oxygen content of the blood. The oxygen concentration of the blood decreases rapidly as the ammonia concentration in the water increases from 0 to 1.0 mg/1 as N, and the blood conditions change drastically (86). The carbon dioxide content of the blood increases about 15 percent, while the oxygen content of the blood decreases to about one-seventh of its normal value. The hemoglobin of the fish blood loses its ability to combine with oxygen or to liberate carbon dioxide. The end result is that the fish actually suffocates even though the oxygen content of the water may be sufficient for normal respiration (86).

Bacteria (Fecal Coliform)--It is common practice in water quality surveys to measure the fecal coliform density to evaluate the sanitary significance of certain wastewaters. These bacteria can be identified and enumerated by either of two reliable techniques (234), the MPN or the milipore filter method. Fecal coliform bacteria are present in the gut of all warm-blooded animals. The presence of these bacteria at significant densities (usually a density of 200 organisms/100 ml or more) is a good indication of the probable presence of pathogens (38, 119). Although fecal coliform bacteria are not expected to be produced by fish (6,78,84,85,120,154,237,253), studies by the U. S. Bureau of Sport Fisheries and Wildlife have shown they increase in some warm-water fish-culturing facilities. Evidence has shown that if the feed or source water is contaminated the bacteria accumulate in the fish. Therefore, in order to monitor the possible presence of pathogens in wastewaters, fecal coliform bacteria should be monitored in warm-water fish operations that hold or culture native or non-native fish.

Flow--The effluent guidelines developed in this report are based on production and require the conversion of concentrations to the production based units of expression. This conversion requires knowledge of the wastewater flow at the time of sampling.

Flow can be measured in a variety of ways and the method employed will depend on the climate, quantity of flow and whether the flow is open channel (e.g. sewers, lined and unlined ditches, etc.) or pressure conduit. Most flows from hatcheries may be measured in open channels.

Some methods commonly employed to measure flow in open channels are:

a) Current meters

b) Weirs

c) Flumes

Where instantaneous flow measurements are sought, the methods listed will provide such information. The current meter can be used for establishing velocities at a selected cross section over a series of depths. From this information, a rating curve can be developed which will allow determination of the flow at other depths. A depth recorder could also be installed to provide a continuous record of flow. However, where a continuous record is desirable, weirs (three common types are the rectangular, V-notch, and the Cipolletti which is trapezoidal in shape) and Parshall flumes may be used effectively. Weirs are generally easy to install at low cost although specific upstream and end conditions must be met. The Parshall flume has an advantage over the weir in that it is self-cleaning. Accurate measurements can be made using a properly installed Parshall flume under both free-flow and submerged-flow conditions (243,252). Head requirements for weirs and flumes are important and may add to operating costs or preclude their use altogether.

# SECTION VII.

# CONTROL AND TREATMENT TECHNOLOGY

## CURRENT STANDARD OF PRACTICE

Although treatment is not normally provided for native fish culturing facilities exeptions occur in both flow-thru and pond subcategories where settleable solids removal is the most common type of waste treatment. The most common control method used for non-native fish culturing facilities is to discharge wastewaters to municipal sewage systems. Current practice in flow-thru, pond, and non-native fish operations is discussed separately. The type, frequency and relative water quality of discharges is presented. Estimates are made of the percentage of fish culturing facilities providing a specific type of treatment.

### Native Fish -- Flow-thru Culturing Systems

Cold-water fish are usually reared in flow-thru systems. Discharges from these culturing units include the continuous normal flow and the intermittent cleaning flow. The normal continuous discharge from fish culturing units is of a relatively constant quality. The flow rate may vary depending primarily upon size of the operation and fish load. It is estimated that approximately 12 percent of the industry provides treatment of the normal continuous discharge. Of this figure an estimated 5 percent remove settleable solids by discharging through a rearing pond at the end of the hatchery flow scheme. Another 5 percent provide a settling basin which acts solely as a treatment unit. The remaining 2 percent remove 80-90 percent of the BOD through secondary treatment or equivalent methods. This latter group is made up almost entirely of those systems which treat in conjunction with recycle reconditioning hatcheries.

The intermittent cleaning discharge is greater in BOD, suspended solids and nutrient concentration than the continuous flow. A steel bristle broom or scraping tool is usually used during cleaning resulting in the resuspension and discharge of accumulated waste solids. The frequency of cleaning varies widely. It is estimated that 5 percent of the flow-thru culturing operations treat the cleaning flow. In most cases the treatment provided is sedimentation although approximately one percent of the flow-thru systems provide secondary or equivalent treatment of the cleaning flow along with the normal flow. An estimated one-tenth of one percent remove accumulated waste solids with the use of a suction device thus, in effect, treating the cleaning flow.

Native Fish -- Pond Culturing Systems

Warm-water fish are usually reared in ponds. Typically, fish are reared in ponds over one or two seasons and then harvested for stocking or market. Discharges from ponds usually occur in two ways. First, there are ponds which have a continuous discharge. Second, the pond volume may be discharged during or after harvesting. In addition, intermittent discharges may occur as a result of overfilling, flooding or flushing of algal blooms. Closed ponds are defined herein as those that operate without a continuous discharge.

Closed ponds typically have a discharge only during harvesting. Exceptions occur in cases where harvesting is accomplished without draining the pond. In some operations draining for harvesting is usually begun by discharging the lowest quality water first (97). This water from the bottom of the pond often contains high concentrations of suspended solids and may be low in dissolved oxygen. Discharges from harvesting of closed ponds may occur from once to several times annually, depending upon water temperature and species of fish reared. The rate at which water is drained may vary greatly depending on the size of the pond outfall pipe. The type of drain outlet also varies with the great majority of ponds included in the following two categories: a) water drained from the bottom of the pond; or b) water drained from the surface of the pond over dam boards. It is estimated that less than one percent of the closed ponds which discharge during harvesting provide any treatment of the discharge. Of those with treatment, most remove settleable solids by discharging the flow through another pond.

Ponds with a continuous discharge, referred to herein as open ponds, may have as many as two distinct types of discharges: a) water drained during harvesting; and b) the normal continuous overflow.

Discharges from open ponds during harvest occur in the same manner as closed ponds. The frequency and character of these discharges is the same as set forth for closed ponds. As in the case of closed ponds, it is estimated that less than one percent of the open ponds provide any treatment during harvesting. Treatment consists of settleable solids removal by discharging the flow through another pond.

The continuous discharge from open ponds does not usually fluctuate markedly in quality. The flow discharged may vary from several liters per minute to several million liters per day at different culturing facilities. Most ponds are unlined; it is estimated that for greater than 99 percent of the facilites, removal of settleable solids is inherent in that the continuous discharges are from quiescent ponds which act as settling basins.

Non-Native Fish Culturing Systems

Non-native fish are primarily cultured in closed pond systems. Discharges from these culturing units include short duration continuous discharge during periods when water temperature must be controlled and intermittent draining discharges related to fish harvesting activities. Fish harvesting occurs at intervals ranging from once every six months to three years. Although chemical and physical characteristics of these discharges are similar in quality to the overflow from native fish pond cultures, non-native fish culturing discharges require control to eliminate biological pollutants.

The current standard of practice is to discharge wastewaters to municipal sewage treatment facilities, no discharge (via land disposal), and to discharge wastewaters directly into navigable waters with no treatment. An estimated 60 percent of the existing non-native fish culturing facilities discharge their waste into municipal sewage treatment systems rather than into navigable waters (91,123,127,191,230,254). This group is primarily composed of importers, distributors, and breeding facilities outside the State of Florida. The next most commonly used control method, especially in Florida, is no discharge with land disposal (12,43,101,102, 179,218). About seven percent of the non-native fish culturing facilities use this method. An estimated 33 percent of non-native fish culturing facilities discharge without treatment or control measures; these appear to be common primarily for dirt pond facilities in the Tampa and Lakeland areas of Central Florida, although a few other direct discharge have occurred in South Florida, Texas, Arkansas, California, and Louisiana. These known direct discharges have been eliminated with the exception of those in Texas and Louisiana.

## IN-PLANT CONTROL MEASURES

Operating parameters such as water use, feeding, cleaning, fish distribution, and harvesting are all variables affecting the quality of water discharged. It is recognized that each of these variables is closely related to fish quality and production, each of vital interest to the hatchery manager (59,139). This section will present changes in hatchery or farm operations to minimize water pollution without compromising fish quality or level of production.

### Native Fish -- Flow-thru Culturing System

Water Conservation--Water use requirements for the successful rearing of fish have been studied extensively (190,258). The carrying capacity of fish farms or hatcheries is limited by oxygen consumption and the accumulation of metabolic products (104). The primary goal in fish culturing is to produce the highest quality fish possible with the available water resource. In addition, at some farms and hatcheries the goal includes producing the greatest number of quality fish possible.

Another goal in fish culturing should be to minimize the pollutants discharged into the receiving water. Most fish rearing facilities operate at considerably less than capacity during much of the year. It is during this period that discharges could be significantly reduced. This in turn would allow treatment systems to operate more efficiently, thus decreasing the discharge of pollutants.

Reduction of water use during periods of low production need not be inconsistent with the primary goal in fish culturing. Fish culturists do not yet know what the ideal rearing space should be relative to the amount of available water (258). However, it has been demonstrated that the rate of growth or food conversion of rainbow trout was not affected as the density increased from less than 16 kilograms of fish per cubic meter of water (1 $lb/ft^3$) to 90 kilograms per cubic meter (5.6 $lb/ft^3$) during a 10 month period (190).

Permits issued by EPA under the National Pollution Discharge Elimination System (NPDES) require that treatment facilities be operated efficiently throughout the year. Reducing water usage will minimize the quantity of pollutants reaching the receiving water by allowing treatment facilities to operate at maximum efficiency.

Feeding Practices--Feeding practices have been studied extensively and many hatchery managers now believe that fish growth is very nearly independent of feeding levels above a minimum. Feeding amounts greater than this minimum only increases the cost and conversion ratio* (40,125,189).

* The conversion ratio is kilograms of feed fed per kilogram of fish produced.

Feeding levels greater than the minimum results in residual food which has been recognized as a source of pollutants discharged from fish hatcheries (139).

Feeding practice has been found to be a major operating factor related to pollutant production. "Proper feeding means that the time and amount of food fed must be properly determined so that most food will be eaten, resulting in little or no food residual. This practice is an economical one since improper feeding does not improve fish growth, and results in higher operating costs as well as higher pollutant production rates. Scheduling is an important factor as it was observed that when the fish were not really hungry, they did not chase food. As a result, most foods released in the water settled out and finally became pollutants. The amount and time of feeding vary with water temperature, fish species and size, and type of food. For each hatchery these factors can be experimentally determined. Therefore, it is suggested that both time and amount of feeding be optimized for each hatchery." (139)

Cleaning Practices-- Periodic cleaning of flow-thru rearing units is necessary to remove solid wastes consisting primarily of uneaten food and particulate fecal matter. If allowed to accumulate, the decomposition of these solids could place unnecessary and harmful stress upon the fish. The frequency and method of cleaning have a significant effect upon effluent quality and pollutant load reaching the receiving water.

The settleable material which accumulates from fish rearing activities will slowly digest and release BOD in a soluble form (235). The time necessary for solubilization to occur varies inversely with temperature and is thought to be in the range of two to three weeks (169). In reviewing the literature, definitive information was not found to support requirements for precise cleaning intervals for various water temperatures. However, based upon the recognition that organic solids digest through bacterial action releasing nutrients and oxygen demanding constituents, it is reasonable to limit the interval between cleanings. The information available suggests that the average interval between cleanings should not exceed three weeks.

Cleaning methods vary based upon facility design or preference of the individual hatchery manager. Factors affecting selection of the cleaning method appear to be manpower, time requirements, fish health and, to a lesser degree, water pollution control. The method of cleaning may affect both the total load and concentration of pollutants reaching the receiving water.

The most common method of cleaning is to resuspend the settled solids and flush them out of the culturing unit into the receiving water. Usually a long handled steel bristle broom is used to resuspend the settled solids. Slime growths on the walls of lined rearing units are removed with a scraping tool known as a Kinney broom. This method of cleaning while the most common is probably the hardest on the fish and has been strongly condemned (59). The accumulated waste material often has a high oxygen demand and may contain toxic products such as ammonia. The conditions existing during and resulting from this type of cleaning are thought to have been the cause of serious mortalities at many fish culturing operations (59).

A variation of the brush-down method of cleaning involves the use of a current carried scraping device followed by a brief period of manual brushdown to dislodge and resuspend settled solids and slime material. While possibly reducing the man hours required for cleaning, this method appears to have all the disadvantages of the brush-down method.

Several types of self-cleaning rearing units have been developed (37,168). These are designed to alleviate the necessity of periodic cleaning and associated fish stress. There are contradictory views, however, concerning the desirability of self-cleaning systems. The rectangular circulating rearing unit has reportedly been found to be less conducive to disease than any other type tested (37). On the other hand, it has been reported that certain diseases found in chinook salmon culture in susceptible areas of Washington are universally more severe in self-cleaning type units (263).

Self-cleaning systems are designed to operate in one of two ways. Either waste solids are continuously flushed from the system with the normal flow or they are moved by the water current to a point where they can be removed from the system by simply opening a valve. Each of these systems will have a different effect on water quality. In the first case, the normal effluent quality would be expected to deteriorate slightly in comparison to a periodically cleaned system. The advantage of this system, in terms of water pollution control, is the elimination of slug loads and high concentrations of pollutants associated with cleaning. In the second case, cleaning wastes are discharged in such a way that the fish are subjected to a minimum of stress and the normal effluent quality is not allowed to deteriorate. Slug loads of pollutants, however, reach the receiving water when waste solids are discharged.

Another method of cleaning involves the use of a suction device to pump or vacuum the solids out of the rearing unit. This method has been described as the best and most logical way to remove excrement and other filth without causing injury to the fish or exciting them unduly (59). In vacuuming, the settled solids may be removed without stirring the material and causing the release of toxic products. The total volume of water used in vacuum cleaning may be considerably less than is used in other methods of cleaning.

Currently the equipment used in vacuum cleaning consists of an efficient suction pump, a section of long flexible hose and a metal vacuum head and handle. Portable trailer mounted units have been used in conjunction with a wastewater collection pipeline with waste receptacles adjacent to each rearing unit. Wastewater flows to a central collection sump from which it is pumped for treatment and disposal (128). For many fish farms or hatcheries it may be possible to pump cleaning wastes to a tank truck which in turn would spread the material on nearby farmland or discharge to a municipal waste treatment system for disposal. On-site dewatering offers the opportunity for reuse of the solids as a fertilizer on hatchery or nearby private property.

Vacuum cleaning appears to be the best method of cleaning consistent with fish culturing and water pollution control objectives. Disadvantages of this method include the possible inability of suction devices to remove attached slimes, the increase in man hours required, and additional energy requirements for cleaning. These disadvantages may be design problems which could be overcome as suction devices are perfected and gain widespread use by the industry.

Fish Distribution--Another operating variable affecting effluent quality is fish distribution. At similar loading rates, large fish are more effective than small fish at keeping waste solids in suspension. Similarly with fish of equal size at a given temperature, units which are heavily loaded would be expected to pass a greater percentage of the total settleable solids generated than units more lightly loaded. Thus, the hatchery manager has some degree of flexibility in determining whether settleable solids will be discharged with the normal or cleaning flows.

Depending upon the type of cleaning method employed, fish distribution may be a significant factor affecting effluent quality. For example, in a hatchery using the vacuum method of cleaning, fish distribution could play an important role in determining the percent of settleable solids which are carried from the hatchery with the normal flow and the percent which are retained and removed during cleaning. It may be possible to distribute fish such that some units would pass most of the settleable solids while other units would act as settling basins.

The points discussed above concerning fish distribution should not be misinterpreted with respect to the primary goal of the fish production industry -- that of producing the highest quality fish possible. It is intended that only those fish distribution schemes consistent with production of a high quality product be used to minimize the level of pollutants discharged.

Native Fish -- Pond Culturing Systems

Water Conservation--The water conservation discussion presented for flow-thru culturing systems applies to lined pond operations with continuous overflow. However, warm-water pond culturing requires water for certain other reasons. In pond culturing water flow is not generally as critical because it is usually not depended upon to supply oxygen or remove waste products. Rather its function is normally to maintain the desired water level in the culturing unit. In some cases, it may be possible that flow could be reduced or that flow-thru ponds could operate just as effectively as closed ponds. Each of these possibilities would reduce the load of pollutants discharged.

Feeding Practices--In pond culture, feeding may or may not be practiced depending upon such factors as species of fish being cultured. For those species not fed a prepared ration, ponds are usually fertilized to stimulate the production of zooplankton. Fertilization in excess of the assimilative capacity of the pond may result in water quality degradation. Where feeding is practiced, the discussion concerning feeding practices in flow-thru operations is pertinent. The amount and scheduling of feeding should be optimized for each hatchery such that excess feeding is eliminated.

Cleaning Practices--Usually only those fish farms and hatcheries with lined ponds or raceways practice cleaning. Therefore, points discussed under flow-thru culturing systems concerning frequency and method of cleaning should be applied to the lined pond operations.

Fish Distribution--Control of pollutants through fish distribution practices would only be effective in ponds that are cleaned routinely. Reference is made to the discussion of fish distribution under flow-thru culturing operations because the same technologies apply.

Pond Draining and Harvesting Practices--During fish harvesting pollutants are discharged as individual ponds are drained. In-plant control measures may be taken to reduce the load of pollutants discharged. These measures, aimed primarily at reducing the suspended and settleable solids concentrations, include: a) control discharge rate to allow settling in the pond; b) discharge through another rearing pond at controlled rate; and c) harvest without draining. While each of these measures is worthy of careful consideration it is recognized that each is not practical for all pond culturing facilities. A discussion of each alternative is given below.

Settleable solids removal may be accomplished in the pond being drained by controlling the draining rate. This would require a surface draining system such that clearer water can be decanted from the surface of the pond. In addition, control would be possible only in cases where harvesting is accomplished in the pond as by seining. After harvesting is completed the remaining water in the pond should be retained to allow settling and the resultant clear water then discharged. This practice would no doubt increase the length of time required for draining and harvesting. However, it would alleviate water pollution by providing an estimated 40 percent reduction in the settleable solids discharged.

Discharging draining water through another rearing pond at a controlled rate offers another alternative method for removing settleable solids. As draining progresses, settleable solids could be monitored. When settleable solids appear in the discharge, the flow could be diverted through another rearing pond. Care should be taken at this point to see that the discharge is introduced into the rearing pond at a point farthest from the outlet.

At many hatcheries, elevations may be such that flow would not be diverted by gravity as described and pumping would be necessary. Harvesting without draining may be a viable alternative in-plant control measure at some facilities. This practice is now used on a limited scale and completely eliminates the discharge of pollutants during harvesting. The practicality of harvesting without draining may depend on soil type and disease problems experienced. Where pervious soils exist all water may be lost through seepage before refilling and restocking of the pond is desired. This could allow time for tilling and other measures aimed at rejuvenating the pond and reducing disease potential.

## Non-Native Fish Culturing Systems

Water Conservation--Because non-native fish are pond or tank cultured, water conservation measures described for native fish pond culture are applicable. Specifically, the discharge from open ponds may be reduced or eliminated altogether; each of these measures would reduce the load of pollutants discharged. In addition, recycle systems are becoming more common and result in considerable water conservation.

Feeding Practices--Some non-native fish are fed prepared rations in much the same manner as many pond-cultured native fish. The feeding rate, however, is usually determined visually rather than as a percentage of body weight. Thus, excess feeding and the resultant increase in pollutant load could easily occur. The amount and scheduling of feeding should be optimized for each hatchery such that excess feeding is eliminated.

Pond Draining and Harvesting Practices--Control of discharges during pond draining and harvesting may be accomplished by the methods described for native fish pond culturing. In addition, the harvesting technique used for non-native fish has a direct bearing on the control of draining discharges. A common practice in non-native fish culturing is to harvest by trapping. In this way draining may be delayed until after harvesting is completed, thus allowing draining to be carried out in such a way that the discharge of pollutants can be minimized. By slowly draining the pond from the surface, solids can be settled in the pond.

## TREATMENT TECHNOLOGY

Eight methods of treatment have been documented in the literature and are available for reducing the discharge of pollutants from native fish flow-thru culturing facilities. Two methods are presented for treatment of discharges from native fish pond-culturing operations. In addition, three technologies have been identified for control of pollution from non-native fish culturing units. Included are technologies based on bench studies, pilot plant studies and full scale operation. The levels of technology are described in the order of the least to the most efficient. Additionally, the problems, limitations and reliability of the treatment methods are discussed as well as an estimate of time necessary for the implementation of each level of technology.

Native Fish -- Flow-thru Culturing System

Settling of Cleaning Flow--Cleaning wastes consist primarily of settleable solids which accumulate in the rearing units. Simple settling will remove most of this material. Bench tests have revealed that 78-93 percent of the settleable solids can be removed [Table VII-1] in 30 minutes of quiescent settling in an Imhoff Cone (76,113). For continuous flow plant scale application, a conventional settling basin with a settling time of one hour should provide comparable removals. A surface overflow rate of 26 liters per minute per square meter (0.7 gpm/sq ft) has been used in conventional settling resulting in 90 percent removal of suspended solids from cleaning wastes (235). Where the necessary land area is not available, high rate sedimentation units including plate separators and tube settlers could be used.

It has been reported that cleaning discharges may account for 15 to 25 percent of the total BOD load from a hatchery (69,182). For purposes of estimating efficiencies of treatment alternatives it is assumed that 20 percent of the BOD load from flow-thru systems is discharged during cleaning. Table VII-1 indicates the percentage removal of various pollutants attained through simple settling of the cleaning flow. Raw waste characteristics (previously presented in Chapter V),

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TABLE VII-1

SETTLING OF CLEANING WASTES
Removal Efficiency

| Study and Reference | Settling Time (min.) | Percent Removal | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Settleable Solids | BOD | Suspended Solids | TKN | $NH_3$-N | $NO_3$-N | Total $PO_4$-P |
| Lamar (113) | 15 | 93[a/] | - | - | - | - | - | - |
| Cowlitz (140) | 120 | - | 80.3 | 88.6 | - | - | - | - |
| Wray (76) | 15 | 67 | 63 | 69 | 40 | 50 | 4 | 82 |
| | 30 | 78 | 72 | 71 | 35 | 57 | 1 | 68 |
| | 45 | 89 | 72 | 76 | 40 | 50 | 3 | 79 |
| | 60 | 100 | 72 | 78 | 43 | 50 | 3 | 83 |
| Willow Beach (251) | 5 | 85.7 | 75.7 | 95.3 | 69.9 | - | 49.2 | 92.9 |
| | 15 | 92.9 | 80 | 96.7 | 74.5 | - | 53.8 | 93.7 |
| | 30 | 100 | 80 | 97.5 | 74.5 | - | 53.8 | 93.7 |

a/ Based on settleable solids removed after 60 minutes equals 100 percent removal efficiency and final effluent characteristics of the cleaning flow are presented in Table VII-2. In terms of the entire waste loads, sedimentation of the cleaning flow would result in an estimated 15 percent reduction of BOD, suspended solids and phosphate loads and a five percent reduction in the total nitrogen load. In addition slug loads of pollutants would be eliminated.

The removal efficiencies indicated in Table VII-2 would be expected to decrease if settled solids were allowed to accumulate and digest in the settling basin. For this reason, provisions should be made for the periodic removal of settled solids. The suggested maximum time interval between solids removal is two to three weeks. Another problem, requiring consideration during design, is the intermittent hydraulic loads on the settling basin. To operate at maximum efficiency, the settling basin should receive a relatively constant flow of cleaning water.

Sludge handling and disposal could be a major problem if not adequately evaluated and designed into the treatment system. Several possibilities for sludge disposal include but are not limited to: a) hauling with direct application of wet sludge to agricultural land; b) on-site dewatering and land application or distribution as garden fertilizer; and c) discharge or hauling of wet sludge to a municipal waste disposal system.

The time for the industry to implement this level of technology is estimated to be 28 months. This includes the following time intervals:

TABLE VII-2

SETTLING OF CLEANING WASTES
Effluent Characteristics[a]

| Pollutant | Raw Waste[b] (mg/l) | Removal Efficiency (percent) | Effluent (mg/l) |
|---|---|---|---|
| BOD | 27.3 | 75 | 6.7 |
| COD | 97 | - | - |
| Suspended Solids | 73.5 | 80 | 14.7 |
| Settleable Solids[c] | 2.2 | 90 | 0.2 |
| $NH_3$-N | 0.59 | 50 | 0.3 |
| TKN | 2.05 | 50 | 1.0 |
| $NO_3$-N | 1.27 | 50 | 0.64 |
| Total $PO_4$-P | 0.59 | 80 | 0.12 |

a/ Effluent characteristics expected with one hour settling at plant scale
b/ Values are gross concentrations
c/ Reported as ml/l

| | |
|---|---|
| Obtain Funding | 6 months |
| Acquire Land | 6 " |
| Engineering Evaluation & Design | 6 " |
| Accept Bids & Award Contract | 2 " |
| Construction | 6 " |
| Operation Adjustment Period | 2 " |

Vacuum Cleaning--Cleaning wastes can be removed directly from the rearing units with a suction device similar to swimming pool vacuum equipment. The waste settleable solids can be removed from the cleaning flow by means of a batch settling operation. After settling the supernatant can be decanted and the solids pumped into a tank truck for land disposal or allowed to air dry in place. At a hatchery in Wisconsin cleaning wastes are discharged to seepage ponds where the liquid percolates and the solids are retained (128).

The removal efficiencies and the resultant effluent quality are the same as those presented for settling [Tables VII-1 and VII-2]. In terms of the entire waste load, it is estimated that the suspended solids and BOD load reduction resulting from the implementation of vacuum cleaning would be 15 percent.

The possible problems associated with vacuum cleaning do not appear to be great. Vacuum cleaning devices may not be effective in some cases in removing attached algal slimes from rearing units. This may be a design problem that would be resolved as cleaning devices are perfected or it may be necessary for additional hours to be spent in manual scraping. Certainly additional man hours would be required in the maintenance of vacuum equipment as compared to equipment used in conventional cleaning methods. Sludge handling and disposal could also become problems and should be carefully considered by the design engineers. Several possibilities for sludge disposal include but are not limited to: a) hauling with direct application of wet sludge to agricultural land; b) on-site dewatering and land application or distribution as garden fertilizer; and c) discharge or hauling of wet sludge to a municipal disposal system.

Time required for the implementation of vacuum cleaning is estimated to be 24 months. The following time intervals are included:

| | |
|---|---|
| Obtain Funding | 4 months |
| Acquire Land | 6 " |
| Engineering Evaluation & Design | 6 " |
| Accept Bids & Award Contract | 2 " |
| Construction | 4 " |
| Operation Adjustment Period | 2 " |

Settling of Entire Flow Without Sludge Removal--Settling has been used to treat the entire flow from fish hatcheries (75,182,184,235). The simplest method, although not the most efficient, is to settle in an earthen pond or lagoon. Solids are allowed to settle and decompose through bacterial action. Many hatcheries use brood stock holding ponds or in some cases rearing ponds for settleable solids removal. Plant scale treatment results for three hatcheries have been documented and are presented with results of two bench studies [Table VII-3].

From the data available, it is reasonable to expect a 25 percent removal of BOD with a settling time of two hours. Removal efficiencies for other pollutants and the resultant effluent characteristics are indicated [Table VII-4]. Effluent concentrations are expected to be essentially constant with possibly slight increases as a result of

TABLE VII-3

SETTLING OF ENTIRE FLOW WITHOUT SLUDGE REMOVAL
Removal Efficiency[a/]

| Study and Reference | Settling Time (hours) | Percent Removal: Settleable Solids | BOD | Suspended Solids | Org-N | $NH_3$-N | $NO_3$-N | Total $PO_4$-P |
|---|---|---|---|---|---|---|---|---|
| Rifle Falls[b/] (182) | 1.5 | - | 22.6 | - | - | - | - | - |
| Big Spring (184) | 1 | - | 2 | - | - | - | - | - |
| Wray[c/] (76) | 0.75 | - | 35 | 49 | 15 | 8 | 2 | 21 |
| Lamar[c/] (113) | 0.25 | 85 | - | - | - | - | - | - |
| Chalk Cliffs[d/] (75) | 5 | - | 36 | 50 | 17 | -17 | 0 | 25 |

a/ Efficiencies for the entire flow are determined by weighting efficiencies during normal and cleaning flows assuming 15 percent of the pollutant load is discharged during cleaning.
b/ Settling basin used also as brood stock holding pond
c/ Bench settling test using Imhoff Cone
d/ Based on two 24-hour composite samples of normal flow

TABLE VII-4

SETTLING OF ENTIRE FLOW WITHOUT SLUDGE REMOVAL
Effluent Characteristics[a/]

| Pollutant | Raw Waste[b/] (mg/l) | Removal Efficiency (percent) | Effluent (mg/l) |
|---|---|---|---|
| BOD | 9.5 | 25 | 7.1 |
| COD | 43 | - | - |
| Suspended Solids | 22 | 45 | 12.1 |
| Settleable Solids[c/] | 0.9 | 90 | <0.1 |
| $NH_3$-N | 0.54 | 0 | 0.54 |
| TKN | 1.37 | 0 | 1.37 |
| $NO_3$-N | 1.63 | 0 | 1.63 |
| Total $PO_4$-P | 0.25 | 20 | 0.20 |

a/ Effluent characteristics expected with two hour settling at plant scale
b/ Raw waste concentrations for the entire flow are gross values determined by weighting concentrations of normal and cleaning flows assuming 20 percent of the pollutant load is discharged during cleaning
c/ Reported as ml/l

cleaning. The slug loads currently discharged during cleaning, however would be reduced in strength.

The ultimate disposal of accumulated solids is thought to be the major operating problem which would be encountered. Periodically it would be necessary to remove and dispose of the settled solids. This material could be hauled wet for land application or in some cases allowed to dry in place before disposal. Thus two settling basins operating in parallel would probably be necessary to maintain treatment during solids disposal.

The estimated time necessary for the implementation of this level of technology is 25 months. Included are the following time periods;

| | |
|---|---|
| Obtain Funding | 6 months |
| Acquire Land | 6 " |
| Engineering Evaluation & Design | 6 " |
| Accept Bids & Award Contract | 2 " |
| Construction | 4 " |
| Operation Adjustment Period | 1 " |

Settling of Entire Flow with Sludge Removal--Removal efficiencies accomplished with settling are improved when sludge is removed from the settling basin before bacterial decomposition releases soluble pollutants. Two methods of sludge removal are applicable. First, sludge may be removed mechanically from concrete clarifiers as is the practice in the treatment of municipal wastes. The treatment process continues uninterrupted during sludge removal. Second, if additional land is available dual earthen settling basins may be operated in parallel. One basin may then be taken out of service while dewatering and sludge removal take place. The other basin remains in service treating the entire flow. This procedure is followed until both basins are clean. Where land is at a premium, high rate sedimentation could be employed using plate separators or tube settlers. Although these devices have not yet been used successfully on fish hatchery wastes, information exists for the rational design of high rate settlers (265,266).

Removal efficiencies obtained using this level of technology are presented in Table VII-5. Projecting this data to plant scale settling with a detention time of two hours, the removal efficiencies in Table VII-6 are expected. The efficiencies indicated are accomplishable only with the removal of accumulated solids prior to measurable breakdown and resolubilization. Available information suggests that sludge removal would be necessary at about two week intervals (196,246).

Sludge handling and disposal is recognized as the major problem associated with the implementation of this technology. For a hatchery with a flow of 37,850 $m^3$/day (10 mgd) that removes 10 mg/l of suspended solids, an estimated sludge volume, assuming 90 percent moisture, of about 3.785 $m^3$/day (1,000 gpd) could be expected. Possibilities for sludge disposal are: a) hauling with direct application of wet sludge to agricultural land; b) on-site dewatering and land application or distribution as garden fertilizer; and c) discharge or hauling of wet sludge to a municipal waste disposal system.

Another problem at some hatcheries may be shock hydraulic loadings to the settling basin during raceway cleaning. Fish farms or hatcheries operated with an increase in water flow during cleaning could experience a reduction in settling efficiency due to short circuiting. This could

TABLE VII-5

SETTLING OF ENTIRE FLOW WITH SLUDGE REMOVAL
Removal Efficiency[a]

| Study and Reference | Settling Time (hours) | Percent Removal | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Settleable Solids | Suspended Solids | BOD | COD | Org-N | $NH_3$-N | $NO_3$-N | Total $PO_4$-P |
| Lamar (113) | 0.07[b] | 38 | 52 | 39 | 69 | - | - | - | - |
| Big Springs (184) | 1 | - | - | 24 | - | - | - | - | - |
| Wray[c] (76) | 0.75 | - | 49 | 35 | - | 15 | 8 | 2 | 21 |

a/ Efficiencies for the entire flow are determined by weighting efficiencies during normal and cleaning flows assuming 15 percent of the pollutant load is discharged during cleaning.

b/ Actual settling time was 3.9 minutes.

c/ Bench settling test using Imhoff Cone

TABLE VII-6

SETTLING OF ENTIRE FLOW WITH SLUDGE REMOVAL
Effluent Characteristics[a/]

| Pollutant | Raw Waste[b/] (mg/l) | Removal Efficiency (percent) | Effluent (mg/l) |
|---|---|---|---|
| BOD | 9.5 | 35 | 6.2 |
| COD | 43 | 60 | 17.2 |
| Suspended Solids | 22 | 50 | 11 |
| Settleable Solids[c/] | 0.9 | 90 | <0.1 |
| $NH_3$-N | 0.54 | 0 | 0.54 |
| TKN | 1.37 | 10 | 1.2 |
| $NO_3$-N | 1.63 | 0 | 1.63 |
| Total $PO_4$-P | 0.25 | 20 | 0.20 |

a/ Effluent characteristics expected with two hour settling at plant scale

b/ Raw waste concentrations for the entire flow are gross concentrations determined by weighting concentrations of normal and cleaning flows assuming 20 percent of the pollutant load is discharged during cleaning.

c/ Reported as ml/l

be a particular problem in smaller operations where the increased flow during cleaning of one unit would be a significant percentage of the total flow.

It is estimated that 28 months would be required for the industry to implement settling with sludge removal. The time intervals are estimated as follows:

| | |
|---|---|
| Obtain Funding | 6 months |
| Acquire Land | 6 " |
| Engineering Evaluation & Design | 6 " |
| Accept Bids & Award Contract | 2 " |
| Construction | 6 " |
| Operation Adjustment Period | 2 " |

Stabilization Ponds--Stabilization ponds are probably one of the simplest methods available for treating fish wastes. The use of rearing ponds for waste stabilization is not uncommon in fish culturing operations. Usually brood stock ponds are used and only the normal hatchery discharge is routed through the pond. Cleaning wastes are disposed of by other methods including direct discharge into the receiving water. The effectiveness of stabilization ponds for treatment of the entire flow has been studied and documented (140). Four rearing ponds of about 1.8 hectares (4.5 acres) each with an average water depth of about 2.5 m (8.2 ft) were selected for the study. Excluding tests one and two [Table VII-7], the average detention time in the ponds was 3.8 days and the average BOD loading was 54.2 kg BOD/hectare-day (48.4 lb BOD/acre-day).

It is reasonable to expect BOD and suspended solids removals of about 60 percent when operated at detention times and loading rates

TABLE VII-7

STABILIZATION PONDS[a/]
Removal Efficiency

| Test No. | Flow | | Detention Time (Days) | BOD loading | | Percent Removal Efficiency | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $m^3$/day | (mgd) | | (kg/hectare-day) | (lb/acre-day) | BOD | Suspended Solids | $NH_3$-N | $NO_3$-N | $PO_4$-P |
| 1[b/] | 8,592 | 2.27 | 4.0 | 10.2 | 9.1 | 35 | 46 | 44 | 43 | 19 |
| 2[b/] | 17,638 | 4.66 | 2.0 | 20.8 | 18.6 | 32 | 40 | 52 | 36 | 0 |
| 3 | 15,064 | 3.98 | 2.3 | 51.6 | 46.0 | 56 | 60 | 77 | 41 | 86 |
| 4 | 5,829 | 1.54 | 6.0 | 78.6 | 70.1 | 48 | 60 | 78 | 58 | 87 |
| 5 | 8,213 | 2.17 | 4.2 | 42.6 | 38.0 | 68 | 65 | - | - | - |
| 6 | 17,525 | 4.63 | 2.0 | 73.4 | 65.5 | 54 | 54 | - | - | - |
| 7 | 12,491 | 3.30 | 2.8 | 52.2 | 46.6 | 61 | 61 | - | - | - |
| 8 | 6,359 | 1.68 | 5.5 | 26.9 | 24.0 | 62 | 65 | - | - | - |

a/ Data from Reference (140). Ponds received normal discharge and cleaning discharge. Author noted that ponds tested were used for rearing fingerling trout during peak season. The pollutant removal efficiency with fish in ponds was comparable to that without fish in ponds.
b/ Author noted that ponds tested had not yet stabilized.

similar to those shown in Table VII-7. The determinations made indicate that stabilization ponds are highly efficient in removing nutrient pollutants, nitrogen and phosphorus. Removal efficiencies and the resultant effluent quality are presented in Table VII-8. These figures are based on a stabilization pond with a detention time of three to four days, a loading rate of approximately 56.0 kg BOD/hectare-day (50 lbs BOD/acre-day) and are independent of whether or not fish are in the pond.

Two potential problems do exist in the use of stabilization ponds. First, over a period of many years some accumulation of solids can be expected. It may therefore become necessary to dewater the pond and dispose of the solids. Such an undertaking could represent a major expenditure in terms of cost and manpower. The other potential problem involves the assimilation of nutrients within the pond. The nutrient removals indicated in Table VII-7 are probably a result of uptake by algae and other plants in the stabilization pond. Eventually, conditions may occur causing an algae die off and subsequent release of nutrients into the receiving water.

Land requirements for stabilization ponds may rule out their application at many hatcheries. However, in cases where existing rearing units may be used for waste treatment, implementation of this treatment technology could be accomplished in a minimum time period. Assuming land acquisition is necessary, implementation time is estimated at 25 months. An estimated implementation schedule is presented below:

| | |
|---|---|
| Obtain Funding | 6 months |
| Acquire Land | 6 " |
| Engineering Evaluation & Design | 4 " |
| Accept Bids & Award Contract | 2 " |
| Construction | 6 " |
| Operation Adjustment Period | 1 " |

TABLE VII-8

STABILIZATION PONDS
Effluent Characteristics[a/]

| Pollutant | Raw Waste[b/] (mg/l) | Removal Efficiency (percent) | Effluent (mg/l) |
|---|---|---|---|
| BOD | 9.5 | 60 | 3.8 |
| COD | 43 | - | - |
| Suspended Solids | 22 | 60 | 8.8 |
| Settleable Solids[c/] | 0.9 | 90[d/] | <0.1 |
| $NH_3$-N | 0.54 | 70 | 0.16 |
| TKN | 1.37 | - | - |
| $NO_3$-N | 1.63 | 50 | 0.82 |
| Total $PO_4$-P | 0.25 | 80 | 0.05 |

a/ Effluent characteristics expected with three to four day detention time at a BOD loading rate of 56 kg/hectare-day (50 lb/acre-day)
b/ Raw waste concentrations for the entire flow are gross concentrations determined by weighting concentrations of normal and cleaning flows assuming 20 percent of pollutant load is discharged during cleaning.
c/ Reported as ml/l
d/ Based on results of bench scale settling tests (113)

Aeration and Settling (5 hours)--Aeration and settling has been studied on pilot scale for treating discharges from fish hatcheries (130,131). A pilot plant was operated during April and May of 1970 at the U.S. Army Corps of Engineers Dworshak National Fish Hatchery in Idaho. The Dworshak hatchery is a recycle facility in which water is reconditioned and recycled through the hatchery. Approximately 10 percent of the reconditioned water is wasted from the system. During the test, the pilot plant treated a portion of the 10 percent waste stream. Characteristics of influent to the pilot plant [Table VII-9] are nearly identical to characteristics of single-pass hatchery effluent.

TABLE VII-9

DWORSHAK PILOT PLANT INFLUENT
FILTER NORMAL OVERFLOW CHARACTERISTICS[a/]

| Pollutant | Concentration (mg/1) |
|---|---|
| BOD | 5.4 |
| Suspended Solids | 12.6 |
| Total Solids | 76 |
| Total Volatile Solids | 25 |
| $NH_3$-N | 1.1 |
| $NO_3$-N | 1.8 |
| $PO_4$-P | 0.8 |

a/ Characteristics are average of pilot plant influent concentrations with pilot plant operating at detention times between 3.2 and 6.6 hours. Data are from Reference 131.

Nine tests were made with the pilot plant operating at detention times between three and seven hours. Results of these tests are presented in Table VII-10. At a total detention time of five hours the removal efficiencies in Table VII-11 would be expected. Applying these efficiencies to the average raw waste concentration of a single-pass hatchery would result in the effluent characteristics in Table VII-11.

For plant scale operation a three cell system could be used consisting of one aeration cell and two settling cells. During the pilot plant testing, under the conditions previously described, the air supply ranged from 970 to 2,020 cc/liter (0.13 to 0.27 $ft^3$/gal.) (130). To permit sludge handling, with some degree of convenience, settling basin design should consider the necessity for sludge removal. This may be accomplished with a single concrete clarifier with mechanical sludge removal or with two earthen settling basins designed for alternate dewatering and sludge removal.

Surges on the system resulting from increased organic loading and possible increased hydraulic loading during cleaning may be a problem. The pilot plant treated both filter normal overflow [Table VII-9] and a mixture of filter normal overflow and backwashing water [Table VII-12]. At the increased pollutant concentrations of the combined influent treatment efficiency was not impaired [Table VII-12].

The time required for implementation of aeration and settling (5 hours) is estimated at 32 months. Time intervals comprising this period are estimated below.

TABLE VII-10

AERATION AND SETTLING - 5 HOUR[a/]
Removal Efficiency

| Date | Detention Time (hours) | Percent Removal | | | | |
|---|---|---|---|---|---|---|
| | | BOD | Suspended Solids | $NH_3$-N | $NO_3$-N | $PO_4$-P |
| 4-23-70 | 3.2 | 76.4 | 33.3 | 8.6 | 15.5 | - |
| 4-24-70 | 3.3 | 63 | 16 | 34 | - | - |
| 4-25-70 | 3.65 | 52 | 80 | 2 | - | - |
| 4-26-70 | 6.6 | 51 | 50 | 27 | - | - |
| 4-26-70 | 5.3 | 67 | 55 | 44 | 65 | 7 |
| 4-27-70 | 4.92 | 90 | 90 | 12 | 24.5 | - |
| 4-30-70 | 4.9 | 27 | 90 | 10 | 44 | 14.5 |
| 4-30-70 | 5.8 | 46.5 | 53 | 8.6 | 30 | 29 |
| 5-01-70 | 4.4 | 60 | 58 | 10 | - | 12 |
| Mean Values | 4.67 | 59.2 | 58.4 | 17.4 | 19.9 | 6.9 |

a/ Data are from Reference 140.

TABLE VII-11

AERATION AND SETTLING - 5 HOUR
Effluent Characteristics[a/]

| Pollutant | Raw Waste[b/] (mg/1) | Removal Efficiency (percent) | Effluent (mg/1) |
|---|---|---|---|
| BOD | 9.5 | 60 | 3.8 |
| COD | 43 | - | - |
| Suspended Solids | 22 | 60 | 8.8 |
| Settleable Solids[c/] | 0.9 | 90[d/] | <0.1 |
| $NH_3$-N | 0.54 | 15 | 0.46 |
| TKN | 1.37 | - | - |
| $NO_3$-N | 1.63 | 15 | 1.39 |
| Total $PO_4$-P | 0.25 | 5 | 0.24 |

a/ Effluent characteristics expected with 1 to 1-1/2 hours aeration and 3 to 3-1/2 hours settling
b/ Raw waste concentrations for the entire flow are gross concentrations determined by weighting concentrations of normal and cleaning flows assuming 20 percent of pollutant load is discharged during cleaning.
c/ Reported as ml/1
d/ Assumption based on 3 hours settling

TABLE VII-12

PILOT PLANT TREATING MIXTURE OF FILTER NORMAL OVERFLOW AND BACKWASHING WATER[a/]

| Pollutant | Influent Concentration (mg/l) | Percent Removal |
|---|---|---|
| BOD | 17.6 | 67 |
| Suspended Solids | 42.7 | 68 |
| Total Solids | 112 | 20 |
| Total Volatile Solids | 34 | 37 |
| $NH_3$-N | 0.9 | 22 |
| $NO_3$-N | 1.9 | 48 |
| $PO_4$-P | 1.0 | 31 |

a/ Data are from Reference 131. Testing was done April 28 and 29, 1970. Concentrations and percent removals tabulated are average of values for the three tests conducted.

| | |
|---|---|
| Obtain Funding | 6 months |
| Acquire Land | 6 " |
| Engineering Evaluation & Design | 8 " |
| Accept Bids & Award Contract | 2 " |
| Construction | 8 " |
| Operation Adjustment Period | 2 " |

Aeration and Settling (10 hours)--Aeration and settling with a total detention time of approximately 10 hours was studied on pilot scale at the Seward Park Game Fish Hatchery in Seattle, Washington from November 22, 1969 to January 21, 1970 (130). During this period ten tests were made in which the total detention time ranged from 8.9 to 12 hours and averaged 10.2 hours. Aeration time averaged 1.9 hours and settling time averaged 8.3 hours. The aeration rate ranged from 1,800 to 2,470 cc/liter (0.24 to 0.33 $ft^3$/gal.) and averaged 1,950 cc/liter (0.26 $ft^3$/gal.).

The BOD and COD removal efficiencies are presented in Table VII-13. Applying the removal efficiencies to average raw waste characteristics of single-pass hatcheries the effluent characteristics indicated in Table VII-14 would be expected from a system operating with a total detention time of 10 hours.

Configurations for plant scale operation, and possible operating problems would be the same as for the 5-hour system previously described. The estimated time necessary for implementing this technology is 32 months. Time intervals for the various steps of implementation are estimated below.

| | |
|---|---|
| Obtain Funding | 6 months |
| Acquire Land | 6 " |
| Engineering Evaluation & Design | 8 " |
| Accept Bids & Award Contract | 2 " |
| Construction | 8 " |
| Operation Adjustment Period | 2 " |

TABLE VII-13

AERATION AND SETTLING - 10 HOUR[a/]
Removal Efficiency

| Date | Detention Time (hours) | Influent BOD (mg/1) | Influent COD (mg/1) | Percent Removal BOD | Percent Removal COD |
|---|---|---|---|---|---|
| 11-22-69 | 9.3 | 14.2 | 20.8 | 78 | 52 |
| 11-23-69 | 9.3 | 13.3 | 32 | 77 | 84 |
| 11-25-69 | 9.3 | 12.7 | 40 | 78 | 88 |
| 11-29-69 | 8.9 | 16.5 | 21 | 89 | 15 |
| 12-02-69 | 8.9 | 18.1 | 52 | 79 | 77 |
| 12-06-69 | 11.9 | 13.1 | 42 | 81 | 80 |
| 12-20-69 | 11.1 | 16.7 | 27.4 | 77 | 86 |
| 12-21-69 | 10.6 | 14.3 | 16 | 84 | 38 |
| 12-23-69 | 10.8 | 14.4 | 27.0 | 83 | 52 |
| 12-24-69 | 12 | 17.3 | 22 | 92 | 68 |
| Mean Values | 10.2 | 15.1 | 30.2 | 82 | 64 |

a/ Data are from Reference 130.

TABLE VII-14

AERATION AND SETTLING - 10 HOUR
Effluent Characteristics[a/]

| Pollutant | Raw Waste[b/] (mg/l) | Removal Efficiency (percent) | Effluent (mg/l) |
|---|---|---|---|
| BOD | 9.5 | 80 | 1.9 |
| COD | 43 | 60 | 17 |
| Suspended Solids | 22 | - | - |
| Settleable Solids[3/] | 0.9 | 90[d/] | <0.1 |
| $NH_3$-N | 0.54 | - | - |
| TKN | 1.37 | - | - |
| $NO_3$-N | 1.63 | - | - |
| Total $PO_4$-P | 0.25 | - | - |

a/ Effluent characteristics expected with 2 hours aeration and 8 hours settling
b/ Raw waste concentrations for the entire flow are gross concentrations determined by weighting concentrations of normal and cleaning flows assuming 20 percent of pollutant load is discharged during cleaning.
c/ Reported as ml/l
d/ Assumption based on 8 hours settling

Reconditioning--Reconditioning refers to fish rearing systems in which water is treated and recirculated through the hatchery. A fraction of the total flow is wasted from the system to prevent a buildup of $NH_3$-N and replaced with an equal flow of source water. Reconditioning systems have been used primarily for reasons other than pollution control. Several reasons for installing water reconditioning include: a) source water requiring sterilization; b) insufficient flow of source water available; and c) temperature control for increased production.

Reconditioning water for fish rearing requires the replenishment of oxygen and the removal of carbon dioxide and ammonia (36). Oxygen replenishment and carbon dioxide removal are usually accomplished by violent aeration. "Bacterial nitrification is said to offer the most practical and economical method of ammonia removal (36)". Several methods of treatment for reconditioning were tested at Bozeman, Montana (159). Pilot reconditioning systems were operated using activated sludge, extended aeration and trickling filtration, all common methods of secondary wastewater treatment. Two nitrification filters referred to as "upflow filter" and "new upflow filter" were also tested on pilot scale. Each of these systems was operated as a nine-pass reconditioning system resulting in 90 percent of the water being recirculated while 10 percent is wasted from the system. Results of the Bozeman pilot studies are presented in Table VII-15. From these data it was concluded that the removal efficiencies and effluent characteristics indicated in Table VII-16 were achievable with a nine-pass reconditioning system.

TABLE VII-15

RECONDITIONING[a/]
Removal Efficiency[b/]

| Reconditioning System | 1971 Period of Operation | Percent Removal[c/] BOD | Suspended Solids | $NH_3$-N | $PO_4$-P (ortho) |
|---|---|---|---|---|---|
| Activated Sludge | 3/3 to 7/29 | 97 | 88 | 23 | 24 |
| Extended Aeration | 3/3 to 7/29 | 93 | 95 | 10 | 25 |
| Trickling Filter | 3/3 to 8/16 | 86 | 91 | 69 | +33 |
| Upflow Filter | 8/7 to 11/11 | 89 | 79 | 49 | +25 |
| New Upflow Filter | 8/23 to 11/11 | 91 | - | 49 | +33 |

a/ Data are from Reference 159 for nine-pass reconditioning (10 percent waste)
b/ Removal is expressed in percent based on pollutant production rates measured in a single-pass system.
c/ Plus sign represents increase

TABLE VII-16

RECONDITIONING
Equivalent Effluent Characteristics[a]

| Pollutant | Raw Waste[b] (mg/l) | Removal Efficiency (percent) | Effluent (mg/l) |
|---|---|---|---|
| BOD | 9.5 | 90 | 1.0 |
| COD | 43 | - | - |
| Suspended Solids | 22 | 90 | 2.2 |
| Settleable Solids[c] | 0.9 | - | - |
| $NH_3$-N | 0.54 | 40 | 0.32 |
| TKN | 1.37 | - | - |
| $NO_3$-N | 1.63 | - | - |
| Ortho $PO_4$-P | 0.25 | - | - |

a/ Because the discharge is approximately 90 percent less than from a single-pass system, the actual effluent concentrations would be higher. However effluent concentrations are expressed in terms of an equivalent single-pass system to simplify comparison.

b/ Raw waste concentrations for entire flow are determined by weighting concentrations of normal and cleaning flows assuming 20 percent of pollutant load is discharged during cleaning.

c/ Reported as ml/l

Possible problems with reconditioning systems center on the high degree of reliance on mechanical equipment. Pumping, sterlization and aeration are all vital parts of the system and should where used be backed up by standby units and an alternate power supply. The man-hours necessary for the proper maintenance of a reconditioning system would probably be several times that of a single-pass system.

The estimated time for implementation of reconditioning technology is 52 months. Time intervals for the various steps of implementation are estimated below:

| | |
|---|---|
| Obtain Funding | 12 months |
| Acquire Land | 6 " |
| Engineering Evaluation & Design | 12 " |
| Accept Bids & Award Contract | 2 " |
| Construction | 16 " |
| Operation Adjustment Period | 4 " |

Native Fish -- Pond Culturing Systems

Pond culturing systems which overflow more than 30 days per year are considered flow-thru culturing systems; therefore, only discharges resulting from pond draining activities are considered here. In-plant control measures are presented below as treatment alternatives because significant construction or capital investment may be required for implementation. In addition to the two alternatives discussed, a third control measure, harvesting without draining, may be implemented with only negligible cost and therefore is not presented here.

Draining at a Controlled Rate--Ponds that are partially drained before fish are harvested can be drained from the surface to allow settling of solids within the pond. To continue the control of setleable solids, fish harvesting can be done in the pond by such methods as seining or trapping. After fish have been removed, pond water can be retained to allow additional settling of solids. Later the supernatant can be carefully drained from the surface to avoid resuspension and the subsequent discharge of settled solids.

With respect to treatment efficiency, settleable solids values shown in Table VII-17 are representative for the industry and can be reduced by an estimated 40 percent if the previously described procedures are followed. This estimate is thought to be conservative inasmuch as simple settling can remove more than 90 percent of the settleable solids. Table VII-18 shows two important facts. First, it shows that settleable solids can be controlled in pond draining discharges when good fish harvesting management is practiced. Second, it shows that water quality stays essentially constant during much of the draining procedure, deteriorating in quality just prior to harvest.

Problems and limitations inherent in this technology are three-fold. First, additional man-hours are required for harvesting. Second harvesting in the pond is thought by some fish culturists to cause higher fish mortality at harvest. Third, these harvesting techniques may require reconstruction of pond outlets and harvesting sumps as well as major modification of piping.

The estimated implementation time for this technology is 15 months. Time increments included in this estimate are as follows:

| | |
|---|---|
| Obtain Funding | 6 months |
| Engineering Evaluation & Design | 3 " |
| Accept Bids & Award Contract | 1 " |
| Construction | 4 " |
| Operation Adjustment Period | 1 " |

TABLE VII-17

COMPARISON OF THE EFFLUENT CHARACTERISTICS[a/]
FROM NATIVE FISH -- POND CULTURING SYSTEMS

| Pollutant | Pond Overflow (mg/l) | Pond Draining (mg/l) |
|---|---|---|
| BOD | 3.9 | 5.1 |
| COD | 29 | 31 |
| Suspended Solids | 29 | 157 |
| Settleable Solids[b/] | <0.1 | 5.5 |
| $NH_3$-N | 0.30 | 0.39 |
| TKN | 0.63 | 0.78 |
| $NO_3$-N | 0.43 | 0.41 |
| Total $PO_4$-P | 0.31 | 0.13 |

a/ Summarized from data presented in Supplement B
b/ Reported as ml/l

TABLE VII-18

COMPARISON OF EFFLUENT CHARACTERISTICS[a/]
DURING DRAINING OF NATIVE FISH-POND CULTURING SYSTEMS

| Pollutant | Start of Draining (mg/l) | Pond Half Drained (mg/l) | Just Prior To Harvest (mg/l) |
|---|---|---|---|
| BOD | 5.7 | 4.8 | 11.7 |
| COD | 50 | 69 | 67 |
| Suspended Solids | 43 | 57 | 253 |
| Settleable Solids[b/] | <0.1 | <0.1 | 0.9 |
| $NH_3$-N | 0.08 | 0.15 | 0.25 |
| TKN | 0.97 | 0.96 | 1.41 |
| $NO_3$-N | 0.27 | 0.23 | 0.22 |
| Total P | 0.19 | 0.23 | 0.71 |

a/ Data are average values for three ponds sampled during draining for harvesting (74).
b/ Reported as ml/l

Draining Through Another Pond--In some fish culturing facilities draining through another pond may not be solely an in-plant control measure. Where another pond is not available, construction of an earth settling basin for batch settling may be necessary. Where other ponds do exist and draining water cannot be treated by gravity discharge, pumping may be necessary.

Draining through an existing rearing pond or a new settling pond can result in the removal of 80 percent of the settleable solids. This is considered a conservative figure because simple settling can remove greater than 90 percent of the settleable solids.

Problems involved with this technology include land requirements where additional pond construction is necessary, maintenance where pumping equipment is used, and additional man-hours required for harvesting.

The estimated time required for implementation is 22 months. This estimate assumes that land must be acquired and a settling pond constructed.

| | |
|---|---|
| Obtain Funding | 6 months |
| Acquire Land | 6 " |
| Engineering Evaluation & Design | 4 " |
| Accept Bids & Award Contract | 1 " |
| Construction | 4 " |
| Operation Adjustment Period | 1 " |

Non-Native Fish Culturing Systems

As one may conclude from Section V, treatment of wastewater from the non-native subcategory is aimed primarily at the control of biological pollutants. Because non-native fish are pond cultured, two assumptions can be made regarding the water quality of discharges with respect to pollutants other than biological pollutants. First, open ponds operate as stabilization ponds settling, digesting and assimilating pollutants such that the water discharged is of a quality similar to overflow from native fish pond culturing facilities. Second, discharges during draining and harvesting activities (where harvesting is accomplished by seining) are similar in quality to draining discharges from native fish operations and are characterized by high concentrations of suspended and settleable solids without appreciable change in the concentration of organic pollutants. Because of the public health significance of many of the organic pollutants from non-native operations, sludge must not be disposed by application to crops raised for human consumption. The three alternatives presented in this section are discussed in order of increasing efficiency in the removal of biological pollutants.

Chlorination--Chlorination is a disinfection method in widespread use for treating water and wastewater. Presently, chlorination is used in treating discharges from non-native fish culturing facilities and for in-plant disease control (33,102).

Biological pollution in pond drainage waters can be controlled by batch chlorination. After harvesting, the pond is charged with granular chlorine to a dosage of 20 mg/1. After a minimum of 24-hours and when no chlorine residual remains the pond can be drained without risk of biological contamination of surface waters.

The following problems and limitations are associated with chlorination.

To insure effective chlorination, adequate contact time and regular monitoring of chlorine residual is necessary. Batch treatment would be most common, however, were continuous chlorination used, preventive maintenance would be necessary for reliable equipment operation. The primary limitations of chlorination are that at usual treatment levels not all organisms are killed and a constant supply of chemicals is required. In addition, improper management of chlorine is hazardous to humans and to living organisms in the receiving water (267).

The time required for the implementation of filtration is estimated at 8 months. Land requirements are negligible, thus the following estimated time intervals do not include a period for land aquisition.

| | |
|---|---|
| Obtain Funding | 2 months |
| Engineering Evaluation and Design | 2 " |
| Accept Bids and Award Contract | 1 " |
| Construction | 2 " |
| Operation Adjustment Period | 1 " |

Filtration and Ultraviolet Disinfection--This treatment alternative consists of filtration followed by ultraviolet (UV) disinfection. Filtration is presently used in a number of non-native fish farms. Types of filter media in use include diatomacious earth, sand, gravel and activated charcoal (44,62,218,229). In the case of granular media, a coagulant may be added as the water enters the filter, and the filter acts as a contact coagulation bed (5).

Filtration is an effective means of removing the larger and more resistant biological pollutants which may not be destroyed by UV disinfection alone. Sand filtration traps most spores and bacteria (44). A diatomaceous earth filter used on a large Florida non-native fish farm removed all particles and organisms larger than a few microns (218). This would include most parasites (111,112).

Ultraviolet (UV) light or short wave length irradiation is used to disinfect water in non-native fish culturing facilities (21,218) in some large public aquaria (61,108), and in research facilities (108). Presently UV is used as an in-plant disease control measure but could be applied as an end-of-process treatment method. In UV disinfection a film of water, up to about 120 mm thick, is exposed to light from low-pressure mercury vapor lamps. The shortwavelength irradiation is believed to destroy the nucleic acids in bacterial cells (5).

The effectiveness of UV disinfection in reducing biological pollutants has been documented. An ultraviolet system at a non-native fish culturing facility reduced total coliforms from 350 per ml to 2-5 per ml (21). At the Steinhart Aquarium, five months of operation without UV resulted in a buildup of bacteria in the aeration tank to 40,000 per ml; after one day of UV, the level was reduced to 57 per ml (108). Spores are more resistant to UV than vegetative cells (5), however, standard UV doses of 35,000 milli-watt-seconds kill spores of the bacterium <u>Myxosoma cerebralis</u>, a form resistant to chemical treatment (111,112). Larger biological contaminants such as copepods, snails fish or fish gill parasites are not killed by UV irradiation (61,108).

Several problems and limitations exist in filtration followed by UV disinfection. With respect to filtration two major problems must be considered. First, filter backwash water is contaminated with biological pollutants and must be disposed of properly. Second, filters may clog when suspended solids concentrations become excessive due to algal blooms or pond draining. Maintenance of associated mechanical equipment is necessary.

Furthermore, the following problems and limitations are associated with the use of UV disinfection. Effectiveness is dependent upon delivery of the energy to the entire volume of water to be disinfected. Turbidity, algae, and color constitute natural barriers to the penetration of ultraviolet irradiations (5), thus thorough water preconditioning is required (256). The main limitation is that not all sizes of biological pollutants are destroyed. In addition, under some conditions, complete DNA cellular repair occurs in bacteria after UV disinfection. Mechanical problems, including lamp burn out and power failures, would result in interruption of treatment. Periodic and preventative maintenance would also be necessary.

Time required for the implementation of filtration followed by UV disinfection is 27 months as estimated below:

| | |
|---|---|
| Obtain Funding | 6 months |
| Acquire Land | 6 " |
| Engineering Evaluation and Design | 6 " |
| Accept Bids and Award Contract | 1 " |
| Construction | 6 " |
| Operation Adjustment Period | 2 " |

No Discharge (Land Disposal)--No discharge as discussed here refers to land disposal such that no discharge exists to surface water. No discharge is presently practiced at both large (218) and very small (43) non-native fish farms and, assuming that control technology is required, is the method most often recommended by representatives of the industry (11,12,43,89,90,101,192,220) and other authorities (48,55,56,204,233,267).

DRAFT

There is a trend toward increased water reuse thus reducing the volume of water for disposal. Four methods of land disposal are currently used to achieve no discharge; irrigation, dry wells, percolation ponds and drainfields used in conjunction with septic tanks. Dry wells are most common in extreme southern Florida (101). Percolation ponds are typically shallow earth ponds constructed in pervious soil and are in use in the Tampa Bay area of Florida (179). Septic tanks with drainfields are in use for the disposal of effluents from non-native fish culturing facilities in the Tampa Bay (12) and Miami (102) areas of Florida.

Biological pollutants are removed by the natural filtering action of the soil such that disinfection or other treatment is not considered necessary prior to land disposal. However in cases where a shallow ground water table or adjacent surface water exist, local authorities may require further treatment to protect water quality.

Problems associated with this technology include land requirements and flooding. Additional land may be required for land disposal. When percolation ponds are used they must be protected against flooding to prevent escapment of biological pollutants during peak flood or hurricane periods. Three foot dikes are sufficient in the main production area of Southern Florida (192,204).

The estimated time required for the implementation of no discharge is 18 months. The following estimated time intervals are included:

| | |
|---|---|
| Obtain Funding | 6 months |
| Acquire Land | 6 " |
| Engineering Evaluation and Design | 2 " |
| Accept Bids and Award Contract | 1 " |
| Construction | 2 " |
| Operation Adjustment Period | 1 " |

Summary

The waste loads achievable through the treatment technologies described are summarized in Table VII-19.

TABLE VII-19

POLLUTANT LOAD ACHIEVABLE THRU ALTERNATE TREATMENT TECHNOLOGIES

| Treatment Technology | BOD | COD | Suspended Solids | Settleable[a/] Solids | $NH_3$-N | TKN | $NO_3$-N | Total $PO_4$-P |
|---|---|---|---|---|---|---|---|---|
| | | | NATIVE FISH -- FLOW-THRU SYSTEMS[b/] | | | | | |
| No Treatment | 1.3 | 5.5 | 2.6 | 0.8 | 0.09 | 0.38 | 0.06 | 0.03 |
| Settling of Cleaning Flow | 1.1 | - | 2.2 | 0.7 | - | - | - | 0.03 |
| Vacuum Cleaning | 1.1 | - | 2.2 | 0.7 | - | - | - | - |
| Settling Entire Flow w/o SR | 1.0 | - | 1.4 | <0.1 | - | - | - | 0.02 |
| Settling Entire Flow w SR | 0.9 | - | 1.3 | <0.1 | 0.09 | 0.34 | 0.06 | 0.02 |
| Stabilization Ponds | 0.5 | - | 1.0 | <0.1 | 0.03 | - | 0.03 | 0.01 |
| Aeration & Settling 5-Hour | 0.5 | - | 1.0 | <0.1 | 0.08 | - | 0.05 | 0.03 |
| Aeration & Settling 10-Hour | 0.3 | 2.2 | - | <0.1 | - | - | - | - |
| Recycle Reconditioning | 0.1 | - | 0.3 | <0.1 | 0.05 | - | - | - |
| | | | NATIVE FISH -- POND DRAINING[c/] | | | | | |
| No Treatment | 5.1 | 31 | 157 | 5.5 | 0.39 | 0.78 | 0.41 | 0.13 |
| In-Plant Control | - | - | - | 3.3 | - | - | - | - |
| Settling | - | - | - | 1.1 | - | - | - | - |

a/ Reported as ml/l
b/ Reported as kg/100 kg·fish on hand/day except for settleable solids
c/ Reported as mg/l

# SECTION VIII.

## COSTS, ENERGY AND NON-WATER QUALITY ASPECTS

### INTRODUCTION

The control and treatment technologies that can be adopted to reduce waste loads from the fish culturing industry were presented in Section VII. The purpose of this section is to examine the treatment alternatives in terms of their costs, energy requirements, and impact on the non-water quality aspects of the environment. Cost information is presented for each alternative by subcategory as follows:

Native Fish -- Flow-Thru Culturing Systems

A -- Settling of Cleaning Flow

B -- Vacuum Cleaning

C -- Settling of Entire Flow Without Sludge Removal

D -- Settling of Entire Flow With Sludge Removal

E -- Stabilization Ponds

F -- Aeration and Settling (5 hours)

G -- Aeration and Settling (10 hours)

H -- Reconditioning

Native Fish -- Pond Culturing Systems

A -- Draining at Controlled Rate

B -- Draining Through Another Pond

C -- Harvesting Without Draining

Non-Native Fish

A -- Chlorination

B -- Filtration and Ultraviolet Disinfection

C -- No Discharge With Land Disposal

In each case, the generation of costs has required the adoption of various assumptions about typical size operations, existing treatment technology, levels of production and many other conditions. Two general assumptions have been made concerning land and power costs for all subcategories; land costs have been calculated at $2,000 per acre and power costs have been calculated at $0.025 per kilowatt-hour. For each alternative an attempt has been made to state explicitly the major assumptions in order to improve comprehension and provide the basis for subsequent review and evaluation.

NATIVE FISH -- FLOW-THRU CULTURING SYSTEMS

Eight levels of control and treatment technologies have been identified. Base level of practice is assumed to be once through flow, with no treatment. All costs and effects are evaluated using the base level of practice as zero cost. Climate, process characteristics, and age of facility were not considered meaningful for the purposes of making cost distinctions. Size, however, was considered significant and costs were developed for four scales of operation: 3,785; 37,850; 94,600 and 378,500 $m^3$/day (1, 10, 25 and 100 mgd) facilities. The following capacities were used in estimating the cost per pound of fish for this subcategory:

| Hatchery Flow | | Fish Produced | |
|---|---|---|---|
| $m^3$/day | mgd | kg | lb |
| 3,785 | 1 | 2,200 | 4,860 |
| 37,850 | 10 | 22,000 | 48,600 |
| 94,600 | 25 | 55,300 | 122,000 |
| 378,500 | 100 | 220,000 | 486,000 |

Several other assumptions specific to this subcategory are made. First, it is assumed that pumping is necessary to operate treatment facilities at elevations above flood levels. Secondly, it is assumed that major piping modifications are necessary to collect discharges for treatment. Sludge handling costs are estimated assuming wet sludge removal and hauling at $0.62/$m^3$ ($0.80/$yd^3$) and disposal at $5.44/m. ton ($6/ton).

The cost estimates also rely on a number of detailed assumptions that remain unstated in this document because it is believed that they are not critical to the acceptance or rejection of the estimates.

Alternative A -- Settling of Cleaning Flow

Cost estimates for Alternative A are presented in Table VIII-1. In addition to the previously stated general assumptions, estimates are based on the construction of an earth settling basin with a one-hour detention time and depth of 1.8 meters (6 ft).

Alternative B -- Vacuum Cleaning

In computing the cost estimates for Alternative B [Table VIII-2] it was assumed that settled solids would be pumped from the culturing units directly to a batch settling basin such that intermediate pumping would not be necessary. The pumping rate during vacuuming was estimated at 3.2 l/sec (50 gpm).

Alternative C -- Settling of Entire Flow Without Sludge Removal

The estimated costs of Alternative C are indicated in Table VIII-3. For purposes of the cost estimate it is assumed that two earth settling

TABLE VIII-1

NATIVE FISH -- FLOW-THRU CULTURING SYSTEMS
ALTERNATIVE A, COST ESTIMATES

| | HATCHERY FLOW | | | |
|---|---|---|---|---|
| | 3,785 $m^3$/day (1 mgd) | 37,850 $m^3$/day (10 mgd) | 94,600 $m^3$/day (25 mgd) | 378,500 $m^3$/day (100 mgd) |
| CAPITAL COSTS: | | | | |
| Pumping Facilities | $ 4,100 | $ 5,600 | $ 7,500 | $ 10,000 |
| Settling Pond | 550 | 1,000 | 1,800 | 4,000 |
| Piping | 2,250 | 4,000 | 6,000 | 9,000 |
| TOTAL COST | $ 6,900 | $ 10,600 | $ 15,300 | $ 23,000 |
| ANNUAL OPERATION AND MAINTENANCE COSTS: | | | | |
| Sludge Handling | $ 300 | $ 1,200 | $ 3,380 | $ 8,000 |
| Labor | 960 | 1,440 | 1,920 | 3,000 |
| TOTAL COST | $ 1,260 | $ 2,640 | $ 5,300 | $ 11,000 |
| ANNUAL ENERGY AND POWER COSTS: | | | | |
| Energy and Power | $ 30 | $ 250 | $ 800 | $ 1,750 |
| ANNUAL COSTS: | | | | |
| Capital | $ 550 | $ 850 | $ 1,250 | $ 1,850 |
| Depreciation | 360 | 530 | 770 | 1,150 |
| Operation and Maintenance | 1,260 | 2,640 | 5,300 | 11,000 |
| Energy and Power | 30 | 250 | 800 | 1,750 |
| TOTAL ANNUAL COST | $ 2,200 | $ 4,270 | $ 8,120 | $ 15,750 |
| COST PER KILOGRAM OF FISH PRODUCED[a/] | $ 0.99 | $ 0.20 | $ 0.15 | $ 0.07 |
| COST PER POUND OF FISH PRODUCED[a/] | $ 0.45 | $ 0.09 | $ 0.07 | $ 0.03 |

a/ For production figures refer to the introductory paragraph of Native Fish -- Flow-Thru Culturing Systems portion of Section VIII.

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TABLE VIII-2

NATIVE FISH -- FLOW-THRU CULTURING SYSTEMS
ALTERNATIVE B, COST ESTIMATES

| | HATCHERY FLOW | | | |
|---|---|---|---|---|
| | 3,785 $m^3$/day (1 mgd) | 37,850 $m^3$/day (10 mgd) | 94,600 $m^3$/day (25 mgd) | 378,500 $m^3$/day (100 mgd) |
| CAPITAL COSTS: | | | | |
| Vacuuming and Piping | $ 1,750 | $ 6,200 | $ 8,900 | $ 19,000 |
| Settling Pond | 200 | 600 | 1,000 | 2,500 |
| TOTAL COST | $ 1,950 | $ 6,800 | $ 9,900 | $ 21,500 |
| ANNUAL OPERATION AND MAINTENANCE COSTS: | | | | |
| Sludge Handling | $ 300 | $ 1,200 | $ 3,380 | $ 8,000 |
| Labor | 1,440 | 2,450 | 3,870 | 6,800 |
| TOTAL COST | $ 1,740 | $ 3,650 | $ 7,250 | $ 14,800 |
| ANNUAL ENERGY AND POWER COSTS: | | | | |
| Energy and Power | $ 30 | $ 250 | $ 800 | $ 2,000 |
| ANNUAL COSTS: | | | | |
| Capital | $ 160 | $ 540 | $ 720 | $ 1,720 |
| Depreciation | 100 | 340 | 450 | 1,080 |
| Operation and Maintenance | 1,740 | 3,650 | 7,250 | 14,800 |
| Energy and Power | 30 | 250 | 800 | 2,000 |
| TOTAL ANNUAL COST | $ 2,030 | $ 4,780 | $ 9,220 | $ 19,600 |
| COST PER KILOGRAM OF FISH PRODUCED[a/] | $ 0.92 | $ 0.22 | $ 0.18 | $ 0.09 |
| COST PER POUND OF FISH PRODUCED[a/] | $ 0.42 | $ 0.10 | $ 0.08 | $ 0.04 |

a/ For production figures refer to the introductory paragraph of Native Fish -- Flow-Thru Culturing Systems portion of Section VIII.

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TABLE VIII-3

NATIVE FISH -- FLOW-THRU CULTURING SYSTEMS
ALTERNATIVE C, COST ESTIMATES

| | HATCHERY FLOW | | | |
|---|---|---|---|---|
| | 3,785 $m^3$/day (1 mgd) | 37,850 $m^3$/day (10 mgd) | 94,600 $m^3$/day (25 mgd) | 378,500 $m^3$/day (100 mgd) |
| CAPITAL COSTS: | | | | |
| Pumping Facilities | $ 5,000 | $ 14,500 | $ 24,000 | $ 45,000 |
| Settling Ponds | 1,350 | 10,600 | 20,700 | 70,000 |
| Piping | 3,100 | 12,700 | 34,500 | 70,000 |
| TOTAL COST | $ 9,450 | $ 37,800 | $ 79,200 | $ 185,000 |
| ANNUAL OPERATION AND MAINTENANCE COSTS: | | | | |
| Sludge Handling | $ 1,200 | $ 12,000 | $ 28,500 | $ 75,000 |
| Labor | 960 | 1,440 | 1,920 | 7,000 |
| TOTAL COST | $ 2,160 | $ 13,440 | $ 30,420 | $ 82,000 |
| ANNUAL ENERGY AND POWER COSTS: | | | | |
| Energy and Power | $ 490 | $ 4,900 | $ 11,750 | $ 30,000 |
| ANNUAL COSTS: | | | | |
| Capital | $ 760 | $ 3,000 | $ 6,350 | $ 15,000 |
| Depreciation | 470 | 1,900 | 3,950 | 9,200 |
| Operation and Maintenance | 2,160 | 13,440 | 30,420 | 82,000 |
| Energy and Power | 490 | 4,900 | 11,750 | 30,000 |
| TOTAL ANNUAL COST | $ 3,880 | $ 23,240 | $ 52,470 | $ 136,200 |
| COST PER KILOGRAM OF FISH PRODUCED[a/] | $ 1.76 | $ 1.06 | $ 0.95 | $ 0.62 |
| COST PER POUND OF FISH PRODUCED[a/] | $ 0.80 | $ 0.48 | $ 0.43 | $ 0.28 |

a/ For production figures refer to the introductory paragraph of Native Fish -- Flow-Thru Culturing Systems portion of Section VIII.

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basins, operated in parallel, would provide a total detention time of two hours with a depth of 1.8 meters (6 ft). Although no attempt would be made to remove sludge before bacterial decomposition takes place, it is recognized that over the long term sludge removal would be necessary at six-month to one-year intervals. The operation and maintenance cost for sludge handling assumed a removal interval of six months.

Alternative D -- Settling of Entire Flow With Sludge Removal

The estimated costs of this alternative are tabulated in Table VIII-4. Similar to the previous alternative, costs for Alternative D are estimated for two earth settling basins, operated in parallel, providing a total detention time of two hours with a depth of 1.8 meters (6 ft). Sludge is removed before bacterial decomposition has the opportunity to affect effluent water quality. It is estimated that during the course of a year, sludge would be removed 12 times.

Alternative E -- Stabilization Ponds

The costs of implementing Alternative E have been estimated and are presented in Table VIII-5. Estimates are based on duel earth stabilization ponds operated in parallel with a total detention time of four days and a depth of 2.4 meters (8 ft).

Alternative F -- Aeration and Settling (5 hours)

Cost estimates for Alternative F are indicated in Table VIII-6. Estimates are based on an aeration time of 1-1/2 hours followed by 3-1/2 hours of settling. The aeration basin was assumed to be of earth construction 3.7 meters (12 ft) in depth. Two earth settling basins,

TABLE VIII-4

NATIVE FISH -- FLOW-THRU CULTURING SYSTEMS
ALTERNATIVE D, COST ESTIMATES

| | HATCHERY FLOW | | | |
|---|---|---|---|---|
| | 3,785 $m^3$/day (1 mgd) | 37,850 $m^3$/day (10 mgd) | 94,600 $m^3$/day (25 mgd) | 378,500 $m^3$/day (100 mgd) |
| CAPITAL COSTS: | | | | |
| Pumping Facilities | $ 5,000 | $ 14,500 | $ 24,000 | $ 45,000 |
| Settling Ponds | 1,350 | 10,600 | 20,700 | 70,000 |
| Piping | 3,100 | 12,700 | 34,500 | 70,000 |
| TOTAL COST | $ 9,450 | $ 37,800 | $ 79,200 | $ 185,000 |
| ANNUAL OPERATION AND MAINTENANCE COSTS: | | | | |
| Sludge Handling | $ 1,300 | $ 13,500 | $ 32,000 | $ 84,000 |
| Labor | 1,760 | 2,640 | 3,500 | 10,000 |
| TOTAL COST | $ 3,060 | $ 16,140 | $ 35,500 | $ 94,000 |
| ANNUAL ENERGY AND POWER COSTS: | | | | |
| Energy and Power | $ 550 | $ 5,500 | $ 12,450 | $ 33,000 |
| ANNUAL COSTS: | | | | |
| Capital | $ 760 | $ 3,000 | $ 6,350 | $ 15,000 |
| Depreciation | 470 | 1,900 | 3,950 | 9,200 |
| Operation and Maintenance | 3,060 | 16,140 | 35,500 | 94,000 |
| Energy and Power | 550 | 5,500 | 12,450 | 33,000 |
| TOTAL ANNUAL COST | $ 4,840 | $ 26,540 | $ 58,250 | $ 151,200 |
| COST PER KILOGRAM OF FISH PRODUCED[a/] | $ 2.20 | $ 1.21 | $ 0.95 | $ 0.68 |
| COST PER POUND OF FISH PRODUCED[a/] | $ 1.00 | $ 0.55 | $ 0.48 | $ 0.31 |

a/ For production figures refer to the introductory paragraph of Native Fish -- Flow-Thru Culturing Systems portion of Section VIII.

TABLE VIII-5

NATIVE FISH -- FLOW-THRU CULTURING SYSTEMS
ALTERNATIVE E, COST ESTIMATES

| | HATCHERY FLOW | | | |
|---|---|---|---|---|
| | 3,785 $m^3$/day (1 mgd) | 37,850 $m^3$/day (10 mgd) | 94,600 $m^3$/day (25 mgd) | 378,500 $m^3$/day (100 mgd) |
| CAPITAL COSTS: | | | | |
| Pumping Facilities | $ 5,000 | $ 14,500 | $ 24,000 | $ 45,000 |
| Stabilization Pods | 34,000 | 160,000 | 320,000 | 600,000 |
| Piping | 13,000 | 12,700 | 34,500 | 70,000 |
| TOTAL COST | $ 52,000 | $ 187,200 | $ 378,500 | $ 715,000 |
| ANNUAL OPERATION AND MAINTENANCE COSTS: | | | | |
| Labor | $ 2,000 | $ 3,000 | $ 5,000 | $ 8,000 |
| ANNUAL ENERGY AND POWER COSTS: | | | | |
| Energy and Power | $ 260 | $ 2,600 | $ 6,250 | $ 20,000 |
| ANNUAL COSTS: | | | | |
| Capital | $ 4,150 | $ 15,000 | $ 30,300 | $ 57,000 |
| Depreciation | 2,600 | 9,360 | 21,000 | 36,000 |
| Operation and Maintenance | 2,000 | 3,000 | 5,000 | 8,000 |
| Energy and Power | 260 | 2,600 | 6,250 | 20,000 |
| TOTAL ANNUAL COST | $ 9,010 | $ 29,960 | $ 62,550 | $ 121,000 |
| COST PER KILOGRAM OF FISH PRODUCED[a/] | $ 4.07 | $ 1.36 | $ 1.12 | $ 0.55 |
| COST PER POUND OF FISH PRODUCED[a/] | $ 1.85 | $ 0.62 | $ 0.51 | $ 0.25 |

a/ For production figures refer to the introductory paragraph of Native Fish -- Flow-Thru Culturing Systems portion of Section VIII.

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TABLE VIII-6

NATIVE FISH -- FLOW-THRU CULTURING SYSTEMS
ALTERNATIVE F, COST ESTIMATES

| | HATCHERY FLOW | | | |
|---|---|---|---|---|
| | 3,785 $m^3$/day (1 mgd) | 37,850 $m^3$/day (10 mgd) | 94,600 $m^3$/day (25 mgd) | 378,500 $m^3$/day (100 mgd) |
| CAPITAL COSTS: | | | | |
| Pumping Facilities | $ 5,000 | $ 14,500 | $ 24,000 | $ 70,000 |
| Aeration Equipment | 45,000 | 235,000 | 485,000 | 750,000 |
| Aeration Ponds | 1,350 | 10,600 | 20,700 | 70,000 |
| Settling Ponds | 1,850 | 15,500 | 31,200 | 80,000 |
| Piping | 5,100 | 23,700 | 64,500 | 95,000 |
| TOTAL COST | $ 58,300 | $ 299,300 | $ 625,400 | $1,065,000 |
| ANNUAL OPERATION AND MAINTENANCE COSTS: | | | | |
| Sludge Handling | $ 1,600 | $ 16,500 | $ 40,000 | $ 100,000 |
| Labor | 1,760 | 2,640 | 3,500 | 5,000 |
| Aeration Maintenance | 2,000 | 4,000 | 6,000 | 15,000 |
| TOTAL COST | $ 5,360 | $ 23,140 | $ 49,500 | $ 120,000 |
| ANNUAL ENERGY AND POWER COSTS: | | | | |
| Energy and Power | $ 1,000 | $ 10,000 | $ 25,000 | $ 70,000 |
| ANNUAL COSTS: | | | | |
| Capital | $ 4,650 | $ 24,000 | $ 50,000 | $ 85,000 |
| Depreciation | 2,860 | 15,000 | 31,300 | 53,000 |
| Operation and Maintenance | 5,360 | 23,140 | 49,500 | 120,000 |
| Energy and Power | 1,000 | 10,000 | 25,000 | 70,000 |
| TOTAL ANNUAL COST | $ 13,870 | $ 72,140 | $ 155,800 | $ 328,000 |
| COST PER KILOGRAM OF FISH PRODUCED[a/] | $ 6.27 | $ 3.26 | $ 2.82 | $ 1.47 |
| COST PER POUND OF FISH PRODUCED[a/] | $ 2.85 | $ 1.48 | $ 1.28 | $ 0.67 |

a/ For production figures refer to the introductory paragraph of Native Fish -- Flow-Thru Culturing Systems portion of Section VIII.

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1.8 meters (6 ft) deep, operating in parallel were assumed. The assumed air supply was 1.9 liters of air per liter of aeration tank volume (0.25 cu ft/gal.).

Alternative G -- Aeration and Settling (10 hours)

Estimated costs for Alternative G are presented in Table VIII-7. All assumptions are identical to Alternative F with the exception of detention time. Alternative G is based on 2 hours aeration followed by 8 hours settling.

Alternative H -- Reconditioning

Cost estimates for Alternative H are presented in Table VIII-8. The estimates are based on a nine-pass reconditioning system receiving 10 percent makeup water and wasting 10 percent from the system. Costs for settling assumed the use of a concrete clarifier with mechanical sludge removal. Filtration figures assume a 1.5 meter (5 ft) filter media depth and a loading rate of 1.4 $lps/m^2$ (2 $gpm/ft^2$). Reaeration is estimated for 10 minutes detention time.

Cost of Achieving Best Practicable Control Technology Currently Available (BPCTCA)

The BPCTCA has been recommended as either of two technologies -- settling of the cleaning flow with sludge removal (Alternative A) or vacuum cleaning of the culturing units (Alternative B). The costs of achieving BPCTCA are presented in Tables VIII-1 and VIII-2.

TABLE VIII-7

NATIVE FISH -- FLOW-THRU CULTURING SYSTEMS
ALTERNATIVE G, COST ESTIMATES

| | HATCHERY FLOW | | | |
|---|---|---|---|---|
| | 3,785 $m^3$/day (1 mgd) | 37,850 $m^3$/day (10 mgd) | 94,600 $m^3$/day (25 mgd) | 378,500 $m^3$/day (100 mgd) |
| CAPITAL COSTS: | | | | |
| Pumping Facilities | $ 5,000 | $ 14,500 | $ 24,000 | $ 70,000 |
| Aeration Equipment | 46,500 | 245,000 | 515,000 | 800,000 |
| Aeration Ponds | 1,850 | 15,200 | 33,000 | 90,000 |
| Settling Ponds | 3,550 | 34,000 | 69,000 | 140,000 |
| Piping | 5,100 | 23,700 | 64,500 | 95,000 |
| TOTAL COST | $ 62,000 | $ 332,400 | $ 705,500 | $1,195,000 |
| ANNUAL OPERATION AND MAINTENANCE COSTS: | | | | |
| Sludge Handling | $ 1,600 | $ 16,500 | $ 40,000 | $ 100,000 |
| Labor | 1,760 | 2,640 | 3,500 | 5,000 |
| Aeration Maintenance | 2,000 | 4,000 | 6,000 | 15,000 |
| TOTAL COST | $ 5,360 | $ 23,140 | $ 49,500 | $ 120,000 |
| ANNUAL ENERGY AND POWER COSTS: | | | | |
| Energy and Power | $ 1,000 | $ 10,000 | $ 25,000 | $ 80,000 |
| ANNUAL COSTS: | | | | |
| Capital | $ 4,950 | $ 26,500 | $ 57,000 | $ 95,000 |
| Depreciation | 3,100 | 16,500 | 35,000 | 60,000 |
| Operation and Maintenance | 5,360 | 23,140 | 49,500 | 120,000 |
| Energy and Power | 1,000 | 10,000 | 25,000 | 80,000 |
| TOTAL ANNUAL COST | $ 14,410 | $ 76,140 | $ 166,500 | $ 355,000 |
| COST PER KILOGRAM OF FISH PRODUCED[a] | $ 6.53 | $ 3.45 | $ 2.99 | $ 1.61 |
| COST PER POUND OF FISH PRODUCED[a] | $ 2.97 | $ 1.57 | $ 1.36 | $ 0.73 |

a/ For production figures refer to the introductory paragraph of Native Fish -- Flow-Thru Culturing Systems portion of Section VIII.

TABLE VIII-8

NATIVE FISH -- FLOW-THRU CULTURING SYSTEMS
ALTERNATIVE H, COST ESTIMATES

| | HATCHERY FLOW | | | |
|---|---|---|---|---|
| | 3,785 $m^3$/day (1 mgd) | 37,850 $m^3$/day (10 mgd) | 94,600 $m^3$/day (25 mgd) | 378,500 $m^3$/day (100 mgd) |
| CAPITAL COSTS: | | | | |
| Clarifier | $ 90,000 | $ 250,000 | $ 400,000 | $ 700,000 |
| Nitrification Filter | 50,000 | 300,000 | 700,000 | 1,000,000 |
| Reaeration | 110,000 | 250,000 | 600,000 | 800,000 |
| Ozonation | 55,000 | 195,000 | 380,000 | 750,000 |
| Sludge Holding Tank | 20,000 | 20,000 | 20,000 | 50,000 |
| Pumps | 10,000 | 30,000 | 75,000 | 200,000 |
| Piping | 5,100 | 23,700 | 64,500 | 100,000 |
| Land | 1,000 | 2,000 | 4,000 | 6,000 |
| TOTAL COST | $341,100 | $1,070,000 | $2,240,000 | $3,621,000 |
| ANNUAL OPERATION AND MAINTENANCE COSTS: | | | | |
| Sludge Handling | $ 2,070 | $ 17,500 | $ 46,000 | $ 130,000 |
| Labor | 15,000 | 30,000 | 45,000 | 60,000 |
| TOTAL COST | $ 17,070 | $ 47,500 | $ 91,000 | $ 190,000 |
| ANNUAL ENERGY AND POWER COSTS: | | | | |
| Energy and Power | $ 1,550 | $ 14,500 | $ 35,000 | $ 100,000 |
| ANNUAL COSTS: | | | | |
| Capital | $ 27,300 | $ 85,000 | $ 180,000 | $ 290,000 |
| Depreciation | 17,000 | 53,500 | 112,000 | 180,000 |
| Operation and Maintenance | 17,070 | 47,500 | 91,000 | 190,000 |
| Energy and Power | 1,550 | 14,500 | 35,000 | 100,000 |
| TOTAL ANNUAL COST | $ 62,920 | $ 200,500 | $ 418,000 | $ 760,000 |
| COST PER KILOGRAM OF FISH PRODUCED [a/] | $ 28.49 | $ 9.09 | $ 7.55 | $ 3.43 |
| COST PER POUND OF FISH PRODUCED [a/] | $ 12.95 | $ 4.13 | $ 3.43 | $ 1.56 |

a/ For production figures refer to the introductory paragraph of Native Fish -- Flow-Thru Culturing Systems portion of Section VIII.

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Cost of Achieving Best Available Technology Economically Achievable (BATEA)

The BATEA has been recommended as settling of the entire flow with sludge removal. The costs of achieving BATEA are presented in Table VIII-4.

Cost of Achieving New Source Performance Standards (NSPS)

The NSPS technology is the same as BATEA. The cost of implementing NSPS is also presented in Table VIII-4.

Cost of Achieving Pretreatment Requirements (PRETREAT)

Pretreatment of wastewaters from fish culturing facilities is not necessary. Therefore the costs are zero for achieving pretreatment requirements for existing and new sources.

NATIVE FISH -- POND CULTURING SYSTEMS

The effluent limitations for BPCTCA for pond culturing systems can be met by at least three technologies which are: A) Draining from the surface at a controlled rate to allow settling in the pond; B) draining through another pond; and C) harvesting without draining. The base level of practice in the industry is no control.

Depending on the particular circumstances of the operation, any one of these three methods might provide the least cost method of achieving the BPCTCA requirements. In some instances, the topography and land availability will allow the construction of a gravity fed earthen settling basin at an elevation below all of the production ponds. In other cases, the proprietor may find it least costly to convert a production pond for use as a settling pond. Some ponds are constructed in such a way that harvesting without draining is already practiced or could readily be adopted. Harvesting without draining is a possibility in shallow ponds and those that have feeding areas that can be readily closed off from the rest of the pond. Finally, in many cases, the least cost approach toward achieving BPCTCA requirements may be the construction of a new outlet structure that allows controlled draining from the pond surface.

Costs have been estimated only for the construction of a new outlet structure [Table VIII-9]. Costs have been developed on the basis of a 0.405 hectare (one acre) pond producing 1,820 kg (4,000 lb) of fish per year. The costs are based upon the construction of a concrete outlet structure that allows controlled draining by means of dam boards. These costs represent the largest expenditure a pond culturing facility would incur in order to comply with BPCTCA. Whereas settling or harvesting without draining may be economically desirable or technically feasible in only certain situations, controlled drainage from the surface could be adopted in all cases.

## Cost of Achieving Best Available Technology Economically Achievable (BATEA)

The BATEA is the same as BPCTCA. The incremental costs of achieving BATEA above those of BPCTCA are zero.

## Cost of Achieving New Source Performance Standards (NSPS)

The NSPS requirements are identical to BPCTCA. Costs to achieve NSPS may be somewhat less than those for BPCTCA for existing sources but not by an appreciable amount.

TABLE VIII-9

NATIVE FISH -- POND CULTURING SYSTEMS
ALTERNATIVE A, COST ESTIMATE

| | |
|---|---|
| CAPITAL COSTS: | |
| Site Preparation | $ 200 |
| Piping Modifications | 300 |
| Outlet Structure | 1,000 |
| TOTAL COST | $1,500 |
| ANNUAL OPERATION AND MAINTENANCE COSTS: | |
| Labor | $ 160 |
| 2 Percent Fish Loss* | 35 |
| TOTAL COST | $ 195 |
| ANNUAL ENERGY AND POWER COSTS: | |
| Energy and Power | $ 00 |
| ANNUAL COSTS: | |
| Capital | $ 150 |
| Depreciation | 150 |
| Operation and Maintenance | 195 |
| Energy | 00 |
| TOTAL ANNUAL COSTS | $ 495 |
| COST PER KILOGRAM OF FISH PRODUCED | $ 0.29 |
| COST PER POUND OF FISH PRODUCED | $ 0.13 |

* Based on $0.44 lb value of live fish (269).

Cost of Achieving Pretreatment Requirements (PRETREAT)

Should waters from native fish pond culturing systems be discharged to a municipal system, they would require no pretreatment. The cost of pretreatment would be zero.

NON-NATIVE FISH CULTURING SYSTEMS

Alternative A -- Chlorination

The cost for chlorination is developed on the basis of batch treatment of a typical pond 18 m x 7.6 m x 1.8 m deep (60 ft x 25 ft x 6 ft) Frequency of draining depends upon many factors including type of fish being cultured and the ability of the pond to sustain production. For cost purposes it has been assumed that the pond is drained an average of once per year. Finally, the costs of control per unit of production are reported on the basis of 10,000 fish per typical pond per year. It is assumed that stocks of granular chlorine can be stored in existing areas not requiring investment for storage facilities. The cost estimates for Alternative A are presented in Table VIII-10.

Alternative B -- Filtration and Ultraviolet Disinfection

Costs for this technology have been developed on the basis of a system combining a standard swimming pool-type diatomaceous earth filter with an ultraviolet purifier. The culturing system consists of ten ponds with an average size of 18 m x 7.6 m x 1.8 m deep (60 ft x 25 ft x 6 ft). Ponds are assumed to be drained once per year and to have an annual production of 10,000 fish per pond. For purposes of flow rate it

## TABLE VIII-10

## NON-NATIVE FISH CULTURING SYSTEMS
## ALTERNATIVE A, COST ESTIMATE

| | |
|---|---|
| CAPITAL COSTS: | $ 00 |
| | |
| ANNUAL OPERATION AND MAINTENANCE COSTS: | |
| Labor | $ 40 |
| Chlorine | 50 |
| TOTAL COST | $ 90 |
| | |
| ANNUAL ENERGY AND POWER COSTS: | $ 00 |
| | |
| ANNUAL COSTS: | |
| Capital | $ 00 |
| Depreciation | 00 |
| Operation and Maintenance | 90 |
| Energy and Power | 00 |
| TOTAL ANNUAL COSTS | $ 90 |
| | |
| COST PER FISH PRODUCED | |
| Production of 10,000/pond/yr | $0.01 |

is assumed that only one pond is drained at any time and that the draining takes place over a period of 24 hours. Owing to the relative small size of the proposed treatment system, no costs are assigned to the space occupied by the control equipment. The estimated costs for a diatomaceous earth filter-UV system for a ten-pond non-native fish culturing operation are presented in Table VIII-11.

Alternative C -- No Discharge With Land Disposal

The viable approaches to land disposal are the application of pond drainage water to the land at irrigation rates or at pond percolation rates depending upon the availability of land and the local soil drainage characteristics. Costs have been developed for each of these alternatives employing conservative assumptions about soil characteristics.

The cost estimates have been developed for the same typical ten-pond system assumed in Alternative B. In the case of the irrigation alternative, a one-day application of 631 cubic meters per hectare (67,500 gal./acre) ten times per year has been assumed. This rate is equivalent to about 63.5 cm (25 in.) of water per year and would allow the drainage of each of the ten ponds once per year. Approximately 0.405 hectare (one acre) of land would be required.

The infiltration-percolation alternative requires the presence of deep, continuous deposits of coarse-textured soils without impermeable barriers; the soil must have high hydraulic conductivity to permit rapid movement of applied liquids. Systems have been operated for secondary effluent with application rates as high as 61 m (200 ft) of water per

TABLE VIII-11

NON-NATIVE FISH CULTURING SYSTEMS
ALTERNATIVE B, COST ESTIMATE

| | |
|---|---|
| CAPITAL COSTS: | |
| Diatomaceous Earth Filter | $1,100 |
| Ultraviolet Disinfection | 2,700 |
| Piping | 1,100 |
| Surge Tank | 1,100 |
| TOTAL COST | $6,000 |
| ANNUAL OPERATION AND MAINTENANCE COSTS: | |
| Labor | $ 800 |
| Diatomaceous Earth | 100 |
| TOTAL COST | $ 900 |
| ANNUAL ENERGY AND POWER COSTS: | |
| Energy and Power | $ 20 |
| ANNUAL COSTS: | |
| Capital | $ 600 |
| Depreciation | 600 |
| Operation and Maintenance | 900 |
| Energy and Power | 20 |
| TOTAL ANNUAL COST | $2,120 |
| COST PER FISH PRODUCED | |
| Production of 10,000/pond/yr | $ 0.02 |

year. In some cases rates have been as low as 21 m (70 ft) of water per year for primary effluents. For purposes of cost estimation, an application rate of 30 m (100 ft) per year has been assumed. This rate translates to an application of 3 m (10 ft) per draining. The infiltration-percolation rate for each pond draining would be 3 m (10 ft) and a percolation pond of about 0.1 hectare (0.25 acre) size would be necessary.

Based on these assumptions, the costs for the two alternative methods of land disposal appear in Table VIII-12.

Cost of Achieving Best Practicable Control Technology Currently Available (BPCTCA)

The BPCTCA has been recommended as no discharge of process wastewater pollutants. The BPCTCA is to be achieved by land disposal via an irrigation or an infiltration-percolation system. The costs for these systems appear in Table VIII-12.

Cost of Achieving Best Available Technology Economically Achievable (BATEA)

The BATEA is the same as BPCTCA. Therefore, the costs of achieving BATEA above those of achieving BPCTCA are zero.

Cost of Achieving New Source Performance Standards (NSPS)

The NSPS technology is the same as BPCTCA. The costs of NSPS appear in Table VIII-12 presented earlier.

TABLE VIII-12

NON-NATIVE FISH CULTURING SYSTEMS
ALTERNATIVE C, COST ESTIMATE

| | Spray Irrigation | Percolation Pond |
|---|---|---|
| CAPITAL COSTS: | | |
| Land | $2,000 | $ 500 |
| Earthwork | 00 | 6,000 |
| Pump and Piping | 1,300 | 2,800 |
| Hose | 1,500 | 00 |
| TOTAL COST | $4,800 | $9,300 |
| ANNUAL OPERATION AND MAINTENANCE COSTS: | | |
| Labor | $1,600 | $1,200 |
| ANNUAL ENERGY AND POWER COSTS: | | |
| Energy and Power | $ 25 | $ 10 |
| ANNUAL COSTS: | | |
| Capital | $ 580 | $ 930 |
| Depreciation | 560 | 560 |
| Operation and Maintenance | 1,600 | 1,200 |
| Energy and Power | 25 | 10 |
| TOTAL ANNUAL COST | $2,765 | $2,700 |
| COST PER FISH PRODUCED | | |
| Production of 10,000/pond/yr | $0.028 | $0.027 |

Cost of Achieving Pretreatment Requirements (PRETREAT)

Wastes from fish culturing ponds are organic in nature and pollutants are not present in concentrations that require pretreatment. The costs of achieving pretreatment for existing and new sources are zero.

## SUMMARY

To facilitate comparison, the costs for each treatment alternative discussed in this section are summarized by subcategory in Table VIII-13.

## ENERGY REQUIREMENTS OF ALTERNATIVE TREATMENT TECHNOLOGIES

Fish production is a very low energy consuming industry. The only energy consumed at most operations is that required for building heating and lighting. Some facilities use well water requiring energy to operate pumping equipment. The great majority of fish culturing facilities, however, use surface water that flows by gravity through rearing units. Automatic feeding equipment that requires very small amounts of energy is sometimes used. Manual feeding is usually accomplished by walking or driving along the edge of the culturing units and broadcasting feed by hand.

Annual energy and power costs have been estimated [Tables VIII-1 through 12] for the alternatives presented for each subcategory. For native fish -- flow-thru culturing systems Alternatives A through E, power costs are composed almost entirely of energy consumed in pumping prior to treatment. Alternatives A or B were selected as BPCTCA and both have very low pumping costs because only a fraction of the flow is treated. Energy requirements for Alternatives F, G and H are high due to the dependence upon mechanical equipment.

TABLE VIII-13

COST ESTIMATES* FOR ALTERNATE TREATMENT TECHNOLOGIES

NATIVE FISH -- FLOW-THRU CULTURING SYSTEMS

| Alternative | Hatchery Flow 3,785 $m^3$/day (1 mgd) | 37,850 $m^3$/day (10 mgd) | 94,600 $m^3$/day (25 mgd) | 378,500 $m^3$/day (100 mgd) |
|---|---|---|---|---|
| A -- SETTLING OF CLEANING FLOW | 0.99 (0.45) | 0.20 (0.09) | 0.15 (0.07) | 0.07 (0.03) |
| B -- VACUUM CLEANING | 0.92 (0.42) | 0.22 (0.10) | 0.18 (0.08) | 0.09 (0.04) |
| C -- SETTLING OF ENTIRE FLOW WITHOUT SLUDGE REMOVAL | 1.76 (0.80) | 1.06 (0.48) | 0.95 (0.43) | 0.62 (0.28) |
| D -- SETTLING OF ENTIRE FLOW WITH SLUDGE REMOVAL | 2.20 (1.00) | 1.21 (0.55) | 0.95 (0.48) | 0.68 (0.31) |
| E -- STABILIZATION PONDS | 4.07 (1.85) | 1.36 (0.62) | 1.12 (0.51) | 0.55 (0.25) |
| F -- AERATION AND SETTLING (5 HOURS) | 6.27 (2.85) | 3.26 (1.48) | 2.82 (1.28) | 1.47 (0.67) |
| G -- AERATION AND SETTLING (10 HOURS) | 6.53 (2.97) | 3.45 (1.57) | 2.99 (1.36) | 1.61 (0.73) |
| H -- RECONDITIONING | 28.49 (12.95) | 9.09 (4.13) | 7.55 (3.43) | 3.43 (1.56) |

NATIVE FISH -- POND CULTURING SYSTEMS

| | |
|---|---|
| A -- DRAINING AT CONTROLLED RATE | 0.29 (0.13) |
| B -- DRAINING THROUGH ANOTHER POND | - |
| C -- HARVESTING WITHOUT DRAINING | - |

NON-NATIVE FISH

| | |
|---|---|
| A -- CHLORINATION | 0.01 |
| B -- FILTRATION AND ULTRAVIOLET DISINFECTION | 0.02 |
| C -- NO DISCHARGE WITH LAND DISPOSAL | 0.03 |

* Costs are in terms of cost per kilogram (pound) of fish produced for native fish and cost per fish for non-native fish.

For native fish-pond culturing systems, annual energy and power costs are zero [Table VIII-9]. Energy and power requirements for non-native fish culturing system alternatives are negligible [Table VIII-10 to Table VIII-12].

NON-WATER QUALITY ASPECTS

Non-water quality aspects for each alternative treatment technology have been identified and discussed in Section VII. Sludge disposal is the only non-water quality consideration of significance in terms of environmental impact.

Sludge resulting from treatment alternatives for the native fish -- flow-thru subcategory is primarily organic in nature and high in oxygen demanding constituents. On the other hand, sludge from pond draining in the native and non-native fish subcategories is characterized by high levels of inorganic solids. In either case this material is of value as a fertilizer or soil conditioner and as such can have a positive environmental impact if properly handled. Sludge may be spread on agricultural land or used as a home lawn or garden fertilizer. Aesthetically, fish waste solids should not be any less desirable as a fertilizer than manure from other agricultural activities. It should be mentioned, however, that wastes from non-native fish culturing activities should not be applied to edible crops due to the possibility of contamination from pathogenic organisms.

To identify the magnitude of the sludge handling problem, sludge volumes have been estimated for each alternative in the native-flow-thru subcategory. These volumes are presented in Table VIII-14 for a

TABLE VIII-14

SLUDGE VOLUMES-NATIVE FISH -- FLOW-THRU CULTURING SYSTEM ALTERNATIVES

| Alternative Technology | Sludge Volume* Per Day | |
|---|---|---|
| | liters | cu ft |
| A | 136 | 4.8 |
| B | 136 | 4.8 |
| C | 294 | 10.4 |
| D | 329 | 11.6 |
| E | 0 | 0 |
| F | 394 | 13.9 |
| G | 524 | 18.5 |
| H | 589 | 20.8 |

* Based on flow of 3,785 $m^3$/day (1 mgd) and sludge moisture content of 90 percent.

3,785 $m^3$/day (1 mgd) flow. The volume of sludge resulting from pond culturing of native and non-native fish is dependent to a large degree on the type of soil in which the ponds are constructed. Due to the small volume of sludge from pond culturing as compared to flow-thru systems, and the inorganic nature of the material, disposal is usually accomplished on site without measurable environmental impact.

# SECTION IX.

# EFFLUENT REDUCTION ATTAINABLE THROUGH THE APPLICATION OF THE BEST PRACTICABLE CONTROL TECHNOLOGY CURRENTLY AVAILABLE

## INTRODUCTION

The effluent limitations which must be achieved by July 1, 1977, specify the degree of effluent reduction attainable through application of the Best Practicable Control Technology Currently Available BPCTCA). The Best Practicable Control Technology Currently Available is generally based upon the average of the best existing performance by plants of various sizes, ages and unit processes within the industry. This average is not based upon a broad range of plants within the fish culturing industry, but upon performance levels achieved by exemplary plants. In industrial categories where present control and treatment practices are uniformly inadequate, a higher level of control than any currently in place may be required if the technology to achieve such higher level can be practicably applied by July 1, 1977.

In establishing BPCTCA effluent limitations guidelines, consideration must also be given to:

1. The total cost of application of technology in relation to the effluent reduction benefits to be achieved from such application;

2. The age and size of equipment and facilities involved;

3. The processes employed;

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4. The engineering aspects of the application of various types of control techniques;

5. Process changes;

6. Non-water quality environmental impact (including energy requirements).

Best Practicable Control Technology Currently Available emphasizes treatment facilities at the end of manufacturing processes, but includes control technologies within the process itself when the latter are considered to be normal practice within an industry. A further consideration is the degree of economic and engineering reliability which must be established for the technology to be "currently available." As a result of demonstration projects, pilot plants, and general use, there must exist a high degree of confidence in the engineering and economic practicability of the technology at the time of commencement of construction or installation of the control facilities.

IDENTIFICATION OF BEST PRACTICABLE CONTROL TECHNOLOGY CURRENTLY AVAILABLE

Native Fish -- Flow-thru Culturing Systems*

Best Practicable Control Technology Currently Available for the flow-thru systems subcategory of the fish culturing industry is sedimentation of the cleaning flow with sludge removal or vacuum cleaning of the culturing units. A description and discussion of sedimentation

* All fish culturing operations which discharge wastewaters more than 30 days per year

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and vacuum cleaning is included in Section VII of this document. Effluent characteristics achievable through implementation of BPCTCA and disinfection as needed are as follows:

| Effluent Characteristic | Effluent Limitation* |
|---|---|
| Suspended Solids | Maximum for any one day = 2.9 kg/100 kg of fish on hand/day<br><br>Maximum average of daily values for any period of thirty consecutive days = 2.2 kg/100 kg of fish on hand/day |
| Settleable Solids | Maximum instantaneous = 0.2 ml/l |
| $NH_3$-N | Maximum for any one day = 0.12 kg/100 of fish on hand/day<br><br>Maximum average of daily values for any period of thirty consecutive days = 0.09 kg/100 kg of fish on hand/day |
| Fecal Coliform Bacteria | Maximum concentration = 200 organisms/100 ml (Salmonid operations are excluded from this effluent limitation). |

Native Fish -- Pond Culturing Systems

Pond culturing systems which overflow more than 30 days per year are considered flow-thru culturing systems and are subject to effluent limitations for the flow-thru culturing subcategory. However, pond

* Effluent limitations are net values

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draining discharges are subject to effluent limitations for the pond culturing subcategory.

Control of pollutants from discharges during pond draining for harvesting is practicable with current technology. The Best Practicable Control Technology Currently Available is in-plant control including: a) draining from the surface at a controlled rate to allow settling in the pond; b) draining at a controlled rate through an existing rearing pond or a settling pond; or c) harvest without draining. These measures and effluent disinfection as needed can be used to achieve the following effluent characteristics:

| Effluent Characteristic | Effluent Limitation* |
|---|---|
| Settleable Solids | Maximum instantaneous concentration during draining period = 3.3 ml/1 |
| Fecal Coliform Bacteria | Maximum concentration = 200 organisms/100 ml (Salmonid operations are excluded from this effluent limitation). |

Non-Native Fish Culturing Systems

Best Practicable Control Technology Currently Available for the non-native fish culturing industry is no discharge of process wastewater pollutants achieved by the use of land disposal practices described in Section VII.

* Effluent limitations are net values

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## RATIONALE FOR SELECTION OF TECHNOLOGY

### Native Fish -- Flow-thru Culturing Systems

Sedimentation of the cleaning flow with sludge removal or vacuum cleaning of the culturing units is judged to be BPCTCA because it is being practiced by exemplary hatcheries within the industry. A factor of 1.3 was used in determining maximum one-day effluent limitations. A larger peaking factor was not selected because sedimentation is considered a stable process not subject to wide variations in treatment efficiency. There are no data available to substantiate that either the age or size of hatchery facilities justify special consideration for different effluent limitations. On the other hand, culturing processes are different and subcategories have been established for flow-thru and pond culturing systems. Process changes are not necessary in the implementation of BPCTCA.

At some hatcheries it may be possible to meet the Level I guidelines solely through implementation of the in-plant control measures discussed in Section VII. Where $NH_3$-N concentrations exceed limitations during cleaning, rearing units will require more frequent cleaning.

The engineering design and operation of sedimentation facilities is well defined. Design criteria may be developed by using the fish waste in question and employing established bench scale

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testing procedures. The operation of sedimentation facilities or vacuum cleaning devices is not complex and should require only minimum training of hatchery personnel.

The major non-water quality environmental impact from the implementation of BPCTCA will be solids disposal. Sludge must be removed periodically from the settling basin. Solids disposal may be accomplished as described in Section VII.

Native Fish -- Pond Culturing Systems

Pond culturing systems which overflow more than 30 days per year are considered flow-thru culturing systems, therefore rationale presented for pond culturing systems applies only to pond draining discharges.

The BPCTCA for pond culturing systems is in-plant control by one of the following measures: a) draining from the surface at a controlled rate to allow settling in the pond; b) draining at a controlled rate through an existing rearing pond or a settling pond, or c) harvesting without draining. Each of these measures will provide some reduction in the settleable solids discharged. Because control of draining discharges is not presently practiced, the following assumptions are included in the rationale for BPCTCA.

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First, draining from the surface at a controlled rate can accomplish a 40 percent removal of settleable solids. Much of this removal may be accomplished after harvesting by allowing settling before the remaining water is discharged. In some cases this may require a change in harvesting procedures.

Second, draining at a controlled rate through an existing rearing pond or settling pond can accomplish an 80 percent removal of settleable solids. Typically, rearing ponds provide detention times measured in days rather than hours. Therefore, settleable solids removal efficiency would be expected to approach 100 percent and the assumed 80 percent removal efficiency is considered conservative.

Third, harvesting without draining can eliminate the discharge of settleable solids and other pollutants. When draining is required after harvesting is completed, ponds can be drained from the surface very slowly to insure settling within the pond. Some discharge of settleable solids may occur; however, an estimate of 80 percent reduction is considered conservative. Where porous soil exists, water may be allowed to seep into the groundwater or nearby surface water. Thus, no settleable solids are released when harvesting is accomplished without draining and very low levels of settleable solids are released when post harvest draining is necessary.

Rationale are not available justifying the establishment of different effluent guidelines based on size or age of hatchery facilities. Subcategories have been established based on culturing processes for flow-thru and pond culturing systems. Harvesting procedures will require changing in most cases for implementation of BPCTCA.

With respect to the engineering aspects of the application of BPCTCA, two factors will require consideration. First, pumping of the turbid portion of the draining discharge may be necessary to implement draining through an existing rearing pond or settling pond. Second, discharge and harvesting structures may require significant modification to allow controlled surface draining and harvesting in the pond. Where such modification is necessary, these measures are considered treatment alternatives and are discussed under Treatment Technology, Section VII.

<u>Non-Native Fish Culturing Systems</u>

No discharge with land disposal of process wastewater pollutants is judged to be BPCTCA. This level of technology is practical because many of the exemplary facilities in the industry are practicing this method of disposal. The concepts are proven, available for implementation and, in some cases, enhance production. Process changes in the industry are usually minor and should not affect the practicability of BPCTCA.

There is no evidence that different effluent limitations are justified on the basis of variations in the age or size of culturing facilities. Industry competition and general improvements in production concepts have resulted in modernization of facilities throughout the industry. This, coupled with the similarities of wastewater characteristics for plants of varying size and the relatively low flow rates required, substantiates that no discharge with land disposal is practical.

All plants in the industry use similar production methods and have similar wastewater characteristics. There is no evidence that operation of any current process or subprocess will substantially affect capabilities to implement best practicable control technology currently available.

At many localities land disposal facilities can be installed at the lowest elevations of the production facility, enabling the use of gravity for water transport. In others, small amounts of energy are now required to pump ponds dry and would be required to distribute wastewater to the land disposal area. In the latter case, land disposal might increase the energy use, but the small increase would be justified by the benefits of no discharge of pollutants and the fact that other treatment methods require more energy use.

# SECTION X.

## EFFLUENT REDUCTION ATTAINABLE THROUGH THE APPLICATION OF THE BEST AVAILABLE TECHNOLOGY ECONOMICALLY ACHIEVABLE

### INTRODUCTION

The effluent limitations which must be achieved by July 1, 1983, specify the degree of effluent reduction attainable through application of the best available technology economically achievable (BATEA). The BATEA is to be based on the very best control and treatment technology employed within the fish culturing industry or based upon technology which is readily transferable to the industry. Since limited data exist on the full-scale operation of exemplary facilities, pilot studies and short-term plant scale studies are also used for assessment of BATEA.

Consideration must be given to the following in determining BATEA:

1. The total cost of achieving the effluent reduction resulting from application of BATEA;
2. The age and size of equipment and facilities involved;
3. The processes employed;
4. The engineering aspects of the application of various types of control techniques;
5. Process changes;
6. Non-water quality environmental impact (including energy requirements).

In contrast to BPCTCA, BATEA assesses the availability of in-process controls as well as additional treatment techniques employed at the end of a production process.

The BATEA is the highest degree of control technology that has been achieved or has been demonstrated to be capable of being designed for plant scale operation up to and including no discharge of process wastewater pollutants. This level of control is intended to be the top-of-the-line of current technology subject to limitations imposed by economic and engineering feasibility. The BATEA may be characterized by some technical risks with respect to performance and certainty of costs. Some further industrially-sponsored development work prior to its application may be necessitated.

## IDENTIFICATION OF BEST AVAILABLE TECHNOLOGY ECONOMICALLY ACHIEVABLE

### Native Fish -- Flow-thru Culturing Systems*

The BATEA is sedimentation of the entire flow with sludge removal as described in Section VII. Effluent guidelines achievable through implementation of BATEA and disinfection as needed are as follows:

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* All fish culturing operations which discharge wastewater more than 30 days per year. Facilities which discharge less than 30 days per year are classified in the pond culturing subcategory.

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| Effluent Characteristic | Effluent Limitation* |
| --- | --- |
| Suspended Solids | Maximum for any one day = 1.7 kg/100 kg of fish on hand/day<br><br>Maximum average of daily values for any period of thirty consecutive days = 1.3 kg/100 of fish on hand/day |
| Settleable Solids | Maximum instantaneous = 0.2 ml/l<br><br>Maximum average of daily values for any period of thirty consecutive days = <0.1 ml/l |
| $NH_3$-N | Maximum for any one day = 0.12 kg/1 100 kg of fish on hand/day<br><br>Maximum average of daily values for any period of thirty consecutive days = 0.09 kg/100 kg of fish on hand/day |
| Fecal Coliform Bacteria | Maximum concentration = 200 organisms/100 ml (Salmonid operations are excluded from this effluent limitation). |

Native Fish -- Pond Culturing Systems

Pond culturing systems which overflow more than 30 days per year are considered flow-thru culturing systems and are subject to effluent limitations for the flow-thru culturing subcategory. However, pond draining discharges are subject to effluent limitations for the pond culturing subcategory.

* Effluent limitations are net values.

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The effluent limitations for BATEA are the same as those established for BPCTCA as developed in Section IX.

Non-Native Fish Culturing Systems

The effluent limitations for BATEA are the same as those established for BPCTCA as developed in Section IX.

## RATIONALE FOR SELECTION OF TECHNOLOGY

Native Fish -- Flow-thru Culturing Systems

The BATEA is sedimentation of the entire flow with sludge removal. Sedimentation ponds have been operated on plant scale by exemplary hatcheries and it is the best documented and proven method of treatment in use. Study results and discussions of this treatment method are presented in Section VII. In establishing the effluent limitations set forth in this section, a factor of 1.3 was used in determining maximum one-day values. A larger peaking factor was not selected because the treatment methods are considered stable processes not subject to wide variations in treatment efficiency.

The selection of BATEA is sedimentation of the entire flow, means that construction could be phased and the investment made for BPCTCA would not be lost. Facilities could be installed to provide sedimentation of the cleaning flow (BPCTCA) and then later enlarged to provide sedimentation of the entire flow (BATEA).

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The major non-water quality environmental impact will be solids disposal. The preferred method of sludge disposal, as with other agricultural waste solids, is direct land application. This practice should not cause an adverse environmental impact as long as disposal sites are located on flat terrain not adjacent to water bodies.

Native Fish -- Pond Culturing Systems

Pond culturing systems which overflow more than 30 days per year are considered flow-thru culturing systems. Therefore, rationale presented for pond culturing systems applies only to pond draining discharges.

The rationale is the same as developed for BPCTCA in Section IX.

Non-Native Fish Culturing Systems

The rationale is the same as developed for BPCTCA in Section IX.

# SECTION XI.

# NEW SOURCE PERFORMANCE STANDARDS

## INTRODUCTION

This level of technology is to be achieved by new sources. The term "new source" is defined in the Act to mean "any source, the construction of which is commenced after publication of proposed regulations prescribing a standard of performance". New source performance standards are evaluated by adding to the consideration underlying the identification of BPCTCA, a determination of what higher levels of pollution control are available through the use of improved production processes and/or treatment techniques. Thus, in addition to considering the best in-plant and end-of-process control technology, new source performance standards are based upon an analysis of how the level of effluent may be reduced by changing the production process itself. Alternative processes, operating methods or other alternatives are considered. However, the end result of the analysis identifies effluent standards which reflect levels of control achievable through the use of improved production processes (as well as control technology), rather than prescribing a particular type of process or technology which must be employed. A further determination made for new source performance standards is whether a standard permitting no discharge of pollutants is practicable.

The following factors were considered with respect to production processes analyzed in assessing new source performance standards:

1. The type of process employed and process changes;
2. Operating methods;
3. Batch as opposed to continuous operations;
4. Use of alternative raw materials and mixes of raw materials; and
5. Recovery of pollutants as by-products.

## IDENTIFICATION OF NEW SOURCE PERFORMANCE STANDARDS

### Native Fish -- Flow-thru Culturing Systems

The effluent limitations for new sources are the same as for BATEA as developed in Section X.

### Native Fish -- Pond Culturing Systems

The effluent limitations for new sources are the same as for BPCTCA as developed in Section IX.

### Non-Native Fish Culturing Systems

The effluent limitations for new sources are the same as for BPCTCA as developed in Section IX.

## SECTION XIII.

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## SECTION XIV.

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# SECTION XV.

## GLOSSARY

DEFINITIONS

BOD-Biochemical Oxygen Demand -- The amount of oxygen required by microorganisms while stabilizing decomposable organic matter under aerobic conditions. The level of BOD is usually measured as the demand for oxygen over a standard five-day period. Generally expressed as mg/l.

Broodfish -- Fish reared and/or maintained for the purpose of taking and fertilizing eggs.

Cleaning Intervals -- The length of time between the cleaning of culturing units. Typically the cleaning interval varies at different hatcheries from daily to weekly to monthly.

COD-Chemical Oxygen Demand -- A measure of the amount of organic matter which can be oxidized to carbon dioxide and water by a strong oxidizing agent under acidic conditions. Generally expressed as mg/l.

Conversion Ratio -- The ratio of total number of pounds of food fed to the total gain in weight of the fish during the period. It is sometimes referred to as "conversion factor."

Fry -- Fish up to the time when the yolk sac has been absorbed.

Milt -- The combination of sex cells (spermatozoa) and fluid medium from male fish.

Plate Separators -- High rate sedimentation units consisting of closely spaced parallel plates resulting in a very short vertical settling distance.

Raceway -- A greatly enlarged trough with a stream of water flowing into one end and out the other.

Rearing Unit -- A container used to culture fish.

Settleable Solids -- A volumetric determination of the solids which settle during a given period of time under quiescent conditions in an Imhoff cone.

Suspended Solids -- The suspended material that can be removed from the wastewater by laboratory filtration but does not include coarse or floating matter that can be screened or settled out readily.

Tube Settlers -- High rate sedimentation units consisting of inclined tubes each of which acts as a small settling basin resulting in a very short vertical settling distance.

SYMBOLS

| | |
|---|---|
| cc/liter | -- volumetric ratio cubic centimeters per liter = $1.337 \times 10^{-4}$ cubic feet per gallon |
| °C | -- temperature in degrees Centigrade = 5/9 (°F-32) |
| cm | -- length in centimeters = 0.3937 in. or 0.03281 ft |
| cu ft | -- cubic feet = 0.02832 cubic meters |
| DO | -- dissolved oxygen |
| gal. | -- volume in gallons = 3.785 liters |
| gm | -- weight in grams = 0.03527 ounces |
| g per $m^2$ | -- grams per square meter = $2.05 \times 10^{-4}$ pounds per square foot |
| gpd | -- flow rate in gallons per day = 0.003785 $m^3$/day |
| gpm | -- flow rate in gallons per minute = 0.0631 liters per second |
| hectares | -- area = 2.471 acres |
| kg | -- weight in kilograms = 2.205 pounds |
| kg/m | -- kilograms per meter = 0.672 pounds per foot |
| l | -- volume in liters = 0.2642 gallons |
| lps/$m^2$ | -- overflow rate in liters per second per square meter = 1.48 gallons per minute per square foot |
| m | -- length in meters = 3.281 feet or 1.094 yards |
| $m^3$ | -- volume in cubic meters = 1.307 cubic yards or 264.2 gallons |

| | |
|---|---|
| $m^3$/day | -- flow rate in cubic meters/day = 22.81 million gallons per second |
| mm | -- length in millimeters |
| mgd | -- flow rate in million gallons per day = 3.785 cubic meters per day |
| mg/l | -- concentration given in milligrams per liter |
| ml | -- volume given in milliliters = 0.0002642 gallons or one cubic centimeter |
| ml/l | -- concentration given in milliliters per liter |
| m. ton | -- weight in metric tons = 1.102 tons or 2204.6 pounds |
| MPN | -- most probable number |
| N | -- nitrogen |
| $NH_3$-N | -- ammonia as nitrogen |
| $NO_3$-N | -- nitrate as nitrogen |
| Org N | -- organic nitrogen |
| pH | -- the logarithm (base 10) of the reciprocal of hydrogen ion concentration |
| ppm | -- concentration given in parts per million parts |
| $PO_4$-P | -- phosphate as phosphorus |
| TKN | -- total Kjeldahl nitrogen |
| $y^3$ | -- volume in cubic yards = 0.7646 cubic meters or 27 cubic feet |

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