Antibiotic Drug Use in U.S. Aquaculture

Dr. Charles M. Benbrook
The Northwest Science and Environmental Policy Center
Sandpoint, Idaho

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"the increasing problems associated with infectious diseases in fish, the limited number of drugs available for treatment and prevention of these diseases, and the rapid increase in resistance to these antibiotics represent major challenges for this source of food production worldwide."

-American Society of Microbiology Task Force on Antibiotic Resistance (ASM 1994)

Introduction

A number of recent reports, press releases and on-going investigations have raised legitimate public concerns about the safety of antibiotic drug usage in aquaculture (e.g., Alderman and Hastings; 1998; Goldburg et al. 2001). Establishing the exact level of drug use and potential dangers is difficult due to lack of data, fragmented laws, regulations, jurisdictions and interpretations of reporting guidelines (OTA 1995) and large quantities of aquaculture imports from countries where legal and illegal drug use may escape documentation.

In the United States, with one exception (NAHMS 1997), there are no public sources of aquaculture drug use data. Regulators and scientists from the Joint Subcommittee on Aquaculture (JSA), the Federal Drug Administration (FDA), United States Department of Agriculture (USDA) and the Environmental Protection Agency (EPA) who work on fish drug use and the environmental impacts of aquaculture have no solid basis to estimate antibiotic drug use. There are some estimates, but these rely on industry sources and ad hoc data compiled during inspections associated with water quality enforcement actions. Industry trade publications and academic publications report that antibiotic use in most segments of the U.S. aquaculture industry is declining (e.g., MacMillan 2001) but there is no proof offered or method to verify. Moreover, recent developments in the aquaculture industry have led to development of drugs with increased potency. Given the speculation regarding drug use in aquaculture the estimates in this report should be considered preliminary. Government agencies need to take up the task of determining precisely the nature of antibiotic use and the impacts of this use on public and animal health.

Why Worry About Antibiotic Use in Aquaculture?

The 1994 American Society of Microbiologists (ASM) antibiotic resistance task force report targets aquaculture as representing 'one of the biggest concerns'. Several summary points are made:

1. Although aquaculture production is growing rapidly, disease prevention and treatment practices are far from standardized or regulated.
1. When antibiotics are used in aquaculture, the drugs typically remain in the open environment and may flow out of production facilities into open waterways or sewage systems, where they may also interact with other environmental contaminants.
1. The antibiotics typically used are also important in treating human disease and infection.
1. Impacts of all these factors on the emergence of antibiotic resistance are unknown. However, we do know the following:
    a. Studies demonstrate an increase in resistant bacteria in the intestines of fish receiving antibiotic drugs. (ASM, 1994 citing Ervik, 1994*)*

a. Recent studies indicate the level of resistant bacteria in the gut of wild fish is affected during antibiotic treatment of farmed fish. (ASM, 1994 citing Ervik, 1994)
a. A total of 74-100 percent of wild fish in close proximity to treated ponds contained quinolone residues – a group of antibiotics (e.g., CIPRO) important in human health (ASM, 1994 citing Ervik, 1994)
a. Prior to medication 0.6 – 1 percent of the fecal bacteria in wild fish were resistant to oxacillin and oxytetracycline, respectively. (ASM, 1994 citing Ervik, 1994)

European researchers have made significant progress in understanding the mechanisms through which antibiotic resistant bacteria that emerge on fish farms can move to humans. First, a team of British and Irish scientists documented the distinct movement of resistant bacterial pieces of DNA from fish hatcheries into *E. coli* and *Aeromonas* species isolated from patients in hospitals (Rhodes et al. 2000). They concluded that:

> "Collectively, these findings provide evidence to support the hypothesis that the aquaculture and human compartments of the environment behave as a single interactive compartment." (Rhodes et al. 2000)

Second, Danish researchers found that many bacteria in and around four trout farms were resistant to "most antibiotic agents presently available for use in Danish aquaculture" (Schmidt et al. 2000). While there are some barriers (e.g., water temperature) to the spread of many common bacteria from fish to humans, there are pathways unique to aquaculture. For example, ornamental fish imported from abroad are often aggressively treated with antibiotics prior to export to the United States. Since ornamental fish are brought into the home and people come into contact with the fish and the water and tanks they are kept in, they can serve as another source of multiple antibiotic resistant bacteria.

Third, in Ecuador, which exports a large quantity of pond-raised shrimp to the United States a cholera outbreak was suspected to be linked to inappropriate use of antibiotics in industrial shrimp farming practices (Weber et al. 1994). What becomes clear in each of these cases is that a number of highly complex environmental scenarios emerge that can lead to bacterial resistance transfers from aquaculture practices to humans.

Attention is urgently needed on aquaculture drug use because it is probable that antibiotic selection pressure in aquaculture systems is intensifying. This is so because there are so few drugs approved for use in U.S. aquaculture (see Appendix 1). The lack of choice increases the potential for abuse and misuse by growers who sometimes use legal drugs, illegal drugs and as FDA (1998) puts it "general-purpose chemicals that are not labeled for drug use, and approved drugs in a manner that deviates from the labeled instructions."

Uses of Antibiotics in Aquaculture

All drugs legally used in aquaculture must be approved by the FDA's Center for Veterinary Medicine. Standard information on approved drug uses is presented in the FDA's 'Green Book', (FDA 1998) as well as a number of entries into the Code of Federal Regulations, Title 21, Volume 5. This information includes drug ingredients, manufacturer, species, route of delivery, dose form, withdrawal times, tolerances, and uses by species, including dose rates and limitations. The most common route of delivery of these legal antibiotics to fish occurs through mixing with specially formulated feed. However, fish do not effectively metabolize antibiotics and will pass them largely unused back into the environment in the feces. It has been estimated that 75 percent of the antibiotics fed to fish are then put into the water through excretion (Goldburg and Triplett 1997).

There are five drugs currently legal for use in U.S. aquaculture. These include just three antibiotics: oxytetracycline HCL (Terramycin 10), sulfamerazine, and a combination drug containing sulfadimethozine and ormetoprim (Romet-30). Table 1 provides an overview of drugs approved by the Food and Drug Administration for specific aquaculture uses.

Despite the often-encountered claim that there are no antibiotics used for growth promotion in aquaculture, a National Seafood HACCP Alliance for Training and Education Compendium identifies 'growth' as one the reasons why producers administer antibiotics (FDA 1998). In Chapter 22, the compendium lists the following reasons for use of drugs in aquaculture production:

- Affect reproduction and growth
- Treat and prevent disease
- Control parasites
- Tranquilization

Contemporary Use Estimates

Estimates are developed to project antibiotic use for major aquaculture species. The best data available to estimate antibiotic use is in industrialized catfish culture, the species that accounts for over two-thirds of total U.S. aquaculture industry production.

Total catfish antibiotic use is estimated to fall between 126,000 and 252,000 pounds annual to treat ESC (Enteric Septicemia of Catfish). Despite significant drug use, losses in catfish production remain as high as 60 percent, with diseases accounting for by far the largest share (NAHMS 1997). Trout and salmon production account for about 12 percent of total aquaculture industry output. We estimate antibiotic use in these species at between 63,000 and 104,600 pounds, with use in salmon production rising the most rapidly. Use in other species likely falls within the range 15,200 to 76,000 pounds annually. *Accordingly, total aquaculture industry use is estimated to fall between 204,000 and 433,000 pounds across the whole industry.* This level of use represents about 2 percent of non-medical use in beef, swine, and poultry production, and about half the level of use in companion animals, as estimated by Mellon et al. (2001) in *Hogging It: Estimates of Antimicrobial Abuse in Livestock.*

Given lack of attention to data collection, current disease reporting and aquaculture product quality surveillance systems, it would be likely that short-term spikes in antibiotic use would not be detected by government regulatory officials or public health experts. This blind-spot in knowledge of antibiotic drug use in aquaculture is serious because the odds of resistant bacteria emerging and spreading beyond farm production sites are greatest during periods of intensive use.

Table 1. Drugs Approved for Use in Aquaculture by the FDA

Drug	Tradename	Supplier	Species	Indications	Dosage	withdrawl	Route
OXYTETRACYCLINE HCL (Antibiotic)	**Terramycin ® 10**	Pfizer, Inc (feed use)	salmonids	For control of ulcer disease caused by Hemophilus piscium, furunculosis caused by Aeromonas salmonicida, bacterial hemorrhagic septicemia caused by A. liquefaciens, and pseudomonas disease.	2.5 - 3.75g / 100 pound fish/ day for 10 days	7d - 21d	Used in feed
			catfish	For control of bacterial hemorrhagic septicemia caused by A. liquefaciens and pseudomonas disease.	2.5 - 3.75g / 100 pound fish/ day for 10 days	21d	Used in feed
			lobster	Control of gaffkemia casued by Aeorccus viridan	1g/pound of feed: Sole ration for 5 days	30d	Used in feed
SULFAMERAZINE (Antibiotic) - not currently marketed	**Sufamerazine in Fish Grade**	Roche Vitamins	trout	Control of furunculosis in salmonids casued by Aeromonas salmonicida	10g/100 pounds of fish per day	21d	
SULFADIMETHOZINE - ORMETOPRIM COMBINATION (Antibiotic)	**Romet ® -30**	Hoffmann-LaRoche	salmonids	Control of furunculosis in salmonids casued by Aeromonas salmonicida	50mg/kg/day for 5 days	42d	Used in feed
			catfish	Control of enteric septicemia of catfish caused by Edwardsiella ictaluri strains	50mg/kg/day for 5 days	3d	Used in feed
FORMALIN (Antiseptic)	**Formalin-F**	Natchez Animal Supply Co.	Salmon/Trout eggs	control of protozoa	1000-2000 microliters per liter		Water, Ambient
			Catfish, Largemouth bass and Bluegill	Control of protozoa	15-250 microliters per liter (dependent on temperature, species and type of pond)		Water, Ambient
			Salmonids, reared	Control of protozoa	15-250 microliters per liter (dependent on temperature, species and type of pond)		Water, Ambient
	Paraside-F	Argent Laboratories	Salmon/Trout eggs	Control of fungi of the family Saprolegniaceae on the eggs of salmon, trout and pike	1000-2000 microliters per liter		Water, Ambient
			Catfish, Largemouth bass and Bluegill	Control of protozoa	15-250 microliters per liter (dependent on temperature, species and type of pond)		Water, Ambient
			Salmonids, reared	Control of protozoa	15-250 microliters per liter (dependent on temperature, species and type of pond)		Water, Ambient
	Parasite-S ®	Western Chemical	Salmon/Trout eggs	Control of external protozoa	1000-2000 microliters per liter		Water, Ambient
			Other finned fish	Control of external protozoa	15-250 microliters per liter (dependent on temperature, species and type of pond)		Water, Ambient
			Shrimp	Control of fungi of the family Saprolegniaceae on the eggs of all fish species	25-100 microliters per liter		Water, Ambient
TRICAINE METHANESULFONATE (MS-222) (Anesethic)	**Finquel**	Argent Laboratories	Fish	anestheic	15-330 mg per liter	21d	Water, Ambient
	Tricaine-S	Western Chemical, Inc.	Fish	anestheic	15-330 mg per liter	21d	Water, Ambient

1. Use in Catfish Production

The USDA's Animal and Plant Health Inspection Service (APHIS) runs the National Animal Health Monitoring System. In 1997 a survey was undertaken of 571 catfish operations in four states (Alabama, Arkansas, Louisiana, and Mississippi). These operations represent almost 96 percent of total production and sales in 1996, according to the NAHMS report.

The two-part survey focused on health status, disease prevalence, and related management practices. Part I covers estimates of major causes of losses, with disease accounting for by far the greatest share (just under 50 percent weighted by sales). Data are also presented on the prevalence of six common diseases, as well as the severity of losses triggered by each disease. Testing for diseases as a management practice is surveyed, as well as who did the testing. Total production and the economic consequences of losses are also reported.

Data on most subjects are presented as industry averages and by size of operation. The tables arraying data by size of operation show clearly the impacts of scale on the prevalence of disease. Forty seven percent of operations with between 1 and 19 acres of ponds experienced losses to ESC (Enteric Septicemia of Catfish, by far the most important and prevalent disease), rising to 69 percent on operations with 20-49 acres of ponds, 86 percent with 50-149 acres, and 96 percent on operations spanning over 150 acres of ponds. In other words, the larger and more industrialized the operation, the more likely to experience disease problems.

The second part of the 1997 NAHMS catfish report, covers –

- Water quality management practices, including tests undertaken and types of ponds and drainage methods.
- Stocking practices and rates.
- Feed methods and amounts.
- Winter feeding practices.
- Harvest methods and percent of fish harvested.
- Health management, including presence and treatment of ESC, (the major catfish disease), as well as records kept and sources of information on catfish health.

Several highlights are noted in the first section of the Part II report –

- "A majority (65.1 percent) of operations regularly tested water quality." Large operations were twice as likely to test water quality than smaller ones.
- "Fingerling stocking rates averaged 7,327 fish per acre and showed a consistently increasing rate with increasing size of operation."
- Average feed efficiency was 2.35 pounds of feed for each pound of fish harvested.
- One of the most common management responses in ponds with ESC was feeding the antibiotic Romet (41 percent of operations).

Section F covers health management. The first table reports the incidence of ESC rising from 45 percent on small operations (1-19 acres of ponds) to 84 percent on large operations (over 150 acres of ponds). Management responses vary significantly by scale of operation.

Key survey data to establish antibiotic use is however, problematic. Farmers only reported whether they used a practice one or more times. Some farms might be applying antibiotics two or three times in a production cycle on nearly all ponds, whereas another operation might be applying them just once on a few ponds. The survey results would record use on these two operations in the exact same way.

In addition, less than 60 percent of operations kept records on disease treatment. Half of large operations do not keep records on mortality, although 96 percent record feed use and 99 percent kept track of stocking rates. Given the prevalence of ESC and magnitude of economic losses triggered by it, the absence of disease treatment records on over one-half of large commercial operations is a severe problem.

We estimated antibiotic use in catfish through use of USDA data on catfish production and the prevalence of ESC along with treatment with antibiotics. In formulaic expression:

Production X frequency of disease X antibiotic dose = TOTAL Antibiotic use

Total Catfish Production

Table 2 sets forth NAHMS population estimates of catfish production in 1996. We estimated total catfish production by size of operation from the population estimates in the NAHMS Part I report.

Table 2. Pounds of Catfish Produced in 1996 by Size of Operation, 1997 (NAHMS)

Number of Acres on the Operation	Average Acres per Operation (A)	Number of Operations (B)	Total Acres (C) = (A x B)	Pounds of Catfish Sold per Acre (D)	Total Pounds of Catfish Sold (E) = (C x D)
1-19	15	273	4,101	2,271	9,314,052
20-49	40	312	12,480	2,789	34,806,720
50-149	120	326	39,120	3,493	136,646,160
150+	240	391	93,840	3,889	364,943,760
				Total	**545,710,692**
Total Number of Operations in 1996 = 1,302					

Section E. on productivity reports an average harvest of 3,775 pounds of catfish per acre of pond. Section IV, A. reports there were a total of 1,302 operations nationally, and producing catfish in 145,265 acres of ponds. We multiplied these numbers together to produce an estimate of total national production -- 548.4 million pounds.

The productivity table in Section E. reports average pounds sold per acre as a function of pond size, as noted in Table 2. We used this data to estimate the pounds of fish produced by farm size, since the data on treatments with antibiotics and other drugs are reported by size of operation. In the second column in Table 2, we set average operation sizes within the ranges covered, such that the total estimate of pounds produced (column E, Table 2) closely matches the estimate based on average production across the 145,265 acres of ponds (545.7 million pounds versus 548.4 million pounds).

Prevalence of Disease in Catfish

Over three-quarters of the operations reported the presence of ESC, with incidence much more prevalent on the larger operations accounting for the largest share of production.

Table 3. Prevalence of Caftfish Diseases by Size of Operation in 1996, NAHMS, 1997

Number of Acres on the Operation	ESC	Winter Kill Syndrome	PGD	CCV	Other
1-19	47%	9.5%	5.5%	1.2%	1.3%
20-49	69.3%	17.9%	7.4%	2.3%	2.4%
50-149	86.3%	37.4%	17.4%	8.5%	2.8%
150+	95.6%	64.9%	40.9%	49.0%	4.0%
Total	**78.1%**	**35.8%**	**19.8%**	**4.6%**	**2.8%**

ESC-Enteric Septicemia of Catfish
CCV - Channel Catfish Virus
PGD - Proliferative Gill Disease

Table 4 projects the amount of Romet-30 and Terramycin fed to catfish by size of operation, drawing on data reported in Part II of the NAHMS report. The methodology developed is defined in large part by the way the USDA reports data on the incidence of disease and the percent of operations with the disease that treated with Romet 30 or an "other treatment," which we assume to be Terramycin (the only other drug approved for use in catfish that is marketed).

We base our estimates on the total pounds of fish produced by size of operation (column A). The NAHMS Part II report estimates the percent of operations reporting ESC by size of operation (column B), and the percent of farms with ESC that treat for the disease by administering Romet 30 (column C). We multiple these percentages by the pounds of catfish produced to yield an estimate of the number of pounds produced on farms treating with Romet 30, by size of farm (column D).

Antibiotic Dosage Rates

The FDA "Green Book" reports that the average dose of Romet 30 to treat catfish disease is 23 milligrams per pound of fish per day in the feed (50mg/kg/day for 5 days). We then multiply 23 mg/pound of fish by the total pounds of fish produced on farms treating with Romet 30 to yield an estimate of the total milligrams of Romet 30 fed in a single day. This estimate of daily use (column E) is converted to pounds in column F. Column G presents total Romet 30 use over a five-day course of treatment.

Table 4. Antimicrobials Used in a Single Course of Treatment of ESC in Catfish Production

Approved Antibiotic	Active Ingredients	Operation Sizes (pond numbers)	Total Pounds of Fish (A)	Percent of Operations That Report ESC (B)	Percent of Operations Reported to Use Romet (C)	Pounds of Fish on Farms Treated for ESC with Romet (D = A x B x C)	Milligrams fed per day* (E)	Pounds Fed per Day (F)	Total Amoun Romet Fed to Tr ESC (5 day Treatment) (G = D x 5)
Romet 30	sulfamethoxine and ormetoprim	1-19	9,314,052	47%	69%	3,016,169.56	69,371,900	153	
		20-49	34,860,269	69%	40%	9,590,792.01	220,588,216	486	2
		50-150	136,436,580	86%	36%	42,270,371.91	972,218,554	2,143	10
		150+	364,570,416	96%	38%	131,744,082.09	3,030,113,888	6,680	33
*Dose per pound of fish = 23mg/day					**Total Romet 30 Fed in One Course of Treatment for ESC**				**47.**

Approved Antibiotic	Active ingredients	Operation Sizes (Pond Numbers)	Total Pounds of Fish (A)	Percent of Operations That Report ESC (B)	Percent of Operations Reported to Use "Other Treatment" (C)	Pounds of Fish on Farms Treated for ESC with "Other Treatment" (A*B*C)	Milligrams fed per day*	Pounds Fed per Day (D)	Total Amoun "Other" Fed to T ESC (10 day Treatment) (D x 10)
Terramycin	oxytetracyline HCL	1-19	9,314,052	47%	9%	398,362	14,938,576	33	[illegible]
		20-49	34,860,269	69%	2%	434,847	16,306,762	36	[illegible]
		50-150	136,436,580	86%	5%	5,887,238	220,771,441	487	4,
		150+	364,570,416	96%	4%	12,198,526	457,444,729	1,008	10,
					Total Terramycin Fed in One Course of Treatment for ESC				**15,**
					Total Antimicrobials Fed in One Course of Treatment for ESC				**62.**

This method leads to an industry-wide estimate of 47,314 pounds of Romet 30 for one (5 day) course of treatment. The same method is used to estimate that 15,641 pounds of Terramycin were fed per course of treatment (10 days). Accordingly, if just one course of treatment were fed for each drug, about 63,000 pounds of antibiotics would be used in the treatment of ECS.

Key Assumptions

This estimate, however, is based on several *assumptions*, some of which are assuredly conservative. First and most important, the USDA reports the percent of farms using Romet 30 for one or more courses of treatment, but our projections are based on one five day course of treatment. Given the prevalence of disease and the documented need to treat early to prevent the disease from getting a foothold in a pond, we assumed that many operators treat multiple times in many ponds during the course of a year. While we have no way of making a firm projection, we assumed that the average pond on farms using Romet 30 is treated with two to four courses of treatment in a year. We also assumed two to four courses of treatment with oxytetracycline (Terramycin).

A second assumption regarding our estimates arises from the fact that we based our projections of antibiotics fed on the pounds of fish harvested, not the number and pounds of fish entering the ponds and growing to harvest weight. Death losses complicate the estimate of the pounds of fish fed during the grow-out cycle.

Part E. in the second 1997 NAHMS catfish report projects the percent of fish harvested based on initial stocking rates. From small to large operations the percent harvested is 48 percent in operations with 1-19 acres of ponds, 40 percent with 20-49 and 50-149 acres, and 39 percent on operations with over 150 acres of ponds. According, the death losses average about 60 percent across the industry – with diseases causing by far the largest portion of losses.

Accordingly, there were about 2.5 fish planted in ponds for each fish harvested. Some portion of the fish dying before harvest was undoubtedly treated once or even twice for ESC. This portion of use is not captured in our estimates. This source of underestimation is largely balanced out by another assumption that leads to an overestimation of use in the harvested fish. We estimated antibiotic use per pound of harvested fish from the pond, based on the weight of the surviving fish at harvest time. If the operator treated the fish at the midpoint in their production cycle, the dosage would have been about half, since the dose rate is based on pounds of fish.

Taking these assumptions into account, we project that antibiotic use to treat ESC, the most common catfish disease, falls in the range of 126,000 and 252,000 pounds on an annual basis.

2. Antibiotic Use in Trout and Salmon Production

There are no survey data available on antibiotic use in the production of trout and salmon. We estimate use indirectly based on the number of fish produced and lost to disease. We employ two key assumptions in estimating a range of use in trout production –

- For every fish lost to disease, the producer treated three fish in an effort to curtail disease outbreaks.
- For every fish lost, the producer treated five fish in an effort to control an outbreak.

Table 5 reports the number of trout sold in 2000 by size, drawing on National Agricultural Statistics Service data. The NASS catfish and trout production report does contain information on total losses – 29,622,000 trout were lost on farms in 2000. We assigned shares of this aggregate number of death losses to each size class, under the assumption that losses would be greatest among small fish, and decline as the fish got closer to market. These estimates appear in the column "Portion of Lost Trout." The number of fish dying is added to the number sold by size of fish (column labeled "Total Trout in Production"). The numbers of fish in production by size class are converted to pounds using the average weight of trout sold within each size class (from NASS data).

Table 5. Number and Pounds of Trout Sold, Death Losses, and Production, 2000

Production Size of Trout	Trout Sold in 2000	Portion of Lost Trout	Total Trout in Production	Trout Weight per Production Size (per Fish)	Weight of Trout in Production (pounds)
12" or greater	58,531,000	6,622,000	65,153,000	1.5	97,729,500
6" - 12"	7,551,000	8,000,000	15,551,000	0.5	7,775,500
1"- 6"	9,832,000	15,000,000	24,832,000	0.3	7,449,600
lost	29,622,000				

The last column in Table 5 is used in Table 6 to estimate antibiotic use under the two assumptions noted above. The NASS report states that disease causes 84 percent of losses. In Table 6, the column "Animals treated = 3 x portion lost to disease" represents the total number lost, times 0.84, times three. We then assumed that 90 percent of these treated animals were administered Terramycin for a full course of treatment and 30 percent, Romet for a full course. The dosage rates and duration of feeding were taken from the FDA "Green Book."

Based on these assumptions, we project between 34,562 and 57,604 pounds of Terramycin use in trout production. Romet use is projected at between 3,533 and 5,888. Total trout antibiotic use is estimated to fall between 38,095 and 63,492 pounds annually.

We estimated salmon antibiotic use based on the estimates for trout. While the production of trout is close to twice salmon production, we think it is likely that antibiotics have to be fed somewhat longer in salmon production because of the longer life spans of salmon compared to trout. Taking these two factors into account, we estimate that salmon use is likely to be about two-thirds of trout use. *Hence our estimate of Salmonid (trout and salmon) use falls between 63,000 and 105,000 pounds*.

A number of researchers and activists have documented the severe disease problems associated with pen-reared salmon, as well as the propensity for disease organisms to spread from salmon farms to wild populations of salmon (Ellis 1996). Pacific Coast salmon farms experienced an outbreak of furunculosis in 1991, leading to antibiotic treatments and the

Table 6. Two Estimates of Antimicrobial Use in Trout Production, 2000

Assumption 1: Three fish are treated with antimicrobials for every fish lost to disease

Production Size of Trout	Trout Sold or Lost in 2000	Portion of Trout Lost	Total Trout in Production	Animals Treated = 3 x Portion Lost to Disease	Animals Treated with Terramycin (90%)	Animals Treated with Romet (30%)	Weight of Fish	Terramycin Used per Day (mgs)	Terramycin Used per Day (Pounds)	Terramycin x 10 Days	Romet Used per Day (mg)	Romet Used per Day (Pounds)	Romet x 5 Days
12" or greater	58,531,000	6,622,000	65,153,000	16,687,440	15,018,696	5,006,232	2	844,801,650	1,862	18,625	172,715,004	381	1,904
6" - 12"	7,551,000	8,000,000	15,551,000	20,160,000	18,144,000	6,048,000	1	340,200,000	750	7,500	69,552,000	153	767
1"- 6"	9,832,000	15,000,000	24,832,000	37,800,000	34,020,000	11,340,000	0	382,725,000	844	8,438	78,246,000	173	863
Lost Fish	29,622,000								**Total Terramycin Fed**	**34,562**		**Total Romet Fed**	**3,533**
												Terramycin	**34,562**
												Total Antimicrobial Fed	**38,095**

Assumption 2: Five fish are treated with antimicrobials for every fish lost to disease

Production Size of Trout	Trout Sold or Lost in 2000	Portion of Trout Lost	Total Trout in Production	Animals Treated = 5 x Portion Lost to Disease	Animals Treated with Terramycin (90%)	Animals Treated with Romet (30%)	Weight of Fish	Terramycin Used per Day (mgs)	Terramycin Used per Day (Pounds)	Terramycin x 10 Days	Romet Used per Day (mg)	Romet Used per Day (Pounds)	Romet x 5 Days
12" or greater	58,531,000	6,622,000	65,153,000	27,812,400	25,031,160	8,343,720	1.5	1,408,002,750	3,104	31,041	287,858,340	635	3,173
6" - 12"	7,551,000	8,000,000	15,551,000	33,600,000	30,240,000	10,080,000	0.5	567,000,000	1,250	12,500	115,920,000	256	1,278
1"- 6"	9,832,000	15,000,000	24,832,000	63,000,000	56,700,000	18,900,000	0.3	637,875,000	1,406	14,063	130,410,000	288	1,438
Lost Fish	29,622,000								**Total Terramycin Fed**	**57,604**		**Total Romet Fed**	**5,888**
												Terramycin	**57,604**
												Total Antimicrobial Fed	**63,492**

emergence of furunculosis bacteria resistant to the antibiotics. This new strain was subsequently transmitted to hatchery fish, via wild salmon returning upriver to spawning grounds after passing by infected farms.

3. Other Species

There are no approved antibiotic drugs for production of crawfish, shrimp, or indeed most other aquaculture species. Still, some "off label" or illegal use occurs. The only way to estimate such use is proportional to other segments of the industry.

Catfish, trout and salmon account for about 638,000,000 pounds of production, or about 81 percent of the industry in the mid-1990s, as shown in Table 8. The table also reports the pounds of antibiotics used per ton of production, based on our low-end and high-end antibiotic use estimates. We constructed this table in part as a basis to extrapolate approximate use in "Other Species." We doubt use is less than 0.2 pounds per ton of production, nor more than 1.0 pound per ton, a wider range than in other species.

Table 7. Overview of Antimicrobial Use in Aquaculture Production, Mid-1990s ("Other Species" use per ton are extrapolated)

	Production in Late 1990s (Pounds)	Share of Total Production	Antimicrobial Use per Ton of Production	
			Low-End Estimate	High-End Estimate
Catfish	550,000,000	69.6%	0.5	0.9
Trout	55,000,000	7.0%	1.4	2.3
Salmon	33,000,000	4.2%	1.5	2.5
Other Species	152,000,000	19.2%	***0.2***	***1.0***
Total Aquaculture	790,000,000			

4. Total Antibiotic Use in Aquaculture

Table 8 aggregates our low-end and high-end estimates of antibiotic use in U.S. aquaculture. Based on the projections presented above, we estimate that use is likely to fall within the range 204,438 pounds to 433,397 pounds. Because of pervasive data gaps, it is possible that our estimates are significantly lower than actual use.

Table 8. Estimates of Antimicrobial Use in Aquaculture Production, Mid-1990s

	Production in Late 1990s (Pounds)	Antimicrobial Use	
		Low-End Estimate	High-End Estimate
Catfish	550,000,000	126,000	252,000
Trout	55,000,000	38,095	63,492
Salmon	33,000,000	25,143	41,905
Other Species	152,000,000	15,200	76,000
Total Aquaculture	790,000,000	204,438	433,397

Our estimates may be low by as much as half in some species, under some circumstances. The remarkably high rates of disease-driven death losses across the industry highlight the pressing need for treatment. In the species for which data are available (catfish, trout), death losses run as high as two-thirds of the total number of fish in production. Such very high losses no doubt pose a significant cost on operations, in some cases triggering aggressive efforts to both treat disease outbreaks where they occur and prevent the initial occurrence of disease. Given the magnitude of losses, prevention is clearly not an effective "stand-alone" strategy on most operations. Accordingly, we believe that we are underestimating use in the treatment and containment of outbreaks.

The USDA survey data we relied on underestimates use in two ways. It likely misses some operations that treat with antibiotics. It also assumes that each operation treats fish just once in a given production, an implausible assumption especially in the case of species like salmon that take more than a year to reach market weights.

Aquaculture Use in Perspective

The 2001 Union of Concerned Scientists report *Hogging It: Estimates of Antibiotic Abuse in Livestock* contains an overview of all antibiotic uses. Our low-end of estimate antibiotic use in aquaculture is about equal to the UCS estimate of use in beef cattle production from birth through 500 pounds of weight, or is about one-fifth the quantity fed to starter pigs (through about 40 pounds).

It is important to emphasize, however, that there is not a direct linkage between pounds used in aquaculture versus other agricultural uses versus human use and the risk of adding to the pool of resistance bacteria threatening public health. Aquaculture uses of antibiotics occur in environments with vastly different pathogens, bacteria, and antibiotic selection pressures (Goldburg et al. 2001). Aquaculture also is associated with novel routes for people to become exposed to resistant bacteria, or genes conferring resistance to a given antibiotic with roots in aquaculture. For this reason, aquaculture may be, or may come to contribute to the pool of antibiotic resistant bacteria triggering infections in humans disproportional to aquaculture's share of antibiotic use. Given the global nature of the antibiotic resistance crisis, any and all uses of antibiotics that are contributing to the problem should be examined.

The Concern Over Aquaculture Imports

In this brief report on U.S. aquaculture and antibiotics, a number of key contacts repeatedly identified imported shrimp, salmon, "catfish" and other farmed fish from exporting countries as the area requiring the greatest immediate attention. Over 68% of all seafood consumed in the United States is imported, most of which is industrially produced. Many of these commodities are farm-raised and often involve little oversight regarding antibiotic drug use. New aquaculture drug developments indicate that in some instances potency is increasing thus leading to lower aggregate poundage rates. While the U.S. government has standards that would ban imports with high levels of antibiotics in seafood, there is essentially no enforcement.

Monitoring Use and Enforcement

Enforcement of animal drug label indications, and indirect control of use of approved drugs, is under the auspices of the FDA. The suggested control measures can include any of the following (FDA 2001):

1. On-farm visits to review usage before receipt of the product.
2. Receipt of supplier's lot-by-lot certification of proper drug usage, with appropriate verification.
3. Review of drug usage records at receipt of the product.
4. Drug residue testing.
5. Receipt of evidence (e.g. third party certificate) that the producer operates under a third party-audited quality assurance program for aquaculture drug use.

In this light, it is relevant to mention a number of new initiatives related to antibiotic drug use in aquaculture that pertain to the development of codes of conduct, best management practices, environmental assessment tools and organic aquaculture standards (see Brister and Kapuscinski 2000). These relatively recent initiatives are currently in a wide array of formative stages and highly complex in regard to applications covering a diverse number of species, production systems and regulatory functions worldwide. Nonetheless, the direction points to some form of certification that includes direct address of antibiotic use.

At the federal level, one interagency, the Joint Subcommittee on Aquaculture (JSA) consisting of thirteen secretaries, chairs and administrators operates under the aegis of the National Science and Technology Council (OTA 1995). The JSA devotes considerable effort to aquaculture drugs, testing, guidelines and approval (JSA 2001). Five agencies are involved, in some capacity in the regulation, monitoring, and promotion of the aquaculture industry. Agencies and their roles are:

FDA – works with the individual states to ensure the safety of seafood products, especially mollusks. Approves drugs and feed additives, monitors manufacturing, distribution and use of fish drugs; provides technical assistance and training to states; conducts research; provides necessary oversight to ensure fish food products are safe, wholesome and properly labeled.

USDA – promotes research and development of aquaculture as an industry.

NOAA(National Oceanic and Atmospheric Administration) provides a service for a fee that guarantees fish are packed under federal inspection.

(FWS) Fish and Wildlife Service– provides research and advice to fish farmers.

EPA – protects and safeguards the environment and water systems by regulating the discharge of water and registering the chemicals used as pesticides and herbicides.

In addition, other state and local authorities include:

- State Fisheries and Wildlife Departments
- Universities and Colleges
- Growers Association
- Professional Organizations
- Pharmaceutical Companies
- Aquatic Veterinarians

Conclusion

This report examined one aspect of *antibiotic* drug use in U.S. aquaculture. Given the lack of reliable data, drug use estimates are considered preliminary and are based on mid 1990s production practices. Importantly, close monitoring of antibiotic *potency* needs to be considered as opposed to sheer poundage of antibiotic use. Recent developments in Norwegian salmon aquaculture for example indicate that this shift to more potent antibiotic drugs (and declining poundage) is well underway. In sum, upwards of an estimated 450,000 pounds of antibiotics were used in U.S. aquaculture. Questions that require further examination relate to antibiotic potency, the post-production phases of processing, distributing and marketing of farmed aquatic products, representative antibiotic residue testing, and eco-epidemiological mechanisms related to farmed fish sites and public health

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