Salmon

AQUACULTURE CURRICULUM GUIDE

YEAR TWO
SPECIES MODULE

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Description: The module consists of the following nine problem areas:

Module: Salmon

Problem Areas:
- Identifying the Salmon Farming Industry
- Describing the Life Cycle of Salmon
- Identifying Salmon Species
- Describing Spawning of Salmon
- Describing Salmon Hatcheries
- Explaining Smolt Production
- Describing Cage Culture
- Describing Feeding Requirements of Salmon
- Identifying Health Care and Diseases of Salmon

Objectives: The objectives for each problem area are given below:

A. Identifying the Salmon Farming Industry
   - Locate major salmon producing and consuming nations
   - Discuss how changing consumer interests affect salmon farming business
   - Describe environmental effects of depleting natural salmon stocks
   - Understand merchants' problems in meeting new market demands for salmon

B. Describing the Life Cycle of Salmon
   - Define anadromous
   - Explain stages in freshwater phase of salmon's life
   - Explain ocean phase
   - Explain spawning phase
   - Explain similarities between steelhead trout and salmon

C. Identifying Salmon Species
   - Identify countries to which salmon are native
   - Explain Tchemavin's theory explaining origins of salmon
   - Explain 2 types of salmon culture
   - Explain life cycle of Atlantic salmon (Salmo)
   - Identify 5 aquaculturally important Pacific salmon and explain how they differ

D. Describe Spawning of Salmon
   - Explain difference between natural and artificial spawning
   - Identify issues in handling broodstock
   - Give reason for selective breeding
   - Explain requirements for healthy egg incubation
   - Discuss factors in choosing an incubator
   - Describe basic anatomical features of a fish
   - Explain 2-person method of artificial spawning
   - Explain incision method of artificial spawning

E. Describing Salmon Hatcheries
   - Explain history of hatchery use in salmon industry
   - Explain design principles of salmon hatchery

F. Explaining Smolt Production
   - Compare and contrast use of management-intensive aquaculture systems
   - Explain relationship between water quality and harvestable fish
   - Explain importance of temperature to fish output
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- Explain relationship between temperature and stocking density
- Calculate tank volumes for cubical and cylindrical tanks

G. Describing Cage Culture
- Explain environmental conditions for successful cage culture
- Explain types of cages used in cage culture
- Discuss management systems for cage culture
- Understand harvest methodology for cage cultured salmon

H. Describing Feeding Requirements of Salmon
- Explain nutritional requirements of salmon
- Explain best way to feed salmon
- Explain difference between dry and wet mixes

I. Identifying Health Care and Diseases of Salmon
- Explain general signs of illness in fish
- Name common fish diseases by external disease
- Name common fish diseases caused by internal bacteria
- Name common fish diseases caused by external protozoa
- Name common internally caused fish diseases
Teaching Plan:

Module: Salmon - Section A

Problem Area: Identifying the Salmon Farming Industry

Goal: The goal of this problem area is to explain who the producers, middlemen, and consumers are in the commercial salmon industry and where the industry is heading in the next 10 years.

Learning Objectives: Upon completion of this problem area, students will be able to:

- locate major salmon producing and consuming nations.
- discuss how changing consumer interests affect salmon farming business
- describe environmental effects of depleting the natural salmon stocks
- understand merchants’ problems in meeting new market demands for salmon

Resources: The following instructional resources are needed to complete this problem area:

Essential:


"Northern Aquaculture."

"Seafood Business."

Aquaculture, E. Horwood, Publishers, NY.

Transparency, overhead projector, and world map.

Additional:

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Content and Procedures

Preparation (Interest Approach):

To develop student interest in this module, ask the students if they eat chicken sandwiches or chicken nuggets at the fast food restaurants. Discuss how the chicken industry expanded its market with innovative new products. Ask the students if they eat fish products at the fast food restaurants. Compare how the chicken industry used new products to what the fish industry might try.

Presentation:

A. How did the salmon industry develop?

Using a large world map, have students locate nations to which salmon are native. Compare and contrast history and development of artificial propagation relative to salmon and other livestock, such as dairy cattle. Discuss difficulties in establishing legal rights for a particular kind of fish. Show TM A1 and discuss today's market trends relative to salmon consumption.

1. Salmon farming began in the 19th century. It followed the development of artificial fertilization by Jacobi in 1765.
2. Artificial propagation was needed:
   a. Most salmon die after spawning. Atlantic salmon and steelhead may survive in substantial numbers in captivity.
   b. Only 3-4% of progeny make it to adulthood. Therefore, need more spawners; need to artificially propagate.
3. Open-sea fishing:
   a. Fish caught by one nation's fishermen often come from streams of another country.
   b. The major salmon producing countries are Norway, Scotland, USA, Canada, Japan, Russia, and Chile.
   c. The industry was developed by imaginative biologists and backed by international businesses.

B. What are the consumer market trends for salmon?

Divide class into several focus groups to discuss the following as they relate to salmon farming industry: changing life styles, supermarkets, convenience stores, disposable income, and advertising. (This activity could be taught with a member of the social studies department.) Groups should explain how these factors changed our eating habits and affected the natural supply of salmon. Groups should also discuss environmental problems resulting from overuse of natural resources (daming rivers, soil, pesticide runoff, poor forest harvest techniques). Discuss major areas of supply for salmon products. See current periodicals for information.

1. Demand for convenience food, due to changing work and life styles.
2. Development of health consciousness.
3. Development of supermarkets vs. specialty shops, e.g., fishmongers.
4. Advances in food technology, packaging, infrastructure for transporting, and support for chilled foods.
5. Increase in disposable income leads to increase in exotic foods.
6. Increased awareness of fish products through TV, etc.
7. Increase in dining out.
8. Market may depend on continued affluence. Better production can lower cost, thus changing market.
C. What are the markets for fish?

Show TM A2 and discuss markets for fish.

1. Originally, most salmon was consumed in either the smoked form or canned.
2. Traditionally sold fresh through specialty fish shops.
3. Today, majority sold as frozen through supermarkets.
4. Current move to have fresh fish counters at supermarkets.
5. Also, sale of fresh, prepacked fish.
6. Increase in new products.
7. Market research is identifying consumer demands as to quality and availability.

D. Where does salmon come from?

1. Base production is of wild Pacific salmon. Annual production around Pacific rim is 750,000 tonnes. Quality is variable.
2. Most is caught between May and October.
3. The majority is frozen or canned.
4. Farmed production in 1986 only contributed 8.2%. Norway dominated supply, with 69% of market.
5. Quality of wild salmon dependent upon how and where the fish are caught.
   a. High fat content, silver scales, and pink flesh support high prices.
   b. Reasonably stable supply at about 8%.
   c. Being farmed in Chile, New Zealand, USA, Japan, and Canada.
6. European Atlantic salmon production is in fast growth rate. May change, as sites become limited and political and environmental constraints apply.
7. Market growth rate depends upon:
   a. Cost.
   b. Continued growth of market demand.
   c. Natural and environmentally caused diseases, e.g., Norway's Hitra disease.
8. Problems from rapid development:

Show TM A3 and discuss problems related to rapid development of salmon farming industry. Discuss problems industry has in meeting consumer demands for consistent quality and supply.

   a. Tighter control on development.
   b. Control on sea bed leases.
   c. Environmental conditions.
   d. Salmon farmers from various countries.

E. What are the opportunities in salmon aquaculture?

Show TM A4 and discuss which countries consume salmon. Have students find salmon recipes in library books and newspapers. Compare different ways that different cultures prepare food.
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1. World production.
   a. Planning. Two important factors from customer standpoint: consistency of quality and continuity of supply.
   b. Problem: It takes up to 36 months to produce a crop. Many variables: weather, predators, disease, and algae blooms.

2. Market demand dominated by seasonal Pacific catch, the majority of which is frozen or canned.
   a. Frozen: most sold to Japan - 2.7 kg/capita (300,000 tons per year).
   b. Smoked: major market in central Europe.
   c. Fresh: U.K. volume farmed Atlantic salmon from 1,000 to 4,100 tonnes from 1984 to 1986.

3. Market channel.

Discuss how today's salmon supply and demand is changing. Divide class into 2 groups: suppliers and consumers to develop new ways of meeting / problem of short supply and growing demand. Discuss moral implications of price of a product becoming so expensive that the workers can't afford the very product they produce. Show TM A5 and discuss how changes in consumption have helped salmon farming industry. Discuss advantages and disadvantages of salmon farming. Discuss role of consumer education in promoting use of salmon.

   a. The majority of salmon is sold through fishmongers or multiple service counters (supermarkets)
   b. A high percent of farmed salmon sold in "white tablecloth" market. These outlets purchase the fish whole and butcher it on the premises.
   c. Prepared salmon, in controlled atmosphere packs, is sold in the steaked and fileted forms.
   d. Both of these sell well in high-end but are prohibitively expensive for large market consumption.
   e. Supply is greater than demand, due to high price.
   f. Need to develop better means of production and extend harvesting season to lower price.
   g. Because they are so expensive, there is a need for retailers to establish new markets for salmon products, e.g., fish oils for health food market.
   h. Smoked salmon still most popular.
   i. 22% of salmon market in U.K. is for restaurants.
   j. European market dominated by Norwegian suppliers.


   a. There is an increase in demand on world market. Current major source is fished wild salmon.
   b. Projected shortage in year 2000 of 30-40 million tonnes of wild fish.
   c. Currently planned aquaculture production to increase by 27 million tonnes by then. That means there is still a projected shortage of 3-13 million tonnes in the year 2000.

5. Fish consumption.

   a. Is related to income. Higher income countries eat more fish, i.e., it is an increasingly expensive source of protein.
   b. Price of supplies for Dover sole went up 18% in U.K., but value increased 35%.
   c. Significant increase in farmed salmon.

6. Advantage of predictability of harvest: continuity of supply and quality.

   a. Still most available in late autumn and early spring due to availability of smolts; therefore, production of smolt currently limiting factor in U.K. Norway already has this.
   b. Need to manipulate egg production by photoperiod.
   c. Laird and Needham say this is true in all salmon farming countries.

7. Another difficulty is mind set and lack of communication between individualistic salmon farmers and entrepreneurial marketers.
a. Need to improve quality of final product served, which is related to selection of stock.
b. Service to customer. Provide right product at the right time.

8. Need consumer education through producer and retailer organizations.

9. Need to develop new products, particularly in area of smoked salmon.

Review:

Review by having students demonstrate their knowledge and understanding of the objectives for this problem area. Lead a discussion with students by asking questions that cause them to explain the content that goes with each objective.

Evaluation:

Evaluation should focus on the extent to which students achieved the objectives of the problem area. Examples include oral questioning and written reports. Example exam questions are attached.
Consumer Market Trends

- Convenience foods
- Health consciousness
- Supermarkets
- New technologies
- Increased income
- Increased awareness through advertising
- Dining out
Markets for Fish

- Specialty shops: fishmongers
- Frozen at supermarket
- New: fresh fish counters at supermarkets
- New: fresh, prepacked products
Problems From Rapid Development of Industry

- Control of development in new areas
- Control of sea-bed leases
- Environmental issues
Market Demand

- Canned: mostly United States
- Frozen: mostly sold to Japan
- Smoked: central Europe
- Fresh: United Kingdom
Increase in Farmed Salmon

- Advantage of predictability
- Extended availability of smolts
- Manipulation of egg production
Quiz for Section A

Name:

Date:

Quiz on Identifying the Salmon Farming Industry

Directions: Complete the following statements:

1. The 4 major salmon producing nations are:

2. Five consumer trends that are affecting the salmon market are:

For the following, circle a T for True statements or an F for False statements.

3. T  F  Fishmongers are shops that specialize in selling fish.

4. T  F  A traditional place to shop for fresh fish has been at the supermarket.

5. T  F  Prepacked fresh fish products are a recent marketing innovation.

6. T  F  Most of the salmon sold in the U.S. is frozen.

7. T  F  Most environmental issues connected to salmon farming have already been solved.

8. Essay: Write one or two paragraphs explaining why the need for farmed salmon should increase.
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Key for Quiz - Section A

1. Producing countries: USA, Canada, Japan, USSR.

2. Consumer trends: convenience foods, consciousness, supermarkets, new technologies, increased income, increased awareness through advertising, dining out.

3. T

4. F Fish counters are an innovation.

5. T

6. F Most Americans buy canned salmon.

7. F Concern for environmental issues is on the rise.

8. Essay: The essay question should cover the following terms. predictability of quantity, predictability of quality, a longer season, due to extended incubation period, changing consumer trends, environmental effects on natural habitat, i.e., dammed rivers, fished out native species, and consumer education.
Teaching Plan:

Module: Salmon - Section B

Problem Area: Describing the Life Cycle of Salmon

Goal: The goal of this problem area is to explain the life phases of an anadromous salmon or trout.

Learning Objectives: Upon completion of this problem area, students will be able to:
- define anadromous
- explain stages in freshwater phase of salmon's life
- explain ocean phase
- explain spawning phase
- explain similarities between steelhead trout and salmon

Resources: The following instructional resources are needed to complete this problem area:

Essential:


"California's Salmon Resource: Its Biology, Use and Management," by Feinberg, L. & Morgan, T., Sea Grant Report Series No. 3, California Sea Grant College Program, CSGCP No .72.
Content and Procedures

Preparation (Interest Approach):

To develop student interest in this module, read the story, "Rattlesnake and Salmon," from the Okinagan Indian tradition. Lead a discussion about the relationship between American Indians and natural resources.

Rattlesnake and Salmon

The lodge of En-tee-tee-ueh Salmon was in the cliffs above the Big Falls. Salmon was a great warrior. Salmon heard of a beautiful girl who lived in the Kalispel country. Many warriors were trying to win her, Salmon heard, and he decided he would win her for himself. So he went to her country and made war on the people. He beat them and took away the maiden. She loved him from the first. She loved him for his red handsome face.

Many warriors wanted to kill Salmon and take his bride, but they did not know how to get at the pair in the lodge above the roaring. But near Salmon's lodge lived Hoh-ah-ooh-lah Rattlesnake, called "Evil of the Earth." He was an old man. He envied Salmon. He decided to kill him. He made war arrows, singing as he worked. And then, one sun, when he had finished the arrows, Rattlesnake strung his bow and stepped outside his bough-covered lodge and sent an arrow into Salmon's head.

Salmon tumbled from his cliff home into the river. His body floated down the river. Salmon's wife cried. The three Wolf brothers had been watching. They saw Salmon die. They took Salmon's wife to their own camp. There she was made to work - to be a slave - and she was watched night and day by the wives of the three brothers. She was unhappy; she felt very bad.

The river carried Salmon's body a long way. Finally it was washed upon a sandbar, to bleach in the sun. Soon only the skull and the backbone remained.

Gou-kouh-ana--Mouse, the Sly One, came there to the sand-bar one day with her sister. They were looking for something to steal. They found what was left of Salmon. Mouse was very sad, for Salmon had been her chief. She went to a camp nearby and stole some salmon oil. With that oil she greased the skull and backbone every sun for many suns. After awhile the flesh began to grow around the bones. Slowly Salmon was restored to life by the oil Mouse rubbed on him. At last he could get up and move around, and after many moons he became strong again. Then he went back to the Big Falls, to his home. As his wife was not there, he went over to Rattlesnake's lodge to ask about her. He heard Rattlesnake singing.

"I shot him, and he ran down the cliffs!" And Rattlesnake sang this: "I shot him! He was chief, but he is a chief no more!"

Salmon walked into Rattlesnake's lodge. Out of the corner of one eye, Rattlesnake saw him, but he did not let on that he saw and he changed his song. He pretended to be mourning Salmon's death. Salmon said nothing. He stooped and picked a piece of blazing wood from the fire and touched it to the dry bough lodge covering. He jumped outside, and the flames leaped up. Rattlesnake was trapped. He could not get out. He was burned to death. From one of Rattlesnake's eyes crawled a small snake. It was Rattlesnake's mystery power.

"Always shall you crawl on your belly," Salmon told the little rattlesnake. "That is my revenge."

Then Salmon started in search of his wife. He found her in the camp of the three Wolf brothers. Two of the brothers he killed, and he told the third, the youngest, to get out of that country. He told him to go into the timber country and never come back. Wolf went. He was the first of the timber wolves. That is how the race of timber wolves originated.

Salmon and his wife did not return to their lodge in the cliffs. He took her into the water below the Big Falls, where they would be safe from the enemies they had among the Land People.

The arrow point that Rattlesnake shot into Salmon's head stayed in his head. All salmon have arrow points like that in their heads today.
Presentation:

A. What makes salmon anadromous?

Show TM B1 and define anadromous.

1. Salmon are born in fresh water, then spend up to 2-3 years in fresh water.
2. Then they migrate to the ocean, where they spend 1-5 years.
3. They return to their native stream and run upriver to spawn.

B. What is the freshwater phase of salmon?

Show TM B2 and discuss the various stages in the freshwater phase of a salmon's life cycle.

1. Begins with hatching of fertilized eggs.
   a. Reddish orange.
   b. Eggs are left in gravel of swift flowing stream. Dark eye develops.

2. Incubation may take 50 days or longer.
   a. The colder the water, the longer the incubation period.
   b. Young hatchlings, called alevins, are small translucent fish with a yolk sac attached.
   c. This sac will be their only food source for several weeks.
   d. Alevins remain under gravel for protection. Alevins can't swim.

3. The fry stage:
   a. After absorbing their yolk sacs, they are only 1 inch long.
   b. Begin foraging for food.
   c. Chum and pinks go to sea.
   d. Coho remain in fresh water for at least 1 year before entering the ocean.
   e. Sockeye stay in freshwater from 1-3 years.
   f. Chinook may not migrate after 6 months.

4. The parr or fingerling stage:
   a. Occurs when the fish reach about 2 inches in length.
   b. They become voracious eaters of insects, worms, mussels, and snails.
   c. This phase is best recognized by the development of dark bars aligned vertically along each side of the fish.
   d. The parr stage is the most vulnerable time in a salmon's life. They are eaten by squaw fish, minks to raccoons, mergansers to kingfishers.

5. The smolt stage:

Show TM B3 and discuss smolt's adaptation for life in sea water. Show TM B4 and discuss hazards a smolt faces as it journeys downstream. Discuss how human activities have affected salmon's ability to journey downstream.

   a. Starts when salmon are about 6 inches or less.
   b. Most salmon begin physical and physiological changes that trigger their downstream migration and adaptation to a saltwater environment.
   c. To adapt to the sea, the fish must change anatomically, endocrinologically, physiologically, and metabolically.
   d. Mortality: 50-100% in captivity.
   e. Alternative is to use captive smelt.
   f. Face hazards from predators and natural and mechanical obstacles.
6. After they begin their migration, they rest in salt water estuaries before entering the ocean.

C. What is the ocean phase of the salmon’s life cycle?

Lead a discussion about the stages in the ocean phase of the salmon’s life cycle.

1. The salmon first head for their hereditary feeding grounds.
   a. Remain in large, loose schools.
   b. Feed on baitfish and herring.
   c. Sockeyes are planktivores.

2. Time in ocean varies from 1 or 5 years, depending on species.

3. Growth rate depends on available food and location. Great Lakes chinook and coho have slowest growth rate.

4. Many hazards: Predators are a major problem.

5. When the time comes they return to the natal streams.
   a. Example: Chinook have spring, summer, fall, and winter stocks, which all behave differently. Also, similar stocks behave differently in different rivers or regions.
   b. Fall salmon, like chinook and coho, concentrate in ocean waters outside their native stream during the summer, where they feed and mature. They wait there until autumn; then they begin their journey upriver.

6. Upon entering fresh water, the salmon quit eating and live off their fat reserves.

D. How do salmon spawn?

Discuss spawning phase of salmon’s life cycle. Discuss how human-constructed dams have affected salmon’s ability to travel up river to its native spawning grounds.

1. Upon reaching the spawning grounds, the males stand guard while the females clear a series of nests (called redds) with their tails.
   a. They do this underneath cold, swiftly running water.
   b. The female lays her eggs in the nest and buries them under gravel. She lays several thousands eggs at a time. Only 1 in 10 will live to maturity.
   c. The males deposit clouds of sperm (milt) over the eggs. This process is repeated in several redds, until the female is depleted of eggs.

2. Atlantic salmon and steelhead can live to spawn again. Others die within days of spawning.

E. What is the life cycle of steelheads?

Have the students compare and contrast salmon and steelhead trout. Using a world map, show the range of the anadromous salmonids.

1. Steelhead are sea-run (anadromous) rainbow trout.

2. Life cycle much like salmon, but differs as follows:
   a. They migrate as individuals, not in schools.
   b. Although most steelhead die upon spawning, some live to spawn 2 or more times.

3. Steelhead have summer and winter runs, with overlap; therefore, they are in rivers most of the time.
Review:

Review by having students demonstrate their knowledge and understanding of the objectives for this problem area. Lead a discussion with students by asking questions that cause them to explain the content that goes with each objective.

Evaluation:

Evaluation should focus on the extent to which students achieved the objectives of the problem area. Examples include oral questioning and written reports. Example exam questions are attached.
Anadromous

- Greek: Anadromous
  ana, "upward" + dromous, "a running"
  from dramein, "to run"

- Going up river to spawn; said of salmon,
  shad, etc.
  (Webster 1968).

- Salmon are:
  Born in fresh water
  Migrate to the ocean
  Return to native stream to spawn
Stages in Fresh Water

- Egg
- Alevin:  
  Young hatchlings
- Fry:  
  After absorbing their yolk sac
- Parr or Fingerling:  
  About 2 inches long
- Smolt:  
  Size ranges with species  
  Up to 6 inches long
Smolt Adaptation

- Smolt must change:
  Anatomically
  Endocrinologically (glandularly)
  Physiologically
Hazards for Salmon in Traveling Downstream

- Predators
- Natural obstacles
- Human-constructed obstacles
Quiz for Section B

Name:

Date:

Quiz on Describing the Life Cycle of Salmon

Directions: Match the terms on the left with the short definitions on the right by writing the appropriate letter in the blank next to the term.

1. ___ anadromous  a. 1-inch fish that have absorbed their egg sacs
2. ___ alevin  b. stage where salmon are about 2 inches long and develop a dark stripe along their sides
3. ___ fry  c. stream in which a particular salmon was born
4. ___ parr  d. nest where eggs are laid
5. ___ smolt  e. young hatchlings
6. ___ natal  f. fish that spend part of their life at sea
7. ___ redd  g. cloud of sperm
8. ___ mit  h. a small sac of the internal ear

9. Essay: In the following space, briefly explain the life cycle of the salmon.
Key for Quiz - Section B

1. f
2. a
3. e
4. b
5. i
6. c
7. d
8. g

9. Essay: Should contain information about the following: eggs, alevin, fry stage, parr or fingerlings stage, smolt stage, ocean stage, return to natal site, spawning.
Teaching Plan:

Module: Salmon - Section C

Problem Area: Identifying Salmon Species

Goal: The goal of this problem area is to explain the names, characteristics, and farming procedures for the salmon species that are important in the aquaculture industry.

Learning Objectives: Upon completion of this problem area, students will be able to:

- identify countries to which salmon are native
- explain Tchernavin's theory explaining origins of salmon
- explain 2 types of salmon culture
- explain life cycle of Atlantic salmon (Salmo)
- identify 5 aquaculturally important Pacific salmon and explain how they differ

Resources: The following instructional resources are needed to complete this problem area:

Essential:


Transparencies, overhead projector, and world map.

Additional:

Trout and Salmon Culture, by Leitritz, E. & Lewis, R.C., State of California, Department of Fish and Game, 1980.
Content and Procedures

Preparation (Interest Approach):

To develop student interest in this module, ask students if they have animals at home or on their farms. Have them describe the similarities and differences between the various breeds. Discuss how this is similar to the species and varieties of salmon.

Presentation:

A. What is the history of salmon?

Using a large world map, have students identify the current, native habitat of salmon. Lead a discussion as to their possible origins, according to Tchernavin’s theory. Discuss global climate change as it pertains to freezing and melting of the polar ice caps. Discuss how today’s global warming trend might affect the polar caps.

1. All salmonids spawn in fresh water.
2. Tchernavin (1939) suggested that the ancestral salmonids were “small brightly colored fishes living in cool streams and lakes of the northern hemisphere. Using fresh water routes, they spread over a wide area. The diversity of regions over which they spread favored the formation of numerous species” (Neave 1958).
3. This suggests that a trout-like fish was ancestral to a salmon. Probably the Pacific salmon are descended from a Salmo ancestor (Neave 1958).
4. It is thought that after the closure of the Arctic link between the north Atlantic and the north Pacific oceans, around 1 million years ago, separate Atlantic and Pacific salmon species evolved.

B. What are the 2 types of salmon cultures?

Show TM C1 and compare and contrast the 2 types of aquaculture practices in salmon farming.

1. Total culture: The fish are kept in captivity through their entire life. This method is used when fish are being grown for sale or when broodstock is being produced.
2. Partial culture: The fish are kept in captivity for only part of their life. This may be a ranching operation, where young farmed fish are released into the wild, to return as marketable fish in a commercial operation, or to enhance or replace wild stock.

C. How are salmon classified and what are the various salmon species?

Show TM C2 and discuss the meaning of the following terms: family, subfamily, and genera. Using the world map, have students identify the natural habitat of Atlantic salmon.

   a. Genera: Salmo (the leaper). This group doesn’t necessarily die after spawning. Care of farmed broodstock can lead to high survival rates. Thus repeated annual spawns can be obtained from the same broodstock.
   b. Oncorhynchus (hooked snout): These fish die after spawning.
2. Atlantic Salmon (Salmo salar).

Show TM C3 and discuss the life cycle of Atlantic salmon.
Salmon

3. The Pacific salmon (*Onchorhyncus*).

Using the world map, identify the natural habitat of Pacific salmon. Compare and contrast the life cycle of the Pacific salmon with that of other salmon.

   a. Pink salmon (*O. gorbuscha*). Most common Pacific salmon and most cold tolerant.
   b. Common names: pink, humpback (USA and Canada), karafutomaru (Japan), gorbuscha (Russia).
   c. Female produces around 2,000 relatively small eggs. Seaward migration takes place a few days after hatching.
   d. The young fish may spend 3-5 months in estuaries and coastal waters. They return to home rivers after 16-20 months, averaging 1.5 kg.
   e. They are the most consistently abundant of the species of Pacific salmon throughout their range.
   f. New populations successfully introduced in Barents Sea and White Sea region of Russia, Lake Superior and Lake Huron. Fish complete life cycle in fresh water.
   g. Natural range: production enhanced by artificial spawning channels, which were started in Fraser River Basin, British Columbia, because hydroelectric schemes reduced spawning runs to fewer than 400 fish per year. Now fry survival is 90%.
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g. Ranching pink salmon in Alaska yields 300 kg adult fish per kilogram of fry released.
h. Advantage of ranching pink salmon is minimal cost of feeding and rearing in fresh water.


Using the world map, identify the natural habitat of the chum. Compare and contrast the life cycle of the chum salmon with that of the other salmon. Lead a discussion about production methods for chum salmon.

a. Common names: chum, dog (USA and Canada), sake (Japan), and keta (Russia).
b. Life characteristics: Second most abundant and also cold tolerant. Has widest geographical distribution.
c. Ranges from Oregon to the Arctic coast of Alaska on the eastern side of the Pacific and from Japan to the Arctic coast of Siberia on the western side. Largest runs on the Amur River.
d. Spawning usually takes place in the lower reaches of rivers, within 150 km of sea. Eggs are laid between October and July, depending on latitude of river.
e. Lay around 3,000 eggs.
f. Fry migrate to sea within 1-3 months after emerging from the gravel. They spend up to 4 years at sea and complete 2 or 3 ocean circuits. They are generally not a sport fish. Flesh is pale, deteriorates quickly, and is low in fat.
g. Hatchery techniques developed in Japan.
h. Alevins, weighing 1 g, are fed on artificial diets and released into estuaries to coincide with blooms of harpactecoel crustaceans in the zooplankton.
i. Comprise 90% of hatchery output in Japan.

E. Sockeye salmon (O. nerka).

On a world map, have students identify the natural habitat of the sockeye salmon. Compare and contrast the life characteristics of the sockeye salmon with that of the other salmon.

a. Common names: sockeye (Canada and USA), red (Alaska), blueback (Columbia River), Benimasu (Japan), nerka (Russia).
b. Life characteristics: Range - eastern limits is Klamath River, California to Yukon River, in Alaska. Western range: north Bering Sea to northern shore of Okhosk Sea, Russia.
c. Mean spawning weight is 3.5 kg.
d. Female lays 3,500-4,000 small eggs.
e. Fry can migrate to the sea, but usually migrate to freshwater lakes where they mature slowly, feeding on planktonic crustaceans and spend 1-3 years in fresh water, depending on species. Then they spend about 3 years at sea.
f. Production: Propagation began in 1894 in Fraser River.
g. Enhancement of sockeye salmon in their natural range uses spawning channels to improve the survival of eggs.

F. Coho salmon (O. kisutch).

Compare and contrast the life cycle of the coho salmon with that of the Pacific salmon.

a. Common names: coho (Canada and Alaska), blueback (Canada), silver (USA), ginmaru (Japan), kizhuch (Russia).
b. Life characteristics: range - coastal California streams to Norton Sound in Alaska and from Hokkaido north to the Anadyr River, Russia.
c. Life cycle: similar to that of Atlantic salmon. In wild, stays in fresh water 1-2 years. Females lay 3,500 eggs.
d. Most coho spend 2 years at sea and grow rapidly during the second year.
e. Production: introduced successfully in the Great Lake and Chile.

G. Chinook salmon (*O. tshawytscha*).

Compare and contrast the life of the chinook salmon with that of the Pacific salmon.

a. Common names: king, (USA), spring (Canada), masunosuka (Japan), chavycha (Russia).
b. Life characteristics: the least abundant of all the Pacific salmon.
c. Native range: Venura River in southern California to Point Hope in Alaska on the eastern rim. From Hokkaido to the Anadyr River on the Asian side.
d. Life cycle. Female lays about 5,000 eggs. Fry migrate to sea after about 120 days and spend 1-5 years at sea, mostly near shore or in inshore waters, like Puget Sound.
e. On the west coast of the U.S., chinook are most favored salmon for sport fishing.
f. Production: Natural habitat often has been disrupted with dams. Major successful transplantations were in New Zealand’s Waitaki River and in Chile.
g. In their native range, chinook salmon numbers are augmented by artificial propagation. 70% of the Pacific salmon juveniles produced in the USA are chinooks. Production of pinks and chums in Alaska’s no-profit hatchery program is greater.

H. Steelhead (*O. mykiss*).

Lead a discussion that compares and contrasts a salmon and a steelhead trout. Using world map, show range of anadromous salmonids.

1. Steelhead are sea-run (anadromous) rainbow trout.

2. Life cycle much like salmon, but differs as follows:
   a. They migrate as individuals, not in schools.
   b. Although most steelhead die upon spawning, some live to spawn two or more times.
   c. Steelhead have summer and winter runs, with overlap; therefore, they are in rivers most of the time.

Review:

Review by having students demonstrate their knowledge and understanding of the objectives for this problem area. Lead a discussion with students by asking them questions that cause them to explain the content that goes with each objective.

Evaluation:

Evaluation should focus on the extent to which students achieved the objectives of the problem area. Examples include oral questions and written reports. Example exam questions are attached.
Types of Culture

- **Total Culture:**
  Fish in captivity throughout entire life

- **Partial Culture**
  Fish in captivity for a part of their life
Elements of Biological Nomenclature

- Family
- Subfamily
- Genera
Phases of Life of Atlantic Salmon

- Redd
- Alevins
- Parr
- Fingerlings
- Smolt
- Kelt
- Grilse
Quiz for Section C

Name:

Date:

Quiz on Identifying Salmon Species

1. Short Essay: In the following space, explain Tchernavin's theory about the origins of salmon.

2-7 Matching: Match the terms 2-7 with the short definitions below by writing the appropriate letter in the blank next to the term.

2. ______total culture
3. ______partial culture
4. ______family
5. ______genus/genera
6. ______grilse
7. ______kelt

a. A subdivision of plants or animals that contain one or more species
b. Salmon that have completed spawning
c. Most common type of Pacific salmon
d. Fish kept in captivity throughout their life
e. A subdivision of plants and animals ranking below an order
f. Salmon that return to their native stream after only one year and several months
g. Fish in captivity for only part of their lives.

8. Completion: Complete the following statements by filling in the blanks.
   a. Name one Atlantic salmon: _______________________________
   b. Name four Pacific salmon: __________, __________, __________, __________
Key for Quiz - Section C

1. Essay: Should discuss fresh water origins and closure of Arctic cap.

2-7 Matching:

2. d
3. g
4. e
5. a
6. f
7. b

8. Completion:

a. Atlantic salmon or Salmo.
b. Pacific or pink, chum, sockeye, coho, and chinook.
Teaching Plan:

Module: Salmon - Section D

Problem Area: Describing Spawning of Salmon

Goal: The goal of this problem area is to explain the biological properties of fish eggs, how they are obtained, and how they are cared for.

Learning Objectives: Upon completion of this problem area, students will be able to:

- explain difference between natural and artificial spawning
- identify issues in handling broodstock
- give reasons for selective breeding
- explain requirements for healthy egg incubation
- discuss factors in choosing an incubator
- describe basic anatomical features of a fish
- explain 2-person method of artificial spawning
- explain incision method of artificial spawning

Resources: The following instructional resources are needed to complete this problem area:

Essential:

*Trout and Salmon Culture,* by Leitritz, E. & Lewis, R.C., State of California, Department of Fish and Game, 1980.

Transparencies, overhead projector, TV monitor, and VCR.

Videotape "Trout Culture in the Southeast," Southern Region Aquaculture Center.

Additional:

Content and Procedures

Preparation (Interest Approach):

To develop student interest in this module, ask the students if they have heard in the news about surrogate mothers, or about women who have babies for other women who are unable to get pregnant. Ask the students if they know about AI, artificial insemination, for livestock. Lead a discussion about various artificial propagation methods. Compare the reasons and techniques for artificial propagation of other animals to those of salmon.

Presentation:

A. What occurs during salmon spawning (egg taking)?

Lead a discussion about how and why natural spawning has been altered. Lead a discussion about how and why natural spawning has been altered. Shows TM D1 and discuss the 4 important things to know about broodstock. Show TM D2 and discuss reasons for selective breeding.

1. The spawning season: different months for different strains.
   a. For example, in Trinity River, California, salmon run almost year-round.
   b. Can alter natural hatchery season by several months by using cold incubation water.

2. Effects of temperature on broodstock and eggs:
   a. Generally, grow faster at warmer temperatures.
   b. Need cold, but not too cold, temperatures, to spawn.

3. Care of broodstock at time of sexual maturity most critical in a fish's life, i.e., it is a time for gentle handling.

4. Selective breeding: Experiments in breeding are being done for production of eggs at right time of year; sexual maturity at 2 instead of 3 years, larger number of eggs, and larger eggs.

5. Sorting of broodstock must be done often.

B. What occurs during egg incubation?

Show TM D3 and discuss main objective in incubating eggs. Show TM D4 and discuss physical requirements for high-quality egg survival.

1. Incubation and first feeding are often done at same facility, but in different buildings, to prevent disease.

2. Main objective: to achieve maximum survival of the fry at the highest weight possible at the start of first feeding, which should be at a predictable date.


Show TM D5 and discuss light requirements for egg and alevin survival.

a. Eggs and alevins should be incubated using low light. Individual batches should be covered in a dimly lit hatchery and only illuminated when it is necessary to inspect them. NOTE: No daylight bulbs should be used.

b. Alevins should only be exposed to continuous light approximately 1-2 days before the start of first feeding.
c. Further exposure can result in smaller fish, because more of the yolk is used for energy, as the fish burrow away from the light.

4. Physical requirement: temperature.

Show TM D6 and discuss temperature requirements for good egg survival.

a. Temperature selected for egg incubation is a compromise.
b. Can accelerate development for maximum egg and alevin survival.
c. Can optimize use of yolk to give large fry.
d. At higher temperatures fish have to be brought onto the feed more skillfully, because the yolk sac is absorbed more quickly at higher temperatures.
e. Too high temperatures cause abnormal growth. Normal temperature regime incubation temperatures is between 4 and 8°C to the eyed stage give the lowest mortalities. Green eggs are usually incubated at 6-8°C.
f. In order to speed up hatching, temperatures can be safely increased to 10°C for eyed eggs and to 12°C from hatch time to swim up.
g. Management of water is important at higher temperatures to maintain oxygen level and to prevent disease.

5. There is an important relation between the timing of the first feeding and the survival rate. Timing depends on species and region.


Show TM D7 and discuss water flow.

a. Approximately 21 min of water, saturated with oxygen, is needed for each 10,000 eggs under incubation at 8°C.
b. This may need to be increased three times at hatch and during the alevin stage.


Show TM D8 and discuss the need for high water quality for egg survival.

a. Dissolved gases. Dissolved oxygen should be kept at a safety level of 6 mg/l or higher.
b. Nitrogen at any level of supersaturation is dangerous.
c. CO₂ should not exceed 10 mg/l; it is poisonous to young fish above 15 mg/l.
d. Suspended solids. Some degree of filtration may be necessary if natural waters, with high rainwater or snow melt runoff, are used.
e. Minerals: Cadmium, copper, lead, and zinc are all highly toxic to salmon eggs. Aluminum and manganese may increase to dangerous levels because of acid rain. This is particularly true in soft water, where the alkalinity is less than 100 mg/l and at a low pH (below 5.5).

8. Choice of incubator systems:
a. Layering eggs in multilayered jars or cylinders is cheaper and requires controlling Saprolegina fungus. Eggs are spread out no more than 2 deep, making them accessible for picking. This way you can count as you go, which can’t be done again until the hand count at smolt transfer.
b. Tray incubation is the most widely used method in the U.S. today.


Discuss the normal expectation for mortality rate of eggs.
Recommended mortalities from strip to first feeding should not exceed 20%, including losses due to nonfertility.

C. What is the anatomy of a fish?

Show TM D9 and lead a discussion about fish anatomy. Discuss the danger of holding pregnant fish incorrectly.

1. Gonads. Mature male and female trout have glands called gonads on each side and above the digestive organs.
   a. The males have testes that produce spermatozoa.
   b. The female have ovaries that produce eggs. Eggs are loosely held in a thin membrane and can easily be manipulated toward the vent for stripping.

2. Avoid holding a ripe female by the tail, head down.
   a. Free eggs may settle into the forward end of the abdominal cavity.
   b. Adhesiveness: Newly taken trout eggs are slightly adhesive. This condition continues until they are water hardened.

D. What are the recommended methods for taking eggs?

Show Southern Region Aquaculture Center film, "Raising Trout in the Southeast." Lead a discussion about the various ways of stripping eggs and milt.

1. The 2-person spawning method, used for Atlantic salmon and trout:
   a. Remember to anesthetize the fish to prevent breaking eggs or injuring the fish.
   b. In the 2-person method, one person, while wearing gloves, holds the fish, while the other induces spawning.
   c. The holder holds male or female by the caudal peduncle with the right hand and by the pectoral fins with the left hand.
   d. The egg pan is placed against a padded block on the spawning bench.
   e. The holder moves the fish over the spawning pan with his right hand resting on the padded block.
   f. Hold the fish tail down so the eggs will flow naturally toward the vent.
   g. The spawn taker stands on the opposite side of the bench and gently presses cut the eggs with the thumb and forefinger, beginning pressure just forward of the vent.
   h. The hand is then moved forward, toward the head and further pressure is applied to assist the natural flow of eggs, until all that will come freely are obtained.
   i. Pressure should never be applied forward of the ventral fins. NOTE: Even slight pressure applied over the heart and liver may injure the fish.

2. Incision spawning for salmon:
   a. Since all Pacific salmon die after spawning, little advantage is derived by stripping the females.
   b. Therefore, females are killed with a club or an overdose of anesthetic before they are stripped.
   c. Milt is stripped from the males, then they may or may not be killed.
   d. Method using 3 workers: The holder grasps the female by the gill cover with a gloved hand and holds the head of the fish waist high, with the tail hanging straight down, over the spawning pan. The spawn taker, holds the fish by the tail, and away from the spawning pan, which keeps the slime from the pan.
   e. He/she then makes an incision in the side of the fish with a blunt, tipped knife, starting just behind the pectoral fins and to the side of the median ventral line.
   f. Continue to cut to the genital papilla until the incision reaches a point just above the ventral fins.
g. The spawn taker then spreads his or her fingers apart and holds the body open so the ripe eggs will fall into the spawning pan.

h. The person spawning the male sits to one side of the spawning pan and strips the milt from the male as required, making sure that each pan of eggs taken receives sufficient milt to fertilize them.

i. Water is then added to the eggs in the pan and stirred.

Review:

Review by having students demonstrate their knowledge and understanding of the objectives for this problem area. Lead a discussion with students by asking questions that cause them to explain the content that goes with each objective.

Evaluation:

Evaluation should focus on the extent to which students have achieved the objectives of the problem area. Example include oral questions and written reports. Example exam questions are attached.
Elements Affecting Broodstock Growth

- Temperature
- Timing
- Diet
- Nets
Reasons for Selective Breeding

- Timing
- Production at right time of year
- Maturity:
  Mature at 2 years, instead of 3
- Number:
  Can breed for a larger number of eggs
- Size:
  Can breed for larger sized eggs
Objective for Using Incubation

- To achieve maximum survival of the fry
- At the highest possible weight
- At the start of first feeding
Physical Requirements

- Correct level of light and dark
- Correct temperature
- Correct water flow
- Water quality
Light Requirements

- Low light levels at egg and alevin stage
- Additional light added at first feeding
Temperature Requirements

Need for compromise

Normal Temperature Regime:
4-8 C to red eye stage
6-8 C for green eggs

For Faster Hatching:
10 C for eyed eggs
12 C from hatch time to swim up

Timing of First Feeding:
Depends on species and region
Water Flow

- At incubation

- Approximately 21 min of oxygen-saturated water is needed for each 10,000 eggs under incubation at 8°C

- Increase at hatching
Important Elements of Water Quality

- Dissolved oxygen
- Dissolved nitrogen
- Carbon dioxide
- Suspended solids
- Minerals
Anatomy

(Adapted from Corson)
Quiz for Section D

Name:

Date:

Part I: Directions: Answer the following questions in the space provided.

1. Explain the difference between natural and artificial spawning.

2. Explain the objective of egg incubation.

3. List 3 things that adversely affect broodstock.

4. List 3 benefits that result from selective breeding.

5. In one or two short paragraphs, explain the requirements for good egg incubation.

Part II. Refer to the diagram below and match the name of the various fish parts to the proper part.

1. ______________  5. ______________
2. ______________  6. ______________
3. ______________  7. ______________
4. ______________
Key for Quiz - Section D

Part I:

1. In natural spawning, different species spawn at different times of the year. In artificial spawning, fish can be spawned during any season.

2. Main objective is to achieve maximum survival of the fry, at the highest weight possible, at the start of first feeding.

3. Things affecting broodstock are temperature, timing, diet, nets.

4. Benefits of selective breeding are timing, maturity, number, and size.

5. Requirements of good egg incubation should include light quantity, light timing, temperature requirements, water quality and flow.

Part II:

1. heart
2. diaphragm
3. liver
4. left ovary (egg filled)
5. anus
6. genitalia papilla
7. right ovary
Teaching Plan:

Module: Salmon - Section E

Problem Area: Describing Salmon Hatcheries

Goal: The goal of this problem area is to identify and explain the various systems in a salmon hatchery.

Learning Objectives: Upon completion of this problem area, students will be able to:

- explain history of hatchery use in salmon industry
- explain design principles of salmon hatchery

Resources: The following instructional resources are needed to complete this problem area:

Essential:

*Trout and Salmon Culture*, by Leitritz, E. & Lewis, R.C., State of California, Department of Fish and Game, 1980.

Transparencies and overhead projector.

Additional:

Content and Procedures:

Preparation (Interest Approach):

To develop student interest in this module, ask the students if they have animal raising facilities at their homes, or if they have visited any, such as a hog or cattle farm, or a dog kennel. Compare and contrast the confinement facilities at such places to a fish hatchery.

Presentation:

A. How have salmon hatcheries developed?

Lead a discussion speculating why the discovery that salmon spent the first part of their lives in freshwater took so long to find out. Show TM E1 and discuss and explain what a fish ladder is. Show TM E2 and discuss the various parts of a salmon hatchery. Discuss difference between green and ripe fish.

1. History.
   a. First developed in Canada, ca. 1857, soon spread to U.S., but was not very successful.
   b. Discovery in 1940s that salmon spent their month to 3 years in freshwater, made salmon management possible.
   c. U.S. work spread to Japan in 1877.
   d. In Russia, industry started slowly but developed with hydroelectric industry, which made artificial propagation imperative. In 1972, Russia was major producer of salmon.

2. "Fish ladders" are often used, which take the fish from their native river up to the spawning ponds or around man-made dams.


   a. Designed to reduce handling.
   b. Fish are first herded into spawning house.
   c. There are many designs for hatcheries. Example: There are 3 parallel ponds that are 100 feet long. The outside ponds are 10 feet wide and the center pond is 3 feet wide. At the end of the channels, covering the ponds, is the spawning house.
   d. The ponds are interconnected, so that the fish can be maneuvered between the various ponds. The house is heated.
   e. The fish are maneuvered into a large metal basket, which is electrically or hydraulically operated, in the spawning house.
   f. The fish in the basket are lifted out of the water and dipped in an anesthetic solution then they are sorted for sex and ripeness.
   g. Green fish (not quite ripe) are sorted and stored in the various holding tanks.
   h. Ripe fish are either killed and stripped of eggs and sperm or are stripped of their eggs and sperm.
Review:

Review by having students demonstrate their knowledge and understanding of the objectives for this problem area. Lead a discussion with students by asking questions that cause them to explain the content that goes with each objective.

Evaluation:

Evaluation should focus on the extent to which students achieved the objectives of the problem area. Examples include oral questioning and written reports. Example exam questions are attached.
Fish Ladder

(Adopted from Stevenson, 1980)
Hatchery Design

(Adopted from Leitritz, 1980)
Quiz for Section E

Name:

Date:

Quiz on Describing Salmon Hatcheries

Directions:

1. Write a paragraph or two explaining the history of fish hatcheries.

2. Draw a diagram of a fish hatchery and label it.
Key for Quiz - Section E

1. Salmon hatcheries were developed first in Canada in 1857. The discovery, around 1940, that salmon spend their first 2 months to 2 years in fresh water made salmon management possible.

2. See TM E2.
Teaching Plan:

Module: Salmon - Section F
Problem Area: Explaining Smolt Production
Goal: The goal of this problem area is to explain the various stages in the production of smolts in the commercial aquaculture industry.

Learning Objectives: Upon completion of this problem area, students will be able to:
- compare and contrast use of management-intensive aquaculture systems
- explain relationship between water quality and harvestable fish
- explain importance of temperature to fish output
- explain relationship between temperature and stocking density
- calculate tank volumes for cubical and cylindrical tanks

Resources: The following instructional resources are needed to complete this problem area:

Essential:


Transparencies, overhead projector, and small aquaria with heaters.
Aquaculture Curriculum Guide

Content and Procedures

Preparation (Interest Approach):

To develop student interest in this module, fill two aquaria with water. Using a heater, keep the temperature of one aquarium warm. By adding cold water, keep the temperature of the other aquarium cold. Fill the aquaria with fish. Compare the behavior of the fish in the two environments. Relate the fish behavior to water temperature. Note: Be sure to use unchlorinated water, or tap water that has sat for a couple of days, or else the chlorine will kill the fish.

Presentation:

A. How did salmon hatcheries develop?

Lead a discussion about the pros and cons of developing small hatchery facilities that require a high degree of management.

1. The following information is based on commercial Atlantic salmon practices in Scotland and Norway.

2. The commercial operator's aim is to produce the maximum number of smolts, suitable for ongrowing, for a given volume of enclosed water.

3. Return on capital investment is the critical measure of success for a commercial smolt producer.
   a. In Europe, smaller facilities are being developed, which require higher maintenance. The strategy is to force the eggs and fry, thereby maximizing growth.
   b. In the U.S., the trend to toward larger facilities.

B. What determines output?

Show TM F1 and discuss oxygen requirements.

1. The ratio of the biomass (weight of fish) to the available dissolved oxygen (ADO) is the primary determinant of output.

2. ADO is a function of water temperature.

Show TM F2 and lead a discussion about water temperature.

   a. Higher water temperature means lower ADO.
   b. More flow relative to biomass is required in summer.
   c. As the temperature increases, the oxygen demand from the fish increases while the ADO in the water decreases.
   d. Flow requirements usually peak in late summer when the available water flow is often at its minimum. Flow requirement is also high during smolt release, when the unit contains its heaviest fish biomass.
   e. Good quality water is expected to contain close to 100% dissolved oxygen saturation.
   f. Oxygen can be added by aeration, or pure oxygen can be injected.

3. Because smolt output and profitability are controlled by temperature, considerable attention is usually paid to devising the best temperature regime.
   a. For continuity in production, a constant temperature/ADO ratio is a crucial business consideration.
   b. Eggs should be raised in a controlled thermal environment. This allows for predicting time of first feeding.
c. First feeding crucial for survival of crop, which grow into yearlings (S-0).

4. Temperature and ADO are related to volume of water enclosed. For a fixed number of tanks or given volume of water, the maximum suitable stocking density determines the smolt production.

Show TM F3 and lead a discussion about the different sized tanks. Show TM F4 and lead a discussion about the advantages of using circular tanks. Using the geometric formula for the volume of a cylinder, have students calculate volumes of various size tanks on the chalkboard.

a. This differs from techniques traditionally used for salmon enhancement programs.

b. It is based on the fact that Atlantic salmon (the best suited for farming) grow well at high flow and low lighting levels, where they stack in the water column provided there is enough depth for them to do so.

c. Greater depth means less area to manage, which means cheaper maintenance.

d. Standard units in Scotland and Norway are covered tanks between 3-4 meters in diameter and at least 1 meter in depth, for yearling smolts. They are usually made of reinforced fiberglass. Stocking density in these is 10-30 kg/m³.

e. Tanks 5-7 meters in diameter are used for 2-year old smolts. They are stocked at a density of 15-20 kg/m³.

f. Larger and older smolts are held in freshwater cages, which are cheaper to construct and maintain.

h. Rule of thumb: In a standard 3-4 meter diameter tank, total volume should be changed at least every hour or twice an hour.

i. Flow velocity is determined by the swimming behavior of the fish, combined with the need to clean the bottom.

Review:

Review by having students demonstrate their knowledge and understanding of the objectives for this problem area. Lead a discussion by asking students questions that cause them to explain the content that goes with each objective.

Evaluation:

Evaluation should focus on the extent to which students have achieved the objectives of the problem area. Examples include oral questioning and written reports. Example exam questions are attached.
Oxygen Requirements

- ADO (available dissolved oxygen) is a function of temperature
- ADO is inversely proportional to temperature
- ADO is proportional to the number of fish, i.e., the biomass
- Biomass is highest in late summer when temperature is also highest
- Add oxygen by aeration, if needed
Temperature Regime

- Temperature/ADO is a crucial business consideration
- Eggs need to be kept at a controlled temperature
Tank Sizes

- Standard unit: 3-4 meter diameter/1 meter depth
- Larger unit: 5-7 meter diameter
Benefits of Circular Tanks

- Optimum flow
- Easy to clean (critical for *S. salar*)
- Easy to calculate water change frequency
Quiz for Section F

Name:

Date:

Quiz on Explaining Smolt Production

Directions:

1. In a short paragraph or two, explain the advantages of developing small hatcheries that require high levels of management.

2. Briefly explain the importance of dissolved oxygen to smolt production.

3. Briefly describe the importance of temperature to smolt production.

4. Calculate the volume of a tank that is 5 meters wide, 7 meters long, and 2.5 meters deep.

5. Calculate the volume of a round tank that has a radius of 3.5 meters and a depth of 2 meters.
Aquaculture Curriculum Guide

Key for Quiz - Section F

1. By using smaller facilities with stronger management a producer can “force” eggs and fry to grow at maximum performance. Higher performance allows for a faster return on one’s investment.

2. Should include relationship of ADO to temperature, to biomass, and to season, and that O₂ can be added by aeration.

3. Temperature affects time of first feeding, which is important in survival of crop.

4. 5 m x 7 m x 2.5 = 87.5 meters.

5. 3.14 x 3.5 m x 3.5 m = 72.7 meters.
Teaching Plan:

Module: Salmon - Section G

Problem Area: Describing Cage Culture

Goal: The goal of this problem area is to describe and explain the use of cages in the raising of salmon.

Learning Objectives: Upon completion of this problem area, students will be able to:

- explain environmental conditions for successful cage culture
- explain types of cages used in cage culture
- discuss management systems for cage culture
- understand harvest methodology for cage cultured salmon

Resources: The following instructional resources are needed to complete this problem area:

Essential:


Additional:


Aquaculture Curriculum Guide

Content and Procedures

Preparation (Interest Approach):

To develop student interest in this module, ask the students to think back to the interest approach used for hatcheries, i.e., animals in confinement systems. Open up a discussion about the advantages and disadvantages of such systems. Have students compare range cattle to feed lot cattle. Compare and contrast active systems of waste management, such as hatcheries, to passive systems such as cages. Discuss the statement, "Intensive aquaculture is about managing water." Examine animal rights issues.

Presentation:

A. What are cage cultures used for?

Using the world map, identify areas where cage culture is being practiced. Show TM G1 and lead a discussion about important factors in site selection.

1. Cages and net pens are useful for Atlantic, coho, chinook salmon, and rainbow trout.
2. Works well for Nordic countries and northern British Isles, in the Bay of Fundy, and northeast Maine.
3. They have been used for several years in Maine, New Brunswick, British Columbia, Washington, and in Chile and Australia for raising S. Salar.
4. Site selection is important.
   a. Should be protected from both wind and waves if possible.
   b. When designed to deal with severe conditions, cost becomes an even more important factor.
5. Tidal conditions are important.
   a. Optimal flow should be about 0.6 m/s.
   b. Summer temperatures also must be measured.
   c. Minimum depth of 10-20 m at low water and low tide.

B. What types of cages are used?

1. Usually a cubical or cylindrical net is suspended from floatation devices.
2. Net usually extended above water to prevent fish from jumping out.
3. Netting often put over top to prevent predation from birds.
4. Square cages with metal walkways are becoming standard.
   a. Typical size is 10 m x 10 m x 7 m.
   b. Typical volume is 700 m$^3$. This yields about 18 tonnes.
5. Circular types called polar-cirkel, or Atlantic collars.
   a. Made with polyethylene pipes filled with polystyrene foam.
   b. Sized up to 25 m diameter.
   c. Volume of 1500 m$^3$.
   d. This would yield approximately 40 tonnes of salmon.

C. What are the 2 types of cage management?
Show TM G2 and discuss the 2 types of cage management. Divide the class in half. Have each section represent a type of cage management and debate the benefits and problems of each system. Discuss production rates as they relate to varieties.

1. Scottish system:
   a. Small cages.
   b. Intensive management.
   c. Grilse (1 year old) harvested.

2. Norwegian system.
   a. Large cages.
   b. Less intensive management.
   c. Grilse seldom harvested.

3. Production rates:
   a. Feeding Scottish varieties at a high rate can cause more than 50% grilse rate.
   b. Second generation of Scottish stock can produce 90% grilse rate.
   c. Norwegian stock will only produce 5% grilse.
   d. A very important management decision, therefore, is whether to raise grilse or older salmon.
      NOTE: Larger salmon usually bring a higher per pound price.
   e. Some farmers split the risk by doing a little of both.

4. Cost of smolt is about 20% of overhead; therefore, selection of smolt is also important.

5. Majority of smolt delivered by wellboat. Helicopters are becoming more popular.

6. First 2 days most critical.
   a. Can have massive mortalities due to dehydration and smolts that are not ready for the salt water.
   b. A frequent problem is that the smolts are not properly smolted, i.e., they are not physically adapted to salt water.
   c. Feeding is most important job during summer and fall.

D. How profitable is cage culture?

Lead a discussion about the importance of smolt to cage profitability. Show TM G3 and discuss the cost breakdown for cage culture. Compare and contrast this cost breakdown for other livestock.

1. Approximate cost breakdown for a 100-tonne cage in Scotland:
   a. Feed: 35.0%.
   b. Smolts: 22.5%.
   c. Wages: 15.0%.
   d. Depreciation: 12.5%.
   e. Overhead: 15.0%.

2. Profit depends on growth during second summer and autumn.

E. How are salmon harvested?

Show TM G4 and discuss harvesting salmon from cages.

1. Salmon must be starved for 5 days, to empty gut, before killing.
   a. This causes loss of fat and firming of meat.
   b. Also causes difficulty because not all fish in a cage are the same size.
2. Fish are usually collected in large net baskets, then transferred to the processing area, or are pumped out of the cages with fish pumps.

3. Some fish are taken directly to the processing plant alive, for slaughter.

4. Other fish are killed humanely by tranquilizing with carbon dioxide or with salt brine.  
   a. They are then bled through a cut near the gill arch.  
   b. After incision, they are returned, in containers, to sea water to bleed.  
   c. After they have been bled, they are gutted and put in iced boxes.

Review:

Review by having students demonstrate their knowledge and understanding of the objectives for this problem area. Lead a discussion with students by asking questions that cause them to explain the content that goes with each objective.

Evaluation:

Evaluation should focus on the extent to which students achieved the objectives of the problem area. Examples include oral questioning and written reports. Example exam questions are attached.
Factors in Site Selection

- Protection from wind and wave

- Tidal Flow:
  Optimum flow: 0.6 meter/second

- Minimum Depth:
  10-20 meters at low tide/low water

- Summer temperatures

- Salinity and temperature relationship
Types of Cage Management Systems

- **Scottish System:**
  Small cages
  Intensive management
  Grilse harvested

- **Norwegian System:**
  Large cages
  Less intensive management
  Grilse seldom harvested
Cost Breakdown

- Feed: 35.0%
- Smolts: 22.5%
- Wages: 5.0%
- Depreciation: 12.5%
- Overhead: 15.0%

(Adapted from Laird & Needham 1988)
Harvesting Style for Norwegian System

- Starved for 5 days
- Collected in basket
- Killed and bled
- Gutted and packed in ice
Quiz for Section G

Name: 

Date: 

Quiz on Describing Cage Culture

Directions: Answer the following questions in the space provided.

1. List 4 important factors in selecting a site for a cage culture.

2. Give approximate cost percentages for cage culture.
   Feed: 
   Smolts: 
   Wages: 
   Depreciation: 
   Overhead: 

3. List the 4 steps in harvesting cage cultured salmon.

4. Briefly describe the difference between the Scottish and Norwegian systems of cage culture.
Key for Quiz - Section G

1. Protection from wind and waves, proper tidal flow, enough depth, proper summer temperatures, proper salinity/temperature relationship.

2. Cost breakdown approximates:
   Feed: 35.0%
   Smolts: 22.5%
   Wages: 5.0%
   Depreciation: 12.5%
   Overhead: 15.0%

3. To harvest, starve the salmon for a week, collect in basket, kill and bleed, and gut and pack.

4. The Scottish system is based on using small cages, doing intensive management and harvesting and marketing grilse. The Norwegian system is based on using large cages, doing less intensive management and harvesting older fish.
Teaching Plan:

Module: Salmon - Section H

Problem Area: Describing Feeding Requirements of Salmon

Goal: The goal of this problem area is to understand the nutritional needs of salmon and how those needs are met.

Learning Objectives: Upon completion of this problem area, students will be able to:

- explain nutritional requirements of salmon
- explain best way to feed salmon
- explain difference between dry and wet mixes

Resources: The following instructional resources are needed to complete this problem area:

Essential:


Trout and Salmon Culture: Hatchery Method, by Leitritz, E. & Lewis, R.C., State of California, Department of Fish and Game, 1980.
Content and Procedures

Preparation (Interest Approach):

To develop student interest in this module, ask the students if they have studied the nutritional needs of other livestock. Compare the nutritional needs of other animals to those of fish. Also compare feeds and methods of feeding between fish and other livestock.

Presentation:

A. What nutrition do salmon require?

Show TM H1 and lead a discussion about the principles of nutrition. Show TM H2, 5 nutrition groups.

1. Nutritionists have been working on salmon actively for over 30 years. The basic requirements are well known and widely recognized. The specific requirements for various species are also known.

2. Because fish are cold blooded, their food requirements are very dependent on water temperature.

3. Because the large and small intestines are both short, synthesis of vitamins by bacteria in intestines is difficult.
   a. Therefore, most nutritional requirements must be supplied.
   b. Also, there isn't enough natural food to meet their requirements.

4. The 5 principal nutrition groups are fats, minerals, vitamins, proteins, and carbohydrates.

B. What is the role of fats in the salmon's diet?

Show TM H3 and discuss fats in the diet.

1. Three sources of fat for bodily use:
   a. Fat of the diet.
   b. Fat produced by excess dietary protein.
   c. Fat produced by excess carbohydrates.

2. The body uses fat for:
   a. Energy.
   b. Insulation.
   c. Cushioning of vital organs.
   d. As an internal lubricant.
   e. Membrane permeability of steroid hormones.

3. Fats aid in the absorption of the fat-soluble vitamins.

4. There are 2 types of fat deposits in the body:
   a. The natural fat, which the fish manufactures from protein and carbohydrates in the diet.
   b. The other is deposited from fat in the diet.

5. It is estimated that the salmon diet should be between 5 and 20% fat.

C. What is the role of minerals in the salmon's diet?

Show TM H4 and discuss minerals in the diet.
Salmon

1. Minerals are important for the skeletal structure.
2. There are 2 major minerals: calcium and phosphorus.
3. There are 10 trace minerals.
4. Calcium, phosphorous, and iron are used in building the body and blood
5. Salmon have the ability to absorb calcium, cobalt, and phosphorus from water, if these minerals are in the proper form.
6. Only iron has proven to be essential.

D. What is the role of vitamins in the salmon's diet?

Show TM H5 and discuss vitamins in the diet.

1. Only minute amounts are needed.
2. Fat-soluble vitamins can be stored in the body, but water-soluble ones can't.
3. It is thought that unknown diseases and unusual severity of bacterial diseases may be caused by vitamin deficiencies.

E. What is the role of proteins in the salmon’s diet?

Show TM H6 and discuss proteins in the diet.

1. A major purpose of protein is growth.
2. Excess protein is used for energy or stored as fat.
3. Essential amino acids must be supplied daily, because amino acids don't store.
4. Animal concentrates, such as fresh meat and fish, are good sources of protein, as are seeds and grains.

F. What is the role of carbohydrates in the salmon’s diet?

Shows TM H7 and discuss carbohydrates in the diet.

1. They are a source of energy in the form of glucose (sugar) and glycogen.
2. Salmon diet should contain a maximum of 9-12% carbohydrates.

G. What sort of feed is best for salmon?

Have students break into focus groups. Assign each group a nutrition group and ask students to report on how that nutrition group related to people, other animals, and fish. Compare and contrast moist and dry feeds. Relate to moist and dry feeds used for other animals.

1. Dry feeds.
   a. Most salmon rations are of the dry kind.
   b. Dry rations are made from meat, fish, and vegetable meals, usually with minerals and vitamins added.
   c. High quality is of utmost importance.

2. Moist and semi-moist feeds.
   a. May offer better results than traditional dry feeds.
   b. Oregon Moist often used as a starter feed.
   c. Keep frozen until use.
   d. Oregon Moist is composed of meal mix, vitamin premix, and wet mix.
H. What feeding practices work best with salmon?

Show TM H8 and discuss practices in feeding salmon.

1. The objective is to meet the nutritional requirements of the fish and promote rapid growth with a minimum of waste and the least amount of labor.

2. The frequency of feeding depends upon the size of the fish.

3. Feeding dry feeds.
   a. Proper hand feeding gives best food conversion rate with the least pollution.
   b. Food should be placed gently onto the surface of the water.

4. Overfeeding will not increase growth. It will only increase the conversion rate by increasing the Food Conversion Ratio.

5. When hand feeding, sample weight counts should be made every 2 weeks.

6. When using demand feeders, floating feed or slowly sinking feed, feed ad libitum.

I. What is the osmotic balance for salmon?

1. Defined as salt multiplied by water. In fresh water, fish must excrete water; therefore, dry food is best.
2. In salt water, fish must conserve water; therefore, wet food is best.

Review:

Review by having students demonstrate their knowledge and understanding of the objectives for this problem area. Review by leading a discussion with students by asking questions that cause them to explain the content that goes with each objective.

Evaluation:

Evaluation should focus on the extent to which students have achieved the objectives of the problem area. Examples include oral questioning and written reports. Example exam questions are attached.
Nutritional Information

- Nutritional needs are fairly well understood
- Fish are cold blooded
- Short intestine system
5 Nutrition Groups

- Fats
- Minerals
- Vitamins
- Proteins
- Carbohydrates
Fats

- Sources
- Uses
- Types in body
- Amounts
Minerals

- Amounts needed
- Storage
- Effect on diseases
- Major minerals
- Absorption from water
- Essential
- Harmful
Vitamins

- Amounts
- Storage
- Relation to diseases
Proteins

- Protein excess
- Amino acids
- Sources
Carbohydrates

- Composition
- Use
- Dietary needs
- Source
Feeding Practices

- Objective
- Frequency
- Overfeeding
- Weight counts
Quiz for Section H

Name:

Date:

Quiz on Describing the Feeding Requirements of Salmon

Directions: Answer the following question in the space provided.

1. List 3 difficulties in determining the nutrient requirements of salmon.

Directions: Circle a T if the statement is True or an F if the statement is False.

2. T F The 5 principal nutrition groups are minerals, vitamins, proteins, carbohydrates, and fats.

3. T F Protein acts as an important internal lubricant.

4. T F Fat can be produced from excess protein.

5. T F The 2 most important minerals are calcium and phosphorous.

6. T F Iron is the least essential of the minerals.

7. T F Water-soluble vitamins store well in water.

8. T F It is thought that some unknown diseases are caused by vitamin deficiencies.

9. T F The main purpose of protein is for growth.

10. T F Grains and grasses are the best source of protein.

11. T F Carbohydrates are made up of carbon, hydrogen and nitrogen.

12. T F Oregon Moist feed has better results than traditional feeds.

13. Write a short paragraph or two explaining the objectives and practices in feeding salmon.
Key for Quiz - Section H

1. Nutritional requirements not well understood. Fish are cold blooded. Fish have short intestine systems.

2. T

3. F  Fats are important.

4. T

5. T

6. F  Iron is the most important.

7. F  Water-soluble vitamins are not stored; fat-soluble vitamins are.

8. T

9. T

10. F  Animal concentrates are the source.

11. F  They are carbon, hydrogen and oxygen.

12. T

13. The objective of feeding is to feed the fish adequately with a minimum of waste and the least amount of labor. It is often best to start the fish on a moist feed, then move to automated dry feeds. Do not overfeed, as it only raises the cost of feeding. Check weight every 2 weeks.
Teaching Plan:

Module: Salmon - Section I

Problem Area: Identifying Health Care and Diseases of Salmon

Goal: The purpose of this problem area is to identify and explain the health requirements of salmon and the major health disorders of fish in the salmon industry.

Learning Objectives: Upon completion of this problem area, students will be able to:
- explain general signs of illness in fish
- name common fish diseases caused by external bacteria
- name common fish diseases caused by internal bacteria
- name common fish diseases caused by external protozoa
- name common internally caused fish diseases

Resources: The following instructional resources are needed to complete this problem area:

Essential:

*Trout and Salmon Culture*, by Leitritz, E. & Lewis, R.C., State of California, Department of Fish and Game, 1980.


Transparencies and overhead projector.
**Aquaculture Curriculum Guide**

Content and Procedures

**Preparation (Interest Approach):**

To develop student interest in this module, ask the students about the last time they visited a medical doctor. Lead a discussion about the various causes of diseases, e.g., viruses and bacteria. Ask the students if they have had to take pets or farm animals to the veterinarian. Relate human illnesses to animal illnesses. Compare these two kinds of illnesses to those of salmon.

**Presentation:**

**A. What are the signs of disease in salmon?**

Show TM I1 and lead a discussion about the symptoms of fish in poor health.

1. Changes in behavior:
   a. Loss of appetite.
   b. Abnormal distribution in pond.
   c. Abnormal swimming behavior.
   d. Loss of vitality.
   e. Death.

2. External physical signs:
   a. Discolored areas on body.
   b. Eroded areas or sores on body.
   c. Swelling.
   d. Popeye.
   e. Hemorrhages.
   f. Cysts containing parasites.

3. Internal physical symptoms:
   a. Color change of organs or tissue (particularly the liver).
   b. Hemorrhages in organs or tissue.
   c. Boils or swollen lesions.
   d. Changes in texture of organs or tissues.
   e. Accumulation of fluid in the body.
   f. Cysts containing parasites.

**B. What external bacterial diseases do salmon get?**

Show TM I2 and discuss diseases caused by external bacteria.

1. Columnaris (*Flexibacter columnaris)*:
   a. Prevalent where water temperature is above 54°F.
   b. Symptoms: grayish white lesions on the body, head, fins, or gills.
   c. Treat with copper sulfate flushes.

2. Bacterial gill disease:
   a. Prevalent where water temperature is above 54°F and there is crowding.
   b. Gills are swollen and clubbed; mucus forms and fish go off feed.
   c. Dip or flush with copper sulfate.

3. Peduncle disease:
   a. Also known as cold water or low temperature disease.
Salmon

b. Affects fingerlings.
c. Signs are destruction of tissue of caudal and peduncle fins.
d. Treat with a combination of copper sulfate flushes and add terramycin to the feed.

4. Fin rot:
   a. Can be caused by bacteria, crowded conditions, abrasions from concrete ponds, and improper diet.
   b. Early signs: a white discoloration along the outer edge of fins.
   c. Treat by dipping in copper sulfate.

C. What internal bacterial and protozoan diseases do salmon get?

Show TM 13 and discuss diseases caused by internal bacteria and protozoans.

1. Furunculosis:
   a. Symptoms: a series of open sores on the body and raised boil-like lesions, which look like small red spots beneath the skin.
   b. Treat with sulfamerazine and terramycin in the diet.

2. Ulcer disease:
   a. Signs: characterized by ulcers or sores on the surface of the fish.
   b. Differs from furunculosis in that the sores are on the outside of the skin.
   c. Also characterized by infection of jaws and roof of the mouth.
   d. Treat with terramycin in the food.

3. Hexamitus salmonis.
   a. Known as octomitus.
   b. Found in the intestine.


5. Plistophora spp.

D. Other internal parasites:

1. Blood flukes (Sanguinicola davisi).
2. Fungus (Dermacystidium salmonis).

E. What external protozoan diseases do salmon get?

Show TM 14 and discuss diseases caused by external protozoa?

1. Trichodina spp.
   a. When numerous, trichodina can cause serious losses among fingerlings and larger fish.
   b. Signs: Irregular whitish areas appear on the body. Fish "flash" in an attempt to scratch off organisms.
   c. Treat by acetic acid dip or formalin.

2. Costia spp.
   a. Can cause severe losses among young fish.
   b. Signs: flashing, listlessness, crowding the bottom, and loss of appetite. Sometimes a bluish film forms on the body.
   c. Treat with acetic acid or formalin.
3. *Ichthyophthirius multifiliis* (Ich).
   a. Made worse by warm water and crowding.
   b. Signs: flashing, crowd water inlet. Have small, white spots on body. When observed under a microscope, all nuclei are horseshoe shaped.
   c. Treat with formalin or a 2% salt solution.
   d. Control by not allowing dead fish to accumulate and sweep the bottom of the ponds daily.

F. What other external parasites do salmon get?

Show TM 15 and discuss other external parasites.

1. Copepods.
2. Parasitic worms.
3. Fungus.

G. Other causes:

1. Gas bubble disease:
   a. Caused by nitrogen that is supersaturated in the water.
   b. Control by passing water through an aerating tower.

2. Viral diseases:

Show TM 16 and discuss viral diseases.

a. Infectious pancreatic necrosis (IPN).
b. Infectious hematopoietic necrosis (IHN).
c. Viral hemorrhagic septicemia (VHS).
d. Diagnosis of viral diseases involves the use of cultures or EM (electron microscopy).

Review:

Review by having students demonstrate their knowledge and understanding of the objectives for this problem area. Lead a discussion with students by asking them questions that cause them to explain the content that goes with each objective.

Evaluation:

Evaluation should focus on the extent to which students achieved the objectives of the problem area. Examples include oral questioning and a written report. Example questions are attached.
Signs of Disease in Fish

- Change in behavior
- External physical symptoms
- Internal physical symptoms
External Bacterial Diseases

- Columnaris
- Bacterial gill disease
- Peduncle disease
- Fin rot
Internal Bacterial and Protozoan Diseases

- *Hexamitus salmonis*
- *Ceratomyxa* spp.
- *Plistophora* spp.
- Blood flukes
- Furunculosis (bacterial)
External Protozoan Diseases

- *Trichodina* spp.
- *Costia* spp.
- Ich (*Ichthyophthirius*)
Other External Parasites

- Copepods
- Parasitic worms
- Fungus
Viral Diseases

- Infectious pancreatic necrosis (IPN)
- Infectious hematopoietic necrosis (IHN)
- Viral hemorrhagic septicemia (VHS)
Quiz for Section I

Name:

Date:

Quiz on Identifying Health Care and Diseases of Salmon

Directions: Answer the following questions in the space provided.

1. List 2 signs of health distress marked by change in a fish's behavior.

2. List 3 signs of health distress marked by external physical symptoms.

3. List 3 signs of health distress marked by internal symptoms.

4. Short Essay: Write a one or two sentence response to the following items.
   a. Name 1 fish disease caused by external bacteria and explain its cause, signs, and treatment.
   b. List 1 fish disease caused by internal bacteria and explain the characteristics of the disease, its signs and treatment.
   c. List 1 disease caused by external protozoa, the characteristics of the disease, its signs and its treatment.
   d. Explain what Ich is.
   e. Name at least 2 other internal fish diseases.
Key for Quiz - Section I

1. Loss of appetite, abnormal swimming, abnormal distribution in pond, and loss of vitality.

2. Discolored areas on body, sores on body swelling, popeye, hemorrhages, cysts caused by parasites.

3. Color change of tissue or organ, hemorrhages in organs or tissue, changes in texture of organs or tissue, boils or swollen lesions, accumulation of fluid, and internal cysts.

4. Short Essay:
   a. See content summary, Section B.
   b. See content summary, Section C.
   c. See content summary, Section E.
   d. Ich is a common protozoan disease which is marked by white specks on the body of the fish. Fish with Ich tend to crowd together near the water inlet and display "flashing" behavior. It is treated with formalin.
   e. See content summary, Sections C and D.