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Disease Transmission from Farmed Salmon in Maine

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By

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1. aquaculture
2. Maine
3. disease transmission

Abstract

This report addresses the dangers associated with the salmon farming industry in the state of Maine with regard to disease transmission. It was prepared by conducting an extensive literature review of the history of, effects of, transmission of, and treatment for select diseases as well as conducting two interviews with experts in the field. Salmon farming is a factor in spreading sea lice, bacterial kidney disease, furunculosis, and infectious salmon anemia to the surrounding species.

Executive summary

This paper analyzed the risks to Maine's native fish species due to the Atlantic salmon farming industry in the state with regard to disease transmission. *Salmo salar* is the species name of sea run Atlantic salmon. The wild sea run Atlantic salmon are an endangered species while the farmed Atlantic salmon are not, even though the two are capable of breeding. The salmon farming industry in Maine is worth $65 million per year, and has an estimated economic impact of $195 million in the area per year.

The life cycle of a farmed salmon begins at a hatchery, where eggs from high quality fish are fertilized under controlled conditions. Eggs, milt, and hatchlings are tested for diseases. In the event of a positive result, all of the fish inhabiting the tank where the positive result occurred are destroyed. Salmon live in the hatchery for approximately 18 months, until they smolt. Once a salmon smolts it is capable of living in salt water and is moved to an ocean site. At the ocean site, salmon are kept in fish pens, which come in different types. The common characteristics of fish pens are that they keep the fish confined by nets. Predator nets keep seals and other fish away from the fish pens, and a bird net is suspended over the top to keep predatory birds out. After an additional 18 months the salmon will have reached market size and are harvested.

Some of the potential concerns from salmon farming include: escaped farmed salmon, spreading of disease, use of antibiotic drugs and chemicals, and waste accumulation beneath salmon farms. Escaped farmed salmon can breed with local wild sea run Atlantic salmon because they are the same species. Salmon farms can act as disease amplifiers. In order to deal with disease occurrence in farms, drugs and chemicals may be applied. These treatments can have unintended effects outside of the farm.

The purpose of this paper is to determine what risks and dangers the salmon farming industry in Maine causes for the surrounding wildlife with regard to disease transmission. The goals include determining which diseases affect the farming industry in Maine, how the diseases are transmitted, and how salmon farming plays a part in propagating them.

The method used to analyze the risks was essentially an information gathering process. An extensive literature review was conducted in addition to interviews with managers from salmon farming plants. This information was synthesized and presented in a manner which demonstrates how the industry affects the native fish species in Maine.

Three diseases, bacterial kidney disease (BKD), infectious salmon anemia (ISA), and furunculosis were chosen to serve as a basis for determining how diseases interact with salmon farming. Sea lice were also included in the results section because they are such an important transmission vector.

The bacterial diseases furunculosis and bacterial kidney diseases share many of the same transmission characteristics. They can be transmitted through ingestion or respiration of infected feces, body fluids, blood, viscera, contaminated water or contaminated feed. Sea lice can also spread each of these diseases. Additionally, bacterial kidney disease can be transmitted through the egg during reproduction. Furunculosis and bacterial kidney disease are fatal. Both of these diseases were originally not found on this continent but are now found all over the world including Maine.

Infectious salmon anemia (ISA) is a viral disease. Infectious salmon anemia originated in Norway and has subsequently spread to all of the major salmon farming countries including the United States. The disease has been found in Maine in both wild and farmed populations. Infectious salmon anemia can be transmitted passively which means that water can carry the pathogen from diseased to healthy salmon. ISA can also be transmitted in all of the same ways as bacterial diseases. Currently there is a one cent per pound tax on Atlantic salmon farmed in Maine, which supports testing for this disease. When a fish is diagnosed with infectious salmon anemia, the fish is removed and destroyed along with any other fish in the same pen.

Sea lice are an important transmission vector. Lice can carry all of the diseases discussed in this paper as well as others. Sea lice are found naturally on salmon. Sea lice can be found in Maine, and all other sites where there are salmonids. Sea lice numbers are increased in areas where salmon farming exists. This means that there is an increased possibility of transmission of disease in the areas surrounding salmon farms. Additionally, sea lice cause immune system suppression, making any fish more susceptible to diseases.

Salmon farms serve as disease amplifiers, which is demonstrated by the following example. First, a pathogen enters a salmon farm and a fish contracts a disease. This fish in turn transmits the disease to the fish surrounding it. This chain reaction causes a large amount of infectious material to be produced and released into the surrounding environment. Salmon farms can also contribute to disease amplification through escaped fish. Salmon escape from the fish farms and are capable of reproducing and competing with wild fish for resources. Additionally escaped fish can transmit diseases to wild fish if the escapee is infected.

Treatment of diseased fish in the farm presents additional problems. The medicines applied to treat the illnesses are released into the environment and may have unintended effects. Pesticides used to treat sea lice also kill any crustaceans which are exposed to the chemicals. Antibiotics used to treat bacterial illnesses enter the environment and bacteria may develop resistance to that type of treatment.

The history of these diseases shows a pattern of new pathogens spreading throughout the areas where salmon farming is practiced. This suggests that if new pathogens are encountered they will follow the same course. The major risk from farming Atlantic salmon lies in a salmon farm's ability to propagate and amplify pathogens. Those species of fish in the area which are susceptible to the same pathogens, especially the endangered *Salmo salar*, are especially at risk.

Acknowledgements

This Interactive Qualifying Project could not have been completed without the continual guidance and support from Professor Plummer and Professor Tyler. Their patience and supervision have been a blessing. The author gives them special thanks for the tremendous effort and time they put forth in order to allow the completion of this project.

The author also thanks Mr. Orren Kephart and Mr. Hume Thompson. Each of these gentlemen were interviewed and provided invaluable information and insight that contributed significantly to the project.

Authorship

All aspects of this project were completed by Daniel Kennedy. In the process of writing this report he was responsible for all data collection, interviewing, writing, and revision. He can therefore claim total authorship.

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1.0 Introduction

Aquaculture is to the farming of marine and freshwater plants and animals such as fish, shrimp, and clams. Many types of fish are farmed throughout the world, including salmon, trout, carp, yellowtail, flounder, and catfish. Fish farming originated in China 3500 years ago. Aquaculture remained a type of subsistence farming until the 1900's.

Salmon were not farmed until the 1960's. Today, the main aquaculture crop within North America, South America, and Europe is Atlantic salmon. The annual harvest for Atlantic salmon is approximately 796,000 metric tons, of which approximately 30,000 metric tons comes from the United States.

Maine is responsible for approximately half of the Atlantic salmon harvest in the United States. The market value of this harvest is estimated at $65,000,000 per year, with an economic impact of nearly three times that in the surrounding area. 2,500 people are employed year round and additional seasonal workers are hired as needed. Maine supplies 18% of the Atlantic salmon consumed in the United States each year.

Several aspects of salmon farming raise concerns including: escaped farmed salmon, disease transmission, disease treatments, and pollution. Escaped farmed salmon can alter the genetic integrity of indigenous *Salmo salar*. Escaped salmon can also carry diseases and spread them to native populations of salmonids. Salmon do not need to escape however to spread diseases, because many can be spread through the water. Treating the salmon for disease in order to stop the transmission of disease can also have unintended effects. Medicines and chemicals may be released into the surrounding environment causing negative effects.

The purpose of this project was to investigate disease transmission from farmed Atlantic salmon to wild salmonids in the state of Maine. The method used to go about addressing these issues was an extensive literature review and interviews with managers in the industry. A study of all the salmon related diseases that affect Maine would not have been within the scope of this paper. In order to go into sufficient depth, the study was limited to research of three diseases and a parasite. The three diseases were chosen because their history and virulence demonstrate how a pathogen can be transmitted. The parasite, sea lice, was chosen because it is an important transmission vector for a variety of diseases.

The paper begins with a background chapter. The background presents information on the history of aquaculture, an overview of the fishing and aquaculture industry, facts about *Salmo salar* and landlocked salmon, basic information on salmon farming, and an outline of some concerns about salmon farming. Following is the procedures chapter, which discusses how the information for the report was gathered. The procedures chapter is divided into sections corresponding to the type of sources used. Each of these divisions discusses the type of information gained from that particular source.

The results chapter is divided into three main areas: bacterial diseases, sea lice, and infectious salmon anemia. Each subheading contains background information and is then further divided into effects, transmission, treatment, and occurrence in Maine. The text of the results chapter is limited to information directly gathered from research and interviews. The analysis chapter synthesizes the information from the results chapter. This chapter also illustrates how the data from the results chapter can be applied to answering whether or not salmon farming in Maine is a significant factor in the transmission of diseases from farmed to wild fish.

The final chapter of the report presents conclusions, and contains recommendations on how the industry could be improved. Recommendations for further research within this subject are provided. At the end of the report is an appendix. This section contains the transcript from an interview reproduced from tape as well as a list of questions and answers from a second interview.

2.0 Background

The practice of fish farming began over 3,500 years ago in China. Carp was the main product of fish farming. Fish farms were usually combined with another crop. As an example, fields were seeded with rice, flooded, and stocked with fish. This combination was mutually beneficial to each staple. The crops attracted insects to the area, and the fish fertilized the area. During this time period, fish farming was not an industry; rather it was a way of providing food for those who ran the farms (Canadian Aquaculture Industry Alliance, 2001).

Aquaculture remained a small scale enterprise until the 1900's. The first salmonid to be farmed was the rainbow trout. This continued to be the case until Norway began to culture salmon in the 1960's. Canada followed suit in the 1970's, as did the United States in the early 1980's. Today, many different types of fish are farmed all over the world. Atlantic salmon, Pacific salmon, chinook, rainbow trout, carp, yellowtail, flounder, catfish, eel, and shrimp are some of the most commonly farmed species (Canadian Aquaculture Industry Alliance, 2001). Asia continues to lead the world in fish farming, constituting an 80% share of the enterprise by dollar amount. Their principal stocks are carp, yellowtail, and Asian red sea bream. The husbandry practices required to raise these fish differ substantially from those used in salmon farming.

Salmon is the main finfish crop for North America, South America, and Europe. Overall Atlantic salmon sustains the majority of what is being farmed with 796,000 metric tons being farmed per year, as opposed to 217,000 metric tons of trout, 100,000 metric tons of Pacific salmon, and 72,000 metric tons of carp. The amount of the salmon farming industry's production is 26 metric tons greater per year than the total annual catch of wild salmon by traditional commercial fishermen.

The largest constituents in the world market for farmed Atlantic salmon include Norway, the United Kingdom, Chile, Canada, Faroe Islands, and the United States of America, in descending order. Norway is responsible for over half of the world harvest, the UK 16%, Chile 13%, Canada 8%, and estimates for the USA range from 3 to 4%. Maine produces 2% of the world's share of farmed Atlantic salmon. The Pacific Northwest is responsible for the other 1-2%. Consumers in the United States import more salmon than is farmed per year. The total production of the Maine salmon farmers constitutes only 18% of the U.S. domestic consumption (Wilson, 2000).

Maine's traditional fishermen catch a total of 104,000 metric tons of fish per year (Blomstrom, 2001). This total harvest is inclusive of all types of fish. With a value of $265,236,000, the state's total harvest is the third highest in the U.S. Traditional fish farmers do not take any Atlantic salmon whatsoever because they are an endangered species. Atlantic salmon farmers in Maine harvest 13,580 metric tons of fish per year, with an estimated value of $65,000,000 (Kling and Opitz, 2000). The economic impact of each of these numbers is considered to be three times these values. Atlantic salmon farms employ approximately 2,500 people year round in Maine. Additional seasonal laborers are also employed in the mid to late summer in order to assist with the abnormally large quantities of work during these periods (Kephart, 2001). There is more work during this season because this is the time of year when the fish are moved from the hatchery to the ocean site. Once the fish are moved to the ocean site, the hatchery needs to be prepared for operation again, which involves a large amount of cleaning and sanitation measures.

2.1 Atlantic salmon

There are two types of Atlantic salmon, sea run and landlocked (Sternberg, 1987). Landlocked salmon are smaller and are commonly called Ouananiche, Sebago, or landlocked salmon. Sea run and landlocked salmon both have silvery or slightly brownish sides and dark spots. The landlocked strain of salmon has larger spots and resembles brown trout except for the fork in its tail. Sea run Atlantic salmon are an anadromous species. The fish hatch in freshwater and are called fry. The fish continue to develop in freshwater until they are able to survive in salt water. This stage of development is called smoltification, the result is a fish called a smolt. Fry become smolt at anywhere from 18 months to 3 years, and typically weigh around 100 g at the time. Once salmon have become smolt they swim to the sea. Once the fish reach sexual maturity, they will return to the streams where they were hatched in order to spawn. Salmon spawn in the fall, when the water temperatures are between 42 and 50 degrees F. Surviving adults will return to sea. Some males will spend the winter in the streams. Some adults live as long as six years and spawn two or three times. Sea run Atlantic salmon can grow to be over 45 kg, while a typical full grown weight is around 11 kg at six years. Survival to adult is approximately one percent. The fish's diet consists mainly of crustaceans and small fish. Red pigmentation in the shellfish gives the Atlantic salmon's meat the red color. The meat of the Atlantic salmon is highly sought after, and the quality and taste are considered excellent (Sternberg, 1987).

Sea run Atlantic salmon are very rare, and were added to the Endangered Species list on November 13, 2000 (Kaufman, 2000). At that time, there were only hundreds left in U.S. waters, which is considered to be below the minimum number required for survival. Fish return to the same streambed where they were hatched in decreasing numbers each year. Efforts to introduce new runs of salmon have failed in the past. Additionally, hatcheries have attempted to increase the wild population by raising eggs and milt taken from wild fish. Unfortunately, hatchery raised fish have not successfully increased the number of wild salmon. The wild salmon are considered to be a distinct population from farmed salmon.

2.2 Farmed Atlantic salmon

Despite the scarcity of *Salmo salar*, consumers still want the option to buy Atlantic salmon. A reasonable way to accomplish this is by farming the salmon, as the farmed fish are not considered endangered. Farmed Atlantic salmon are bred from Penobscot, St John's, Icelandic, and European strains (Kling and Opitz, 2000). Fish are not genetically altered. Brood stock is taken from previous generations of farmed fish, selected for excellence in farm qualities. These qualities include but are not limited to fast growth, resistance to disease, and lack of abnormalities.

The life cycle of farmed Atlantic salmon is the same as that of their wild counterparts. Milt and eggs are mixed at the hatchery (Kephart, 2001). Meanwhile the milt and eggs are being tested for disease. While the results are pending, the offspring from each parent are kept separated in different cages within different tanks. When the eggs and milt are certified disease free, and the fry have developed to the point where they can tolerate light, the cages are removed and the fish are allowed the full use of the tanks. If it is discovered that any of the parents had a disease, the offspring are destroyed. The fry stay in those tanks until the larger tanks in the smolt field are emptied, which is usually in late August. At that time, the fish are transferred to the larger tanks in the smolt field. There they grow to approximately 100 grams. The majority of the industry raises one year classes of salmon. This actually means that the fish spend approximately 18 months at the hatchery, and another 18 months in the sea pens. Survival rates for farmed salmon are typically around 80%.

Salmon are transferred to the sea pens by truck. The trucks are loaded with one cubic meter boxes filled with water and fish. Once the salmon arrive at the sea pens, they are put into different cages based upon their size (Thompson, 2001). The current fish pens used in Maine are made of metal and are square. Buoyancy is provided by floats. The sea pens the industry in Maine is moving towards are called polar cages. These are large circular nets. The circle is given its shape by plastic pipes, which float on water. The main advantage of polar cages is their greater flexibility. During storms this added flexibility prevents the cages from breaking apart and allowing escapes. Each type of pen has a predator net surrounding the outside of the pen to keep seals away. Additionally there is a bird net suspended over the top which keeps birds from getting into the fish pens.

The salmon typically remain in the fish pens for a minimum of 18 months. This time varies according to the needs of customers and the market price. Fish generally weigh between 4 and 7 kg when they are sent to market. Different customers prefer different weights and sizes of fish, causing the salmon farmers to harvest the fish in a staggered manner. This staggered harvesting also ensures that there is a supply of fish through out the entire year.

Fish are harvested by removing them from the pens and bringing them, still live, to the processing plant, which is ideally located adjacent to the farm. At this point, exciting or panicking the fish causes them to thrash about and damages the product. Consumers do not want to buy fish with bruises or cuts, so care is taken to keep the process as smooth as possible. Fish are cooled with slush ice, in order to slow them down, and then the oxygen in the water is reduced. Immediately after the fish die, they are removed from the water, bled, gutted, and sent to be graded. The gutted fish are transported to the next station through a trough, which uses gravity, flowing water, and ice to carry the fish to the next station. Fish are graded according to size and quality. Immediately after grading, the fish are packed in flake ice and are prepared for shipping. The removed fish innards are collected, ground, and shipped to animal feed companies or other customers. Fish innards end up in dog and cat food; however, notably they are not used in the production of fish feed (Canadian Aquaculture Industry Alliance, 2001).

2.3 Fish farming concerns

Industry practices have been developed in order to keep the fish production at efficient levels. At the hatchery, losses can occur from a variety of factors. Loss of power is a large concern to hatchery staff (Kephart, 2001). Northern Maine experiences significant snowfall and snowstorms each winter. With these storms comes the possibility of a loss of electricity due to downed power lines. If the power goes out, oxygen levels in the water will plummet immediately. Fish will begin to die at a rapid rate after about 15 minutes. For this reason, there are generators with a zero second time delay. Water temperature is also a concern during the winter, and fish can freeze if the water is not closely monitored. The hatchery tanks are all wired with an alarm system that monitors oxygen levels and water temperature. This alarm system goes off in the event that either is not at the proper levels, and sounds in the farm and the plant manager's house. The plant manager's house is located adjacent to the farm because quick response is necessary in order to avoid problems.

At the sea site, losses can come in the form of escaped fish (Thompson, 2001). Storms can thrash around pens with great force and cause holes or tears in the nets. Farmers have to go out to the pens during these storms to shore up the nets in order to protect their stock. Predators can also tear holes in the nets and agitate the fish. To keep the predators away, larger nets are placed around the smaller fish nets. Sometimes, sounds that drive away predators are continually played in the areas under the nets.

At a first glance, salmon farming seems like an ideal way to provide consumers with Atlantic salmon, which they would otherwise not be able to have. There are, however, several concerns that need to be considered, including disease, effects on endangered Atlantic salmon, pollution, and public perception.

As with other forms of life, Atlantic salmon are also subject to an array of diseases. Concern is raised that the farmed salmon are responsible for spreading or could possibly spread diseases in a very prolific way. Farmed salmon are kept together in very high concentrations, and if even one fish contracts a communicable disease, then the rest of the fish in the farm are in danger of infection unless immediate action is taken. Concern is also raised about natural populations being contaminated with diseases from being in the same area as the farmed salmon. Additionally, diseased salmon could escape farms and spread whatever ailments they have.

Escaped farmed salmon also raise other concerns. Wild sea run Atlantic salmon are now on the endangered species list. Farmed salmon are the same species as the wild Atlantic salmon and are therefore capable of breeding with natural stock. This is a problem because the natural populations will lose the genetic characteristics which make them distinct. Additionally, even if the escaped salmon are not successful at breeding, they could still compete with the wild salmon for food and territory, thereby making the wild salmon less successful.

Farmed Atlantic salmon need to eat in order to live and grow. At the sea sites feed is hand spread at the surface (Thompson, 2001). The feeding is stopped when underwater cameras detect that excess feed is making it down below the cages. Even though the farmers are very careful not to use too much feed, they still lose some at every feeding, which ends up on the bottom of the ocean directly below the pens. After the fish eat, they naturally have waste products associated with the metabolic process. The fish discharge their waste directly into the water. This is a concern because so many fish are concentrated in the same area. Solid portions of fish waste accumulate below the sea pens the same way the feed does. Also, the medicines applied to the fish in order to keep them free of disease have to be applied to the water in many cases. These medicines do not just stay inside of the fish pens, and may have an effect upon the surrounding life. The hatcheries also have similar issues with the feed, waste, and drugs. At the hatchery, however, the water is run through a settling tank and a gravel filter, at the very least, before being discharged into a river (Kephart, 2001).

Public perception is an equally important factor in salmon farming (Brennan, 1999). Proponents take the point of view that salmon farming is beneficial because it supplies the consumers with a product that they want. Public perception is important because it has a large influence upon the legislation. Additionally, if the public looks at salmon farming in an unfavorable way, the potential customers are going to be limited.

3.0 Procedures

In order to determine the disease associated risks involved with salmon farming in Maine, this investigation synthesized information from various types of sources. Newspaper articles, scientific journal articles, whitepapers, interviews, internet sites, a book, and industry reports each served as sources of data for this report. Facts were determined by finding multiple sources of information to support the same information.

3.1 Newspaper articles

Newspaper articles provided specific dates for background information as well as historic references for the diseases. The Bangor Daily News is a Maine newspaper and reports frequently on matters concerning the fish farming industry. In order to find the specific articles used in this report, the archives of this newspaper were searched.

3.2 Scientific journal articles

Scientific journal articles were the main effort of the information gathering process. These articles were used to verify the facts and history of diseases. The majority of information on history, effects of the diseases on salmon, and transmission came from this type of source. In order to find articles from scientific journals a variety of means was used. The predominant method used to obtain articles was searching the databases accessed from the WPI George C. Gordon library website. A secondary method used to gather this type of article was searching the internet. A topic of interest was entered into an internet search engine such as google.com, infoseek.com, or lycos.com and suitable articles available in Adobe Acrobat PDF format were downloaded.

3.3 Whitepapers

A series titled *Maine and the Atlantic Salmon* was written by several different professors from the University of Maine. This series contained information specific to Maine in the areas of economic impact, diseases, and disease transmission. These whitepapers were used to determine the issues affecting Maine as opposed to the general salmon farming industry.

3.4 Interviews

In order to find out the actual practices used in salmon farming, interviews were necessary. These interviews focused on how the salmon farmers in the state of Maine operated normally and when faced with diseases. There are two main aquaculture companies that operate in the state of Maine: Atlantic Salmon of Maine and Heritage Salmon. Each of these companies was contacted in order to schedule interviews. Atlantic Salmon of Maine declined an interview while Heritage Salmon agreed to interviews with a manager of a hatchery and a manager at an ocean site. In preparation for the interviews, I prepared a list of questions to ask if they were not answered in the course of conversation.

On August 10, 2001, I interviewed Mr. Oren Kephart. Mr. Kephart is the manager of Gardner Lake Fish Culture Station, a hatchery for the Heritage Salmon company. His contact information is below.

Oren Kephart

HCR 74 Box 36

East Machias, Maine 04630

Tel: (207) 259-3900

Fax: (207) 259-7719

Mr. Kephart took me on a tour of the hatchery facilities and explained the entire process of events at that location. At the end of the interview he answered several questions about disease that were not answered during the tour. This interview was recorded and a transcript recreated from the tape is included in the appendix.

I also interviewed Mr. Hume Thompson on August 10, 2001. Mr Thompson is a manager at Connor's Aquaculture Incorporated, which is an ocean site for the Heritage Salmon company. Mr. Thompson's contact information is below.

Hume Thompson

Connor's Aquaculture Incorporated

P.O. Box 263, Estes Head

Eastport, Maine 04631

(207) 853-6081

Mr. Thompson took me on a boat and showed me the fish pens. He explained the daily operations at that facility. At the end of the tour, I asked him additional questions about how disease and parasites are dealt with. A list of the questions and answers from this interview, recreated from my notes, is included in the appendix.

3.5 Internet sites

The internet was used to gain information in a variety of areas including specific information on diseases, history of diseases, treatment, background information, and industry information. The types of sites used gather information varied from salmon industry web pages to web sites for classes on biology at the University of Maine. Information from the internet was considered valid as long as it properly cited other sources of information such as newspaper articles, scientific journal articles, or industry reports.

3.6 Books

The book that was used in this report was *Freshwater Gamefish of North America*. This book was used to obtain background information on Atlantic salmon and other salmonids. This book contained data on life cycle and breeding habits.

3.7 Industry reports

Industry reports were used to collect statistics on the salmon farming industry, including the amount of salmon farmed per year. Information from these reports was used in the background section of this report.

4.0 Results

The diseases and parasites discussed in this chapter are not the only ones present in aquaculture. They have been selected because they are well documented, affect the Maine salmon farming industry, and illustrate a variety of factors related to disease.

4.1 Bacterial diseases

There have been two bacterial diseases which have caused widespread conspicuous fatalities among salmon. These diseases are bacterial kidney disease (BKD) and furunculosis. Both BDK and furunculosis can be found all over the world.

4.1.1 Background information on bacterial kidney disease

Bacterial kidney disease was first documented in 1933 in Scotland (Gumundsdottir *et al.*, 2000). Originally called Dee Disease, it was found in wild Atlantic salmon in two freshwater rivers (Scientific Committee On Animal Health and Animal Welfare, 1999). Little is known about the exact numbers or percentage of the wild population it affected (Maule *et al,*. 2000); however the disease caused more than one epidemic (Gumundsdottir *et al.*, 2000). It first appeared in the United States and Canada in the early 1980's. Today the disease can be found all over the world, wherever salmonid populations exist (Bullock and Herman, 1980). Bacterial kidney disease is caused by *Renibacterium salmoninarum,* a gram-positive bacterium (Bullock and Herman, 1980).

4.1.2 Background information on furunculosis

Furunculosis was first documented in the early 1900's in England. The disease caused several epidemics as it spread. Furunculosis first appeared in Britain as a freshwater strain in

1911 and had spread to Scotland by 1920. Furunculosis appeared in Denmark in 1964, and then Norway in 1969 (Bakke and Harris, 1998). This original strain of furunculosis was exterminated. A marine strain emerged in Scotland in 1985 and quickly spread to Norway. Although exact numbers are not available due to the inaccuracy of industry records of the time, furunculosis caused mortalities in less than 42% of wild *Salmo salar* during the peak of the epidemic in 1989 in Scotland (Hiney and Smith, 2000). According to Austin (1997), 25% of the production or 10,000 tons of salmon were lost that year. An epizootic began in Norway in 1987 and peaked in 1991. In 1991, 398 farms in Norway alone were experiencing infections at their premises. The problem was effectively over by 1994 when all of the remaining farmed fish had been vaccinated against furunculosis (Hiney and Smith, 2000). Today furunculosis can be found wherever there is a salmonid population to support it. *Aeromonas salmonicida* is the pathogen responsible for furunculosis (Bakke and Harris, 1998).

4.1.3 Effects of bacterial kidney disease

Once a fish becomes infected with *Renibacterium salmoninarum*, the causative agent for bacterial kidney disease, the bacteria begins to reproduce within and outside of the cells. The disease develops slowly, and a fish may not show any symptoms until the infection is quite thorough (Bullock and Herman, 1980). The incubation period can be as long as several months to years depending on temperature and the particular strain of pathogen (Scientific Committee On Animal Health and Animal Welfare, 1999). Symptoms include open lesions on the fish skin, exophthalmos, and closed blisters. Exophthalmos is a condition where the eyes develop lesions and bacteria deposits form behind the eyes. The closed blisters are filled with blood, destroyed fish tissue, and bacteria. In the event of an outbreak at a farm, fish farmers recognize infected fish by their tendency to swim slower than the others (Thompson, 2001). Additionally the fish may exhibit pale gills (Scientific Committee on Animal Health and Animal Welfare, 1999). The most notable effect of the disease is the damage the bacteria cause to the kidneys, which is not easily discernable without destroying the fish. The kidney cells are eventually destroyed and internal bleeding occurs. Once damage to the kidneys ensues, the ability to filter blood properly is lost, and the excretory system is affected as well.

4.1.4 Effects of furunculosis

When a fish becomes infected with *Aeromonas salmonicida*, the causative pathogen for furunculosis, the fish develops deep lesions on its muscles (Atlantic Salmon Federation, 1999). The lesions tend to develop on the cardiac and gill muscles. Death occurs after the fish are debilitated by the loss of their muscle. According to Austin (1997), classic furunculosis involves a hemorraghagic septicaemia, and boils on the sides of the fish. Furunculosis also causes the fish's immune system to be repressed (Brown and Bruno, 1999)

In a laboratory situation, the first deaths will occur approximately 5 days after introduction of the disease (Nordmo *et al.*, 1997). The disease continues to progress and 50% mortality is observed between the 17thth and 36th day after introduction of the pathogen. According to the authors of this research, these results mimic that of a natural outbreak.

4.1.5 Transmission of bacterial kidney disease

Bacterial kidney disease is transmitted both horizontally and vertically. Vertical transmission is transmission from parent to offspring. *Renibacterium salmoninarum* is one of few bacteria that can be transmitted vertically (Bakke and Harris, 1998). The bacteria are transmitted through the egg, while the sperm does not transmit the bacteria. Horizontal transmission can be through a variety of vectors, such as exposure to infected fish or blood, viscera, feces, or on the outside surface of an egg. The disease is transmitted horizontally through discharge in feces as well as through contaminated feed or water. The pathogen can enter orally or through any discontinuities in the skin (Scientific Committee on Animal Health and Animal Welfare, 1999). Another horizontal vector is sea lice. Sea lice can carry the bacteria and infect new individuals once they have fed on an infected individual.

R. salmoninarum can be carried by any salmonid. After discharge the bacteria can survive up to 21 days in the sediment (Bullock and Herman, 1980). The bacteria grow fastest at 15-18 degrees C, and do not grow at all at 25 degrees C (Scientific Committee on Animal Health and Animal Welfare, 1999).

4.1.6 Transmission of furunculosis

Furunculosis is only transmitted horizontally. The most common method of contraction is exposure to an infected fish or water (Austin, 1997). In a study by Nordmo *et al.* (1997), infected fish were added to the same tank as healthy ones. A mortality rate of 50% was observed between 17 and 36 days. Greater mortality rates were achieved in different test runs of the same experiment and the results were widely varied. The additional test runs saw mortality rates between 55 and 90% over a period of 20 to 38 days. For the fish that were purposely infected and added to the tank mortality rates varied between 92 and 100% after 13 days. The horizontal vectors of transmission include the same horizontal transmission vectors as of BKD. Furunculosis can be spread through body fluids of fish as well as sea lice.

4.1.7 Treatment

The primary objective in fish farms is to prevent bacterial kidney disease and furunculosis from occurring. In order to achieve this goal, a variety of strategies are employed.

Selective breeding is among the first line of defense. Identifying genetic resistance to furunculosis was the objective of a study by Nordmo *et al.* (1997). This study found that certain family lines in *Salmo salar* exhibit increased resistance to furunculosis. Iodine baths for eggs entering the hatchery reduce the likelihood that the bacteria will enter on the surface of the eggs (Kephart, 2001). Another method used to stem infections from this bacterium includes vaccinations. These vaccines are typically injected into pre-smolts. The vaccines for each of these bacteria are oil adjuvanted. Oil adjuvanted means that the vaccine is oil based and therefore oil soluble. An example of a vaccine for furunculosis is MULTIVaCC4. This vaccine is made of stabilized antigens from *Aeromonas salmonicida*, *Vibrio anguillarum* serotypes 01 & 02, and *Vibrio salmonicida* (Bayotek, 2001). Fish vaccinated for each type of disease exhibit resistance.

Should the preventative measures fail, treatments still exist for furunculosis. Romet® and Terramycin® are antibiotics that can be applied externally to fish with furunculosis. Both of these drugs are approved by the Food and Drug Administration and are commercially available (Everson *et al.*, 1998). Although treatments are available for furunculosis, farmers will remove the infected fish if an epizootic is likely, or the disease has progressed too far. According to Bakke and Harris (1998), the bacterium *Aeromonas salmonicida* transfer plasmids between strains when they are in contact with other bacteria. Plasmids can be transferred in the sediment where large accumulations of bacteria build up. These plasmids are responsible for drug resistance. This means that furunculosis is continually represented by new strains.

If a fish is diagnosed with BKD, the disease is usually too well established to take any action to save the fish. As with all gram positive bacterium, *Renibacterium salmoninarum* have thick cell walls. These particular thick walled bacteria reproduce outside of the fish cells, which cause them to be a difficult target for existing drugs. This is because the existing drugs need to be absorbed to be effective. The medications end up inside the cells of the fish while the bacteria remain within the fish cells, unaffected. Additionally, the fish tissue would be too damaged due to the progression of the disease for the fish to be sold. Fish farmers cull the fish suspected of being infected and dispose of them in order to keep additional fish from danger.

4.1.8 Occurrence in Maine

Although bacterial kidney disease is present in the United States and Canada, there has been infrequent occurrence of this disease in the northeast, inclusive of Maine (Atlantic Salmon Federation, 1999). Measures taken by fish farmers keep the rate of this disease down. Before eggs are brought to a hatchery, they are required to be certified as disease free. The first thing that happens to the eggs when they enter the hatchery is an iodine bath (Kephart, 2001). This ensures that bacteria on the surface of the eggs are killed. After the fish hatch, but before the fish are brought to the sea, they have to be certified as disease free again. Once the fish are in the fish pens in the ocean, the fish are monitored for signs of the disease and are removed and destroyed should they exhibit any symptoms (Thompson, 2001). Mr. Thompson said that he had found several fish with BKD two years ago, which were dealt with according to the policy of removal.

Furunculosis is more widespread than bacterial kidney disease (Atlantic Salmon Federation, 1999). Wild salmonids in both fresh and saltwater carry the disease. Preventative measures for this disease are the same as for BKD, which keeps the occurrence of disease low in fish farms. Both Mr. Kephart and Mr. Thompson said that they had not encountered furunculosis at their premises. Mr. Kephart went on to say that when he started working in the industry in

1986 concern was focused on furunculosis, but it is not now because the farmed fish are vaccinated against it.

All wild salmonids including *Salmo salar* are at risk for furunculosis (Atlantic Salmon Federation, 1999). Data on the numbers of wild salmon that die from this disease are not available because the fish are not under observation. The fish live in the wild and there is no one to notice when a salmon contracts a disease and dies from it.

4.2 Sea lice

There are two types of sea lice: *Lepeoptheirus salmonis* and *Caligus elongatis*. The former are commonly known as salmon lice. While each type of these lice affects Atlantic salmon, *L. salmonis* is more abundant and is more harmful. The effects of the louse *C. elongates* are negligible unless the parasite is in very high concentration.

L. salmonis is a type of crustacean called a copepod. A common feature of copepods is a single simple eye in the middle of the head during the larval stage. Adult copepods have a shield over their head and thoracic segments. Most are parasitic and shorter than 1 mm in length.

4.2.1 Life

Salmon lice have a ten stage life cycle (Bonga *et al.*, 1999). Their life cycle is a direct life cycle and they require no intermediate host in order to reproduce or attain adulthood. The first two stages are planktonic naupliar, or in more common terms, larval. The third stage is called the copepodid stage and is generally the infectious stage in the life cycle. The remaining seven stages take place on the host. Of these seven stages the first four are chalimus, or immature, the next two are pre-adult, and the final stage is the adult stage. Infestation of a host is also common during the chalimus stages.

Salmon lice are ectoparasites, meaning that they feed and live on the outer parts of their hosts. More specifically, lice feed on the gills, epithelium, mucus, scales, and dermis (Mendiola, 2001). They naturally feed on a variety of species of fish. As is the case with all parasites, their feeding causes damage to the tissues of the host. The host in turn has to spend its energy and resources repairing the damage.

4.2.2 Effects

Sea louse infestations cause problems for hosts in two ways. Firstly, the attachment and feeding sites are damaged due to the mechanical degradation of the fish's body. Secondly, non-feeding sites are damaged due to induced stress (Bonga *et al.*, 1999). At the feeding and attachment sites, lice eat the fish and cause tissue damage. Feeding sites turn light grey or even white. Eventually the skin in these areas becomes loose and sloughs off. Breaks in the skin make the host more susceptible to a secondary infection. After sufficient damage has occurred fish can lose osmotic control and die.

Damage is also caused at non-feeding sites. According to a study by Bonga *et al.* (1999), even low numbers of lice had a significant impact on the health of fish due to stress induced by the parasites. Necrosis, or cellular death, occurs at the non-feeding sites. Infestation also causes accelerated aging and increased mucus discharge. The skin of fish is very sensitive to stressors. After fish are subjected to even a low number of lice (10 louse/fish) for prolonged period, immunosuppression ensues, and makes a secondary infection more likely. Immunosuppression decreases the ability of a fish to fight off diseases that it may normally be exposed to, but which would have no affect on it.

4.2.3 Transmission

Salmon lice are found naturally on many species of fish. A fish becomes infected when one of the copepodid or other chalimus stages lands on the fish and attaches itself. Infection is more common during the late summer because the water is more conducive to lice. The water has higher salinity and higher temperature. The ideal location for lice is in warm shallow costal waters, where they can infect other fish more easily (Bakke and Harris, 1998).

Wild louse populations become stable after time (Bakke and Harris, 1998). In farmed conditions, louse populations go from nearly extinct to epidemic levels at an exponential rate. The difference in these two populations is because of the concentration of the fish. Close proximity of infected fish to additional hosts lends to rapid transmission. According to Paone (2000b), Atlantic Salmon are especially susceptible to the effects of sea lice.

The areas around the fish pens have higher concentrations of sea lice than would normally be found in nature (Paone, 2000b). This phenomenon is caused by the large amount of fish in close proximity. Wild fish in the areas where fish farming is practiced have been found to have ten times the number of sea lice a fish would have in areas where there is no fish farming (Windsor and Hutchinson, 1995). According to Paone (2000b), sea lice can be found in concentrations up to 20 times their natural level near the farms and as distance from the farms increased, the level of infestation decreased.

Another important issue of transmission with sea lice is their ability to carry diseases such as furunculosis and infectious salmon anemia (Paone, 2000b). If a sea louse feeds on an infected fish, then that louse and its offspring can transmit the disease to any other fish it feeds on.

4.2.4 Treatment

There are several methods used to treat infestations of sea lice in salmon farms. Among the options for drugs are phrethrin, ivermectin, and hydrogen peroxide. According to Mendiola (2001), pyrethrin is used to kill lice. This drug is approved for two maximum dosages, 10 ppb and 40 ppb, dependent upon the water temperature and the number of lice. This treatment is toxic to any shellfish within the treated area. Additionally, if the drug is applied at a concentration higher than 40 ppb, then the fish will also die. Hydrogen peroxide is used as a bath treatment for infected fish. The drawback to this treatment is that it only kills the adult lice. In order for this treatment to be effective, two applications are necessary. The first application kills the adults; the second is conducted 4 weeks later and kills the juveniles that have become adults (Mendiola, 2001). Ivermectin is a drug which is administered in the feed (Davies *et al.*, 1998). Ivermectin kills adult and pre-adult sea lice. Fish expel large amounts of undigested chemically unaltered ivermectin from the gut. This drug has a low solubility and a long half life of 93 to 240 days. The drug accumulates in the top five centimeters of soil beneath the cage area, and kills shellfish. In short, ivermectin has been shown to cause extremely adverse effects on the marine environment (Paone, 2000b, Davies *et al.*, 1998). A natural solution is also available to control the lice populations. Wrasse, a small coral dwelling fish, naturally eat lice. These fish are effective when the salmon are small, however as the salmon increase in size, the wrasse become increasingly shy of the salmon.

4.2.5 Occurrence in Maine

Mr. Thompson (2001), manager at the ocean site for Connors Brothers Aquaculture, said that the farmed fish required treatment for outbreaks of salmon lice an average of twice per year. He also said that the farmed fish had contracted the salmon lice from other fish in the area. Mr.

Kephart (2001) said that they "generally don't run into that here" in reference to sea lice at the hatchery.

Wild *Salmo salar* naturally carry sea lice (Paone, 2000a). The salmon in Maine are not an exception. Wild fish in the areas where salmon farming exists show increased number of sea lice (Treasurer, 1997). Beyond that statement it is not possible to determine how many times sea lice are transferred from wild populations to farmed populations or vice versa.

4.3 Infectious salmon anemia

Infectious salmon anemia (ISA) was first discovered in farmed Atlantic salmon off the coast of Norway in 1984. The disease spread to New Brunswick in 1996. In 1998 salmon farms in Scotland and Nova Scotia both found fish infected with the disease (Paone, 2000b). Chile reported its first case in 1999 (University of Maine, 2001). The disease was found in Maine in the year 2000.

In 1998, 25% of the salmon farms in New Brunswick were affected by ISA and needed to be shut down. In order to attempt to control the disease, 1,200,000 salmon were destroyed. The next year, an additional 120,000 fish were destroyed with the same intention (Paone, 2000b).

The disease was originally believed to be carried only by *Salmo salar*. This belief persisted until it was determined that it could be carried by all salmonids in the early 1980's (Goehring, 2001). The first documented case of a wild fish with the disease occurred in October 1999 in New Brunswick (Atlantic Salmon Federation, 1999). Progress has been made in classifying the virus, and the transmission characteristics. There is no cure yet available.

4.3.1 Effects

Once infectious salmon anemia is found at a salmon farm, if remedial action is not taken, the disease will spread slowly through the entire farm. After only a couple months, mortality rates will range between 15 and 100%. The most conspicuous effect caused by the disease is death. Secondly, however, is the severe anemia. Fish experience an increase in white blood cells, and their hematocrit values become excessively low (Goehring, 2001). Such a combination causes severe blood loss to result from any injury. Additionally, the peritoneum, a lining of the abdominal cavity, hemorrhages. That means that the fish bleed internally after they have been infected. The fish also display necrosis of the liver, a condition in which the cells in the liver die faster than they are being replaced. This is in spite of the fact that the liver is becoming enlarged. Petichiae are small bruises. These petichiae can be found in the mucosa, the visceral fat, and the ascites or abdomen. Additionally the spleen and foregut become swollen. Outward symptoms include a general darkening of the skin, pale gills (Goehring, 2001), lethargy, and swollen eyes (University of Maine, 2001).

The virus that causes ISA also causes hemorrahagic kidney syndrome (Byrne *et al.*, 1998). This illness causes lesions to form on the kidneys of the infected fish, which compound problems for the infected fish.

4.3.2 Transmission

Infectious salmon anemia is a virus. It is considered communicable, and anywhere outside of Norway, it is considered exotic because this disease was introduced to these areas. The virus only causes disease in Atlantic salmon (Anderson, 2000). Other salmonids however can carry the virus, as it still replicates within their cells. Birds and mammals do not carry the disease (Dannevig *et al.,* 1997), nor does it affect them. The virus reproduces at its fastest rate at a temperature of 15°C. The virus does not reproduce at all at temperatures near 25°C. This suggests that the disease is limited to cold blooded animals (Dannevig *et al.,* 1997). The virus is an orthomyxo-like viral agent, similar to flu viruses. In particular the virus is very similar to Influenza C (Brech *et al.*, 2000).

The virus can be spread through passive transmission, which involves a variety of vectors from an infected fish to a new host through seawater. The virus enters the water by means of contact with an infected individual or any of that individual's blood, viscera, or body fluids. Once the virus enters the water, it remains infectious for up to 48 hours in salt or fresh water at 10 degrees C (University of Maine, 2001). A healthy individual can contract the disease by respiration or ingesting any of the infectious material. Sea lice can also transmit the disease. Sea lice, in fact, make the fish more susceptible to disease in the first place. The sea lice make the fish more susceptible by breaking the skin of the fish and causing it stress, each of which lowers the immune response. Sea lice also contribute to the amount of infectious material entering the water from mechanical degradation of the host's skin.

4.3.3 Treatment

There is no cure available for infectious salmon anemia. When infected fish are found at a farm, the affected individuals are immediately removed and destroyed. This is the only way to keep from losing the entire stock. As of yet, there are no effective vaccinations against this disease. The virus can not survive longer than 20 minutes under a UV-dose of 25 mw-s/cm^2 (Torgersen, 1998). This means that water coming into a hatchery could be treated in order to ensure that the fish do not get the disease from upstream. By the same measure, the effluent could be treated with UV in order to ensure that hatcheries do not spread the disease. This method would not be possible to employ at the fish pens in the ocean.

4.3.4 Occurrence in Maine

New Brunswick, which is adjacent to Maine, destroyed over $20 million worth or one third of their salmon in 1999 in order to stop the spread of ISA (Young, 2001). Heritage Salmon was forced to destroy 11,000 salmon because they were in a Canadian ISA control zone in year 2000. Canadian ISA control zones are areas that have a likelihood of there being infectious salmon anemia within its boundaries as determined by Canadian authorities. Any aquaculture company who has salmon within those control areas are required to destroy their fish. The effort was a failure and the disease did spread to Maine. In one incident in 2001, an unspecified Maine aquaculture company was forced to destroy 45,000 salmon because they shared the same cage as fish infected with ISA. In another incident the same year, 78,000 salmon were destroyed for the same reason (Clancy, 2001a). The total estimated value for the destroyed salmon is $1,230,000 for 2001. There is a 1 cent per pound tax on Atlantic salmon in the state of Maine which is used to pay for testing farmed fish for the disease (Young, 2001).

Each of the men interviewed for this report said that they had not personally encountered fish with the disease (Thompson, 2001; Kephart, 2001). Mr. Thompson, from the ocean site, said that he had been "lucky" thus far and that the disease had not been found in the Bay of Fundy, which is the bay that the farm is located on. Oren Kephart (2001) said that although he had not encountered any fish with the disease at the hatchery, he helped identify it at another farm. The solutions each of these gentlemen had were the same. If an individual is infected, it will be destroyed. In the hatchery situation, this means that the entire tank's contents would be culled. In the ocean site situation, this involves destroying the entire contents of a fish pen.

5.0 Analysis of Results

This chapter synthesizes the information from the results chapter. This chapter also illustrates how the data from the results chapter can be applied to answering whether or not salmon farming in Maine is a significant factor in the transmission of diseases from farmed to wild fish.

5.1 Disease amplification

By their very nature, fish farms bring large numbers of fish together in a small area. Studies have shown that fish exhibit reduced immune capability under these conditions. Stress can result from predators such as seals attacking the outside of the nets (Kling and Opitz, 2000) or from the proximity to a larger number of fish for a prolonged period than would not normally be found in the natural environment (Nicholson, 2000). Stress causes fish to produce hormones that weaken their immune system (Paone, 2000a).

Paone (2000b) provides an explanation of the disease amplification concept. In nature, fish live with the pathogens that cause disease. After a long period of time, equilibrium is reached. Fish in the areas where a pathogen naturally occurs are not as susceptible to its effects because they have developed a resistance to it. Farmed salmon, on the other hand, do not exhibit the same type of resistance. The salmon in fish farms are bred from stock from several different locations. Not all of the genetic resistance is transferred to the progeny in this case, because the brood stock is selected primarily for growth characteristics. Additionally, the salmon at fish farms are not necessarily (nor likely) from the same geographical area as the farm. This means that when a naturally occurring pathogen comes in contact with a salmon farm, the fish have certain disadvantages. First, they are not naturally resistant to the disease, and second their immune system is not functioning at full capacity.

If even a single individual becomes infected in a fish cage, the problem can spread rapidly. For the diseases discussed in this paper, the pathogens can be spread through contact with other fish, sea lice, and feces. In nature, the diseased fish would be at a disadvantage because it is slower than its peers. In turn, the fish would be less able to compete and would likely die on its own or be taken by a predator. Thus, in nature, the diseased and therefore disease spreading individuals are removed from the system. In the farmed case however, this diseased individual is forced to stay in contact with the remainder of the stock.

Another difference between diseased individuals in wild and farmed situations is the number of other fish that they will come in contact with. With only hundreds of wild sea run Atlantic salmon left in Maine (Kaufman, 2000), the farmed salmon are obviously going to be in contact with a larger number as they are in cages with 49,000 or more other fish (Thompson, 2001). The result is that farms end up with a high concentration of diseased fish. Compared to an individual wild fish, larger numbers of diseased fish create a larger amount of infectious material. The fish feces build up beneath the fish farms, mixed with bits of food that fall through the cages. If the feces are infected, this becomes a very likely vector of transmission to any wild fish in the area susceptible to the pathogen. Additionally, other means of horizontal transmission become more likely. For example, passive transmission vectors become more likely because the amount of water respirated by and put into contact with the infected fish increases with the number of infected individuals.

Sea lice are amplified as well. Sea lice flourish in shallow costal waters, which happen to be the very place that salmon farms are located. Sea lice are capable of transmitting each of the diseases discussed here as well as others. Wild fish in the areas of salmon farms exhibit a greatly increased number of sea louse per fish as a result of their proximity to the fish pens. Diseases can be passed between wild fish and the salmon in the cages with the transmission of the lice they carry. Sea lice are a very important transmission vector because of their ubiquitous presence and their ability to carry a variety of diseases. Another problem with sea lice infestation is their effect upon smoltification. Berry and Davison (2001) estimated that as much as 86% of the deaths of juvenile salmon are the result of sea lice.

The problem of disease transmission can not easily be solved. Sea lice and pathogens are too small to be contained by any type of net or cage that could be attached to fish pens. If a secondary cage was employed to keep other fish away from the fish pens, the buffer distance required would be prohibitive. A pathogen or a sea louse could travel several miles in the current in a matter of hours, which is well within the time period that each remains infectious.

5.2 Escaped farmed salmon

Escaped farmed salmon can pose a variety of threats. The salmon can interfere with the genetic integrity of the wild sea run salmon and can also compete with the wild salmon for food. Those two topics, however, are not within the scope of this paper. The threat from escaped farmed salmon for the purposes of this paper lies in their potential to transmit disease to wild populations. The threat is valid for two reasons. First, farmed salmon do get diseases and are capable of spreading them to other individuals they come in contact with. Second, farmed salmon do escape. 500,000 salmon escaped from 78 farms in Scotland in year 2000 alone (Berry and Davison, 2001). According to Carlton (2001), tens to hundreds of thousands of farmed salmon regularly escape from farms in the United States each year. In 2001, 13,000 salmon escaped from Heritage Aquaculture in Maine. Two weeks later, over 100,000 salmon escaped from a Maine farm owned by Atlantic Salmon of Maine (Clancy, 2001b). Escaped *Salmo salar* are capable of reproducing after they have escaped (Carlton, 2001). This actually happened in the Pacific Northwest in the United States in 1998. This is significant because Atlantic salmon are not indigenous to that area. There is no reason to believe that escaped farmed *Salmo salar* in Maine could not reproduce as well, especially since the species is naturally found there already.

5.3 Treatment

The death of each farmed fish costs farmers a potential profit. Even if death does not occur, disease reduces the value of the fish because of the degradation of the fish tissue. With this being the case, fish farms will treat diseases in their farms if there is a chance that their fish can be saved. The threat lies in the use of chemicals and drugs to accomplish this goal. Chemicals such as ivermectin are used to kill sea lice. Ivermectin does kill the sea lice, but it also has a negative effect upon the surrounding sea life. Sea lice are crustaceans, and ivermectin is a pesticide used to kill crustaceans. The problem lies in the fact that other crustaceans living in the vicinity of the treated area can be killed along with the parasites.

Antibiotics pose another set of potential problems. Bacteria can exchange plasmids which impart resistance to antibiotics. Bacteria can transfer these plasmids whenever they come in contact with another bacterium regardless if the two bacterium are of the same type (Paone, 2000a). This means that new and more resistant strains of bacterial pathogens are continually appearing.

There are other methods of dealing with diseases, infections, and parasites. These methods are, however, not likely to be completely effective in disease treatment. UV light can be applied to water to kill pathogens such as the virus responsible for ISA. This method could be used at a hatchery with success. This method is impractical at an ocean site however because water enters and exits the fish pens from all directions.

Wrasse eat sea lice. The wrasse are an effective control measure for small salmon, however larger salmon scare the wrasse away. This means that a large amount of a fish farm's population is not able to be protected by this means.

Selective breeding is an effective tool to protect farmed salmon from disease. An example of a program to find fish with resistance to a disease was done by Nordmo *et al.* (1997). This program was to find fish with resistance to furunculosis; however, the process is the same for other diseases. The fish to be tested are in a fish pen. Individuals are infected by injection and added to the pen. Fish with less resistance are infected first and die first. The infected individuals are removed at some point and the remaining healthy fish have higher resistance to the disease and are bred with others who exhibit similar resistance. Successive generations have higher and higher resistance. This method is effective but time consuming. The study described above lasted five years. This means that in five years the study found families of fish that exhibited resistance to one disease. If the salmon farmers wanted their fish to exhibit resistance to multiple diseases, it is easy to see how that could take a significant amount of time to accomplish.

Vaccinations are another way to protect fish from diseases. Vaccinations are applied to fish while they are still in the hatchery (Kephart, 2001). Smaller fish are easier to handle, and the conditions at the hatchery are more regulated. Additionally, the manufacturers of the vaccinations recommend injection into pre-smolts prior to transfer into seawater (Bayotek, 2001). Vaccinations are effective in preventing specific diseases to salmon. The disadvantage of vaccinations is that they are time consuming and require that each fish be injected individually.

Another method used to control disease is culling. Fish farmers remove and destroy diseased fish in order to prevent others from becoming infected (Thompson, 2001). Salmon can be removed by netting them or divers can use a vacuum to transfer fish into a storage tank. Fish at the hatchery are tested for disease (Kephart, 2001). If any of the fish in a tank in a hatchery test positive for a disease, the entire contents of the tank are destroyed. An important consideration when destroying the diseased fish is to ensure that the remains will never make it back to the ocean. It is important to take that caution because the blood, viscera, body fluids, and tissue of these fish are infectious. The disadvantage of culling is that it costs the farm money in loss of potential profit.

5.4 Risks to humans

Although the diseases discussed in the results section of this paper do not infect humans, salmon do carry some types of bacteria that could affect humans. Salmon can carry the bacterium *E. coli, Salmonella,* and *Serratia* (Paone, 2000a). The preceding bacterium can cause illness in humans if ingested. A more important risk lies in the ability of bacteria to transfer plasmids across different types of bacteria. This is a risk because salmon may come in contact with bacteria that have resistance to antibiotics used in fish farming. A person could then eat this fish and any bacteria present within the person could be fortified with resistance to the same drugs. Although the bacteria could be killed by cooking them, they still retain their plasmids and can still transfer them to live bacteria (Paone, 2000a).

5.5 Future threats

The diseases discussed in this paper thus far are not the only disease threats faced by the wildlife and ecology surrounding salmon farms. There is a high likelihood that there are still many undiscovered diseases. Additionally, the diseases currently present are capable of developing resistance to the current treatments.

5.5.1 History

In order to understand how a newly discovered or introduced pathogen could cause significant problems, history can serve as an example. Infectious salmon anemia was first discovered in 1984. The disease spread rapidly throughout the world, causing a large numbers of casualties. Millions of salmon had to be destroyed in order to slow the spread of the disease. ISA has been found in Norway, New Brunswick, Scotland, Chile, and the United States. These countries constitute the overwhelming majority of farmed salmon production throughout the world. Wild sea run salmon have been found to have the disease in these countries as well. Furunculosis is another good example of an exotic disease causing widespread casualties. A new marine stream emerged in 1985 and can now be found everywhere there are salmonids. Furunculosis caused epidemics as it spread in wild as well as farmed populations of salmonids. These two examples show how a pathogen introduced into a new environment can cause significant damage. These two are used here as examples because they are fairly recent.

5.5.2 Introduced species

An analogy to use when evaluating the threat of new salmon diseases is the concept of introduced species. An introduced species is an organism that spreads its habitat to new areas where it was not originally found and reproduces there. Some introduced species flourish because there is no natural competition in this new area. The inhabitants in the invaded area have not been exposed to the new competitor and may or may not be able to contend with it. In that respect exotic diseases are similar to introduced species because the exotic diseases are acting upon organisms that have never seen the infectious agent before. Carlton (2001) provides a detailed account of marine introduced species in the United States.

New species of all sorts are introduced to the United States in hundreds per year. These introductions come from all over the world. There are many vectors capable of transporting new organisms from shore to shore. Ballast water is taken in by large transport ships in one country and expelled at a destination in order to adjust the trim and handling characteristics of a ship. In the results section it has already been stated that pathogens can live in water for a short period of time. This short period of time is long enough to allow a ship to move a considerable distance from where it took in its ballast water. Organisms in the ballast water range in size from microscopic life to 12 inches or longer. One of the organisms could in fact be a new pathogen. It is also possible that there are large organisms such as fish carrying pathogens or parasites. Trade routes change over time. This means that ships travel to different places or in different orders which also facilitates the exposure to new organisms. It is estimated that there are at least 7,000 species of marine life transported by this means every day (Carlton, 2001).

Just because an organism is transported does not mean that it will necessarily take root in its new environment. In the case of a parasite or pathogen, the organism may die before it has a chance to find a suitable host. This means that a potential menace could be transported many times without result.

Ballast water is not the only vector that may give rise to the occurrence of new diseases. Eggs of fish transported around the world have the potential to carry disease with them. There are many vectors capable of introduction, possibly too many to list. Fish, parasites, or disease may be transported across the ocean or just into an area where they were not found before.

5.6 Relevance to Maine

Thus far, the topic has been presented as a general one of disease. This was to introduce and develop all of the ideas necessary to understand how the diseases are spread and their potential for damage. This section shows how all of these factors apply to the industry inMaine.

Each of the diseases in the results section as well as sea lice are found in Maine in both farmed and wild salmon. The diseases discussed here are communicable and are capable of being transferred from the farmed salmon to the wild salmon or vice versa. The transmission can be through a variety of vectors, each of which are difficult to control in an ocean environment. Since the fish are kept in pens with no control over the water entering or exiting, passive transmission is very likely if the farmed fish have a disease. Additionally, sea lice which spread diseases between wild and farmed salmon can not be contained within or excluded from the fish pens.

The histories of these diseases show a pattern of a disease affecting salmon being discovered in one location and spreading to other areas where salmon are being farmed. These diseases, whether they originally affected only farmed or wild salmon, now affect both.

The potential for introduced species in Maine is valid. Asian Shore crabs arrived in Maine in 1994 (Carlton, 2001). A pathogen could be introduced in the same manner.

6.0 Conclusions and Recommendations

Salmon farming in Maine can be evaluated in the same way as in other areas. Salmon are housed in the same fashion, face the same parasites and diseases, and therefore present the same threat. The special case of Maine is that wild *Salmo salar* are an endangered species. Farmed salmon are the same species and play a part in spreading diseases to their wild counterparts. The main risk from farming Atlantic salmon is that an endangered species which is declining in number lives in the same water as an industry that harbors and can spread potentially fatal diseases.

Diseases and parasites are transmitted between farmed and wild salmon. The existence of salmon farming in Maine increases the probability that wild salmon will contract disease. Salmon farming contributes significantly to the number of sea lice in the surrounding area, causing the probability of transmission of any diseases present to increase even further. The population of wild *Salmo salar* is only in the hundreds. Salmon farming in the state of Maine is likely contributing to their declining numbers by transmitting diseases to this endangered species.

My recommendations to make the industry safer include moving the portion of the industry currently in the ocean onto land. This would be a major change in the way business is conducted for salmon farmers. The idea behind this change is to raise all stages of the salmon in the same manner. The water could be taken in from the ocean, filtered and treated by UV, circulated through the farm, and then filtered and treated by UV before it is returned to the ocean. This method would mean that the diseases and sea lice discussed here would not be transferred between wild and farmed populations. Escapes would also be eliminated because the fish are in containers on land. Finally, food and feces would not accumulate in the ocean because it would be filtered out before the water is returned to the ocean. An operation such as this would require a larger initial investment, however losses due to disease would be greatly reduced. Additionally this method would be much more ecologically sound. This method would also require higher operating costs due to electricity usage for pumps and UV devices.

Additional benefits could be derived by locating the hatchery on the same premises. Some of the machinery would be redundant and that would reduce operating costs. Additionally, transportation of smolts from the hatchery to the ocean site would be eliminated, which would reduce if not eliminate the need for hiring seasonal laborers. This recommendation would be strongly opposed by the salmon farming industry because of the investments it would require. However, given the virulent nature of the diseases, it may be the only way to keep aquaculture from spreading diseases to wild fish.

If a student wishes to conduct additional research related to this subject, I recommend that they pursue research the numbers of wild fish affected by disease. Very little information is available in this area and it is a field where there is room for research.

Bibliography

Atlantic Salmon Federation. 1999. Status Report on Maine Salmon http://www.asf.ca/Overall/diseases.html.

Anderson, E. 2000. Infectious salmon anemia virus (ISAV): An emerging viral pathogen of Atlantic salmon. U. of Maine Col. Of Nat. Sci., For., and Agr. White Papers. Series 3.

Austin, B. 1997. Progress in understanding the fish pathogen Aeromonas salmonidica. Tibtech. **15** 131-135.

Bakke, A., and Harris, P.D.. 1998. Diseases and parasites in wild Atlantic salmon (*Salmo salar*) populations. Can. J. Fish. Aquat. Sci. **55**(Suppl. 1) 247-266.

Bayotek. MULTIVaCC4 Vaccine. http://www.bayotek.com/html/products/multi4.html (accessed October 2001).

Berry, C. and Davison, A. 2001. Bitter harvest: A call for reform in Scottish Aquaculture. Weyside Park Godalming, Surrey, UK.

Blomstrom, D. Fishing Industry Fun Facts & Statistics (Geobopological Survery). http://www.geobop.com/World/NA/Topics/Industry/Fisheries/States/ (accessed October 2001)

Bonga, S., Nolan, D. and Reily, P. 1999. Infection with low numbers of the sea louse *Lepeophtheirus salmonis* induces stress-related effects in postsmolt Atlantic salmon (*Salmo salar*). Can. J. Fish. Aquat. Sci. **56** 947-959

Brech, A. *et al.* 2000. Initial events in infectious salmon anemia virus infection: Evidence for the requirement of a low-pH step. J. of Virology **74** , No. 1, 218-227.

Brennan, W. J. 1999. Aquaculture in the Gulf of Maine: A Compendium of Federal, Provincial and State regulatory controls, policies and issues. Gulf of Maine Council on the Mar. Env. Aquaculture Committee.

Brown, L. and Bruno D. 1999. The occurrence of *Renibacterium salmoninarum* within vaccine adhesion components from Atlantic salmon, *Salmo salar* L. and coho salmon, *Oncorhynchus kisutch* Walbaum. Aquaculture **170** 1-5.

Bullock, G. L., and Herman, R.L. 1980. Bacterial kidney disease of Salmonid fishes caused by Renibacterium Salmoninarum. U.S. Dep. Of the Int. Fish Disease Leaflet #78.

Byrne, P.J., MacPhee, D.D., Ostland, V.E., Johnson, G., Ferguson, H.W. 1998. Haemorrhagic kidney syndrome of Atlantic salmon, *Salmo salar* L. J. Fish Dis. **21** 81-91.

Canadian Aquaculture Industry Alliance http://www.aquaculture.ca/EnglishWeb.html (accessed October 2001)

Carlton, J. T. 2001. Introduced Species in U.S. Coastal waters: Environmental Impacts and Management Priorities. Pew Ocean Commission.

Clancy, M. 2001a. Disease found in fish farm. Bangor Daily News, April 21,2001 [online, http://www.bangornews.com/editorialnews/article.html?id=32454]

Clancy, M. 2001b. 100,000 salmon escape from pens. Bangor Daily News, February 23, 2001 [online, http://www.bangornews.com/editorialnews/article.html?id=29627]

Cotter, D. *et al.* 2000. An evaluation of the use of triploid Atlantic salmon (*Salmo salar* L.) in minimising the impact of escaped farmed salmon on wild populations. Aquaculture. **186** 61-75.

Dannevig, B., Falk, N.,Mjaaland, S., Namork, E.,and Rimstad, E. 1997. Characterization of infectious salmon anemia virus, an orthomyxo-like virus isolated from Atlantic salmon (*Salmo salar L.*). J. of Virology **71**, No. 12, 9016-9023.

Davies, I.M., Gillibrand, P.A., McHenry, J.G., and Rae, G.H. 1998. Environmental risk of ivermectin to sediment dwelling organisms. Aquaculture. **163** 29–46.

Everson, J. *et al.* U.S. 1998. U.S. Geological Survey Biological Information & Technological Notes. Windrow Composting as an Effective Method to Dispose of Large Numbers Fish. [online, www.biology.usgs.gov/news/98-013.htm]

Goehring, B. 2001. Infectious Salmon Anemia – The Disease. http://www.hmsc.orst.edu/classes/MB492/ISAbrad/disease.html.

Gumundsdottir, S. *et al.* 2000. Measures applied to control *Renibacterium salmoninarum* infection in Atlantic salmon: a retrospective study of two sea ranches in Iceland. Aquaculture **186** 193-203.

Hiney, M. and Smith, P. 2000. Oil-adjuvanted furunculosis vaccines in commercial fish farms: a preliminary epizootiological investigation. Aquaculture **190** 1-9.

Kaufman, M. 2000. Atlantic Salmon Placed on Endangered Species List. The Washington Post, November 14, 2000 [online, http://www.washingtonpost.com/ac2/wp-dyn?pagename=article&node=&contentId=A13031-2000Nov13]

Kephart, O. 2001. Interview. Gardner Lake Fish Culture Station, East Machias Maine August 10, 2001

Kling, L. J. and Opitz, M. 2000. The Farming of Atlantic salmon in the State of Maine. University of Maine College of Nat. Sci., Forestry, and Agr. White Papers. Series 3.

Maule, A., Mesa, G., Poe, T., and Schreck, C.. 1998 Influence of bacterial kidney disease on smoltification in salmonids: is it a case of double jeopardy? Aquaculture **174** 25-41.

Mendiola, A. 2001. Salmon Lice. http://www.hmsc.orst.edu/classes/MB492/LICEgus/salmonlice.html (accessed October 2001)

Nicholson, B. L. 2000. Fish Diseases in Aquaculture. University of Maine College of Nat. Sci., Forestry, and Agr. White Papers. Series 3.

Nordmo, R., *et al.* 1997. Induction of experimental furunculosis in heterogenous test populations of Atlantic salmon (*Salmo salar* L.) by use of a cohabitation method. Aquaculture **1162** 11-21.

Paone, S. 2000a. Farmed and Dangerous: Human Health Risks Associated with Salmon Farming. A Friends of Clayoquot Sound Report.

Paone, S. 2000b. Industrial Disease: The Risk of Disease Transfer from Farmed Salmon to Wild Salmon. A Friends of Clayoquot Sound Report.

Scientific Committee On Animal Health and Animal Welfare, 1999. Bacterial Kidney Disease Report. Eur. Com. Health and Consumer Protection Directorate. Gen. Directorate B. Unit B3.

Sternberg, D. 1987. Freshwater Game Fish of North America. Cy DeCosse Inc: Minnesota.

Thompson, H. 2001. Interview. Connors Brothers Aquaculture, Eastport, Maine August 10, 2001.

Torgersen Y. 1998. Physical and chemical inactivation of the infectious salmon anaemia (ISA) virus. 6th Annual New England Farmed Fish Health Workshop Eastport, Maine. App 3-10.

Treasurer, J. W. 1997. Parasites of wrasse (Labridae) in inshore waters of west Scotland stocked as cleaner fish of sea lice (Caligidae) on farmed Atlantic salmon. J. of Fish Bio. **50** 895-899.

University of Maine, 2001. MaineSci Science and Engineering http://www.umaine.edu/mainesci/archives/marinesciences/salmon-farming.htm. (accessed October 2001).

Wilson, J. 2000 Impact of the Atlantic Salmon Industry on the Maine Economy. University of Maine College of Nat. Sci., For., and Agr. White Papers. Series 3.

Windsor, M. and Hutchinson, P. 1995. Minimizing the Impacts of Salmon Aquaculture on the Wild Salmon Stocks. Sustainable Fish Farming **17** 187-196.

Young, S. 2001. Salmon anemia hits state. Bangor Daily News. March 17, 2001, [online, http://www.bangornews.com/editorialnews/article.html?id=30793]

Appendix

Interview with Mr. Kephart

Transcript of interview with Oren Kephart, Manager of Gardner Lake Fish Culture Station.

Oren Kephart

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In an interview on August 10, 2001, Oren Kephart provided me with an interview and tour of the hatchery facilities. His title is Manager, Gardner Lake Fish Culture Station. The hatchery is located in East Machias, Maine. I recorded the interview; however some portions are not audible due to machine made noise. The exact transcription is shown in quotations, while sections which are not audible have been paraphrased and are not in quotations.

The tour began where the unfertilized eggs and milt are brought into the facilities.

Kephart: "This is where the eggs and milt are brought in from the ocean site. The first thing we do is to bathe them (the eggs) in a disinfectant solution. From there we fertilize the eggs and bring them in to the hatch house."

Inaudible, in the hatch house. Mr. Kephart explained what happens next In here the eggs are kept in these containers. "Until they eye up, at which point we shock them."

Kennedy: "and by shock them you mean?"

Kephart: "Literally shock the eggs. This helps break em up. From there we put them into these"]He indicates large green circular containers. There are many of these containers in the room.]

"Each parent's offspring are separated. We keep them separated while we are waiting for certification for the parents that they are disease free. If we find that one parent had a disease, the container with those (fish) are destroyed." We have to get the fry certified as well. They are certified twice per year by an independent agency. We have some of the facilities here to do the testing, however we don't do much of that. "Once the smolt field is empty these fish come out of here."

Kennedy: "So all of the fish that leave this room are certified disease free?"

Kephart: "Yes."

Next, we went into the room where the water entering the hatch house is controlled. Mr. Kephart went into great detail about how the water is enriched with oxygen, and how the temperature is controlled. He indicated that the temperature can only be warmed by a couple of degrees due to the large amount of water running through the facility. The reason the oxygen is important is because if all of a sudden the water stops being oxygenated, then in as little as 15 minutes he will begin to lose fish at a rapid rate. For this reason, there are alarms which monitor the oxygen level. Additionally there are back up generators which are on a 0 second time delay, in the case that the power is cut.

From there we went into the feed building, and then the water processing building for the smolt field. In the water processing plant, the water is taken from a lake upstream of the facility, oxygenated, heated if necessary, and distributed to the smolt field.

Next we went to the smolt field. The smolt field is outdoors and consists of circular tanks about 8' diameter and approximately 2' high. The tanks are made of metal and are covered. One side of the cover is opened slightly and a wire mesh prevents anything larger than ½ inch from getting in or out .

<u>Kephart</u>: "these tanks are all single flow through single pass. Got your water coming in through here. Goes around your tank, and you've got a center cut pipe, with a screen up top and you've got a clean out hauler on the inside. That cleans up any waste, anything like that. This is a single pass system, like I said, I'll explain more as we go along. Then these three tanks all enter the central channel, and it goes down to the pond. This is all new technology comin' on." He was explaining the path of the water from the lake, to the processing plant, to the individual smolt field tanks, to where the water is treated before it is discharged.

<u>Kennedy</u>: "how many smolts do you have in each of these?"

<u>Kephart:</u> "About seventy five hundred. This is a million fish facility. We'll fill this group up then bail out about half of the tank or a third of the tank. So once the water is gone from here out of the tank, what we used to have, and I'll show you down here, is two settling tanks. The water would disperse and go evenly to each settling pond. Split it in half. And this end is a little bit lower than the other. So it slowly migrates up and any solids would drop out. Well technology and production rates that we are at, it's kind of old news for a facility like this. So right now we are in major construction. And what we are going to be doing is building a facility down here to filter all this effluent water. Collect the sludge into a bin. Then the water that comes off the cleaning bars or the spray bars, will go through this side which will be filled with a lime stone. So right now this side is still a settling pond. Normally both sides of this would be filled. Now the supernaten, which is the high water off the filters, goes up a smaller screen type filter, which is obviously not in place yet. We'll dewater it at some point and bring it down to 25% of the water that's normally in a sludge. Then we'll pump that over to here, and that will be filled with gravel, cover it with sand, and we are hoping to put some type of plants on top of it. And the water will just run through there. But you're not gonna be talking the entire

flow of the farm, you're gonna be talking 100 gallons a minute. So like I said, we turned this pond into this building."

Kennedy: "Is the water quality monitored once it's discharged?"

Kephart: "Yes. We have, it depends what time of the year the battery of tests we have to do. Summer, July, August, September, we do upstream, downstream, plus what's on the farms, and the influent. In the wintertime, it's just basically on the ponds (indicates settling ponds) and the influent."

Kennedy: "Are there any salmon upstream, in the water that's coming in?"

Kephart: "There are salmon in this lake, yes."

Kennedy: "Is there any possibility that they could have a disease that would be transmitted to this water?"

Kephart: "Oh yeah. Anything like that's possible. Bass, trout, anything that could be transmitted. We don't have a disinfection system or anything like that on our incoming water. So we'll pretty much take it at grade. But what we do is certify that our fish are disease free before shipping them."

Kephart: "The morts are picked, the feeders are filled every day. The morts are picked every day. We'll fill the feeders to the amount that I say depending upon their body weight, and that varies depending upon temperature. This is the feeder, it's just a circular feeder. We'll fill it up to whatever, if I tell em 5 scoops, they'll put it on, and in the morning, there's just this little bit, so they can get a little bit of feed while we aren't in. And then 5 times a day and twice during the night, I'll have a person go and they'll hand feed. And that's in case that some don't get enough. You see these containers across the road, that's how we ship em out of here. Those are the old style washing machine boxes we call em. They are all 1 cubic meter. We have now two trucks worth. And we'll have a third one next spring. Which'll be there five, five cubic meter boxes on a truck. They are much more efficient and a they handle a lot easier. W don't have any pumps or aeration, we just haven't gotten that far yet."

Kennedy "You are just bringing them to Eastport from here though, right?"

Kephart "For the most part. I do ship to Canada, I ship to Jonesport, it depends where our customers are at the time."

That ended the tour and we went inside for an interview. We talked for a few minutes about subjects not related to aquaculture and then continued with the interview.

Kennedy "I hear a lot about infectious salmon anemia, and sea lice, and I don't' know if you see anything about the swimbladder sarcoma virus."

Kephart "That was an unheard of one, I'm not sure where it came from, um, I know about it, because I was there when they supposedly found it, but I am unsure of that. I couldn't even give you any clue. But I knew the hatchery that had to destroy their entire crop. Basically, we'll vaccinate our fish here for frunc (Frunculosis) going out to the smolt field, we'll give em a second vaccine in December, and probably ISA now that it's been here, that's normally for the ocean, but we'll try and get them their degree here. For the sea lice, we don't normally run into that here. I don't know the name of the drug they use, but locally it's called Slice. They use some stuff in Canada we can't use here. But when I started in 86 it was frunc. And then it went to fibrio, fibriosis. From that to BKD. BKD came in time for the lice, and that's when ISA came in and that's pretty much the disease of the day right now. Basically it's biosecurity these days. Fallowing your nets, fowling your cage sites."

<u>Kennedy</u>" "These are all one year classes?"

Kephart: "These are all one year classes. What I always say is 18 months here, 18 months in the ocean, and we'll pull em out earlier if they are big enough.

After that, Mr. Kephart said that if I didn't have any more questions now, but thought of some later, I could call him or email him and he would be happy to help me out. I thanked him and left.

Interview with Mr. Thompson

Transcript of interview with Hume Thompson, Manager, Connor's Aquaculture Incorporated.

Hume Thompson

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I interviewed Hume Thompson from Heritage Salmon on August, 10 2001. I could not use the recorder during this interview, so it is reproduced here from notes.

Kennedy: Where do the initial fish come from?

Thompson: Broodstock are selected from successful fish at the nets

Kennedy: How are the fish housed?

Thompson: In side polar cages (circular). (see pictures)

Kennedy: How do you keep predators from getting in?

Thompson: Thick predator nets on outside of cages and bird nets suspended over top. (see pictures)

Kennedy: How old are the fish when they get put in the pens?

Thompson: 18 months/100g

Kennedy: How long does it take for them to mature to the point where you can sell them and how much do they weigh at that point?

Thompson: 18 months/9-15 lbs

Kennedy: How do you deal with diseases once or if they do turn up?

Thompson: Tarp the fish and treat them then release the fish, also put drugs in food

Kennedy: Infectious Salmon Anemia is in the news quite a bit today, could you tell me about your experience with it?

Thompson: It is in the bay of fundy but has not turned up in any of these cages.

Kennedy: Can you tell me about sea lice?

Thompson: Sea lice get transmitted to our fish from the other fish in the area. We try to take care of any problems with them as soon as we encounter them. We gather the fish up in a tarp and apply a drug called slice and also add oxygen. You can't let sea lice go for too long or the fish's skin starts to come loose. I have seen fish with what looks like a main around their head. Sea lice are a problem and the fish have required an average of 2 treatments of tarping and excis with oxygen added per year

Kennedy: Does this slice have any affect on the area around the fish cages?

Thompson: You hear about how salmon farming destroys the benthic community around the cage sites, but if you dive beneath the cages, it's not that bad. I have been diving all over this bay and I can tell you that there are other places around here that there is no benthic community and they are no where near the salmon cages.

Kennedy: What other kinds of diseases have you run into?

Thompson: We have had BKD in the past, luckily it was right before harvest, so we weren't particularly hard hit. We had to pull out and destroy a few slow swimmers. A few years ago hitra hit our farm and we lost a great number of fish to it. The divers would go in there with a fish pump and take out all of the fish exhibiting symptom s and then we would take them inland and destroy the fish, making sure that there was no way that any part of the fish could get back to the water. The divers had different wet suits for each cage, and they were stored in iodine while not in use. Frunculosis is also a problem this time of year.

Kennedy: Have escapes been a problem in the past?

Thompson: In the last two years, we have not lost a single fish. However they have escaped in the past. The cage broke open during a storm last year and I was out here in the middle of it, but we didn't lose any. This winter, we shouldn't see any problems, we are moving to the new polar cages. They are much more storm resistant. They are plastic and much more flexible. Additionally they are spread out, and won't be smashing into each other. They have other benefits as well, because the water flows through them more easily and since the cages aren't right next to each other, infectious diseases are less of a threat.

Kennedy: How many fish are in each cage?

Thompson: 49,000-75,000 depending on size.