CHAPTER 6
WATER USE, WASTEWATER CHARACTERIZATION, AND POLLUTANTS OF CONCERN

6.1 WATER USE BY SYSTEM TYPE

The quantity of water required for aquatic animal production (AAP) depends on the type of production system and the facility's management practices. For AAP facilities, water is required to replace evaporative and seepage losses, to replenish oxygen, and to flush wastes from the system. Most AAP facilities are constructed to allow the operators at least some control over the water supply to the production units. There are a wide array of production systems, many unique in their layout and design. The unique characteristics of an individual system often take advantage of site-specific water supply characteristics. The following subsections describe typical water use by production system type.

6.1.1 Pond Systems

The type of water supply for a pond system is primarily a function of the type of pond. Levee ponds are built with berms above grade to exclude surface water and allow the operator almost complete control of the water that enters the pond. Rainwater falling directly onto the surface of the pond and interior slopes of the berms is the only uncontrolled input of water to levee ponds; all other water is pumped or piped into the ponds.

Watershed ponds are constructed to capture water from a contributing watershed during storm events. Ideally, watershed ponds are constructed so that the contributing watershed provides good-quality water (free of sediment and other pollutants) and sufficient quantities of water to maintain adequate volumes throughout the year. The pond operator does not usually have much control over the runoff into the pond. Water is sometimes pumped or piped into watershed ponds to maintain pond volumes.

Depression ponds are constructed below grade, and most take advantage of groundwater seepage to maintain water levels in the pond. Depression ponds capture direct rainfall and some runoff, depending on the topography of the surrounding landscape. Water is sometimes pumped or piped into depression ponds to maintain pond volumes.

For many ponds the water supply is one or more wells located on-site at a facility. Some facilities rely on pumped or free-flowing water from surface water bodies such as lakes, streams, or coastal waters. Those relying on surface waters, however, must be careful not to introduce undesirable species or organisms into the culture ponds. To prevent this, water might need to be screened or filtered as it is pumped into the pond. Rainwater falling directly on the pond is also captured and can be a source for maintaining water levels, but most commercial aquaculture ponds cannot be filled with rainfall alone because rainfall events are sporadic.

Pond systems initially require a large supply of water to fill the ponds and then smaller amounts of water to regulate the water levels and compensate for seepage and evaporation. For example, a 10-ac pond with an average depth of 4 ft holds about 13 million gal of water. Adding 3 in. of water to compensate for evaporation requires about 815,000 gal of water in a 10-ac pond. Generally, ponds are drained infrequently; therefore, after initially filling the ponds, operators typically do not use large volumes of additional water. For those systems that rely on well water, water conservation and rainwater capture are important management tools to minimize pumping costs.

Pond system sizes vary depending on the species and lifestage (fingerlings versus food-size) raised and among facilities producing the same species. Typical pond sizes for catfish production vary from 7 to 15 ac of surface area and from 3 to 5 ft in depth (Hargreaves et al., 2002). Striped bass are cultured in ponds with an average size of 2 to 4 ac as fingerlings and then moved to growout ponds with 5 to 10 ac of surface area and a maximum depth of 6 ft (Hodson and Jarvis, 1990). Crawfish production ponds typically range in size from 10 to 20 ac (LSU, 1999).

Water use in pond systems varies based on the size and draining frequency of the pond. For example, a 10-ac catfish pond with a depth of 4 ft would contain about 13 million gal of water, but the water would be used for an average of 6 yr before being discharged (Boyd et al., 2000). Striped bass, shrimp, and crawfish production ponds are drained annually. Crawfish ponds usually are managed to contain about 8 to 10 in. of water, but water is exchanged throughout the harvest season (LSU, 1999). Water exchange can increase the water use in crawfish ponds to 651,800 gal/ac/yr (Lutz, 2001).

6.1.2 Flow-through Systems

Flow-through systems rely on a steady water supply to provide a continuous flow of water for production. The water is used to provide dissolved oxygen and to flush wastes from the system, which produces a high volume of continuous discharge. Most flow-through systems use well, spring, or stream water as a source of production water. These sources are chosen to provide a constant flow with relatively little variation in rate, temperature, or quality.

Sources of culture water for AAP facilities include groundwater, springs, surface water, rainwater, municipal water, and seawater (Lawson, 1995). Many of these water sources require either the filtration or purification of before use (Wheaton, 1977a). Common problems with source water include insufficient dissolved oxygen, heavy solids loads, and biological contaminates such as predator fish and insects.

Source water treatment systems are designed specifically to treat specific contaminates or problems with the source water before it is added to the culture system. Source water problems are usually specific to the water source. Groundwater lacks oxygen, but is usually free of other pollutants and therefore must only be aerated before use. Surface waters may contain one or more of a variety of contaminates including solids loads, wild fish, parasites, waterborne predators, and disease organisms. Surface waters are often filtered with fine mesh screens to remove these contaminates before use (Wheaton, 1977a).

Flow-through systems require high volumes of water. Water requirements for single-pass raceways can be as high as 30,000 to 42,000 gal/lb production; however, this requirement can be reduced to 6,600 gal/lb production using serial raceways (Hargreaves et al., 2002). Facilities with flow-through systems are found throughout the United States, wherever consistent quantity and quality of water are available. Flow-through systems are the primary method used to grow salmonid species such as rainbow trout. These species require high-quality cold water with high levels of dissolved oxygen. Flow-though systems are therefore located where water is abundant, allowing farmers to efficiently produce these types of fish.

6.1.3 Recirculating Systems

Recirculating systems do not require large volumes of water because the culture water is continuously filtered and reused before it is discharged. System water volumes include the volume of the production units, filters, and reservoirs. The production water treatment process is designed to minimize water requirements, which leads to small-volume, concentrated waste streams as well as makeup water overflow. Waste streams from recirculating systems are typically a small but continuous flowing effluent. (Refer to Chapter 4, section 4.2.3 for more information about internal treatment processes used in recirculating systems.) Facility operators typically rely on a supply of pumped groundwater from on-site wells or municipal water supplies. Most systems add makeup water (about 5% to 10% of the system volume each day) to dilute the production water and to account for evaporation, solids removal, and other losses. A recirculating production system operating at 10% added makeup water per day, would complete one water exchange every 10 d; a flow-through production system, on the other hand, might complete more than 100 volume exchanges per day (Orellana, 1992).

6.1.4 Net Pen Systems

Net pen systems rely on the water quality of the site at which the net pens are located. Open systems like net pen facilities can implement fewer practices than closed or semi-closed systems to control water quality parameters such as temperature, pH, and dissolved oxygen. Net pens and cages rely on tides and currents to provide a continual supply of high-quality water to the cultured animals and to flush wastes out of the system. The systems may be located along a shore or pier or may be anchored and floating offshore or in an embayment. Strict siting requirements typically restrict the number of units at a given site to ensure sufficient flushing to distribute wastes and prevent degradation of the bottom near the net pens.

6.1.5 Other Production Systems: Alligators

Alligator production systems use water primarily to provide resting pools and to clean the holding areas where alligators are kept. The amount of water used varies greatly between facilities depending on the cleaning frequency, pool depth, and water recirculating practices practiced at the facility. Water use estimates for the alligator industry varied between 0.5 gal and 2 gal per alligator per day (Pardue et al., 1994; Shirley, 2002, personal communication).

6.2 WASTEWATER CHARACTERISTICS

CAAP facilities produce a variety of pollutants that may be harmful to the aquatic environment when discharged in significant quantities. The most significant of these pollutants are nutrients (nitrogen and phosphorus), total suspended solids (TSS), and biochemical oxygen demand (BOD). Each of these pollutants causes a variety of impacts on water quality or ecology in different bodies of water. Each type of production system produces different quantities and qualities of effluents, which are determined by the following:

- Amount and type of feed used for production
- Volume and frequency of discharge
- In-system treatment processes (including natural processes)
- Other inputs to the process water (such as drugs or chemicals).

The following subsections describe some of the production system wastewater characteristics.

6.2.1 Pond Systems

Characteristics of effluent from pond systems are influenced by the culture practices used to raise different species and the type of pond used. The composition of pond effluents during water exchange, overflow after heavy rains, and initial stages of pond draining is similar to that of pond water (Boyd and Tucker, 1998). Pond systems are unique because they are capable of assimilating wastes within the pond. Over time, natural processes within the pond lower the concentrations of nitrogen, phosphorus, and organic material. If water is retained in catfish ponds over a long enough period of time, biological, chemical, and physical processes remove some of the waste generated by fish. Some of the organic matter from phytoplankton production and fish waste is oxidized in the natural process of microbial decomposition (JSA, 2000). Total nitrogen levels in catfish pond waters are lowered as nitrogen is lost from the water column as organic matter when nitrogen particulates decompose on the bottom of the pond. Nitrogen is also lost from the water as a gas through denitrification and volatilization. Finally, total phosphorus concentrations in the water are lowered as phosphorus is lost to the pond bottom soils as particulate organic phosphorus and precipitates of calcium phosphates.

6.2.1.1 Catfish

In catfish aquaculture ponds, the most important constituents of potential effluents are nitrogen, phosphorus, organic matter, and settleable solids (JSA, 2000). These materials are a direct or indirect product of feeds added to the ponds to promote rapid fish growth. Inorganic nutrients in fish waste stimulate the growth of phytoplankton, which, in turn, stimulate the production of more organic matter through photosynthesis. For both watershed and levee ponds, nitrogen and phosphorus compounds and organic matter are present in the pond water throughout the growout period, and they represent potential pollutants if discharged.

Table 6.2-1 shows effluent loadings for TSS, 5-day biochemical oxygen demand (BOD_5), total nitrogen (TN), and total phosphorus (TP) from channel catfish ponds in Alabama. These data illustrate the influence of draining frequency on annualized effluent loadings. For example, TSS loads from levee foodfish production ponds, which are drained an average of once per 6.5 yr, are about an order of magnitude lower than TSS loads from levee fry and fingerling ponds, which are drained once per year. Annual effluent loads in watershed ponds are about four times lower in the less frequently drained foodfish ponds than in fry and fingerling ponds.

Table 6.2-1. Mass Discharge of TSS, BOD_5, TN, and TP from Channel Catfish Farms in Alabama

Pond Type	*Source of Effluent*	*TSS (lb/ac/yr)*	*BOD_5 (lb/ac/yr)*	*TN (lb/ac/yr)*	*TP (lb/ac/yr)*
Fry and Fingerling Ponds Annual Draining					
Levee ponds	Overflow	58	7.9	4.5	0.48
	Partial drawdown	823	112.3	75.3	2.98
	Final drawdown	3,062	94.8	1.8	4.73
	Total	3,943	214.7	108.3	8.19
Watershed ponds	Overflow	232	31.5	9.82	1.94
	Partial drawdown	822	112.2	75.2	2.98
	Final drawdown	3,062	94.8	28.5	4.74
	Total	4,116	238.5	113.5	9.66
Foodfish Production Ponds Average 6 yr Between Drainings					
Levee ponds	Overflow	58	7.8	4.5	0.48
	Partial drawdown	123	16.9	6.1	0.45
	Final drawdown	204	6.3	19.0	0.31
	Total	385	31	29.6	1.24
Watershed ponds	Overflow	738	50.9	15.8	3.15
	Partial drawdown	123	16.9	6.1	0.45
	Final drawdown	204	6.3	19.0	0.31
	Total	1,065	74.1	40.9	3.91

Source: Boyd et al., 2000.

6.2.1.2 Hybrid Striped Bass

Effluents from hybrid striped bass ponds are similar to catfish pond effluents; however, hybrid striped bass facilities typcially drain their ponds more frequently because they must be drained and completely harvested before restocking. To avoid draining the ponds, some farmers treat the ponds with a piscicide (a pesticide, such as Rotenone, used to kill fish) to eliminate remaining fish before restocking. Ponds are usually drained annually or biennially, depending on stocking size and production management.

In a study in South Carolina (Tucker, 1998), water samples were collected and analyzed from 20 commercial hybrid striped bass ponds (Table 6.2-2). To provide a broad representation of the industry, researchers included large and small operations, as well as ponds from both the coastal plain and piedmont areas of the state. Most of the commercial ponds sampled were freshwater ponds, but some saltwater ponds were also represented in the study. Water samples were collected from the surface and the bottom of each pond. Overall, the quality of effluents from hybrid striped bass ponds varied greatly from pond to pond. Concentrations of suspended solids, TN (including total ammonia), and BOD were the parameters that were most elevated relative to the source water and could potentially have the greatest impact on receiving bodies of water.

Table 6.2-2. Means and Ranges for Selected Water Quality Variables from Hybrid Striped Bass Ponds in South Carolina

Variable	*Mean*	*Range*
Suspended solids (mg/L)	49	0–370
Volatile suspended solids (mg/L)	29	0–135
Biochemical oxygen demand (mg/L)	11.5	1.4–64.4
Kjeldahl nitrogen (mg/L)	7.1	0–97.0
Total ammonia (mg N/L)	0.95	0.02–7.29
Nitrite (mg N/L)	0.07	0–2.94
Nitrate (mg N/L)	0.36	0–4.61
Total phosphorus (mg P/L)	0.31	0–1.9
Soluble reactive phosphorus (mg P/L)	0.02	0–0.18

Source: Tucker, 1998.

6.2.1.3 Penaeid Shrimp

There is some evidence to suggest that effluent characteristics for marine shrimp ponds are similar to effluent characteristics for catfish farms (Table 6.2-3), but that the final portion of effluent from marine shrimp ponds is higher in pollutant concentrations by 20% to 30% (Boyd and Tucker, 1998). For example, total annual TSS for shrimp ponds is about 5,000 lb/ac and for catfish fingerling ponds about 4,000 lb/ac. When shrimp ponds are drained for harvest, the effluent is almost identical in composition to pond water until about 80% of the pond volume has been released (Boyd, 2000). During the draining of the final 20% of the pond volume, concentrations of BOD_5, TSS, and other substances increase because of sediment resuspension caused by harvest activities, crowding of agitated shrimp, and shallow and rapidly flowing water. The average BOD_5 and TSS concentrations often are about 50 mg/L and 1,000 mg/L, respectively (Boyd, 2000).

Although catfish ponds and shrimp ponds might have similar effluent characteristics, shrimp ponds are drained more frequently than food-size catfish ponds to facilitate harvest; therefore, the volume of water discharged from a shrimp farm is typically higher than the volume of water discharged from a catfish farm. Shrimp farms in the United States have responded to state regulatory concerns regarding the discharge of solids during draining and harvesting. In Texas, shrimp farms use drainage canals and large sedimentation basins to hold water on the farm and reuse the water in other ponds to minimize TSS in effluents. Most Texas facilities try to discharge during the winter, after harvests are complete and solids have had maximum time to settle (Tetra Tech, 2002).

Table 6.2-3. Average Concentrations and Loads of BOD_5 and TSS in a Typical Shrimp Farming Pond with a Water Exchange of 2% per day

Type of Effluent	*Concentration (mg/L)*		*Load (lb/ac)*	
	BOD_5	*TSS*	*BOD_5*	*TSS*
Water exchange	5	100	107	2,142
Draining (first 80%)	10	150	71	1,071
Final draining	50	1,000	89	1,785
Total	–	–	267	4,998

Source: Boyd, 2000.

South Carolina shrimp farmers also try to reuse water, when possible. Some South Carolina shrimp farms are holding water in harvested ponds and growing clams and other shellfish. The “treated” water is then slowly discharged after the shellfish are harvested (Whetstone, 2002 personal communication).

6.2.1.4 Other Species

Tilapia ponds are drained to harvest fish, to adjust fish inventories, or to repair ponds. At the start of pond draining for harvest, pond water effluent characteristics can be expected to be similar to production water characteristics. However, fish harvest by seining stirs up sediments at the bottom of the pond. In fertilized tilapia ponds, sediments are likely to contain significant quantities of nitrogen and phosphorus. As draining and seining continue, effluent water quality can be expected to deteriorate (Tucker, 1998).

Although there is little data on ornamental fish farm effluent characteristics in the literature, the impact from water discharged from ornamental fish production facilities is likely to be minimal. Assuming the average size of a growout pond is 2,152 ft^2 with approximately 80,000 gal of water, ornamental culture facilities typically discharge the volume of one pond, or less, per year (Watson, 2002 personal communication). There is also very little data available on water quality in commercial baitfish ponds or on effluents from these ponds. Baitfish production uses low biomass stocking densities. The combination of low biomass and reduced feed input before draining makes it likely that baitfish effluents will have lower solids concentrations than effluents from catfish ponds (Stone et al., n.d.).

There is limited information about the quality of water discharged from crawfish ponds for either rotational ponds or permanent ponds. Crawfish production relies on the forage-based system for feeding, so unlike other aquaculture production systems that rely on pelleted feed, feed management practices will not significantly affect water quality because the feed input is so low. Also, although dissolved oxygen levels are a concern, particularly as vegetation decays, crawfish farmers routinely check levels and use best management practices (BMPs) and technologies, such as mechanical aeration, to maintain appropriate dissolved oxygen levels. Very little data is available on water quality within commercial ponds for other finfish production or on effluents from these ponds; however, the effluent is likely to be similar to the effluent from hybrid striped bass ponds.

6.2.2 Flow-through Systems

Effluents from flow-through systems can be characterized as continuous, high-volume flows containing low pollutant concentrations. Effluents from flow-through systems are affected by whether a facility is in normal operation or whether the tanks or raceways are being cleaned. Waste levels can be considerably higher during cleaning events (Hinshaw and Fornshell, 2002; Kendra, 1991).

Boardman et al. (1998) conducted a study after surveys conducted in 1995 and 1996 by the Virginia Department of Environmental Quality (VDEQ) revealed that the benthic aquatic life of receiving waters was adversely affected by discharges from several freshwater trout farms. Three trout farms in Virginia were selected to represent fish farms throughout the state. This study was part of a larger project to identify practical treatment options that would improve water quality both within the facilities and in their discharges to receiving streams.

After initial sampling and documentation of facility practices, researchers and representatives from VDEQ discovered that although pollutants from the farms fell under permit regulation limits, adverse effects were still being observed in receiving waters. Each of the farms was monitored from September 1997 through April 1998, and water samples were measured for dissolved oxygen (DO), temperature, pH, settleable solids (SS), TSS, total Kjeldahl nitrogen (TKN), total ammonia nitrogen (TAN), 5-day biochemical oxygen demand (BOD_5), and dissolved organic carbon (DOC).

Sampling and monitoring at all three sites revealed that little change in water quality between influents and effluents occurred during normal conditions at each facility (Table 6.2-4). The average concentrations of each regulated parameter (DO, BOD_5, TSS, SS, and AN) were below their regulatory limit at each facility; however, raceway water quality declined during heavy facility activity like feeding, harvesting, and cleaning. During these activities, fish swimming rapidly or employees walking in the water would stir up solids that had settled to the bottom. During a 5-day intensive study, high TSS values were correlated with feeding events. TKN and ortho-phosphate (OP) concentrations also increased during feeding and harvesting activities. Overall, most samples taken during this study had relatively low solids concentrations, but high flows through these facilities increased the total mass loadings.

Table 6.2-4. Water Quality Data for Three Trout Farms in Virginia

Parameter	FARM A			FARM B			FARM C		
	Inlet	Within Farm	Outlet	Inlet	Within Farm	Outlet	Inlet	Within Farm	Outlet
Flow (mgd)	1.03–1.54[a] (*1.18*)[b]			4.26–9.43 (*6.39*)			9.74–10.99 (*10.54*)		
DO (mg/L)	9.2–14.2 (*10.6*)	3.2–13.3 (*7.0*)	5.7–9.5 (*8.5*)	8.2–11.5 (*10.5*)	5.8–10.8 (8.6)	6.8–9.6 (*7.9*)	9.4–10.6 (*10.5*)	4.8–9.7 (*7.6*)	7.2–9.4 (*8.1*)
Temp (ºC)	10.5–13 (*12.2*)	11.5–15 (*13*)	11–15.5 (*12.9*)	6–12.5 (*9.7*)	6–14 (*9.1*)	5–16.5 (*11.4*)	8.5–13.5 (*10.5*)	8–14 (*11.0*)	8.5–14 (*10.4*)
pH (SU)	7.1–7.4 (*7.3*)	7.0–7.4 (*7.2*)	7.3–7.8 (*7.5*)	7.3–7.6 (*7.5*)	7.2–7.6 (*7.4*)	6.9	7.3	7.1–7.6 (*7.3*)	7.8
TSS (mg/L)	0–1.1 (*0.2*)	0–30.4 (*3.9*)	0.8–6 (*3.2*)	0–1.8 (*0.5*)	0–43.7 (*5.3*)	1.5–7.5 (*3.9*)	0–1.5 (*0.3*)	0–28 (*7.1*)	4.1–62 (*6.1*)[c]
SS (mg/L)	0		0–0.04 (*0.02*)	0		0.01–0.08 (*0.04*)	0		0.04–0.08 (*0.07*)
BOD_5 (mg/L)	0–1.25 (*0.7*)	0.5–3.9 (*1.5*)	0.96–1.9 (*1.3*)	0–1.4 (*0.5*)	0.3–7.2 (*2.1*)	0.6–2.4 (*1.2*)	0–2.0 (*1.1*)	0.4–7.5 (*2.5*)	0.5–1.8 (*1.3*)
DOC (mg/L)	0.93–4.11 (*2.1*)	0.9–7.9 (*2.9*)	1.5–2.4 (*1.9*)	0.91–2.56 (*1.6*)	1.2–8.1 (*2.7*)	1.2–3.1 (*1.9*)	1.1–2.7 (*2.0*)	1.1–11.1 (*2.4*)	1.5–3.8 (*2.3*)
NH_3-N (mg/L)	0.6	0.2–1.1 (*0.5*)	0.5–0.6 (*0.6*)	0.2	0.06–1.1 (*0.5*)	0.45	0.03	0.03–2.2 (*0.4*)	0.02–0.17 (*0.1*)

[a] When available the range of values has been reported
[b] The average is indicated using italics.
[c] Two outliers were discarded for calculation of mean.
Source: Boardman et al., 1998.

Table 6.2-5 describes the water quality data for two flow-through systems sampled as part of EPA's data collection efforts at CAAP facilities.

Table 6.2-5. Flow-through Sampling Data Table

Parameter	Facility A			Facility B		
	Inlet	OLSB Effluent	Bulk Water Discharge	Inlet	OLSB Effluent	Final Effluent
Biochemical oxygen demand (mg/L)	ND (4)[a]	56.0–185.0[b] (*125.70*)[c]	3.50–4.20 (*3.85*)	ND (2)	13	ND (2)
Flow (mgd)	192.4	0.914	91.4	2.481–2.777	0.017	2.481–2.777
pH (SU)	7.98–8.14 (*8.05*)	6.11–6.58 (*6.43*)	7.50–7.83 (*7.72*)	7.73–8.06 (*7.93*)	7.27	7.93–8.19 (*8.03*)
Total phosphorus (mg/L)	0.7–0.25 (*0.14*)	8.32–11.10 (*9.81*)	0.15–0.25 (*0.21*)	0.02–0.03 (*0.03*)	0.36	0.03–0.07 (*0.05*)
Total suspended solids (mg/L)	ND (4)	44.0–78.0 (*63.0*)	ND (4)	ND (4)	38	ND (4)

[a] ND: Non-detect, the minimum level is listed in parenthesis.
[b] When available the range of values has been reported.
[c] The average is indicated using italics.
Source: USEPA sampling data.

6.2.3 Recirculating Systems

Recirculating systems have internal water treatment components that process water continuously to remove waste and maintain adequate water quality. Overall, recirculating systems produce a lower volume of effluent than flow-through systems. The effluent from recirculating systems usually has a relatively high solids concentration in the form of sludge. The sludge is then processed into two streams—a more concentrated sludge and a less concentrated effluent (Chen et al., 2002). Once solids are removed from the system, sludge management is usually the focus of effluent treatment in recirculating systems.

In a study describing the waste treatment system for a large recirculating facility in North Carolina, Chen et al. (2002) characterize effluent at various points in the system (Table 6.2-6). Approximately 40% of the solid waste produced by this particular facility is collected in the sludge collector and composted. The remaining 60% of the solids are treated with two serial primary settlers (septic tanks) and then a polishing pond (receiving pond). Table 6.2-7 describes the water quality data for one recirculating system sampled as part of EPA's data collection efforts at CAAP facilities.

Table 6.2-6. Water Quality Characteristics of Effluent at Various Points in the Waste Treatment System of Recirculating Aquaculture Systems at the North Carolina State University Fish Barn[a]

Parameter	*TKN (mg/L)*	*NH_3-N (mg/L)*	*NO_2N (mg/L)*	*NO_3N (mg/L)*	*TP (mg/L)*	*PO_4-P (mg/L)*	*COD (mg/L)*	*TS (%)*	*TSS (mg/L)*
Primary settling 1 inflow	50.3	2.96	5.35	109.0	28.6	5.98	1043	0.22	752
Primary settling 2 inflow	47.5	2.42	31.17	78.5	22.7	11.50	690	0.18	364
Septic tank 2 outflow	37.7	3.42	44.00	36.4	17.6	12.20	409	0.16	205
Receiving pond effluent	8.94	0.12	1.93	8.2	4.95	3.68	153	0.11	44

[a] Results are from sampling conducted 4 wk after startup of the waste handling system. Flow from the system into the receiving pond for the sampling period was 15.5 m^3/d.
Source: Chen et al., 2002.

6.2.4 Net Pen Systems

Although net pen systems do not generate a waste stream like other production systems, waste from the system can adversely affect water quality. The release of nutrients, reductions in concentrations of dissolved oxygen, and the accumulation of sediments under the pens or cages can affect the local environment through eutrophication and degradation of benthic communities (Stickney, 2002).

Table 6.2-7. Recirculating System Sampling Data

Parameter	Facility C	
	Inlet	Discharge
Biochemical oxygen demand (mg/L)	ND (2)[a]	35.0–48.0[b] (*42.0*)[c]
Flow (mgd)	0.22	0.22
pH (SU)	7.8	6.97–7.25 (*7.15*)
Total phosphorus (mg/L)	ND (0.01)	8.58–10.50 (*9.32*)
Total suspended solids (mg/L)	ND (4)	26.0–60.0 (*42.80*)

[a] ND: Non-detect, the minimum level is listed in parenthesis.
[b] When available the range of values has been reported.
[c] The average is indicated using italics.
Source: EPA sampling data.

6.2.5 Other Production Systems: Alligators

Wastewater from alligator production facilities is generated during the cleaning of production pens and when discharges are released from the building heating system. Wastewater characteristics from alligator farms are analogous to those of strong municipal wastewater (Pardue et al., 1994). Values for alligator farm wastewater constituents are shown in Table 6.2-8.

Table 6.2-8. Alligator Wastewater Characteristics

Parameter	Concentration (mg/L)
BOD_5	452
Total solids	379
Volatile solids	219
Total phosphorus	11
Ammonia (NH_3)	78
Nitrite (NO_3)	5
TKN	153
pH	6.9 (SU)

Source: Pardue et al., 1994.

6.3 WATER CONSERVATION MEASURES

6.3.1 Pond Systems

Pond systems provide many opportunities to conserve water. Water conservation practices can be grouped into structural conservation measures and management conservation measures. Structural conservation measures are those measures that can be installed at the time the production pond is constructed or added at a later date. Structural water conservation measures include seepage reduction, watershed-to-pond area ratios of 10 or less, and vegetated levees. Ongoing management water conservation measures include maintaining storage volume, harvesting without draining, and reducing or eliminating water flushing (Hargreaves et al., 2002).

6.3.2 Flow-through Systems

The opportunities to conserve water in flow-through systems are usually limited and can involve substantial expense. Often, more fish can be grown in a flow-through system with a fixed inflow of water through increased stocking densities in production raceways, with additional oxygenation of the production water. Water use can also be maximized through the use of multi-pass serial raceways or tanks, which use re-oxygenated water passing through multiple raising units prior to discharge. Using water more efficiently allows flow-through system operators to reduce water use from high rates of 30,000 to 42,000 gal/lb to much lower rates of 6,600 gal/lb.

Facilities reusing multi-pass serial raceways must use active or passive aeration systems in order to maintain adequate dissolved oxygen concentrations in the culture water. Facilities with sufficient hydraulic head between raceways often use passive or gravity aeration systems to increase the air-water interface thereby increasing the dissolved oxygen content of the culture water (Wheaton, 1977b).

Facilities with insufficient head to passively aerate must use mechanical aeration systems to increase the dissolved oxygen content of the culture water. Mechanical aeration systems include liquid oxygenation systems and diffuser aerators. Liquid oxygen systems operate by adding liquid oxygen below the surface of the culture water. Diffuser aerators inject air or pure oxygen below the culture waters surface in the form of bubbles. As the bubbles pass through the water column oxygen is transferred across the air-water interface (Wheaton, 1977b).

6.3.3 Recirculating Systems

Recirculating systems are designed to conserve water by raising fish in small volumes of water, treating the water to remove waste products, and then reusing it (Rakocy et al., 1992). Normal stocking densities in recirculating systems vary from 0.5 to over 1 lb per gallon of culture water (Losordo and Timmons, 1994). Opportunities to conserve water in recirculating systems include operating all filter systems as efficiently as possible, increasing stocking densities, and reducing daily makeup water to below 10%. These practices would not amount to significant reductions in water use and might not be achievable in most recirculating systems.

6.3.4 Other Production Systems: Alligators

Water conservation measures at alligator production systems have focused on reusing or recirculating cleaning water. Each alligator holding pen contains a shallow pool that accumulates waste products and must be cleaned regularly to remove the wastes and ensure good skin quality for the alligators. The pen-cleaning process takes place daily or every other day and causes the loss of a large amount of heated water (Delos Reyes, Jr. et al., 1996). Properly operating recirculating systems can reduce daily loss of heated water to as little as 5% (Delos Reyes, Jr. et al., 1996), but these systems are not commonly used in alligator production (Pardue et al., 1994; Shirley, 2002, personal communication).

6.4 POLLUTANTS OF CONCERN

6.4.1 Characterization of Pollutants of Concern

Four sources of data were reviewed to provide an initial assessment of the pollutants of concern (1) data from a sampling event at a flow-through facility; (2) data from a sampling event at a recirculating facility; (3) discharge monitoring report (DMR) data submitted to EPA from the EPA regions; and (4) Permit Compliance System (PCS) data from an EPA database.

EPA used several criteria to identify the list of pollutants of concern. For the sampling data, the identification criteria were as follows: (1) raw wastewaters with analytes that had three or more reported values with an average concentration greater than 5 times the minimum limit (ML); (2) raw wastewaters with analytes that had three or more reported values with an average concentration greater than 10 times the ML; and (3) treated effluents with analytes that had at least one reported value with an average concentration greater than 5 times the ML. The results for determining pollutants of concern are presented in Appendix C.

The first two criteria were applied to the same data (e.g., a raw wastewater from a sampling event) and were used as a measure to determine how a more stringent criterion (> 5 ML) contrasted with a less stringent criterion (> 10 ML) in determining an analyte as a pollutant of concern. In almost all cases, both criteria (> 5 ML and > 10 ML) produced the same results.

For the PCS and DMR data sets, the original data were first associated with a system type as defined by NPDES permit information. Parameters with measurements in the DMR and PCS data without a value or with a value of zero were excluded from the data sets and assumed to be nondetectable. All other data were summarized by system type and analyte, with an analysis for the average sampling value, the maximum sampling value, the minimum sampling value, and the number of samples taken.

The PCS and DMR data, composed mainly of state and federal facilities and large commercial facilities that have NPDES permits, represent the best available information. One limitation of the data is the lack of information on pond systems. Generally, the pollutants identified in the DMR or PCS database are included in the list of pollutants of concern (POCs) provided below.

The POCs that are currently indicated for the CAAP industry, based on the available data, include the following: conventional and nonconventional pollutants (ammonia, biochemical oxygen demand, chemical oxygen demand, chlorine, nitrate, nitrite, oil and grease, ortho-phosphate, pH, settleable solids, total Kjeldahl nitrogen, total phosphorus, and total suspended solids), metals (aluminum, barium, boron, copper, iron, manganese, selenium, and zinc), microbiologicals (*Aeromonas*, fecal *streptococcus*, and total coliforms), organic chemicals, and hexanoic acid.

6.4.2 Methodology for Proposed Selection of Regulated Pollutants

EPA selects the pollutants for regulation based on the POCs identified for each subcategory. Generally, a pollutant or pollutant parameter is considered a POC if it was detected in the untreated process wastewater at five times the minimum level in more than 10% of samples. The ML is a metric of the sensitivity of the analytic testing procedure to measure for a pollutant or pollutant parameter.

Monitoring for all POCs is not necessary to ensure that AAP wastewater pollution is adequately controlled because many of the pollutants originate from similar sources (the feed), are associated with the solids, and are treated with the same pollutant removal technologies and similar mechanisms. Therefore, monitoring for one pollutant as a surrogate or indicator of several others might be sufficient.

Regulated pollutants are pollutants for which EPA may establish numerical effluent limitations and standards. EPA evaluates a POC for regulation in a subcategory using the following criteria:

- Not considered a volatile compound.
- Effectively treated by the selected treatment technology option.
- Detected in the untreated wastewater at treatable levels in a significant number of samples, e.g., generally five times the minimum level in more than 10% of the raw wastewater samples.

6.5 Pollutants and Pollutant Loadings

CAAP facility effluents can have high concentrations of nutrients and suspended solids, high BOD and low levels of DO. When discharged into receiving waters, effluents with high levels of suspended solids can cause turbidity, which can reduce light available for photosynthesis. Low dissolved oxygen levels can affect estuarine organisms in the receiving waters, and excessive nutrients can accelerate plankton growth, resulting in die-offs and increased BOD in receiving waters.

6.5.1 Sediments and Solids

Solids are the largest pollutant loading generated in CAAP facilities. Most pond systems, however, are managed to capture and hold solids in the pond, where the solids naturally degrade. In addition, management of flow-through and recirculating systems captures most of the generated solids, which must then be properly disposed of. Although most solids are land-applied, solids that leave the facility in the effluent stream can have a detrimental effect on the environment. Many CAAP facilities with NPDES permits must control and monitor their discharge levels of solids. In Idaho, NPDES permits specify average monthly and maximum daily TSS limits that vary according to production and system treatment technology (USEPA, 2002b).

Although some solids from CAAP facilities are land-applied, other solids leave the facility in the effluent stream and can have a detrimental effect on the environment. Suspended solids can degrade aquatic ecosystems by increasing turbidity and reducing the depth to which sunlight can penetrate, which decreases photosynthetic activity and oxygen production by plants and phytoplankton. If sunlight is completely blocked from bottom-dwelling plants, the plants stop producing oxygen and die. As the plants are decomposed, bacteria use up more of the oxygen and decrease dissolved oxygen levels further. Subsequently, low dissolved oxygen can cause fish kills. Decreased growth of aquatic plants also affects a variety of aquatic life, which use the plants as habitat. Increased suspended solids can also increase the temperature of surface water because the particles absorb heat from the sunlight. Higher temperatures result in lower levels of dissolved oxygen because warm water holds less dissolved oxygen than cold water (Murphy, 2000c).

Suspended particles can abrade and damage fish gills, increasing the risk of infection and disease. They can also cause a shift toward more sediment-tolerant species, reduce filtering efficiency for zooplankton in lakes and estuaries, carry nutrients and metals, adversely affect aquatic insects that are at the base of the food chain (Schueler and Holland, 2000), and reduce fish growth rates (Murphy, 2000c). Suspended particles reduce visibility for sight feeders and disrupt migration by interfering with a fish's ability to navigate using chemical signals (USEPA, 2000). Finally, suspended particles cause a loss of sensitive or threatened fish species when turbidity exceeds 25 nephelometric turbidity units (NTU) and a decline in sunfish, bass, chub, and catfish when monthly turbidity exceeds 100 NTU (Schueler and Holland, 2000).

As sediment settles, it can smother fish eggs and bottom-dwelling organisms, interrupt the reproduction of aquatic species, destroy habitat for benthic organisms (USEPA, 2000) and fish spawning areas, and contribute to the decline of freshwater mussels and sensitive or threatened darters and dace. Deposited sediments also increase sediment oxygen demand, which can deplete dissolved oxygen in lakes or streams (Schueler and Holland, 2000).

Increased levels of suspended solids and nutrients have very different effects on aquatic plants. High levels of suspended solids can kill off desirable species, while elevated nutrient levels can cause too many plants to grow. In either situation, an ecosystem can be drastically altered by increases in these pollutants. As a result, it is important to maintain a balance in the levels of suspended solids and nutrients reaching waterbodies to reduce such drastic impacts on aquatic plants.

6.5.2 Nutrients

Nitrogen from CAAP facilities is discharged mainly in the form of nitrate, ammonia, and organic nitrogen. Most nitrogen from these facilities, however, is in the form of ammonia, which is not usually found at toxic levels in CAAP discharges. Some facilities with ponds and recirculating systems might also have high levels of nitrite. Organic nitrogen decomposes in aquatic environments into ammonia and nitrate. This decomposition consumes oxygen, reducing dissolved oxygen levels and adversely affecting aquatic life. Phosphorus is discharged from CAAP facilities in both the solid and dissolved forms. The dissolved form, however, poses the most immediate risk because it is available to plants. Although the solid form of phosphorus is generally unavailable, depending on the environmental conditions, some phosphorus may be slowly released from the solid form.

6.5.2.1 Nitrogen

Nitrates cause problems in aquatic environments because they are directly available for plant or algae uptake (Murphy, 2000a). They are soluble in water and do not bind to particles, making them highly mobile (Kaufman and Franz, 1993). Elevated levels of nitrate cause increased plant and algae growth. When the algae sink to the bottom and die, they are decomposed by bacteria, which consume oxygen. As a result, increased nitrate indirectly decreases dissolved oxygen, and low dissolved oxygen can adversely affect fish and other aquatic life. This process is referred to as eutrophication. In addition, high concentrations of nitrate and/or nitrite can produce “brown blood disease” in fish. In this disease, the blood is unable to carry enough oxygen, despite adequate oxygen in the surrounding water (Murphy, 2000a). As a result, fish may die of suffocation.

Ammonia causes two main problems in the aquatic environment. First, it can be toxic to aquatic life, affecting hatching and growth rates of fish. For example, when un-ionized levels of ammonia exceed 0.0125 to 0.025 mg/L, growth rates of rainbow trout are reduced and damage to liver, kidney, and gill tissue may occur (Murphy, 2000a). Second, ammonia is easily converted to nitrate in waters where oxygen is available. Once ammonia is converted to nitrate, it is available for plant uptake. As previously mentioned, elevated levels of nitrate may increase plant and algae growth, which can decrease dissolved oxygen levels and affect aquatic life (Murphy, 2000a). The proportion of total ammonia in the un-ionized form can vary with temperature and pH levels (IDEQ, n.d.). Organic nitrogen decomposes in aquatic environments into ammonia and nitrate. This process consumes oxygen, reducing dissolved oxygen levels and adversely affecting aquatic life.

6.5.2.2 Phosphorus

CAAP facilities release phosphorus in both the solid and dissolved forms. Although the solid form is generally unavailable, the dissolved form is readily available and it poses the most immediate risk to the environment. Plants and bacteria require phosphorus in the dissolved form, generally as orthophosphate, for their nutrition (Henry and Heinke, 1996). Phosphates are not toxic unless they are present at very high levels (Murphy, 2000b); however, excessive amounts of orthophosphate in the aquatic environment increase algae and aquatic plant growth. As before, this change results in decreased dissolved oxygen levels as bacteria decompose dead algae, consuming oxygen in the process. When dissolved oxygen concentrations fall below the levels required for metabolic requirements of aquatic biota, both lethal (e.g., fish kills) and sublethal effects can occur. Oxygen loss in bottom waters can also free phosphorus previously trapped in the sediment, increasing the amount of available phosphorus and continuing the process of decreasing dissolved oxygen (Murphy, 2000b).

Nitrogen and phosphorus are the primary causes of cultural eutrophication. The most recognizable evidence of eutrophication is algal blooms that occur during the summer. Symptoms of nutrient overenrichment include murky water, low dissolved oxygen, fish kills, and depletion of desirable flora and fauna. In addition, the increase in algae and turbidity in drinking water supplies heightens the need to chlorinate drinking water. Chlorination, in turn, leads to higher levels of disinfection by-products that have been shown to increase the risk of cancer. Excessive amounts of nutrients can also stimulate the activity of microbes, such as *Pfiesteria piscicida* that may be harmful to human health (Grubbs, 2001).

6.5.3 Organic Compounds and Biochemical Oxygen Demand

Organic matter is discharged from CAAP facilities primarily from feces and uneaten feed. Elevated levels of organic compounds contribute to eutrophication and oxygen depletion. This occurs because oxygen is consumed when microorganisms decompose organic matter. BOD is used to measure the amount of oxygen consumed by microorganisms when they decompose the organic matter in a waterbody. The greater the BOD, the greater the degree of pollution and the less oxygen available. When a sufficient level of oxygen is not available, aquatic species become stressed and might not eat well. Their susceptibility to diseases can increase dramatically, and some species might even die. Even small reductions in dissolved oxygen can lead to reduced growth rates for sensitive species.

6.5.4 Metals

Metals may be present in CAAP wastewaters for various reasons. They might be used as feed additives, occur in sanitation products, or result from deterioration of CAAP machinery and equipment. Many metals are toxic to algae, aquatic invertebrates, or fish. Although metals can serve useful purposes in CAAP operations, most metals retain their toxicity once they are discharged into receiving waters. EPA observed that many of the treatment systems used in the CAAP industry provide substantial reductions of most metals. Because most of the metals are present in particulate form or bind to solid particles, they can be adequately controlled by controlling solids.

6.6 SPECIAL POLLUTANTS

6.6.1 Pathogens

Pathogens associated with the CAAP industry include those that can impair human health and those that are harmful to aquatic animals if discharged. Total coliform bacteria, fecal coliform bacteria, *Esherichia coli*, fecal streptococci, *Enterococcus faecium*, *Mycobacterium marinum*, and *Aeromonas* were sampled at two of the sampling event facilities to determine the presence of these indicator organisms in CAAP effluents. Sampling points included influent water, process water, treated effluents, and solids storage effluents. Most of the data show nondetectable levels of these organisms, including in influent water. However, some of the indicators, including *aeromonas*, total coliform bacteria, and fecal *streptococcus*, had average measured levels greater than 60,000 bacteria/100 mL in treated effluents and solids storage effluents.

6.6.1.1 Human Health Concerns

When testing for the presence of pathogens, it is important to note that there is a distinction between indicator microorganisms and pathogens. Human pathogens found in aquatic systems can include bacteria (e.g., *Salmonella* sp., *Vibrio* sp.), viruses (e.g., Norwalk viruses, enteroviruses, rotaviruses), and protozoans (e.g., *Cryptosporidium parvum*, *Giardia intestinalis*). EPA has long recognized that it is difficult to assay waters for the presence of human pathogens. Given the difficulty in detecting pathogens in aquatic systems, EPA relies on the detection of indicator microorganisms, which are used to infer the presence of pathogens and to predict public health risks due to ingestion or contact with water.

A range of indicator organisms has been used over time. However, all indicator organisms have a few common traits: (1) they are commonly found in contamination that also contains pathogens, (2) they persist in the aquatic environment as long as pathogens, and (3) they can be easily detected. Total coliforms, fecal coliforms (or more specifically *E. coli*), and enterococci have all been used as indicators of water quality. Even though these bacterial indicators have been used with some success for protecting public health, they are limited in their use in more complex systems. Because of varying rates of degradation and persistence in aquatic environments, these bacterial indicators do not always adequately represent risk due the presence of pathogenic bacteria.

Human pathogens in CAAP effluents can stem from animal feed, other animals, and source waters to the facility. In the majority of cases, levels of human pathogens are likely to be minimal, especially in finfish CAAP facilities. Transfer of animal viral pathogens to humans is highly unlikely because most viruses are species-specific.

CAAP facilities are not considered a significant source of pathogens that adversely affect human health (MacMillan et al., 2002). CAAP facilities culture cold-blooded animals (fish, crustaceans, molluscs, etc.) that are unlikely to harbor or foster pathogens that would adversely affect warm-blooded animals like humans by causing disease. CAAP facilities could become contaminated with such pathogens if, for example, wastes from warm-blooded animals were to contaminate CAAP facility waters or the source waters used by CAAP facilities, but this is not considered a substantial risk in the United States (MacMillan et al., 2002).

6.6.1.2 Aquatic Animal Pathogens

Most fish pathogens are not hazardous to humans; however, some, such as streptococcus bacteria, can infect humans. Transfer of other microorganisms like *Vibrio* sp. and protozoan pathogens could also be expected. High levels of antibiotics and genetically engineered components in fish feed (e.g., soya additives) can also pose risks due to increased antibiotic resistance. At this point, the amount of research conducted in this area is so small that no concluding statements can be made regarding the need to regulate effluents based on their pathogen content.

Fish pathogens already exist in the natural environment. Theories of disease must account for the fact that in any community, a large percentage of healthy normal individuals continually harbor potentially pathogenic microbes without suffering any symptoms (Dubos, 1955). In aquaculture, fish are no longer in the natural environment; instead, they are confined within a finite amount of space from which they cannot escape even when conditions become undesirable or unbearable. It is the responsibility of the fish culturist to prevent such conditions from occurring because of increased susceptibility of fish to diseases when raised in artificial environments. Not only do disease outbreaks cause economic hardship, but the affected facility also becomes a primary site to amplify the specific disease organism, potentially disseminating these pathogens into the natural environment.

Obligate fish pathogens are pathogens that cannot survive as free-living organisms but depend on a fish host for their continuous survival and propagation. These pathogens include viruses, bacteria, and protozoans such as *Myxosoma cerebralis,* which causes whirling disease*; Ceratomyxa shasta,* which infects salmonids; viral hemorrhagic septicemia (VHS); and *Yersinia ruckeri,* which causes enteric redmouth (ERM). Facultative pathogens, such as Motil Aeromonas Septicemia (MAS) caused by *Aeromonas hydrophila,* can live independently of a host organism by obtaining nutrients from organic matter present in the environment. These opportunistic bacteria are ubiquitous on a worldwide scale in freshwater environments and typically can cause disease episodes after fish have been exposed to unfavorable temperatures, low dissolved oxygen levels, accumulated metabolic waste products, handling, marking, and crowding (Meyer, 1970). There are two major strategies to avoid outbreaks of fish diseases in aquaculture facilities: (1) keep obligate fish pathogens out and (2) avoid stress by maintaining proper water quality conditions.

CAAP facilities can be sources of infectious disease transmission to wild populations of aquatic organisms. Such infectious diseases include those caused by pathogens that are exotic to native ecosystems, as well as the much larger group caused by pathogenic microbes that already exist in wild fish populations. For example, wastes and escapement of infected shrimp from CAAP facilities is considered a major potential pathway for wild shrimp exposure to viral diseases (JSA Shrimp Virus Work Group, 1997). In addition, in light of potentially serious risks of disease transmission from hatcheries to wild populations, guidelines (USDA, 2002) have been developed to define certain practices to prevent the spread of pathogens that might result from the release of infected salmon from hatcheries.

There are a number of studies that indicate how CAAP facilities may be sources of disease transmission to wild populations. For example, the Asian tapeworm *Bothriocephaus acheilognathi* was identified in North America in 1975 in fish farms where golden shiners *Notemigonus crysoleucas*, fathead minnows *Pimephales promelas*, and grass carp were raised. More recently, the use of poeciliids, such as mosquitofish *Gambusia affinis*, for mosquito control and possible releases of exotic fishes from aquaria have been suggested as mechanisms for introduction of the parasite into native fish in areas such as Hawaii. Font and Tate (1994) found that native Hawaiian fish from streams where no exotic species were found were completely free of adult helminthes (a type of parasite). Conversely, in two rivers with exotic species, nematodes and Asian tapeworms were found in both the exotic species and the native fish (Blazer and LaPatra, 2002).

Another parasite associated with fish farms is *Myxobolus cerebralis*, which causes whirling disease. The disease was first identified in the United States in 1956 in brook trout in Pennsylvania. Although widely distributed by the 1970s, clinical whirling disease was only reported in fish from CAAP facilities. However, a survey of wild fish in Michigan found that the parasite had become established in native brook and brown trout below a CAAP facility that contained infected fish. Other surveys have observed a lack of effect on wild populations. The fact that *M. cerebralis* may cause effects in some wild populations and not others makes whirling disease the subject of much current research (Blazer and LaPatra, 2002).

Blazer and LaPatra's (2002) discussion on the potential pathogen risks to wild fish populations from cultured fish also provided a summary of risks from viruses, such as infectious hematopietic necrosis virus (IHNV), infectious pancreatic necrosis virus (IPNV), and infectious salmon anemia virus (ISAV), and bacteria, such as *Edwardsiella ictaluri* and *Renibacterium salmoninarum*. Although these viruses and bacteria are hazardous to wild fish populations, a weaker causative association was made between CAAP facilities and disease outbreaks in wild populations.

6.6.2 Nonnative Species

Some aquatic animal species in commercial production are considered "nonnative" to the geographic area of production. These are species that have been brought into the United States from abroad or into a region of the United States where they would not occur naturally. Whenever nonnative species are introduced to an area, there is potential for these species to become invasive, outcompeting and threatening the survival of the native species. There is also the potential that the introduction of nonnative species may introduce diseases against which native populations have no natural defenses. The Department of the Interior's Fish and Wildlife Service, along with the Department of Commerce's National Marine Fisheries Service, oversee the introduction of nonnative species into the United States.

In addition, many state Departments of Fish and Wildlife have established programs to control the introduction and release of nonnative species within their states. The United States, however, has banned the importation of very few nonnative species. There are several examples of species becoming established in the United States (e.g., Atlantic salmon, grass carp, and some ornamental species) after being introduced, in part, through aquatic animal production. Potential problems associated with the introduction and establishment of nonnative species include disease, parasitism, interbreeding with native species, habitat destruction, and competition with native species.

The introductions of nonnative aquatic organisms, through intentional or accidental releases from CAAP facilities, can cause adverse environmental impacts. There is great inconsistency in the terminology used by literature and scientists when discussing nonnative species. Therefore, it is important to note that a nonnative species is defined as an individual, group, or population of a species that is introduced into an area or ecosystem outside its historical or native geographic range. One glossary in which the term *nonnative* is defined considers the term to include both foreign (exotic) and transplanted species and uses it synonymously with "alien" and "introduced" (Fuller et al., 1999).

6.6.2.1 General Impacts

Nonnative species, which are often considered biological pollutants, can alter and degrade habitat. When species are introduced into new habitats, they often overrun the area and crowd out new species. If enough food is available, populations of nonnative species can increase considerably. Once they are established in an area, they can be difficult to eliminate (UMN, 2000).

Many nonnative species are introduced into the environment by accident when they are carried into an area by vehicles, ships, produce, commercial goods, animals, or clothing

(UMN, 2000) or when they escape from CAAP facilities. Other species are introduced intentionally. Although some species can be harmless or beneficial to an environment, others can be detrimental to ecosystems and recreation (UMN, 2000).

Impacts of nonnative aquatic organisms on native aquatic species in North America can be classified into five general categories: habitat alteration, trophic alteration, spatial alteration, gene pool deterioration, and introduction of diseases.

6.6.2.2 Habitat Alteration

Nonnative fish, such as carp and tilapia, introduced to control vegetation can cause a variety of habitat impacts. Both exotic and native vegetation can be destroyed as a result of carp predation. This, in turn, results in bank erosion, restrictions on fish nursery areas, and acceleration of eutrophication as nutrients are released from the plants. Grass carp can adversely affect rice fields and waterfowl habitat, while common carp reduce vegetation by direct consumption and by uprooting, as they dig through the substrate in search of food. Digging also increases turbidity in the water (AFS, 1997; Kohler and Courtenay, n.d.).

6.6.2.3 Trophic Alteration

Nonnative species can also cause complex and unpredictable changes in community trophic structure. Communities can be changed by explosive population increases of nonnative fish or by predation of native species by introduced species (AFS, 1997). Several studies have documented dietary overlap in native and introduced fishes. As a result, there is potential for competition. However, it has proven difficult to link dietary overlap to competition (Kohler and Courtenay, n.d.).

6.6.2.4 Spatial Alteration

Spatial changes can result from overlap in the use of space by native and nonnative fish, which can lead to competition if space is limited or of variable quality (AFS, 1997).

6.6.2.5 Gene Pool Deterioration

Heterogeneity can be decreased through inbreeding by species being produced in a hatchery. This risk is most serious with species of intercontinental origin because the initial broodstock already has a limited gene pool. If these species are introduced to new habitat, they might lack the genetic characteristics necessary for them to adapt or perform as predicted. There is also a possibility that native gene pools might be altered through hybridization when nonnative species are introduced to a habitat; however, hybridization events in open waters are rare (AFS, 1997; Kohler and Courtenay, n.d.).

6.6.2.6 Introduction of Diseases

Nonnative species can transmit diseases caused by parasites, bacteria, and viruses to an environment. The transmission of diseases from nonnative species to native species is considered one of the most serious threats to native communities (AFS, 1997).

There are numerous examples of nonnative species introducing diseases in native species. Transfer of diseased nonnative fish from Europe is believed to be responsible for introducing whirling disease in North America. Infectious hypodermal and hematopoietic necrosis (IHHN) virus has been spread to a number of countries as a result of shipments of live penaeid shrimp. IHHN was first diagnosed at Hawaiian shrimp culture facilities in shrimp from Panama. "Ich," a common fish disease that is caused by a ciliated protozoan, might have been transferred from Asia throughout the temperate zone with fish shipments (Kohler and Courtenay, n.d.).

6.6.3 Nonnative Species Associated with CAAP Facilities

Potentially nonnative species associated with CAAP facilities include Atlantic salmon, grass carp, shrimp, and tilapia.

6.6.3.1 Atlantic Salmon

Atlantic salmon (*Salmo salar*) are raised in net pens off the east and west coasts of the United States and in British Columbia. Escapement has become a concern to some, particularly Alaska, because of potential impacts from disease, parasitism, interbreeding, and competition. In areas where the salmon are exotic (i.e., the West Coast), most concerns focus not on interbreeding with other salmon species but on whether the escaped salmon will establish feral populations, reduce the reproductive success of native species through competition, alter the ecosystem in some unpredictable way, or transfer diseases (EAO, 1997).

Although it remains uncertain whether escaped farmed Atlantic salmon can definitely transfer diseases, it is useful to examine some biological information on escaped salmon reported by the Environmental Assessment Office of British Columbia. Between 1991 and 1995, 90 adult Atlantic salmon recovered in British Columbia and Alaska were examined to determine if they were infected with any diseases. Two fish were infected with *Aeromonas salmonicida*, the causative agent of furunculosis, and none of the fish contained unusual parasite infestations. Additionally, none of the 56 fish tested were infected with common viral infections (Alverson and Ruggerone, 1998).

In contrast, Atlantic salmon stocked in Puget Sound were believed to have been responsible for introducing a new disease, viral hemorraghic septicemia (VHS), to the west coast. This disease has been found in two salmon hatcheries in Puget Sound (Dentler, 1993). VHS is a systemic infection of various salmonid and a few nonsalmonid fish. It is caused by a rhabdovirus and can cause significant cumulative mortality. Fish that survive become carriers of the disease. VHS is constantly present in most countries of continental Eastern and Western Europe. However, the virus has been isolated off the coast of Washington, in Puget Sound (McAllister, 1990).

Experiments have shown that Atlantic salmon (*Salmo salar*), brook trout (*Salvelinus fontinalis*), golden trout (*Oncorhynchus aguabonita*), rainbow trout x coho salmon hybrids, giebel (*Carassius auratus gibelio*), sea bass (*Dicentrarchus labrax*), and turbot (*Scophthalmus maximus*) are all susceptible to VHS. Experiments have also shown that common carp (*Cyprinus carpio*), chub (*Leuciscus cephalus*), Eurasian perch (*Perca fluviatilis*), roach (*L. rutilus*), and tench (*Tinca tinca*) are all resistant to VHS (McAllister, 1990).

6.6.3.2 Grass Carp

The grass carp (*Ctenopharyngodon idella*), or white amur, is native to the Amur River in China and Russia. It was first imported to the United States in 1963 by aquaculture facilities in Alabama and Arkansas and is used for biological control of vegetation. In the past few decades, the grass carp has spread rapidly as a result of research projects; escapes from ponds and aquaculture facilities; legal and illegal interstate transport; releases by individuals and groups; stockings by federal, state, and local government agencies; and natural dispersion from introduction sites (Dill and Cordone, 1997; Lee et al., 1980; Pflieger, 1975).

Many states have restrictions on the use of grass carp. For example, Pennsylvania, New Jersey, Delaware, and Virginia have all approved the use of grass carp for weed control, with certain restrictions. These states require that the fish be "triploid," meaning that they must have three sets of chromosomes instead of two, which makes the fish sterile (University of Delaware, 1995). Although researchers have reported that the probability of successful reproduction of triploid grass carp is "virtually nonexistent" (Loch and Bonar, 1999), some researchers have questioned the sterility of triploids because techniques used to induce triploidy are not always effective. Therefore, each fish should be genetically checked (USGS, 2001). In addition, measures should be taken to reduce the number of escapes by these fish. Barriers could be constructed and maintained to prevent migration from lakes. Consideration should also be given to the location and type of water bodies stocked with grass carp. Lakes and ponds that are prone to flooding should not be stocked with these carp (Loch and Bonar, 1999).

According to the literature, there are a variety of actual and potential impacts of introducing grass carp to an area. Shireman and Smith (1983) concluded that the effects of grass carp on a water body are complex and depend on the stocking rate, the macrophyte abundance, and the ecosystem's community structure. Negative effects of grass carp include interspecific competition for food with invertebrates and other fish, interference with fish reproduction, and significant changes in the composition of macrophyte, phytoplankton, and invertebrate communities. Chilton and Muoneke (1992) reported that grass carp might affect other species indirectly, by modifying preferred habitat, or directly, through predation or competition when food is scarce. Bain (1993) reports that grass carp have significantly altered the food web and trophic structure of aquatic ecosystems by causing changes in fish, plant, and invertebrate communities. More specifically, he indicates that these effects are largely a result of decreased density and composition of aquatic plants.

The removal of vegetation by grass carp can result in the elimination of food, shelter, and spawning substrates for native fish (Taylor et al., 1984). Additionally, the partial digestion of plant material by grass carp results in increased phytoplankton populations because grass carp can digest only half of the plant material they consume. The rest of the material is released into the water and increases algal blooms (Rose, 1972), which decreases oxygen levels and reduces water clarity (Bain, 1993).

Grass carp may carry diseases and parasites that are known to be infectious or potentially infectious to native fish. Grass carp imported from China are believed to be responsible for introducing the Asian tapeworm *Bothriocephalus opsarichthydis* (Ganzhorn et al., 1992; Hoffman and Schubert, 1984).

6.6.3.3 Pacific White Shrimp

The Pacific white shrimp (*Paneaus vannamei*) and the blue shrimp *(P. stylirostris*) from the Pacific coast of Central and South America were introduced to the United States as productive culture species for the U.S. industry, when smaller native species (brown shrimp (*P. aztecus*), white shrimp (*P. setiferus*), and pink shrimp (*P. duorarum*) proved unsuitable for commercial production. The giant tiger prawn (*P. monodon*) from the western Pacific has also been introduced into the United States for shrimp farming.

Today most commercial ventures in the United States produce the Pacific white shrimp for a single annual crop (Iverson et al., 1993). Most shrimp farms are in South Carolina, Florida, and Texas. Escapement of nonnative shrimp is a major concern because of the possible spread of disease, as well as various bacterial, fungal, and viral infections, to wild populations. Because diseases like white spot disease are very contagious and have high mortality rates, states have taken precautions to prevent escapement from shrimp farms. Other diseases that commonly affect shrimp include infectious hypodermal and hematopoietic necrosis (IHHN) virus, Taura syndrome virus (TSV), and the yellow head virus syndrome (YHV) (Treece, 2000). In Florida state laws regulate where Pacific white shrimp can be grown, including containment within controlled facilities. Texas and South Carolina have similar guidelines to prevent the release of nonnative shrimp and to minimize their potential impact on wild populations. In Texas, the Pacific white shrimp is the only nonnative species permitted to be cultured in AAP facilities.

6.6.3.4 Tilapia

The most commonly raised species of tilapia are blue tilapia (*Oreochromis aureus*), Nile tilapia (*O. niloticus*), and Mozambique tilapia (*O. mossambicus*). Native to Africa and the Middle East, tilapia have been introduced throughout the world as cultured species in temperate regions (Stickney, 2000). They are freshwater fish from the family Cichlidae and are primarily herbivores or omnivores. Feeding lower on the food chain has enhanced their popularity as a culture species (Stickney, 2000). Tilapia were first introduced to the Caribbean islands in the 1940s and then eventually were introduced to Latin America and the United States. In addition to production for foodfish, one species, *Tilapia zillii*, an herbivore, has been stocked in irrigation canals to control aquatic vegetation. Tilapia have also been used for aquarium and bait bucket releases, as a sport fish, and as forage for warmwater predatory fish (Courtenay et al., 1984; Courtenay and Williams, 1992; Lee et al., 1980).

Tilapia are competitors with native species for spawning areas, food, and space (USGS, 2000a). There have been reports that certain streams where blue tilapia are abundant have lost most vegetation and nearly all native fish (USGS, 2000a). In Hawaii, Mozambique tilapia has been considered a significant factor in the decline of the desert pupfish (*Cyprinodon macularius*) in the Stalton Sea area (USGS, 2000b)

Because of its nonnative status, the tilapia has been regulated by various states to prevent escapement and impacts on wild stocks of native species. Importation and movement of tilapia are regulated in the United States. The following states have some form of restriction on tilapia culture: Arizona, California, Colorado, Florida, Hawaii, Illinois, Louisiana, Missouri, Nevada, and Texas (Stickney, 2000).

6.6.4 Drugs and Chemicals

Drugs are substances, including medicated feed, that are added to the production facility to maintain or restore animal health, and they can be subsequently discharged into the waters of the United States. The following summary includes drugs that can be injected directly into aquatic animals or used in immersion baths, but are not discharged to the waters of the United States; however, the proposed rule does not address this category of drugs. Chemicals are substances that are added to an AAP facility to maintain or restore water quality for aquatic animal production and that subsequently might be discharged to waters of the United States.

By providing food and oxygen, AAP facilities can produce fish and other aquatic animals in greater numbers than natural conditions would allow. This means that system management is important to ensure that the animals do not become overly stressed, making them more vulnerable to disease outbreaks. When diseases do occur, facilities might be able to treat their populations with drugs. Operators producing aquatic animals that are being produced for human consumption must comply with requirements established by the Food and Drug Administration (FDA) with respect to the drugs that can be used to treat their animals, the dose that can be used, and the withdrawal period that must be achieved before the animals can be harvested. Drugs can be divided into four categories: approved drugs, investigational drugs, extra-label use drugs, and unapproved drugs. Approved drugs have already been screened by the FDA to ensure that they do not cause significant adverse public health or environmental impacts when used in accordance with label instructions. Currently, there are only six approved drugs for AAP species consumed by humans:

- Chorionic gonadotropin (Chorulon)
- Oxytetracycline (Terramycin)
- Sulfadimethoxine, ormetoprim (Romet-30)
- Tricane methanesulfonate (Finquel and Tricane-S)
- Formalin (Formalin-F, Paracide and Parasite-F)
- Sulfamerazine

FDA authorizes use of investigational drugs on a case-by-case basis to allow a way of gathering data for the approval process (21 USC 3606(j)). Quantities and conditions of use are specified. FDA, however, sometimes relies on the NPDES permitting process to establish limitations on pollutant discharges to prevent environmental harm. NPDES permits to date have required only reporting of the use of drugs and chemicals. EPA suspects that permits have not established limitations on the use of drugs and chemicals because of the frequency of use and the lack of analytical methods to measure such drugs and chemicals in wastewater matrices. Extra-label drug use is restricted to use of approved animal and human drugs by, or on the order of, a licensed veterinarian and must be within the context of a valid veterinarian-patient relationship. New unapproved animal drugs are sometimes used in discrete cases where the FDA exercises its regulatory discretion.

6.6.4.1 FDA-Approved Animal Drugs

Drugs included in this category are those that the FDA has approved for use at AAP facilities. These drugs are widely used at facilities to treat various specified diseases and species, often at application rates that are greater than necessary. Because of the widespread use of some of these drugs, there is potential for antibiotic resistance.

Antibiotics are typically applied orally or by immersion. These routes can allow significant amounts of antibacterial agents (through uneaten medicated feed or leached, unabsorbed, or excreted drug) to escape into the environment and cause resistance. A number of studies support the fact that antibacterial resistance is associated with the frequency of antibiotic use in an environment. Additionally, the frequency of resistance can be increased by antibacterial agent concentrations that are inadequate for killing the bacteria. Insufficient concentrations may result from choosing the wrong drug, failure to deliver the proper dose, faulty treatment regimes, prophylactic treatment, and heavy reliance on a limited number of antibacterial agents because of regulations or specific applicator preferences (GESAMP, 1997).

Table 6.6-1 describes the drugs approved by the FDA for use at AAP facilities, their approved uses, and their environmental effects.

Table 6.6-1. FDA-Approved New Animal Drugs for Aquaculture

Drug	***Use***	***Environmental Effects***
Formalin (All finfish eggs)	Control of the fungi of the family of Saprolegniaceae	*Fate in the Environment*: The Center for Veterinary Medicine has found that no environmental impacts are expected from using formalin, provided that the finfish egg treatment water is diluted 100-fold. *Aquatic Life*: A National Fisheries Research Center study showed that formalin concentrations of 1,000 to 2,000 ppm is safe for finfish eggs of the orders Cypriniformes (common carp and white sucker), Perciformes (walleye), and Siluriformes (channel catfish). *Human Health*: An Auburn University study showed that the use of formalin at the recommended concentration (1,000 to 2,000 μL/L for 15 minutes for all finfish eggs except Acipenseriformes and up to 1,500 μL/L for 15 minutes for Acipenseriformes eggs) has not been shown to result in formaldehyde accumulation above naturally occurring levels in the edible tissues of these fish. Source: FDA, n.d.a.
Formalin (All finfish)	Control of the external protozoa and monogenetic trematodes	*Fate in the Environment*: The Center for Veterinary Medicine has determined that no environmental impacts are expected from using formalin, provided that the finfish treatment water is diluted 10-fold. *Aquatic Life*: Tolerances to formalin may vary with strains and species of finfish. Auburn University studies indicated that mortality may occur in striped bass exposed to more than 250 ppm for more than 1.5 hours and that the 96-hour LC_{50} for hybrid striped bass was 60.1 ppm. *Human Health*: An Auburn University study showed that the use of formalin at the recommended concentration (up to 250 μL/L for up to 1 hour in tanks and raceways and 15 to 25 μL/L indefinitely in earthen ponds) has not been shown to result in the accumulation of formaldehyde above naturally occurring levels in the edible tissues of a wide range of cold and warm water fish, including striped bass, the most sensitive species. Source: FDA, n.d.a.

Drug	Use	Environmental Effects
Human chorionic gonadotropin (HCG) Chorulon is the recommended HCG product for use with brood finfish	Aid in improving spawning function in all male and female brood finfish	*Fate in the Environment*: The Center for Veterinary Medicine has concluded that HCG does not individually or cumulatively have a significant effect on the human environment. *Aquatic Life*: Chorionic gonadotropin should be administered, depending on the fish species, at a dose of 50 to 510 I.U. per pound body weight for males and 67 to 1,816 I.U. per pound body weight for females, for one to three injections. Animal safety studies indicate that HCG can be administered to broodfish at the levels recommended in the product labeling without significant adverse effects. *Human Health*: The total dose administered (all injections combined) must not exceed 25,000 I.U. (25 mL) in fish intended for human consumption. There is no withdrawal period required for broodfish treated according to label directions. For specific dose recommendations and summaries of animal safety and human health studies for various species, refer to FDA, 1999. Source: FDA, 1999
Oxytetracycline (catfish)	Control of bacterial hemorrhagic septicemia and pseudomonas disease	No environmental fate information was available. *Aquatic Life*: The FDA recommends 2.5 to 3.75 g per 100 lb of fish per d, administered in mixed ration for 10 d. Oxytetracycline should not be administered when water is below 16.7 °C (62 °F). *Human Health*: Fish should not be liberated or slaughtered for 21 d following the last administration of medicated feed. Source: FDA, 1996
Oxytetracycline (lobster)	Control of gaffkemia	No environmental fate information was available. *Aquatic Life*: The FDA recommends 1 g/lb, fed for 5 d as the sole ration. *Human Health*: Oxytetracycline should be withdrawn from feed 30 d before harvesting lobsters. Source: FDA, 1996
Oxytetracycline (salmonids)	Control of ulcer disease, furunculosis, bacterial hemorrhagic septicemia, and pseudomonas disease	No environmental fate information was available. *Aquatic Life*: The FDA recommends 2.5 to 3.75 g per 100 lb of fish per d, administered in mixed ration for 10 d. Oxytetracycline should not be administered when water is below 9 °C (48.2 °F). *Human Health*: Fish should not be liberated or slaughtered for 21 d following the last administration of medicated feed. Source: FDA, 1996

Drug	Use	Environmental Effects
Oxytetracycline (pacific salmon)	Marking of skeletal tissue	No environmental fate information was available. *Aquatic Life*: The FDA recommends 250 mg per kilogram of fish per d (11.35 g per 100 lb of fish per d) for salmon not over 30 g body weight, administered as sole ration for 4 d in feed. *Human Health*: Fish should not be liberated for at least 7 d following the last administration of medicated feed. Source: FDA, 1996
Sulfadimethoxine and ormetroprim (catfish)	Control of enteric septicemia	No environmental fate or aquatic life information was available. *Human Health*: Sulfadimethoxine and ormetroprim have a 3-d withdrawal time for catfish. Source: FDA, 2002
Sulfadimethoxine and ormetroprim (salmonids)	Control of furunculosis	No environmental fate or aquatic life information was available. *Human Health*: Sulfadimethoxine and ormetroprim have a 42-d withdrawal time for salmonids. Source: FDA, 2002
Sulfamerazine (not currently available)	Control of furunculosis for rainbow trout, brook trout, and brown trout	No environmental fate or aquatic life information was available. *Human Health*: Sulfamerazine has a 21-d withdrawal time. Source: FDA, 2002
Tricaine methanesulfonate	Temporary immobilization (anesthetic) for Ictaluridae, Salmonidae, Esocidae, and Percidae (In other fish and cold-blooded animals, the drug should be limited to hatchery or laboratory use)	No environmental fate information was available. *Aquatic Life*: FDA has not required any animal safety studies for this drug because it is a generic copy of the brand name drug, whose safety has been established. When tricaine methanesulfonate is used in fish food, water temperature should not exceed 10 °C (50 °F) and use should be restricted to Ictaluridae, Salmonidae, Esocidae, and Percidae. *Human Health*: For human food safety, tricaine methanesulfonate may not be used within 21 d of harvesting fish for food. Source: FDA, n.d.b.

6.6.4.2 Drugs of Low Regulatory Priority

The drugs included in this group have undergone review by the FDA and have been determined to be new animal drugs of low regulatory priority (LRP). The FDA is unlikely to object to the use of any of these drugs if the substances are used for the proper indications, at the prescribed levels, and according to good management practices. In addition, the product should be of an appropriate grade for use in food animals and there should not be an adverse effect on the environment (FDA, 1997).

The FDA does not require labeling for low-priority use for chemicals that are commonly used for non-drug purposes even if the manufacturer or distributor promotes the chemical for the permitted low-priority use. However, a chemical that has significant animal or human drug uses in addition to the low-priority aquaculture use must be labeled for the low-priority uses if the manufacturer or distributor uses promotion or other means to establish the intended low-priority use for the product. Additional labeling requirements are available from the FDA (FDA, 1997).

Table 6.6-2 summarizes the LRP drugs, their intended uses, and their environmental effects. Based on the information provided in the table, LRP drugs are expected to cause minimal adverse effects on aquatic life and the environment.

Table 6.6-2. LRP Drugs

Drug	***Use***	***Environmental Effects***
Acetic acid	Used as a dip concentration of 1,000–2,000 milligrams per liter (mg/L) for 1–10 min as a parasticide for fish	*Fate in the Environment*: When released into water, acetic acid should readily biodegrade and it is expected to have a half-life of between 1 and 10 d (J.T. Baker, 2001). *Aquatic Life*: Acetic acid is expected to be slightly toxic to aquatic life. The LC_{50}/96-h values for fish are between 10 and 100 mg/L (J.T. Baker, 2001). Dilution is expected to eliminate pH risks. *Human Health*: Symptoms of exposure to acetic acid include irritation of the eyes, nose, throat, and lungs, vomiting, diarrhea, circulatory collapse, breathing difficulties, coughing, and chest pains (NTP, 1991a).
Calcium chloride	Used to increase water calcium concentration to ensure proper egg hardening. Dosages used would be those necessary to raise calcium concentration to 10–20 mg/L as calcium carbonate. Also used to increase water hardness up to 150 mg/L to aid in maintenance of osmotic balance in fish by preventing electrolyte loss.	*Fate in the Environment*: Based on available information for calcium chloride anhydrous, this material will not biodegrade or bioaccumulate (J.T. Baker, 1999a). *Aquatic Life*: The LC_{50}/96-h values for fish are over 100 mg/L (J.T. Baker, 1999a). *Human Health*: Calcium chloride can cause irritation if it is inhaled, ingested, or comes in contact with the eyes or skin. Ingestion of large doses can lead to renal damage, dehydration, and hypercalcaemia (Syndel, 2001a).
Calcium oxide	Used as an external protozoacide for fingerling to adult fish at a concentration of 2,000 mg/L for 5 s.	*Aquatic Life*: Calcium oxide is expected to be toxic to aquatic life (J.T. Baker, 1998). Dilution is expected to eliminate pH risks. *Human Health*: Calcium oxide can irritate the eyes, skin, nose, and lungs (New Jersey, 1996).
Carbon dioxide gas	Used for anesthetic purposes in cold, cool, and warm water fish.	No environmental effects are expected.

Drug	***Use***	***Environmental Effects***
Fuller's earth	Used to reduce the adhesiveness of fish eggs to improve fish hatchability.	No environmental fate, aquatic life, or human health information was available.
Garlic (whole)	Used to control helminth and sea lice infestations in marine salmonids at all life stages.	No environmental effects are expected.
Hydrogen peroxide	Used at 250–500 mg/L to control fungi on all species and at all life stages of fish, including eggs.	No aquatic life information was available. *Human Health*: Large doses of hydrogen peroxide can cause gastritis, esophagitis, rupture of the colon, proctitis, and ulcerative colitis (NTP, 1991b). Hydrogen peroxide can irritate the eyes, skin, nose, throat, and lungs. It is considered a mutagen and should be handled with extreme caution. Health effects are unlikely to occur with commercial solutions of hydrogen peroxide used as a skin disinfectant (New Jersey, 1998).
Ice	Used to reduce metabolic rate of fish during transport.	No environmental effects are expected.
Magnesium sulfate (Epsom salts)	Used to treat external monogenetic trematode infestations and external crustacean infestations in fish at all life stages. Used in freshwater species. Fish are immersed in a solution of 30,000 mg/L magnesium sulfate and 7,000 mg/L sodium chloride for 5–10 min.	No environmental effects are expected.
Onion (whole)	Used to treat external crustacean parasites and to deter sea lice from infesting external surface of fish at all life stages.	No environmental effects are expected.
Papain	Used as a 0.2% solution in removing the gelatinous matrix of fish egg masses to improve hatchability and decrease the incidence of disease.	No environmental effects are expected.
Potassium chloride	Used as an aid in osmoregulation to relieve stress and prevent shock. Dosages used would be those necessary to increase chloride ion concentration to 10–2,000 mg/L.	*Aquatic Life*: The highest concentration of chloride to which an aquatic community can be exposed briefly without an unacceptable effect is 860 mg/L. The highest concentration of chloride to which an aquatic community can be exposed indefinitely without an unacceptable effect is 230 mg/L (USEPA, 1999a). *Human Health*: Large doses of potassium chloride usually induce vomiting, so acute intoxication by mouth is rare (NTP, 1991c).

Drug	***Use***	***Environmental Effects***
Povidone iodine compounds	Used as a fish egg disinfectant at rates of 50 mg/L for 30 min during water hardening and 100 mg/L solution for 10 min after water hardening.	No environmental fate or aquatic life information was available. *Human Health*: There is no evidence of adverse effects from inhalation, ingestion, skin contact, or eye contact with povidone iodine (Syndel, 2001b).
Sodium bicarbonate (baking soda)	Used at 142–642 mg/L for 5 min as a means of introducing carbon dioxide into the water to anaesthetize fish.	No environmental effects are expected.
Sodium chloride (salt)	Used as a 0.5%–1% solution for an indefinite period as an osmoregulatory aid for the relief of stress and prevention of shock. Used as a 3% solution for 10–30 min as a parasticide.	*Freshwater Aquatic Life*: Certain life stages might be affected by changes in sodium chloride concentrations (Syndel, 2001c). The highest concentration of chloride to which an aquatic community can be exposed briefly without an unacceptable effect is 860 mg/L. The highest concentration of chloride to which an aquatic community can be exposed indefinitely without an unacceptable effect is 230 mg/L (USEPA, 1999a). *Human Health*: There is no evidence of adverse effects from inhalation, ingestion, or skin contact with sodium chloride. However, ingesting very large doses may cause nausea, vomiting, diarrhea, dehydration, and congestion in most internal organs (Syndel, 2001c).
Sodium sulfite	Used as a 15% solution for 5–8 min to treat eggs to improve hatchability.	No aquatic life information was available. *Human Health*: Sodium sulfite is an irritant when it is inhaled, ingested, or comes into contact with the eyes. It is unlikely to irritate skin after brief contact, but may be irritating after prolonged contact (Syndel, 2001d).
Urea and tannic acid	Used to denature the adhesive component of fish eggs at concentrations of 15 g urea and 20 g NaCl per 5 L of water for approximately 6 min, followed by a separate solution of 0.75 g tannic acid per 5 L water for an additional 6 min. These amounts will treat approximately 400,000 eggs.	*Fate in the Environment*: Urea may moderately biodegrade in water and is not expected to evaporate significantly (J.T Baker, 1999b). No environmental fate information for tannic acid was available. *Aquatic Life*: Urea has an experimentally determined bioconcentration factor of less than 100 and is not expected to significantly bioaccumulate (J.T. Baker, 1999b). Dilution is expected to eliminate pH risks from tannic acid. *Human Health*: Exposure to urea may cause eye irritation, headache, nausea, convulsions, and vomiting (NTP, 1991d; CDC, n.d.). Tannic acid can irritate the skin and eyes (ProSciTech, 1998).

6.6.4.3 Investigational New Animal Drugs

Investigational new animal drugs (INADs) are those drugs for which FDA has authorized use on a case-by-case basis to allow a way of gathering data for the approval process (21 USC 3606(j)). Quantities and conditions of use are specified. FDA, however, sometimes relies on the NPDES permitting process to establish limitations on pollutant discharges to prevent environmental harm. Table 6.6-3 provides information about INADs, their uses, and their environmental effects.

Table 6.6-3. Investigational New Animal Drugs for Aquaculture

Drug	*Use*	*Environmental Effects*
AQUI-S	Approved for use as an anesthetic and sedative in New Zealand and Australia. It has been used for harvesting salmon since 1994 and is also widely used in transporting lobster, eels, and other finfish (AQUI-S, 1998).	No environmental fate information was available. *Aquatic Life*: Fish have a fast recovery from AQUI-S, which is effective at low concentrations of 10–20 mg/L. Specific efficacy data and dosage information are available from New Zealand Ltd. (AQUI-S, 1998). *Human Health*: There is no withholding period for AQUI-S, allowing the aquatic animal to be harvested for human consumption (AQUI-S, 1998).
Chloramine-T (Halamid)	Halamid is used in major European trout farming countries to prevent and cure bacterial gill disease. It can be used at all stages of farming for the general disinfection of passage bath tanks, pond surfaces and equipment, water preconditioning, water quality maintenance, and disinfecting eggs and artemia. The United States is researching its use in controlling bacterial gill disease in salmonids (FDA, 1998) and flavobacteriosis in cold, cool, and warm water fishes.	According to the manufacturer, Halamid has a low toxicity, is readily biodegradable, and does not accumulate in the environment. Aquatic toxicity information is available from the manufacturer's web site, but a password is required (Halamid, n.d.).

Drug	***Use***	***Environmental Effects***
Copper sulfate (Triangle Brand Copper Sulfate)	Used to control bacterial diseases, fungal diseases, and external protozoan and metazoan parasites.	*Fate in the Environment*: Copper is adsorbed to organic materials and to clay and mineral surfaces. The degree to which it is adsorbed depends on the acidity or alkalinity of the soil. Copper sulfate is highly soluble in water, making it one of the more mobile metals in soil. However, its leaching potential is low in all but sandy soils because of its binding capacity. Copper sulfate can persist indefinitely, although it will bind to water particulates and sediment (Extoxnet, 1996a). Copper sulfate can aggravate low dissolved oxygen problems in ponds by killing the primary source of oxygen (the algae) and by adding a large biochemical oxygen demand in the form of dead and decomposing algae. Therefore, consideration should be given to dissolved oxygen before treating a pond (Cornell, 1998). *Aquatic Life*: Copper sulfate is highly toxic to fish. It can be poisonous to trout and other fish, especially in soft or acidic waters, even when it is applied at recommended rates. Copper sulfate's toxicity to fish tends to decrease as water hardness increases. Fish eggs are more resistant to the toxic effects of copper sulfate than young fish fry. Copper sulfate is also toxic to aquatic invertebrates such as crabs, shrimp, and oysters (Extoxnet, 1996a). *Human Health*: The acute toxicity of copper sulfate is due largely to its being caustic. The lowest dose of copper sulfate that has been toxic when ingested by humans is 11 mg/kg. Ingestion of copper sulfate is often not toxic because vomiting is an automatic reflex of its irritation of the gastrointestinal tract. However, symptoms are severe if it is retained in the stomach. Symptoms include a burning pain in the chest and abdomen, intense nausea, repeated vomiting, diarrhea, headache, sweating, shock, and injury to the brain, liver, kidneys, and stomach (Extoxnet, 1996a). It can also irritate the skin and eyes (Syndel, 2001e). Copper sulfate has been shown to cause reproductive effects in test animals (Extoxnet, 1996a).
Crude carp pituitary	Aid in improving spawning function in various fish (FDA, 1998).	No environmental fate, aquatic life, or human health information was available.
Erythromycin	Control of bacterial kidney disease in salmonids (FDA, 1998).	No environmental fate, aquatic life, or human health information was available.
Florfenicol (Aquflor)	Used to control flexibacteriosis and furunculosis.	No environmental fate, aquatic life, or human health information was available.
Formalin	Used as a fungicide on fish and their eggs at public aquaculture facilities.	Effects vary, based on the concentration used and the conditions in which it is used.

Drug	Use	Environmental Effects
Gonadotropin releasing hormone analog (Ovaplant, Ovaprim)	Ovaplant is used to advance maturation and ovulation and has been tested in Atlantic salmon and other fish species (Syndel, 2001h). Ovaprim is used to promote and facilitate reproduction of many species of fish (Syndel, 2001i).	No environmental fate or aquatic life information was available. *Human Health*: Ovaplant and Ovaprim might be harmful if they are inhaled, ingested, or come into contact with the eyes or skin. Although the toxicological properties have not been studied, it is possible that Ovaplant and Ovaprim might modify reproductive ability (Syndel, 2001f, 2001g).
Hydrogen peroxide	Used to control bacterial gill disease in various fish (FDA, 1998), fungal infections, external bacterial infections, and external parasites.	No environmental fate or aquatic life information was available. *Human Health*: Large doses of hydrogen peroxide can cause gastritis, esophagitis, rupture of the colon, proctitis, and ulcerative colitis (NTP, 1991b). Hydrogen peroxide can irritate the eyes, skin, nose, throat, and lungs. It is considered a mutagen and should be handled with extreme caution. Health effects are unlikely to occur with commercial solutions of hydrogen peroxide used as a skin disinfectant (New Jersey, 1998).
17∝ methyltestosterone	Used in rainbow trout (FDA, n.d.c.).	No environmental fate, aquatic life, or human health information was available.
Oxytetracycline	For control of columnaris in walleye, vibriosis in summer flounder, Streptococcus infection in tilapia (FDA, 1998), and flavobacteriosis in cold, cool, and warm water fishes. Also used in otolith marking of fish.	Effects will vary, based on the concentration used and the conditions in which it is used.
Potassium permanganate (Cairox)	Used to control external Ichthyophthirius multifilis in catfish (FDA, 1997), external protozoan, metazoan parasites, and bacterial and fungal diseases.	No environmental fate or aquatic life information was available. *Human Health*: Potassium permanganate is an irritant when it is inhaled, ingested, or comes into contact with the eyes, skin, or nasal and respiratory passages. Early symptoms of exposure include sluggishness, sleepiness, and weakness in the legs. Symptoms of advanced cases include fixed facial expression, emotional disturbances, and falling (Syndel, 2001j).

6.6.4.4 Registered Pesticides

Pesticides may be used to control animal parasites and aquatic plants and might be present in wastewaters. Some pesticides are bioaccumulative and retain their toxicity once they are discharged into receiving waters. Although EPA observed that many of the treatment systems used in the CAAP industry provide adequate reductions of pesticides, most systems are not specifically designed and operated to remove pesticides.

Table 6.6-4 provides information about registered pesticides, their uses, and their environmental effects.

Table 6.6-4. Pesticides Registered for Aquaculture

Chemical	***Use***	***Environmental Effects***
Chelated copper	Used to control algae.	Effects are the same as effects of copper.
Copper	Used to control algae.	*Fate in the Environment*: Soluble copper compounds, which dissolve in water, are more likely to threaten human health than those that bind to solids. Soluble copper compounds released into rivers and lakes, however, tend to rapidly become attached to particles in neutral and basic water within almost a day, making these compounds less threatening to human health (ATSDR, 1990). In contrast, copper compounds can leach from acidic environments and as a result become bioavailable and threatening to human health. *Aquatic Life*: Crayfish have an LC_{50} value of 600 micrograms per liter (μg/L) for copper. LC_{50} values for bluegill sunfish have been measured as low as 400 μg/L in soft water. Blue mussel embryos are very sensitive to copper exposure, with an LC_{50} value of 5.8 μg/L for copper sulfate. Generally, juvenile aquatic organisms appear to be more sensitive to the effects of copper compounds than adults (USEPA, 1985). Red blood cell damage in Mozambique tilapia was observed during both 96-h and 4-wk exposure periods to 0.40 mg/L of copper (Nussey et al., 1995). Fathead minnow embryos exhibited a 96-h LC_{50} value of 250 μg/L (Scudder et al., 1988). *Human Health*: At high doses, copper has been shown to cause kidney and liver damage, stomach and intestinal distress, and anemia (TEC, 1998). Symptoms observed from accidental ingestion or intentional poisonings include metallic taste in the mouth, abdominal pain, diarrhea, and vomiting. Ingesting copper in gram amounts can cause systemic toxicity, including liver and kidney damage, intestinal bleeding, cardiovascular effects, convulsions, coma, and death (Faust, 1992).
Copper as elemental	Used to control algae.	Effects are the same as effects of copper.

Chemical	***Use***	***Environmental Effects***
Copper sulfate pentahydrate	Used to control algae.	*Fate in the Environment*: Copper is adsorbed to organic materials and to clay and mineral surfaces. The degree to which it is adsorbed depends on the acidity or alkalinity of the soil. Copper sulfate is highly soluble in water, making it one of the more mobile metals in soil. However, its leaching potential is low in all but sandy soils because of its binding capacity. Copper sulfate can persist indefinitely, although it will bind to water particulates and sediment (Extoxnet, 1996a). Copper sulfate can aggravate low dissolved oxygen problems in ponds by killing the primary source of oxygen (the algae) and by adding a large biological oxygen demand in the form of dead and decomposing algae. Therefore, consideration should be given to dissolved oxygen before treating a pond (Cornell, 1998). *Aquatic Life*: Copper sulfate is highly toxic to fish. It may be poisonous to trout and other fish, especially in soft or acidic waters, even when it is applied at recommended rates. Copper sulfate's toxicity to fish tends to decrease as water hardness increases. Fish eggs are more resistant to the toxic effects of copper sulfate than young fish fry. Copper sulfate is also toxic to aquatic invertebrates such as crabs, shrimp, and oysters (Extoxnet, 1996a). *Human Health*: The acute toxicity of copper sulfate is due largely to its being caustic. The lowest dose of copper sulfate that has been toxic when ingested by humans is 11 mg/kg. Ingestion of copper sulfate is often not toxic because vomiting is an automatic reflex of its irritation of the gastrointestinal tract. However, symptoms are severe if it is retained in the stomach. Symptoms include a burning pain in the chest and abdomen, intense nausea, repeated vomiting, diarrhea, headache, sweating, shock, and injury to the brain, liver, kidneys, and stomach (Extoxnet, 1996a). It may also irritate the skin and eyes (Syndel, 2001e). Copper sulfate has been shown to cause reproductive effects in test animals (Extoxnet, 1996a).
Diuron	Used to control algae.	*Fate in the Environment*: Diuron is moderately to highly persistent in soils and relatively stable in neutral water. Microbes are the primary agents in the degradation of diuron in water (Extoxnet, 1996b). When used properly, the chemical will not accumulate in pond bottom soils (Tucker and Leard, n.d.). *Aquatic Life*: Diuron is moderately toxic to fish and highly toxic to aquatic invertebrates. The LC_{50} (48-h) values for diuron range from 4.3 mg/L to 42 mg/L in fish and from 1 mg/L to 2.5 mg/L in aquatic invertebrates. The LC_{50} (96-h) for rainbow trout is 3.5 mg/L (Extoxnet, 1996b). *Human Health*: Diuron is slightly toxic to mammals. Animal studies indicate that it can cause increased mortality, growth retardation, abnormal blood pigment, anemia, and changes in the spleen, bone marrow, and blood chemistry (Extoxnet, 1996b). Diuron has been classified as a known/likely human carcinogen by all routes (USEPA, 1999b).

Chemical	***Use***	***Environmental Effects***
Acid blue and acid yellow (Aquashade)	Used to control vascular aquatic plants.	No environmental fate information was available. Aquashade is reported to be nontoxic to humans, livestock, and aquatic organisms (Washington Department of Ecology, 1994). Yet, it may cause eye and skin irritation, nausea, or gastric disturbances (Applied Biochemists, 1999). In a study that examined the effect of Aquashade on the oxygen consumption of crayfish, no effects were found at a concentration of 1 mg/L over 5 d (Danish Technological Institute, 1998).
Dichlobenil	Used to control vascular aquatic plants.	*Fate in the Environment*: Dichlobenil is persistent in water and groundwater and especially in soil. It has the potential to reach groundwater based on its water solubility, chemical structure, and use patterns. EPA requires a warning about this on labels of dichlobenil-containing products (Cox, 1997). Some formulations may not be labeled for commercial fish production ponds. Label instructions should be followed carefully (UGA, 2001). *Aquatic Life*: The acute toxicity of dichlobenil to fish under lab conditions varies, depending on the species and the length of exposure. Over a 10-d period, concentrations of less than 2 ppm killed fish. Rainbow trout are especially sensitive, with an LC_{50} of less than 5 ppm over 4 d. The LC_{50} for other species ranges from 6 to 16 ppm. In a field study in which small ponds were treated with dichlobenil, some fish developed tumors, inflamed kidney nodules, and reproductive problems. Dichlobenil can bioconcentrate in fish by a factor of 40 (Cox, 1997). The acute toxicity of dichlobenil on aquatic invertebrates varies widely among species. Sand fleas, water fleas, and stonefly nymphs are especially susceptible. Sublethal effects that can occur include a “narcotizing” effect on many invertebrates, gill irritation in damselflies, immobilization of caddisflies, and a loss of pigmentation in water boatmen. Aquatic invertebrates may also be affected indirectly when aquatic plants are killed and they have no place to hide (Cox, 1997). *Human Health*: Fish from treated waters should not be used for human consumption for 90 d following application (Riemer, 1984). Chronic exposure to dichlobenil may cause inactivity, loss of appetite, sedation, coma, or respiratory arrest (Information Ventures, 2000a). Exposure can also damage the olfactory system or cause eye and skin irritation. Animal studies show that long term exposure may result in liver nodules, kidney stones, reproductive effects, decreased weight gain, decreased food consumption, and increased liver and kidney weights. EPA has classified dichlobenil as a possible human carcinogen (Cox, 1997).

Chemical	***Use***	***Environmental Effects***
Diquat dibromide	Used to control vascular aquatic plants.	*Fate in the Environment*: Diquat dibromide is highly persistent in soil and ground water. Although it is water soluble, its capacity for strong adsorption to soil organic matter and clay suggest that it will not easily leach through the soil, be taken up by plants or soil microbes, or broken down by sunlight. When applied to open water, diquat dibromide disappears rapidly because it binds to suspended particles in the water. Diquat dibromide stays bound to these particles, remaining biologically inactive in surface waters. Its half life is less than 48 h in the water column. Microbial degradation and sunlight play roles in the breakdown of diquat dibromide in surface waters (Extoxnet, 1996c). *Aquatic Life*: Diquat dibromide is practically nontoxic to fish and aquatic invertebrates. The 8-h LC_{50} for diquat dibromide is 12.3 mg/L in rainbow trout and 28.5 mg/L in Chinook salmon. Research indicates that yellow perch suffer significant respiratory distress when herbicide concentrations in the water are similar to those normally present during aquatic vegetation control programs. There is little or no bioconcentration of diquat dibromide in fish (Extoxnet, 1996c). *Human Health*: Diquat dibromide is acutely toxic when absorbed through the skin and moderately toxic via ingestion. Ingestion of sufficient doses can cause severe irritation of the mouth, throat, esophagus, and stomach, followed by nausea, vomiting, diarrhea, severe dehydration, and alterations in body fluid balances, gastrointestinal discomfort, chest pain, kidney failure, and toxic liver damage. Very large doses can result in convulsions and tremors. Absorption of the herbicide from the gut into the bloodstream is low. Oral doses are metabolized within the intestines and then excreted in the feces. It is unlikely that diquat dibromide will cause reproductive effects in humans under normal circumstances (Extoxnet, 1996c).
Endothall	Used to control vascular aquatic plants.	*Fate in the Environment*: Endothall is highly mobile in soil; however, rapid degradation limits the extent of leaching. Endothall disappears from soil in 7–21 d. Its half-life is 4–5 d in clay soils and 9 d in soils with high organic content. Endothall is rapidly degraded in surface water, where its half-life is 4–7 d for dipotassium endothall and approximately 7 d for technical endothall. Biodegradation is slower without the presence of air (Extoxnet, 1995). *Aquatic Life*: Endothall is toxic to some species of fish. Inorganic salts of endothall in aquatic formulations are safe for fish in 100–500 ppm concentrations. However, amine salts of endothall are more toxic to fish than the dipotassium endothall. Endothall has a low toxicity to crustaceans and a medium toxicity to aquatic insects. Long term ingestion may cause severe damage to the digestive tract, liver, and testes in fish (Extoxnet, 1995). *Human Health*: Endothall is highly irritating to mucous membranes and precautions should be taken to keep it out of eyes, nose, mouth, and other sensitive areas (Riemer, 1984). Endothall is not classified as a carcinogen (Extoxnet, 1995).

Chemical	***Use***	***Environmental Effects***
Fluridone	Used to control vascular aquatic plants.	*Fate in the Environment*: Fluridone is moderately persistent in water and sediments following treatment. It is strongly adsorbed to organic matter in soil. Field tests have shown that the average half-life in pond water is 21 d and longer in sediments (90 d in hydrosoil). Residues may persist longer, depending on the amount of sunlight and the water temperature. Fluridone is stable to hydrolysis and it is primarily degraded by sunlight and microorganisms (DOH, 2000; Cornell, 1986). *Aquatic Life*: Fluridone does not significantly bioaccumulate or biomagnify in fish (DOH, 2000). Maximum Acceptable Theoretical Concentration (MATC) values indicate a potential hazard for aquatic organisms in shallow areas at higher treatment rates described on the label (Cornell, 1986). *Human Health*: Consumption of fish from treated water does not pose a threat to human health. Fluridone is not considered to be a carcinogen or mutagen (DOH, 2000).
Glyphosate	Used to control vascular aquatic plants.	*Fate in the Environment*: Glyphosate is not generally active in the soil and is not usually absorbed from the soil by plants. Its half-life in soil ranges from 3 to 130 d, depending on soil texture and organic content, and it is broken down by soil microorganisms. Glyphosate dissolves easily in water and its potential for leaching into ground water is low. The half-life of glyphosate in water ranges from 35 to 63 d (Information Ventures, 2000b). *Aquatic Life*: Glyphosate is practically nontoxic to fish and may be slightly toxic to aquatic invertebrates. The common glyphosate product is acutely toxic to fish. Acute toxicities of glyphosate vary widely due to differences in toxicity between the salts and the parent acid or to surfactants used in the formulation. There is a very low potential for glyphosate to bioaccumulate in aquatic invertebrates or other aquatic organisms (Extoxnet, 1996d). *Human Health*: Glyphosate can cause irritation of the eyes and skin, nausea, dizziness (Information Ventures, 2000b), low blood pressure, lung congestion or dysfunction, erosion of the gastrointestinal tract, and kidney damage or failure (Cox, 1995).

Chemical	***Use***	***Environmental Effects***
2, 4-D (acids, esters)	Used to control vascular aquatic plants.	*Fate in the Environment*: 2,4-D has low persistence in soil, with a half-life of less than 7 d. Soil microbes are primarily responsible for breaking it down. Despite its short half-life, 2,4-D has been detected in groundwater supplies in at least 5 states. Very low concentrations have also been detected in surface waters throughout the United States. In aquatic environments, 2,4-D is readily degraded by microorganisms. The rate of degradation increases with increased nutrients, sediment load, and dissolved organic carbon. The half-life of 2,4-D in water under oxygenated conditions is 1 wk to several weeks (Extoxnet, 1996e). *Aquatic Life*: Some formulations of 2,4-D are toxic to fish. Depending on the formulation used, the LC_{50} in cutthroat trout ranges between 1 and 100 mg/L. Channel catfish had less than 10% mortality when exposed to 10 mg/L for 48 h. Green sunfish showed no effect on swimming response when exposed to 110 mg/L for 41 h (Extoxnet, 1996e). *Human Health*: The human health criterion for 2,4-D, which is used to protect people from the carcinogenic risks of consuming water and/or organisms contaminated with 2,4-D, is 10 μg/L for consumption of water plus an organism. This indicates the concentration of 2,4-D that has a 10^{-6} risk of carcinogenicity (USEPA, 1999a). Symptoms of exposure to 2,4-D include nausea, eye irritation, central nervous system effects, gastrointestinal effects, vomiting, diarrhea, convulsions, coma, and liver and kidney damage. Exposure can also cause weakness, muscle twitching, headache, and fatigue. For additional symptoms, refer to NTP's Chemical Repository (NTP, n.d.). Due to conflicting study results, it is unclear whether 2,4-D is carcinogenic (Extoxnet, 1996e).
Antimycin	Used to kill fish.	Environmental fate information was unavailable. *Aquatic Life*: Antimycin is toxic to fish. Toxicity tests indicate that ruffe and brown trout are approximately five times more sensitive to antimycin than yellow perch (Boogaard et al., 1997). Antimycin should be applied when water temperatures are 60 °F or greater (Kentucky State University, n.d.). *Human Health*: Symptoms of acute exposure to Antimycin may include incoordination, impaired reflexes, respiratory distress, and central nervous system depression (USEPA, n.d.). Fish killed by antimycin are not approved for human or livestock consumption (Kentucky State University, n.d.).

Chemical	Use	Environmental Effects
Rotenone	Used to kill fish.	*Fate in the Environment*: The time for natural degradation of rotenone by hydrolysis is governed primarily by temperature. Studies show that rotenone completely degrades within 1 to 8 wk within the range of 10–20 °C. Its half life ranges from 13.9 h to 10.3 d for water temperatures of 24 °C and 5 °C, respectively. Rotenone dissipates quickly (less than 24 h) as a result of dilution and increased rates of hydrolysis and photolysis. Although it can be found in lake sediments, levels approximate those found in water and breakdown of rotenone lags 1 to 2 wk behind water levels. It is uncommon to find rotenone in stream sediments (AFS, 2000). *Aquatic Life*: Fish are more susceptible to rotenone than other aquatic animals. All animals have natural enzymes in the digestive tract that neutralize rotenone. However, fish are more susceptible because rotenone is readily absorbed into their blood through their gills, and thus digestive enzymes cannot neutralize it (AFS, 2000). *Human Health*: Research shows that rotenone does not cause birth defects, reproductive dysfunction, gene mutations, or cancer. When used according to label instructions, rotenone poses little if any hazard to public health. EPA has concluded that the use of rotenone for fish control does not present a risk of unreasonable adverse effects on humans and the environment (AFS, 2000).

6.6.4.5 Summary of Potential Impacts

Antibiotics and Antibiotic Resistance

A variety of antibiotics are heavily used in the CAAP industry, including oxytetracycline, sulfadimethoxine, and sulfamerazine. Effluents produced from these facilities can contain not only appreciable concentrations of the antibiotics themselves but also a variety of bacterial species, some of which are antibiotic-resistant. These antibiotic-resistant strains of bacteria have the potential to confer antibiotic resistance to the resident bacteria in the guts of humans, along with native aquatic bacteria species that are found in the effluent release areas. Many bacteria in aquatic environments have a pronounced capacity for acquisition and transfer of resistance genes. The route of transmission from animals to humans by meat products is well established. The transfer of antibiotic resistance from fish to humans by fish consumption is not as well studied, but it is presumed to occur at the same rates. To assess the impacts of antibiotics and antibiotic resistance on public health, animal health, and ecosystem health, some basic assessments of the types and concentrations of antibiotics used will be necessary to determine whether CAAP effluents should be monitored for excess antibiotics or antibiotic-resistant bacterial species (particularly those that represent a public health risk).

Biological Impairment

One of the most difficult to quantify, and potentially most dangerous, impacts of CAAP effluents is biological impairment. Effluents from CAAP facilities can contain a range of altered species, including antibiotic-resistant microorganisms and escaped organisms. In addition, the dangers of the added drugs and chemicals used for increased production are not well known. Extensive surveys of the amounts and types of chemicals used in aquaculture facilities is necessary, along with an understanding of the impacts of these drugs and chemicals on the surrounding ecosystems.

Another area of acute concern is invasive species introduction from CAAP facilities, which poses serious potential and observed risks to native fishery resources and wild native aquatic species from the establishment of escaped individuals (Carlton, 2001; Hallerman and Kapuscinski, 1992; Volpe et al., 2000). In some regions of the United States, ecological and natural resource threats associated with invasive species are among the most critical concerns facing environmental protection agencies. A particular concern is a potentially higher risk of adverse impacts on native populations that might arise from the introduction of genetically modified organisms ("transgenic organisms"), which are being contemplated for use in this industry (Hedrick, 2001). CAAP facilities also employ a range of drugs and chemicals used both therapeutically that may be released into receiving waters. The absence of adequate information on potential risks to ecosystems and possibly to human health from the consumption of organisms inadvertently exposed to these substances after their release into the environment has led to regulatory action at the regional level to prohibit certain drug and chemical applications (USEPA, 2002a). Finally, CAAP facilities also may inadvertently introduce pathogens into receiving waters, with potentially serious adverse impacts on native biota.

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