CHAPTER 9

ENVIRONMENTAL IMPACTS OF THE AAP INDUSTRY IN THE UNITED STATES

9.1 INTRODUCTION

Concentrated aquatic animal production (CAAP) facilities produce a variety of waste products that are discharged to receiving waters. CAAP facilities, such as those covered by the proposed rule, add nutrients and solid loadings to receiving waters. In the absence of treatment, pollutant loadings from individual CAAP facilities can contribute up to several thousand pounds of nitrogen and phosphorus per year and up to several million pounds of total suspended solids (TSS) per year. Water quality concerns related to these pollutant loadings are among several environmental concerns associated with the CAAP industry. CAAP facilities may also be associated with risks to native fishery resources and wild native aquatic species from the establishment of escaped individuals. Several chemicals and therapeutic drugs are used by the CAAP industry and can be released into receiving waters. CAAP facilities can also be associated with the introduction of pathogens into receiving waters with potential impacts on native biota. This chapter summarizes background information on these environmental concerns.

9.2 WATER QUALITY IMPACTS FROM NUTRIENTS AND SOLIDS

The nutrient (nitrogen and phosphorus) and organic solids generated by CAAP facilities and contained in their effluents have the potential to contribute to eutrophication (e.g., NOAA, 1999). Eutrophication can be defined as an increase in the rate of supply of organic matter in an ecosystem (NSTC, 2000). The increase in organic matter can be caused either by increased inputs from sources outside of the ecosystem (e.g., CAAP effluents, agricultural runoff, or industrial effluents) or by enhanced organic matter production within the ecosystem caused by increased nutrient inputs to the system. Eutrophication can lead to many water resource and aquatic ecosystem effects. Consequences of eutrophication have long been a concern in the protection and development of water resources and include algal blooms, increased turbidity, low dissolved oxygen and associated stresses to stream biota, increased water treatment requirements, changes in benthic fauna, and stimulation of harmful microbial activity with potential consequences for human health (e.g., Dunne and Leopold, 1978, Wetzel, 1983).

Ammonia, which is a form of the nutrient nitrogen, can also be directly toxic to aquatic life, affecting hatching and growth rates of fish. It can also cause changes in the tissues of the liver, kidneys, and gills during structural development (Murphy, 2000a). When un-ionized levels of ammonia exceed 0.0125 - 0.025 mg/L, growth rates of rainbow trout are reduced and damage to liver, kidney, and gill tissue may occur (IDEQ, n.d.).

Solids (both suspended and settleable) can degrade aquatic ecosystems through multiple mechanisms. Suspended solids can increase turbidity and reduce the depth to which sunlight can penetrate, which decreases photosynthetic activity and oxygen production by plants and phytoplankton and potentially causes plant death and oxygen depletion associated with organic matter decomposition. 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 waters by absorbing heat from sunlight. Suspended particles can also abrade and damage fish gills, increasing the risk of infection and disease. Increased levels of suspended solids can also cause a shift toward more sediment tolerant species, reduce filtering efficiency for zooplankton in lakes and estuaries, carry nutrients and metals, adversely impact aquatic insects that are at the base of the food chain, (Schueler and Holland, 2000), and reduce fish growth rates (Murphy, 2000b). Suspended particles reduce visibility for sight feeders and disrupt migration by interfering with a fish's ability to navigate using chemical signals (USEPA, 2000a). As sediment settles, it can smother fish eggs and bottom-dwelling organisms, interrupt the reproduction of aquatic species, destroy habitat for benthic organisms (USEPA, 2000a) 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).

A number of studies have quantified relationships between solid loadings and specific biological endpoints. These include studies relating suspended solids or turbidity levels to stream macroinvertebrate and invertebrate abundance and diversity (Gammon, 1970; Quinn et al., 1992) and reduced growth rates of stream invertebrates (Herbert and Richards, 1963; Buck, 1956). Turbidity and suspended solids have also been associated with reduced food consumption by certain life-stages of such species as striped bass (Brietburg, 1988); coho salmon (Gregory and Northcote, 1993; Redding, 1987); and cutthroat trout (European Inland Fisheries Advisory Council, 1964).

The following subsections describe general characteristics of each major production system that affect the potential of CAAP facilities to discharge nutrients and solids to receiving waters. Descriptions for ponds, crawfish production, lobster pounds, bottom and off-bottom shellfish culture, aquariums, and alligator production systems are not included because they are not subject to the proposed rule.

Flow-Through Systems[1]

Flow-through systems consist of raceways, ponds, or tanks that have constant flows of water through them. Flowing water in the systems is used to maintain water quality in the production system by carrying away accumulating waste products, including feces, uneaten feed, and other metabolic wastes. Discharges from flow-through systems tend to be large in volume and continuous.

Raceway systems typically have quiescent zones located at the tail ends of the raceways to collect solids. The flowing water and swimming fish help move solids down through the raceway. The quiescent zones allow solids to settle in an area of the raceway that is screened off from the swimming fish. The settled solids are then regularly removed from the quiescent zone by vacuuming. Designs, which include baffles or other solids-flushing enhancements, help move solids to the quiescent zones without breaking them into smaller particles. Some systems, typically smaller raceway systems, use full-flow settling in which all of the effluent passes through prior to discharge. Tanks can be self-cleaning or use concentrating devices to collect solids, enabling solids to be efficiently removed from the system. Most facilities treat the collected solids in settling basins or some other type of dewatering process. When solids in tanks or raceways are collected and removed, waste streams from the treatment systems are usually higher in pollutant concentrations, including solids, nutrients, and biochemical oxygen demand than bulk flow discharges.

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[1] Information for the following four subsections was adapted from J. Avault, *Fundamentals of Aquaculture* (AVA Publishing, Baton Rouge, Louisiana, 1996).

Recirculating Systems

Recirculating systems are highly intensive culture systems that actively filter and reuse water many times before it is discharged. Recirculating systems usually have tanks or raceways to hold the growing animals, and they have extensive filtration and support equipment to maintain adequate water quality. Recirculating systems use filtration equipment to remove ammonia from the production water. Solids removal, oxygenation, temperature control, pH management, carbon dioxide control, and disinfection are common water treatment processes used in recirculating systems. The size of the recirculating system depends primarily on available capital to fund the project and can be designed to meet the production goals of the operator.

The production water treatment process is designed to minimize water requirements, which leads to small-volume, concentrated waste streams. A typical recirculating facility has one or more discrete waste streams. Solids removal from the production water produces an effluent that is high in solids, nutrients, and BOD. Most systems add make-up water (about 5 to 10 percent of the system volume each day) to dilute the production water and to account for evaporation and other losses. Some overflow water, which is dilute compared to the solids water, is usually generated.

Recirculating system facilities use a variety of methods to treat, hold, or dispose of the solids collected from the production water. Some facilities send the collected solids, and some overflow water directly to a publicly owned treatment works (POTW) for treatment. Other facilities pretreat in settling ponds or other primary treatment systems to concentrate solids and send a more dilute effluent to the POTW. Still others concentrate solids and then land-apply the solids slurry when practical. The overflow water may be directly discharged, land-applied, or otherwise treated.

Net Pens

Net pens are suspended or floating holding systems used to culture some species of fish in larger water bodies, such as lakes, reservoirs, coastal waters, and the open ocean. The systems may be located along a shore or pier or may be anchored and floating offshore. Net pens rely on tides and currents to provide a continual supply of high-quality water to the cultured animals. In most locations, net pens are designed to withstand the high-energy environments of open waters and are anchored to keep them in place during extreme weather events. 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.

Net pens use a floating structure to support nets, which are suspended under the structure in the water column. The net pens vary in shape but are typically circular, square, or rectangular on the water surface. Their size also varies, depending on the available surface area and depth. A common practice in net pen culture is to use two nets—a containment net on the inside and an outer predator net to keep out predators, such as seals. At the surface, jump nets are used to keep fish from jumping out of the net pen. Bird nets are also suspended above the surface of the net pens to prevent bird predation.

For net pen culture, the mesh size of the netting used to contain the fish is as large as possible to prevent reduced water flows when fouling occurs, while still keeping the cultured fish inside the structure. Most nets are cleaned mechanically with brushes and power washers. Antifoulants have limited use in the United States. A few have been approved for food fish production, but those typically show minimal effectiveness.

Most net pens are regularly inspected by divers. The divers look for holes in the nets, dead fish, and fouling problems. State regulatory programs require benthic monitoring at many net pen sites to ensure that degradation is not occurring under or around the net pens.

9.2.1 CAAP Industry Pollutant Loadings

Pollutant concentrations in CAAP facility process waters are generally low because cultured species require relatively high water quality for optimal production. However, pollutant concentrations in effluents from waste treatment systems (e.g., settling basins) and solids storage structures can be quite high, although discharges typically occur in small volumes. Table 9-1 indicates example raw (in the absence of effluent pollutant reduction treatments) pollutant concentrations from two different kinds of CAAP facilities, as estimated by EPA for CAAP model facilities (Hochheimer and Mosso, 2002b, Mosso, 2002).

Table 9-1

Example Raw Pollutant Concentrations for Flow-Through and Recirculating Model Facilities

	BOD_5 (mg/L)	**TSS (mg/L)**	**NH_3 (mg/L)**	**Organic N (mg/L)**	**NO_2 (mg/L)**	**NO_3 (mg/L)**	**Dissolved P (mg/L)**	**Organic P (mg/L)**
Flow-Through	11.172	9.576	0.010	0.014	0.001	0.023	0.059	0.053
Recirculating	1,838.66	1,576.00	1.58	2.36	0.20	3.77	11.37	8.67

Source: EPA estimates (Hochheimer and Mosso, 2002b).

The values in Table 9-1 do not represent actual facilities but were derived using an engineering model developed by EPA to calculate raw pollutant loadings from model facilities. The model calculates wastes generated in an CAAP system based on feed inputs, which were acquired from literature reviews (Hochheimer and Mosso, 2002b).

In the absence of treatment, CAAP facilities can generate locally significant loadings of pollutants in terms of total annual mass (Table 9-2). These values are derived by multiplying appropriate facility effluent flow rates, as estimated by EPA (Mosso, 2002) for a given facility type by the corresponding raw pollutant concentrations in Table 9-1. Raw pollutant loading estimates are presented in Table 9-2 for several flow-through and recirculating systems model facilities. Raw pollutant loadings from large net pen systems can be equal to or greater than the pollutant loading values shown in Table 9-2.

Table 9-2

Example Model Facility Raw Pollutant Loadings for Flow-Through and Recirculating Systems

Model facility	Effluent flow (ft^3/s)	BOD_5 (lb/yr)	Total Suspended Solids (lb/yr)
Large salmon flow-through	92.7	2,019,852	1,731,301
Medium striped bass flow-through	2.7	62,149	53,271
Medium tilapia flow-through	6.0	155,373	133,177
Large tilapia flow-through	22.3	388,433	332,943
Medium trout flow-through	4.7	77,687	66,589
Large trout flow-through	47.2	1,009,926	865,651
Medium trout stockers flow-through	4.9	77,687	66,589
Large trout stockers flow-through	20.7	466,120	399,531
Large striped bass recirculating	0.1	383,564	328,770
Large tilapia recirculating	0.05	127,855	2,039,478

Note: See text for description of calculation.
Source: Hochheimer and Mosso, 2002b; Mosso, 2002.

Table 9-2 demonstrates that total annual BOD_5 and TSS loadings from medium and large CAAP model facilities can be considerable. To place these annual loadings in context, the BOD_5 and TSS loading from a large salmon flow-through system is equivalent to the BOD_5 and TSS loading in the domestic wasteload of a city with over 20,000 individuals. Appendix D documents the conversion factors for this calculation. Loadings from net pen facilities can also be relatively high. For example, the annual BOD_5 loading produced by a single large salmon net pen facility (e.g., a facility with annual production of over 3 million pounds, estimated to produce over 4 million pounds of BOD_5 per year, is equivalent to the BOD_5 loading in the domestic wasteload of a city of approximately 65,000 people (Hochheimer, 2002).

In addition, when multiple CAAP facilities are located on a single receiving water, which occurs in such states as Idaho and Maine, cumulative pollutant loadings to the receiving water may be correspondingly higher and may be of concern from a stream ecology perspective. EPA's Region 10 identified discharges from CAAP facilities as contributors to phosphorus loadings in the middle Snake River, where over 70 CAAP facilities, several municipal treatment plants, and several food processors were identified. The region adopted strict numeric limits on phosphorus from the CAAP facilities that led to an overall reduction in phosphorus over the past 5 years (Fromm and Hill, 2002). Finally, observations in Idaho receiving waters downstream of aquaculture facilities suggest that in the absence of solids capturing treatments, sediment deposition can occur. Observations of 18 inches or more of organic accumulations downstream of aquaculture facilities in Billingsley Creek, prior to the adoption of solids capturing, and six feet deep below Box Canyon, also prior to solids capturing, have been reported (USEPA, 2002b).

9.2.2 Literature Review on Potential and Observed Water Quality Impacts

EPA performed a literature review for reports of environmental effects associated with aquatic animal production facilities (Tetra Tech, 2001; Mosso, 2002). EPA's review focused on scientific research reports in the United States. EPA also recognizes that research has been performed on the environmental effects of CAAP facilities in other countries (e.g., within the European Union) as well.

Much of the literature reviewed by EPA describes observations of nutrient and solids within the discharge from CAAP facilities. Some of these studies also discuss the release of biochemical or chemical oxygen demand. There are limited studies in which biological variables downstream of CAAP facilities have been measured. Impacts such as the presence of pollution-tolerant benthic invertebrates have been observed; but in other cases, pollutants were not found to negatively impact the receiving stream (e.g., Kendra, 1991; Selong and Helfrich, 1998). Overall, EPA's initial literature search did not identify extensive research literature regarding ecological effects arising from water quality degradation downstream of CAAP facilities in the United States. Appendix E lists publications found in EPA's literature review that describe water quality measurements associated with CAAP facilities, by major production system, as well as citations to additional literature describing aquatic animal production practices or studies outside of the United States.

9.2.3 State Listings of Impaired Waters

Nutrient impacts from aquatic animal production facilities can also be evaluated from reports to EPA on the causes and status of impaired water bodies (TMDL listings or State 303(d) reports). State listings of waters for which CAAP has been identified as a potential source of impairment have been compiled from 1998 and 2000 State TMDL listings (i.e. all 1998 State listings plus any new listings added between 1998 and 2000). Approximately forty-five different sources of impairment have been identified on State TMDL listings. These other sources include general agricultural runoff, hydromodification, and urban runoff. According to these recent reports, seven States (IL, LA, NH, NM, NC, OH, and VA) have identified CAAP facilities as a potential source of impairment for one or more water bodies. Again, however, multiple potential causes of impairment are frequently cited for an impaired water body.

Table 9-3 provides information about water bodies that are listed as impaired, where CAAP has been identified as a potential source of impairment. Data which isolate the exclusive impact of CAAP facilities on stream/river miles, lake/reservoir/pond acres, or square miles of estuaries/bays does not exist. Thus, the values presented in the tables below represent water bodies and areas impacted by a number of sources, where CAAP is one of the potential sources. The table also provides the specific cause (e.g., pollutants) contributing to the impairment and the number of miles or acres affected. Types of causes include nutrients, solids, organic enrichment, benthic degradation, other water quality concerns, and listings where the cause was unknown.

Table 9-3

Impaired Water Bodies Where CAAP is Listed as a Source of Impairment

ID	State	Water Body Name	Stated Cause(s)	Miles	Acres
ILNDDA01_NDDA01	Illinois	L Grassy Creek	Flow Alterations, Nutrients, Siltation, Suspended Solids	4.6	
LA-120201	Louisiana	Lower Grand River and Belle River	Nutrients, Organic Enrichment/Low DO, Pathogens	39.5	2,026.0
LA-120302	Louisiana	Company Canal	Organic Enrichment/Low DO, Pathogens	5.9	183.1
NHL70002010	New Hampshire	Marsh Pond	Phosphorus		59.4
NHL80101150(B)	New Hampshire	York Pond	Phosphorus		180.0
NM-MRG2-20400	New Mexico	Rio Cebolla	Stream Bottom Deposits, Temperature	15.0	23.5
NC_27-86-26	North Carolina	Little Contentnea Creek	Low DO	27.0	
NC_2-SANTEETLAH_LAKE_GRAHA M	North Carolina	Santeetlah Lake	Nutrients		280.0
NC_6-10-1b	North Carolina	Morgan Mill Creek	Unknown	0.3	
NC_6-10b	North Carolina	Peter Weaver Creek	Unknown	0.8	
NC_6-2-(0.5)b	North Carolina	West Fork French Broad	Unknown	0.5	
OH70 1	Ohio	Auglaize River (Blanchard R. To Little Auglaize R)	Habitat Alterations, Siltation, Organic Enrichment/Low DO, Metals	7.5	
OH71 16	Ohio	Flatrock Creek (OH/IN Border To Wildcat Creek)	Flow Alteration, Organic Enrichment/ Low DO, Pathogens	10.1	
OH80 17- 86	Ohio	Bucyrus Reservoir #2	Flow Alteration, Noxious Aquatic Plants, Nutrients, Siltation, Turbidity		36.4
VAV-B10R-02	Virginia	Cockran Spring	Benthic Degradation	16.0	
VAV-B47R-03	Virginia	Lacey Spring	Benthic Degradation	16.0	
VAV-B52R	Virginia	Orndorff Spring Branch	Benthic Degradation	16.0	
VAV-H09R	Virginia	Montebello Spring Branch	Benthic Degradation	0.2	
VAV-I14R	Virginia	Coursey Springs Branch	Benthic Degradation	16.0	
VAV-I32R-01	Virginia	Castaline Spring Branch	Benthic Degradation	16.0	

Summary of Water Bodies Listed as Impaired

The information from Table 9-3 can be summarized by water body type and scope of impact to provide a general summary of the impact of CAAP on impaired water bodies. Table 9-4 summarizes the specific causes of impairment for each water body type. According to the data, streams and rivers have the most reported impairments (sixteen) from causes in which CAAP was a contributing source. Only four lakes, reservoirs, and ponds were listed as impaired, while only no estuaries/bays were reported as impaired.

Table 9-4

Source of Impairment by Water Body Type

Water Body Type	Nutrients	Solids	Organic	Benthic	Other Water	Total Number
Stream/River	X	X	X	X	X	16
Lake/Reservoir/Pond	X				X	4

Table 9-5 provides information about the number of stream/river miles and lake/reservoir/pond acres listed as impaired (where CAAP is a source of impairment) in each State.

Table 9-5

Miles/Acres for Which CAAP is Listed as a Potential Source of Impairment.[a]

State	Miles of Streams/Rivers Impaired	Acres of Lakes/ Reservoirs/Ponds Impaired
Illinois	5	n/a[b]
Louisiana	45	2,209
New Hampshire	n/a	239
New Mexico	15	24
North Carolina	29	280.0
Ohio	18	36
Virginia	80	n/a
Total	**192**	**2,788**

[a] Other sources in addition to CAAP may have been cited as a potential source of impairment by the State
[b] n/a = not available.

Comparison to National Information

Nutrients, solids, organic enrichment, benthic degradation, and other water quality concerns (which as a group include flow alteration, siltation, low dissolved oxygen, turbidity, pathogens, metals, temperature, and habitat alterations) are the leading pollutants in impaired streams and rivers in which CAAP may be a contributing factor to the impairment. Nationally, the leading pollutants causing impairment in streams and rivers are nutrients and other water quality concerns, such as metals and siltation (USEPA, 2000b). Thus, nutrients are frequently identified as a potential cause of impairment both nationally and in waters where CAAP facilities are a potential source of impairment. Additionally, metals and siltation are important causes of impairment both nationally and with CAAP-related listings.

The leading pollutants in impaired lakes, reservoirs, and ponds in which CAAP may be a contributing factor to the impairment are nutrients and other water quality concerns (which include flow alteration, noxious aquatic plants, siltation, and turbidity). Nationally, the leading pollutants causing impairment in lakes, reservoirs, and ponds are nutrients, metals, and siltation (USEPA, 2000b). Thus, nutrients are frequently identified as a potential cause of impairment both nationally and in waters where CAAP facilities are a potential source of impairment. Siltation is also an important cause of impairment both nationally and in water bodies where CAAP may be a source of impairment.

CAAP is listed as one of the sources of impairment for 192 miles of rivers and streams, based on 1998 and 2000 TMDL State listings. Nationally, a total of 291,264 miles of rivers and streams are impaired (USEPA, Appendix A-2, 1998a). For lakes, reservoirs, and ponds, CAAP was listed by the States as a source of impairment for 2,788 acres. By comparison, in the entire United States, a total of 7,897,110 acres of lakes, reservoirs, and ponds are listed as impaired (USEPA, Appendix B-2, 1998b). No information was available about the number of square miles of estuaries and bays listed as impaired, in cases where CAAP was a potential source of impairment. Again, it is important to note that not all of the water bodies in the United States have been assessed.

Comparison to Other Sources of Impairment

To compare the leading pollutants associated with select sources of impairment, information about the types of pollutants generally associated with each source was compiled in Table 9-6. Based on the information in this table, nutrients and solids are the most common pollutants associated with each of the sources of impairment examined.

Table 9-6

Comparison of Leading Pollutants Among Sources of Impairment

Source of Impairment	Pollutants					
	Nutrients	**Solids**	**Organic Matter**	**Pathogens**	**Metals**	**Oil/Grease**
Agriculture	X	X				
Animal Feeding Operations	X	X	X	X		
Natural Sources	X	X	X	X		
Urban Runoff	X	X		X	X	X

The leading sources of impairment in assessed streams, rivers, lakes, reservoirs, and ponds are agriculture, hydromodification, and urban runoff/storm sewers. Hydromodification is defined as the alteration of the hydrologic characteristics of coastal and noncoastal waters, which in turn could cause degradation of water resources (USEPA, 1997). It includes such changes as channelization or channel modification. The leading sources of impairment in estuaries are municipal point sources, urban runoff/storm sewers, and atmospheric deposition (USEPA, 2000b).

The scope of impact on various water bodies can be compared among sources of impairment. Information from Table 9-7, where the scope of impact was provided for those States that reported CAAP as a source of impairment, was compared to the scope of impact for other sources of impairment. For the purposes of this comparison, other sources of impairment include agriculture, animal feeding operations, natural sources, and urban runoff. These other sources are known to be large contributors to the same causes of impairment (e.g., nutrients) as CAAP. Table 9-7 compares the miles of impaired streams and rivers among different sources of impairment.

Table 9-7

Comparison of Sources of Impairment in Rivers and Streams (Miles)

State	CAAP Industry	Animal Feeding Operations	Urban Runoff/ Storms Sewers	Natural Sources	Agriculture
Illinois	5	124	1,865	213	10,977
Louisiana	45	269	1,122	1,377	1,662
New Mexico	15	0	97	221	3,179
North Carolina	28	0	700	0	2,496
Ohio	17	28	508	240	1,121
Virginia	80	0	341	532	842
Total	**192**	**421**	**4633**	**2583**	**20277**

Note: Only States that reported CAAP as an impairment source are listed.
Note: New Hampshire was not included in this table because the number of impaired miles in the State was not provided.
Source: *National Water Quality Inventory, Appendix A-5* (USEPA, 1998a).

Table 9-8 provides information to compare the acres of impaired lakes, reservoirs, and ponds among different sources of impairment. No impairment information was provided for animal feeding operations for this category of water body.

Table 9-8

Comparison of Sources of Impairment in Lakes, Reservoirs, and Ponds (Acres)[a]

State	Urban Runoff/ Storms Sewers	CAAP Industry	Natural Sources	Agriculture
Louisiana	60	2,209	76,397	17,040
New Hampshire	68	239	75	0
New Mexico	18	24	11,357	92,834
North Carolina	470	280	0	74
Ohio	0	36	0	0
Total	**616**	**2,788**	**87,829**	**109,948**

[a] Only States that reported CAAP as an impairment source are listed. Illinois and Virginia were not included in this table because the number of impaired acres in these States was not provided.
Source: *National Water Quality Inventory, Appendix B-5* (USEPA, 1998b).

Comments

It is also important to recognize that not all water bodies have been assessed in every State and the percentage assessed may vary widely. In some States, a very small percentage of water bodies have been assessed. In other States, most or all of the water bodies have been assessed. For example, it is reported that Louisiana has only assessed 9 percent of their rivers and streams (USEPA, 1998a) and that Ohio has not assessed any of their lake, reservoir, and pond acres (USEPA, 1998b). In contrast, North Carolina has assessed 89 percent of their river and stream miles (USEPA, 1998a) and New Hampshire has assessed 95 percent of their lake, reservoir, and pond acres (USEPA, 1998b). Differences in percentage of water bodies assessed makes comparisons among States difficult. More important, for States that have a low percentage of assessed water bodies, conclusions from limited data may not accurately represent the condition of a State's water bodies. Finally, when more than one source of impairment and more than one pollutant are listed for a water body, it is difficult to determine which source of impairment is "responsible" for which pollutant. For example, if CAAP and animal feeding operations (AFOs) are both listed as the sources of impairment and nutrients and pathogens are both listed as the pollutants causing impairment, such a listing makes it appear as if the nutrients and pathogens are caused by both sources. It is possible that CAAP may not be a source of pathogens for that particular listed water body. As a result, 303(d) data can complicate linkages between sources of impairment and pollutants.

9.3 NON-NATIVE SPECIES

Another area of concern regarding environmental impacts of CAAP facilities relates to potential introductions of non-native aquatic organisms via intentional or accidental releases from CAAP facilities. Non-native species can be defined as an individual, group, or population of a species that is introduced into an area or ecosystem outside its historic or native geographic range. This term may include both foreign (i.e., exotic) and transplanted species, and it can be used synonymously with "alien" and "introduced" (Fuller et al., 1999). There is some inconsistency in the terminology used by literature and scientists when discussing non-native species. The following terms are also used and their differences should be noted:

- *Aquatic nuisance species* (ANS) – nonindigenous species that threaten the diversity or abundance of native species; the ecological stability of infested waters; or commercial, agricultural, aquacultural, or recreational activities dependent on such waters (Fuller et al., 1999).

- *Exotic species* – an organism introduced from a foreign country; a species native to an area outside of, or foreign to, the national geographic area under discussion (Fuller et al., 1999).

- *Nonindigenous species* – synonymous with non-native species (Fuller et al., 1999).

- *Introduced* – An organisms moved by humans (or by human actions) to an ecosystem, or region where it was not found historically due to human actions (i.e., an individual, group, or population of organisms that occur in a particular locale because of human actions (Fuller et al., 1999).

- *Invasive species* – a species that is 1) non-native (or alien) to the ecosystem under consideration and 2) whose introduction causes or is likely to cause economic or environmental harm or harm to human health (USDA, 2002).

Scientists and resource managers have identified CAAP as a potential source of concern with respect to non-native species issues (e.g. Alaska Department of Fish and Game, 2002; Carlton, 2001; Goldburg et al., 2001; Naylor et al., 2001; and Volpe et al., 2000). In addition, scientists have highlighted concerns related to potential risks associated with the possible future use of genetically modified organisms in aquatic animal production (e.g. Hedrick, 2001; Reichardt, 2000).

9.3.1 Impacts of Non-Native Species

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

Many non-native 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 non-natives 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 non-native aquatic organisms on native aquatic species in North America can be classified into five general categories, which include habitat alteration, trophic alteration, spatial alteration, gene pool deterioration, and introduction of diseases.

Habitat Alteration

Non-native fish, such as carp or 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 may adversely impact 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.).

Trophic Alteration

Non-native species may also cause complex and unpredictable changes in community trophic structure. Communities can be changed by explosive population increases of non-native 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.).

Spatial Alteration

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

Gene Pool Deterioration

Heterogeneity may 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 has a limited gene pool to begin with. If these species are introduced to new habitat, they may lack the genetic characteristics necessary for them to adapt or perform as predicted. There is also a possibility that native gene pools may be altered through hybridization when non-native species are introduced to a habitat. However, hybridization events in open waters are rare (AFS, 1997; Kohler and Courtenay, n.d.).

Introduction of Diseases

Non-native species may transmit diseases caused by parasites, bacteria, and viruses to an environment. The transmission of diseases from non-native species to native species is considered one of the most serious threats to native communities (AFS, 1997). There are numerous examples of non-native species introducing diseases in native species. Transfer of diseased non-native 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, may have been transferred from Asia throughout the temperate zone with fish shipments (Kohler and Courtenay, n.d.).

9.3.2 Case Studies of Non-Native Species

EPA reviewed the literature for examples that illustrate the potential or actual role of aquatic animal production in releases of non-native species. Several examples are presented below describing Atlantic Salmon and several carp species.

Atlantic Salmon

Atlantic salmon (*Salmo salar*) are native to the Atlantic Coast drainages from northern Quebec to the Housatonic River in Connecticut; inland to Lake Ontario. They are also found in eastern Atlantic drainages from the Arctic Circle to Portugal (USGS, 2000b). Atlantic salmon are raised in net pens off the East and West Coasts of the United States and in British Columbia. Escapement has become a critical concern due to potential impacts from disease, parasitism, interbreeding, and competition. In areas where the salmon are exotic, most concerns do not focus on interbreeding with other salmon species. Rather, they center 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).

Smolts and adult salmon are lost mainly as a result of operator error, predation, storms, accidents, and vandalism. However, it is important to note that escapement reports may not always be accurate. While most escapement reports involve large numbers of fish, small escapements are often unnoticed or unreported. Leakage may occur from small holes in the net, during handling, or during transfer of fish to another cage. Therefore, the number of escapements may be considerably greater if small escapes were accounted for (Alverson and Ruggerone, 1998). It is also important to consider the fact that losses of salmon from net pens may not always result from escapements. Fish may be lost because of decomposition of carcasses or scavenging by birds, mammals, and fish (Nash, 2001). As a result, this could reduce the estimated number of escapes. Reported escapes of Atlantic salmon in the United States are summarized in Table 9-9.

In addition to accidental escapes, some Atlantic salmon have been introduced intentionally. Between 1951 and 1991, the State of Washington released 76,000 Atlantic salmon smolts into the Puget Sound Basin in an attempt to establish this species on the west coast (Nash, 2001).

Table 9-9

Atlantic Salmon Escapements in Maine and Washington

Year	Area	No. of Escapes	Comments	Reference
Maine				
1996	Trumpet Island	18,000	Approximately 18,000 fish escaped when seals ripped open one net pen.	Lewis, 2002, personal communication
2000	Maine	22,315	Atlantic salmon escaped off the coast of Maine, near one of the rivers where wild Atlantic salmon are listed as endangered. The fish escaped from a net pet, when a boat slammed into the pen and tore a hole. The number of escaped fish reported by Clancy (2000) was 13,000. However, the Department of Marine Resources reported the number of escapes as 22,315.	Clancy, 2000; Lewis, 2002, personal communication
2000	Maine, Stone Island	170,000	Atlantic salmon escaped from net pens when a December Northeaster rocked Maine's Machias Bay and uprooted the pen's moorings. The number of fish that escaped has frequently been reported as 100,000. However, the actual number, which was obtained from the Department of Marine Resources, was 170,000.	Daley, 2001; ASF, 2001; Lewis, 2002, personal communication
2001	Maine	3,000-5,000	Atlantic salmon escaped from a net pen in Eastport, Maine.	Daley, 2001; ASF, 2001
Washington				
1996	Cypress Island	107,000	Atlantic salmon smolt and adults escaped from net pens near Cypress Island	Amos and Appleby, 1999; Appleby, 2002, personal communication; Mottram, 1996; Goldburg and Triplett, 1997
1997	Bainbridge Island	369,000	Atlantic salmon escaped near Bainbridge Island when the net pens were damaged pens as they were towed away from a toxic algae bloom.	Amos and Appleby, 1999; Appleby, 2002, personal communication; Mottram 1999
1999	Bainbridge Island	115,000	Atlantic salmon escaped from pens near Bainbridge Island when extreme tidal flows snapped anchor lines.	Amos and Appleby, 1999; Appleby, 2002, personal communication

It is also important to note the number of escapes of Atlantic salmon in British Columbia because these fish may end up in U.S. waters. Between 1987 and 1996, an estimated 154,554 Atlantic salmon were reported to have escaped from marine farms in British Columbia. These losses do not include "leakage," which could be substantial over time and may double estimated escapes as a worst-case scenario (Alverson and Ruggerone, 1998). Additionally, the average number of escapees in British Columbia reported from 1992 to 1996 was approximately 42,000 fish per year (EAO, 1997). Specific examples of escapements of Atlantic salmon in British Columbia include the following (Alverson and Ruggerone, 1998):

- Based on a 1994 report, 7,000 Atlantic salmon escaped from a trucker tank spill at Morstrom Lake.
- In the same year, more than 20,000 salmon escaped at Johnstone Strait because of seals.
- Over 21,000 salmon escaped at Johnstone Strait in 1994 because of a break in the mooring lines.
- In 1995, more than 31,000 salmon escaped because of a 15-foot tear at 30 feet depth.
- 40,000 young Atlantic salmon escaped in 1996 from a net pen in Georgia Lake.

Although it remains uncertain whether escaped Atlantic salmon can definitely transfer diseases, it is useful to examine some biological information on escaped salmon, which was reported by the Environmental Assessment Office (EAO) of British Columbia. Between 1991 and 1995, ninety 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 tested fish 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 may result in significant cumulative mortality. Fish that survive become carriers of the disease. VHS is enzootic 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 (*O. 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 refractory to VHS (McAllister, 1990).

Common Carp

Common carp (*Cyprinus carpio*), which are also referred to as German carp, European carp, mirror carp, leather carp, and koi, are native to Eurasia. There is some uncertainty concerning when and where they were first introduced into the United States (USGS, 1999). However, early reports state that common carp were brought to the United States from Europe in 1831. After that time, common carp were produced and distributed throughout the Upper Mississippi River System (USGS, 2001a). Common carp can be used as an example to show how other carp species can become an environmental problem.

The common carp can be considered a nuisance species because it is widely distributed throughout the United States and it detrimentally affects aquatic habitats (USGS, 1999). Richardson et al. (1995) found that common carp adversely affect biological systems, causing increased turbidity and destruction of vegetated breeding habitats for birds and fish. The carp stirs up bottom sediments during feeding, which increases turbidity and siltation (Lee et al., 1980). This type of behavior also destroys rooted aquatic plants, which provide habitat for native fish species and food for waterfowl (Dentler, 1993). Laird and Page (1996) also found that common carp might compete with ecologically similar species such as buffalos and carpsuckers.

Common carp sometimes prey on the eggs of other fish species (Taylor et al., 1984; Miller and Beckman, 1996). This may have caused the decline of the razorback sucker (*Xyrauchen texanus*) in the

Colorado River basin (Taylor et al., 1984). Additionally, Miller and Beckman (1996) found white sturgeon (*Acipenser transmontanus*) eggs in the stomachs of common carp in the Columbia River.

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 to aquatic animal production facilities in Alabama and Arkansas and is used for biological control of vegetation. The first release of grass carp occurred in Arkansas, when fish escaped from the Fish Farming Experimental Station (Courtenay et al., 1984). Grass carp were first documented in the Mississippi River along Illinois in 1971 (USGS, 2001a). In the last 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 (Pflieger, 1975; Lee et al., 1980; Dill and Cordone, 1997).

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, 2001b). Measures should also be taken to reduce the number of escapes by these fish. Barriers could be constructed and maintained to prevent migration from lakes. Additionally, consideration should 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, 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 only digest half of the plant material that 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* (Hoffman and Schubert, 1984; Ganzhorn et al., 1992).

Other Species of Carp

Black carp (*Mylopharyngodon piceus*), which are also known as Asian black carp, black amur, snail carp, and Chinese roach, are native to eastern Asia, from the Pearl River basin in China north to the Amur River (USGS, 2000a). Black carp are currently maintained in research, resource management, and other fish production facilities in several States and were first brought into the United States in the early 1970s as a "contaminant" in imported stocks of grass carp. In the early 1980s, black carp were imported as a food fish and as a biological control agent to combat the spread of yellow grub *Clinostomum* *margaritum* in aquaculture ponds (Nico and Williams, 1996). Although black carp have been in the United States for about 30 years, they have not been found in the wild (USFWS, 2002).

Although Asian black carp provide a cheap means for controlling trematodes in catfish ponds, they feed on many different mollusks. This may pose an ecological risk in the Mississippi Basin because black carp are currently held in eight southern States and 90 percent of the freshwater mollusks designated as threatened, endangered, or of special concern are found in the Southeast. Additionally, black carp have escaped and colonized open water in all other countries where they have been introduced. Although most of the carp in the eight States are in sterile triploid form, Mississippi permitted the use of fertile diploids in 1999 in response to a major outbreak of trematodes. This caused fishing and conservation groups to petition for black carp to be listed as "injurious" under the Federal Lacey Act (Naylor et al., 2001). The U.S. Fish and Wildlife Service has proposed to list black carp as an injurious species (67 FR 49286, July 31, 2002).

Black carp are very similar to grass carp. The body shape and size and the position and size of both the eyes and fins are similar with both species. Additionally, it is difficult to distinguish between juveniles of the two species. Nico and Williams (1996) expressed concern that if black carp become more common in U.S. aquaculture, there will be an increased risk of accidental introductions as grass carp if the two species are identified incorrectly.

Silver and bighead carp are two Asian carp that have been identified as species of significant, immediate concern to aquatic resource managers. Bighead carp first began to appear in open waters in the Ohio and Mississippi rivers in the early 1980s "likely as a result of escapes from aquaculture facilities" (Jennings 1988, as cited in Fuller et al., 1999). According to the International Joint Commission (Schomack and Gray, 2002), Asian carp pose a tremendous threat to the biological integrity of the Great Lakes and may result in economic and ecological damages to the Great Lakes ecosystem that far exceed those brought about by the previous introduction of the sea lamprey and the zebra mussel. The International Joint Commission recently urged that U.S. and Canadian governments should consider implementing regulatory controls to prevent introduction of Asian carp via other pathways including the food and bait fish industries, the aquarium trade, and aquaculture (Schomack and Gray, 2002).

9.4 PATHOGENS

CAAP facilities are not considered a source of pathogens that adversely affect human health. CAAP facilities culture cold-blooded animals (fish, crustaceans, mollusks, etc.) that are unlikely to harbor or foster such pathogens (MacMillan et al., 2002). Although it is possible for CAAP facilities to become contaminated with human pathogens (e.g., by contamination of facility or source waters by wastes from warm-blooded animals) and, as a result, become a source of human pathogens, this is not considered a substantial risk in the United States (MacMillan et al., 2002).

On the other hand, some CAAP facilities may serve as sources of pathogens that adversely affect aquatic organisms (JSA, 1997). 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, 1997). The Pacific Northwest Fish Health Protection Committee (PNFHPC) has established policies to prevent the spread of pathogens that might lead to release from hatcheries of seriously infected salmon (Strom et al., n.d.). With respect to fish hatcheries, however, while they may potentially be reservoirs of infectious agents (due to higher rearing densities and stress), little evidence suggests that disease transmission to wild stocks from hatcheries occurs routinely (Strom et al., n.d.).

9.5 DRUGS AND OTHER CHEMICALS

A number of drugs and chemicals are in use at CAAP facilities. For example, formalin and hydrogen peroxide are used to control fungus on salmon and esocid eggs (Hochheimer and Mosso, 2002a). In addition, antibiotics are also used at CAAP facilities, are typically incorporated into feed, and can ultimately be released into the environment. Once in the environment, antibiotics are most commonly bound to sediment and other particles. Prolonged exposure to residual antibiotics can alter target organisms, making them antibiotic resistant with effects that may spread beyond the original area of use (NOAA, 1999).

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

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

The U.S. Food and Drug Administration (FDA)/Center for Veterinarian Medicine (CVM) regulates animal drugs under the Federal Food, Drug, and Cosmetic Act (FFD&CA). Four categories of drugs are used in aquaculture: (1) six commercial drugs currently approved for specific species, specific diseases, and at specific doses or concentrations; (2) investigational new animal drugs which are used under controlled conditions under an Investigational New Animal Drug (INAD) application; (3) other veterinary and human drugs as determined by a veterinarian under the extra-label use provisions of the Animal Medicinal Drug Use Clarification Act of 1994 (AMDUCA); and (4) drugs designated by FDA as low regulatory priority. The use of these drugs is regulated by FDA/CVM, which requires that users read the label directions to ensure that the product is used in a safe and effective manner. The label directions may include directions on proper dilution before discharge and can require other conditions that affect the amount of drug contained in effluents. FDA/CVM approves new animal drugs based on scientific data provided by the drug sponsor. This data includes environmental safety data that is used in an environmental risk assessment for the drug (Eirkson et al., 2000).

Reviews of literature relating to drugs and chemicals used in aquaculture have been published (e.g., GESAMP 1997; Boxall et al., 2001). Although these reviews are not focused on practices in the United States, certain observations may have relevance to the United States. GESAMP (1997) reviewed chemicals used in coastal aquaculture, which include chemicals associated with structural materials, soil and water treatments, antibacterial agents and other therapeutic drugs, pesticides, feed additives, and anaesthetics. According to this review, most aquaculture chemicals, if properly used, can be viewed as wholly beneficial with no adverse environmental impacts or increased risks to aquaculture workers. However, the authors identified several factors that could make the use of otherwise acceptable chemicals unsafe: these include excessive dosage and failure to provide for adequate neutralization or dilution prior to discharge. Among potential environmental issues of concern relating to improper use include chemical residues in wild fauna, toxic effects in non-target species, and antibacterial resistance. The authors conclude with recommended measures to promote safe and effective use of chemicals in coastal aquaculture.

Boxall et al. (2001) present a summary of environmental impacts from drug use in aquatic animal production that includes a comprehensive review of the potential impacts of oxytetracycline, which is the most widely used antibiotic medication at CAAP facilities in the United States. Because most CAAP treatments with medications use medicated feed and treatment baths, the direct application of the drug to the production water presents higher risks for water quality and ecological problems. In net pen systems, the production water is the receiving water and any uneaten or residual drug directly transfers to the water around and bottom sediments under the net pen. For other CAAP facilities, like flow-through and recirculating systems, much of the unmetabolized drug can be bound to feces and other solids in the effluent. Unless all of the solids are captured in these systems, some of the drug is released to the surrounding receiving water bound to the released solids, as well as any of the drug still in aqueous forms.

Using oxytetracycline as an example, the drug is administered through the feed, which presents several challenges. Oxytetracycline is administered in the feed, to sick fish that often have reduced appetites. Most forms of oxytetracycline are not readily assimilated by the fish, so much of the medication in the feed eaten by the fish passes through unmetabolized. Boxall et al. (2001) reported that oxytetracycline is very persistent in manures and manure slurries, soils, and sediments with detection in these media ranging from 9 to over 400 days post treatment. These bound forms of oxytetracycline create the potential for uptake by non-targeted species (i.e., wild populations of fish, crustaceans, and other organisms). Some of the studies reported by Boxall et al. (2001) indicate evidence of oxytetracycline residue in wild species (see Capone et al., 1996 for an example from net pen systems in the western United States).

In the United States, some attention has been given to potential water quality and environmental effects of the release of drugs and chemicals into receiving waters (e.g., Goldburg et al., 2001). EPA's Region 10 office has included requirements in a general permit for CAAPs in Idaho to submit data on disease control drugs, disinfectants, and similar products. As stated in the proposed permit, these data would be used to enable EPA to determine whether there is a reasonable potential for the effluent discharge to cause or contribute to an instream excursion above the state of Idaho's water quality standards. In addition, in the Response to Comments document accompanying the proposed permit, EPA noted that such data were deemed necessary to determine whether aspects of these products' application may have adverse effects on aquatic biota (USEPA, 2002b). Similarly, in a final permit issued to a salmon net pen CAAP in Maine, EPA's Region 1 office required certain limits and monitoring requirements to ensure that the discharge of some chemicals will meet state water quality standards. These provisions include limiting of the discharge of drugs to those approved by FDA for treatment of salmonids; prohibition of prophylactic use of drugs except for specific situations which warrant such use; monthly reporting requirements regarding drug use; monitoring for the presence of copper in sediments if nets are impregnated with copper-based antifoulants; and monitoring for the presence of zinc in sediments if feed contains zinc additives. In addition, EPA reserved the right to require the permittee to monitor the discharge of FDA approved drugs if EPA suspects that the frequency, concentration, or method of application creates a reasonable potential to cause or contribute to a violation of state water quality standards (USEPA, 2002a).

9.6 OTHER POTENTIAL IMPACTS

Maintenance of the physical plant of aquaculture facilities can generate organic materials that may contribute to water quality degradation (NOAA, 1999). For example, the activity of cleaning fouling organisms from net pens can contribute solids, BOD, and nutrients, although these inputs are generally produced only over a short period of time. Cleaning algae from flow-through raceway walls and bottoms similarly generates pollutants in effluent. Net pen facilities in both Maine and Washington are prohibited from cleaning net pens in place and must take them onshore for cleaning.

Some concern about the potential presence of contaminants (e.g., PCBs, dioxins, pesticides, and mercury) in aquatic animals produced at CAAP facilities has been reported and debated in the technical literature. EPA found limited evidence that contaminants, primarily from feed ingredients, could be infrequently present in the aquatic animals and presumably in the effluents. EPA also found that the most comprehensive studies indicate very few problems associated with such contaminants in aquatic animals produced at CAAP facilities.

The Massachusetts Office of Coastal Zone Management asserts that the fish consumption advisories set by the Department of Public Health do not pertain to fish cultured in aquaculture facilities because fish from aquaculture facilities come from clean water sources and do not bioaccumulate contaminants during the short time they are being grown out to market size (Massachusetts Office of Coastal Zone Management, 2001). The World Bank Group argues that aquaculture facilities can minimize public health risks by proper site evaluation and good aquacultural practices because operators of aquaculture facilities have more control over the environment of their cultured fish than anyone has over wild fish, and can therefore reduce health risks (The World Bank Group, 2001).

The Pennsylvania Department of Environmental Protection laboratory conducted testing from Pennsylvania Fish and Boat Commission hatcheries revealed levels of PCBs in trout did not warrant a fish consumption advisory, as the hatchery fish were below the Food and Drug Administration (FDA) tolerance level of two parts per million (ppm). In fact, the PCB levels were found to be less than 0.10 ppm (Pennsylvania Department of Health, 2001; Fish and Boat Commission, 2001). Santerre et al., (2000) studied contaminants in channel catfish, rainbow trout, and red swamp crayfish collected from 8 southern States in the United States. The research revealed that 45% catfish, 72% trout, and 92% crayfish contained no detectable residues of organochlorine, organophosphate, pyrethroid compounds. Of the detectable residues, most were well below FDA action limits for fish. Chlorpyrifos was detected in some samples of catfish, but there is not an established limit for this and these residues were not found in fish collected after the first year of study (Santerre et al., 2000). This study also showed that levels of mercury in the fish were 40 to 100 times lower than the 1-ppm limit set by FDA. In a related study, these researchers found very low levels of 34 pesticides in the same fish species (Scientific America, 2001).

Results from these studies tend to indicate that most aquaculturally grown fish contain very low and safe amounts of potentially harmful pollutants. When they occur, the most likely source of these pollutants is the feed or ingredients used to formulate the feed, although source water or local soil conditions could contribute pollutants as well. A study conducted by Rappe et al., (1998) analyzed a combined catfish feed sample from Arkansas and concluded that one of its ingredients (soybean meal) was highly contaminated with polychlorinated dibenzo-p-dioxens (PCDDs). A more extensive study by the same researchers showed that samples of farm-raised catfish from the southeast US contained significant levels of PCDD, polychlorinated dibenzofurans (PCDF), and PCB. They concluded that the major source for the PCDD, PCDF, and PCB appeared to be from the feed, which, as discovered earlier, contained high levels of PCDD (Fiedler, 1998). The source of contaminants in the catfish feed was identified and subsequently eliminated from the feed ingredients.

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