Skein 3

Salmon Eggs

Overview:
This skein gives students the opportunity to:

- **P / I** Hatch salmon from eggs.
- **P / I** Study the role of temperature in egg development.

Big Ideas:
The egg contains a developing salmon.

- **P** It needs certain elements in a protected environment to survive.
- **I** It is highly sensitive to disturbances in water quality, variation in temperature, and pollution in its habitat.

Vocabulary:

redd, yolk, hatch, gravel, shell, oxygen parts per million (ppm), concentration, molecule, oxygen, dissolved, impurities, pollutant, silt, embryo, alevin, Accumulated Thermal Units (ATU)

Important Standards Netted by Teaching Skein 3

SCIENCE

	Fourth Grade	**Fifth Grade**	**Sixth Grade**
Classroom Incubation of Eggs	SA 1.1 SA 1.2 SC 2.2	SA 1.1 SC 1.2 SC 1.1 SC 2.1 SC 2.2	SA 1.1 SA 1.2 SA 3.1 SC 1.1 SC 2.3

MATH	**Fourth Grade**	**Fifth Grade**	**Sixth Grade**
Eggs: Salmon and ATUs	M 6.2.1 M 2.2.1 M 4.2.5 M 4.2.1 M 7.2.2	M 6.2.1 M 2.2.1 M 4.2.5 M 4.2.1 M 7.2.2	M 6.2.1 M 2.2.1 M 4.2.5 M 4.2.1 M 7.2.2

READING			
Salmon Eggs	R1.1	R2.1	

WRITING 3-6

None

BACKGROUND INFORMATION

EGG DEVELOPMENT

When adult salmon return upstream to spawn, each female lays from 2,000 to 6,000 spherical, pinkish-orange eggs, which are about 6 to 9 mm (1/4 in) in diameter. Instead of a hard shell like a chicken, each egg has a soft, transparent membrane for its outside surface. This surface offers little protection against predators or other disturbances, so the female covers the eggs with gravel in a rocky stream or lakebed nest called a redd.

The redd is a shallow depression in the gravel, about one to three meters (3-9 ft) long and one to two meters (3-6 ft) wide. The female chooses a site in a stream with a high flow of fresh water or near a lakeshore where waves keep the water fresh. Different sized gravel is used for redds by each species. The larger salmon, chinook, spawn in coarser gravel and the smallest salmon, pink, spawn in the finest gravel of the river bottom. The other species spawn in gravel and locations between these two.

Salmon eggs are very sensitive - only one in 10 survives to hatch. In the first days, even a slight disturbance of the stream or lakebed can be fatal.

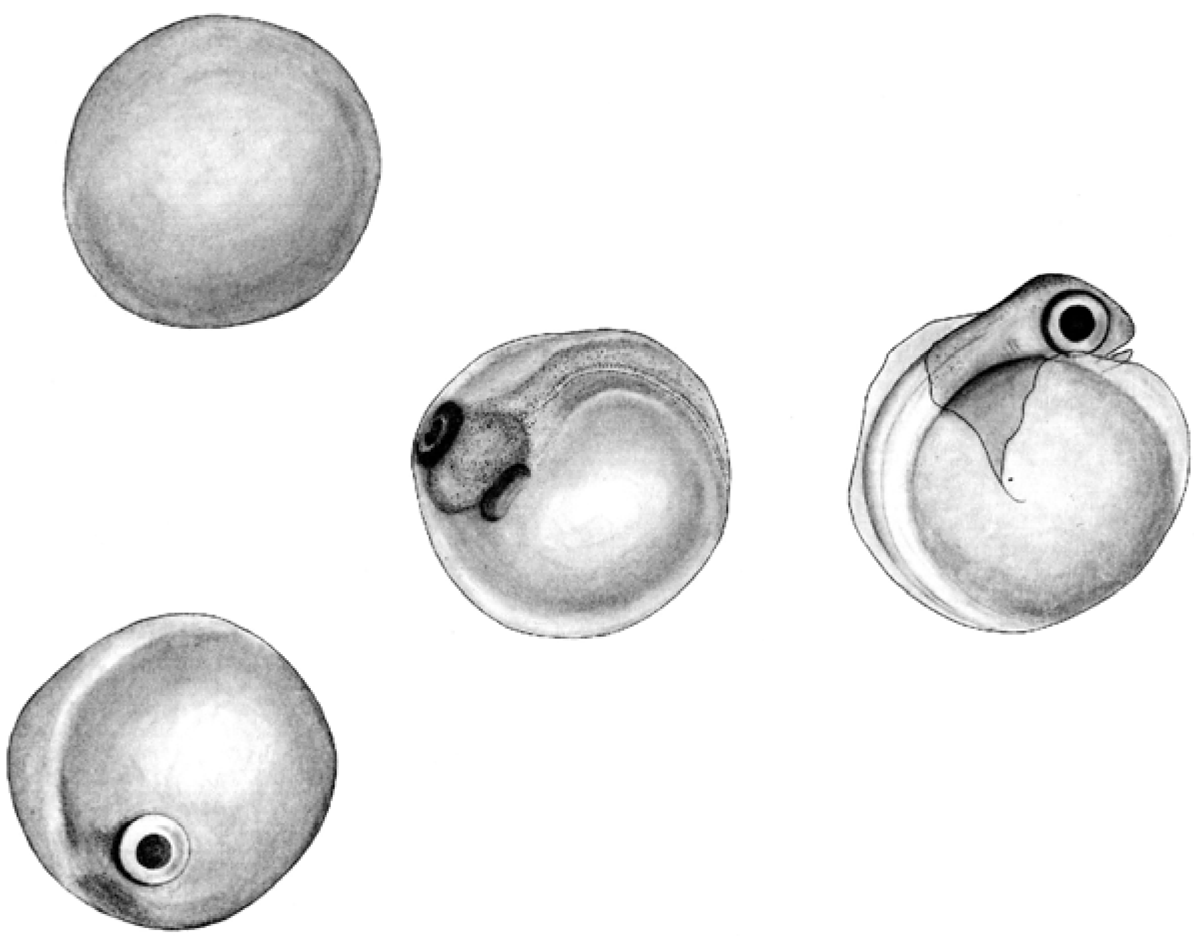


Illustration: Karen Uldall-Ekman

Changes in water level or temperature can kill the eggs. Predators such as birds, bears and trout feed on the eggs, if they can find them, and flooding, pollution, and disease also destroy eggs.

The salmon embryo begins to develop inside the egg, growing cells and gradually forming distinct organs. Because they are cold-blooded, the rate at which fish develop depends on the outside temperature. The ideal water temperature for salmon eggs is from 5-10°C (42-50°F). Eggs develop more slowly at lower temperatures. In average temperatures, the embryonic development takes place at the following rate:

After 7 to 10 days	head and body begin to form
After about 1 month	eyes begin to appear
After about 2 months	embryo begins to move inside the egg
After about 3 months	embryo hatches from the shell

Inside the egg, the developing embryo feeds from its yolk sac and obtains oxygen through the egg membrane, through which the oxygen passes from the running water flowing through the gravel of the stream or lakebed. The eggs can smother if the gravel is covered with silt or if the water flows too slowly and stagnates.

As development progresses, the embryo begins to move and wiggle around. Scientists believe that, when the embryo can no longer get enough oxygen through the egg wall, it releases an enzyme that weakens the membrane. The embryo then breaks through the membrane and wiggles out. It lives the next stage of its life in the gravel as an alevin.

BACKGROUND INFORMATION

EGG DEVELOPMENT

The development of salmon eggs, like the early development of most organisms, is a process of cell formation, division, and differentiation.

An egg is fertilized when one sperm from the milt of the male salmon finds and enters a narrow canal in the egg. Sperm must enter the canal soon after the eggs are laid because the egg membrane reacts to the water and closes off the canal. After fertilization, the clear egg fluids concentrate over the surface of the yolk, forming a dome that becomes the blastodisc of cells after many cell divisions. The blastodisc eventually becomes the embryo.

After fertilization, egg development goes through three main phases:

- Cleavage or cell division. The first cell forms inside the fertilized egg on the cytoplasmic dome, and within 10 to 25 hours, depending on the water temperature, it divides to form two cells. The cells continue to divide and begin to show some differentiation into tissues within four to eight days.
- Epiboly or embryo development. After four to eight days, the first bud of the tail begins to form and, a few days later the shape of the embryo becomes distinct, attached to the yolk within the egg.
- Organogenesis or organ formation. After a period varying from 12 to 30 days, the individual organs and body parts of the embryo become distinct, beginning with the tail. The heart begins to beat and blood vessels form over the yolk. After 22 to 50 days, the dark eyes are visible through the egg membrane and, after 60 to 120 days, the embryo has developed a backbone, fins and gills. It is ready to hatch from the egg.

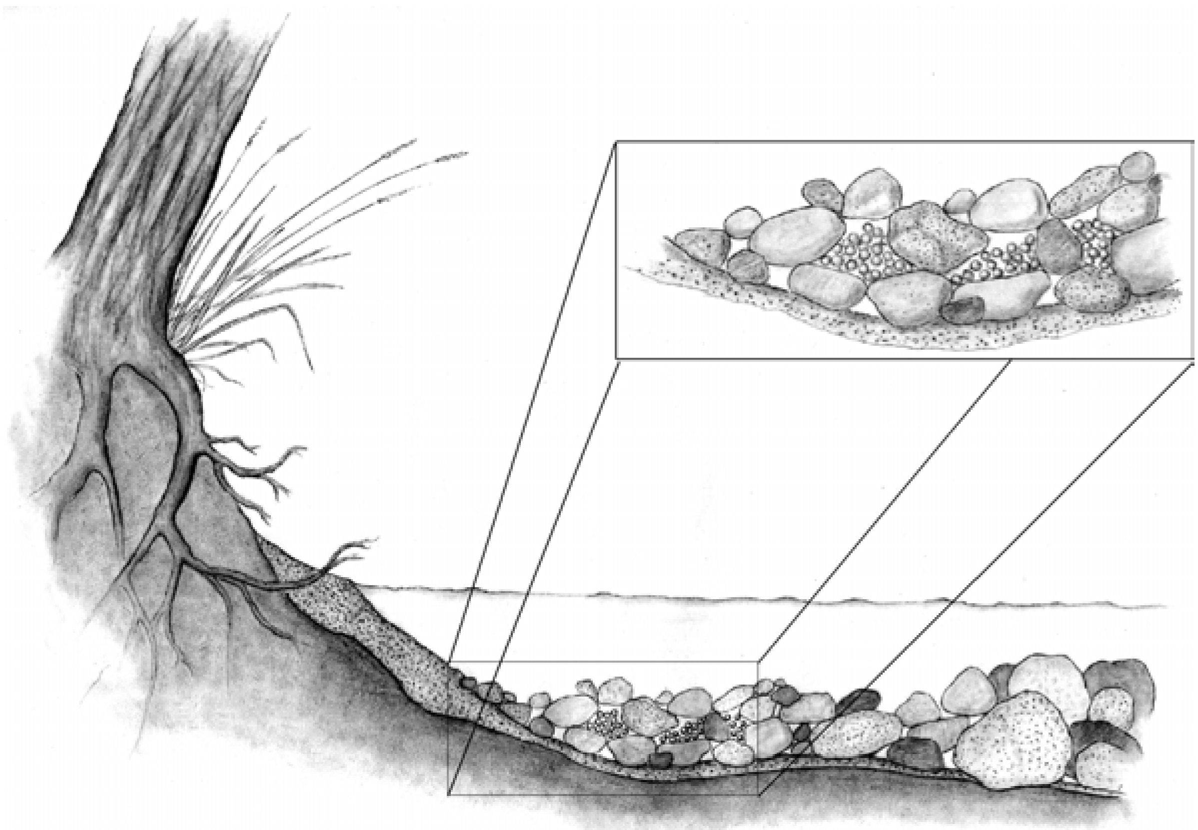
As the embryo starts to grow, it moves within the egg. First the heart sac begins to contract, then the body begins to twitch. The developing pelvic and pectoral fins begin to twitch. Their fanning motion is essential to move oxygen, enzymes and fluids through the egg. The twitching movements also build up the muscles the embryo will use when it hatches.

As the embryo grows and becomes more active, it needs more oxygen. The oxygen that transfuses through the egg membrane becomes insufficient for the growing embryo. Scientists believe this insufficiency may trigger the embryo to release a chemical called a hatching enzyme, which digests the egg membrane. The movement of the embryo spreads the enzyme through the egg, further weakening the membrane. By stretching and pushing, the embryo breaks through the cell membrane, then slowly wiggles out of the egg, dragging the yolk sac with it.

Virtually all organisms, except one-celled ones, develop through a process of cell division and differentiation.

Salmon Eggs

Illustration: Karen Uldall-Ekman



Salmon lay eggs in a stream or lake. They lay their eggs in a nest made of small, rounded rocks called gravel. The nest is called a redd. The salmon cover their eggs with gravel to keep them safe.

Salmon eggs are like small orange balls. They have a soft shell. Inside is a yolk and egg white.

Salmon eggs need cold water to live. If the water is too cold or too hot, the eggs will die. A salmon begins to grow inside the egg. The yolk gives it food. The salmon gets air through the egg wall from the stream or lake water. If the water stops running, the growing salmon inside the egg will die. Dirt in the water can bury the egg and smother the salmon that is growing inside.

Salmon grow eyes, tails, and other parts inside the egg. You can see a salmon's dark eye through the egg wall. After spending the winter in the water, salmon hatch from the eggs.

Salmon Eggs

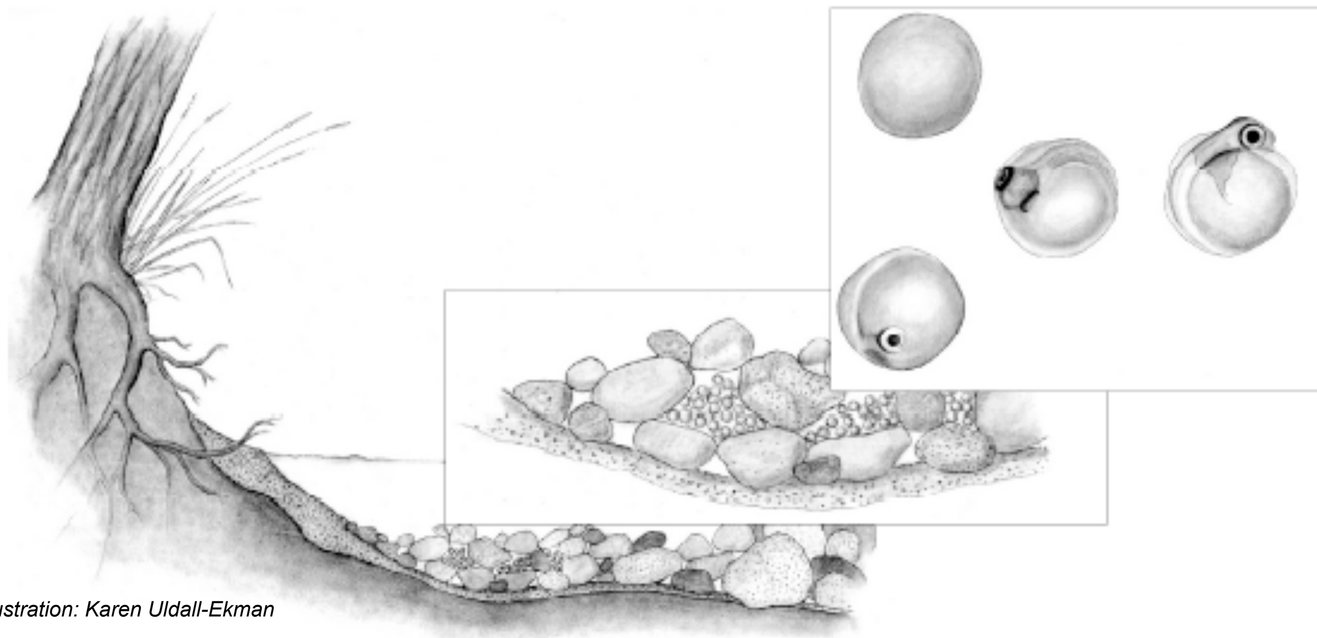


Illustration: Karen Uldall-Ekman

When adult salmon swim upstream to spawn in the fall, the female chooses a site in a stream with a gravel bed and plenty of flowing, fresh water. With her body, she digs a shallow depression called a redd, like a nest in the gravel.

Depending on the species and size, each female lays from 2,000 to 6,000 round, pinky-orange eggs, about 6 to 9 mm (1/4 inch) in diameter. Instead of a hard shell like a chicken egg, each salmon egg has a soft, transparent wall. This wall, or membrane offers little protection against predators or other disturbances, so after the male fertilizes them the female covers the eggs with gravel. Birds, bears, and trout eat the eggs if they can find them, and flooding, pollution, and disease also destroy eggs.

Salmon eggs are very sensitive—only one in 10 survives to hatch. In the first days, even a slight disturbance of the stream bed can be fatal. Changes in water level or temperature can kill many eggs; they are also very sensitive to pollution in the water. The eggs need pure, clean water, with dissolved oxygen and little silt in the water.

Salmon begin to develop inside the egg. Because they are cold-blooded, the water temperature controls the rate at which the salmon develop. The ideal water temperature for salmon eggs is from 5° to 9°C (41°-48°F). The eggs will die above 20°C (68°F) or below freezing. Eggs develop more slowly at lower temperatures. (See the box on ATUs.)

Salmon Eggs

Salmon biologists use accumulated thermal units (ATUs) to measure the heat an egg receives. ATU is the total heat an egg receives over a period of time. To calculate ATUs, you add the water temperature each day to the total for the previous days. For example, if the water temperature is 8°C (46°F) on the first day, the ATUs are 8. If the temperature is 8°C again on the second day, the ATUs are 16. If the temperature falls to 6°C (43°F) on the third day, the ATUs are 22.

The ATUs control the time a salmon takes to develop. Coho salmon, for example, develop as outlined below. (Other salmon species have a slightly different schedule.)

Head and body 50 ATUs (About 7 to 10 days)
Eyes begin to appear 220 ATUs (About one month)
The salmon begins to move inside the egg 400 to 500 ATUs (About two months)
The salmon hatches 700 to 800 ATUs (About three months)

Inside the egg, the developing salmon feeds from a yolk sac. However, the embryo still needs to get oxygen from air dissolved in the water that flows through the gravel. Some oxygen can pass through the wall of the egg. However, if silt covers the gravel under which the egg is buried, oxygen cannot transfer through the egg membrane and the embryo can smother. The embryo can also die if the water flows too slowly and the dissolved oxygen cannot reach the egg.

As development progresses, the embryo begins to move and wiggle around. At a certain point, it releases a chemical that weakens the wall. The embryo breaks through and wiggles out. It will live the next stage of its life in the gravel as an alevin.

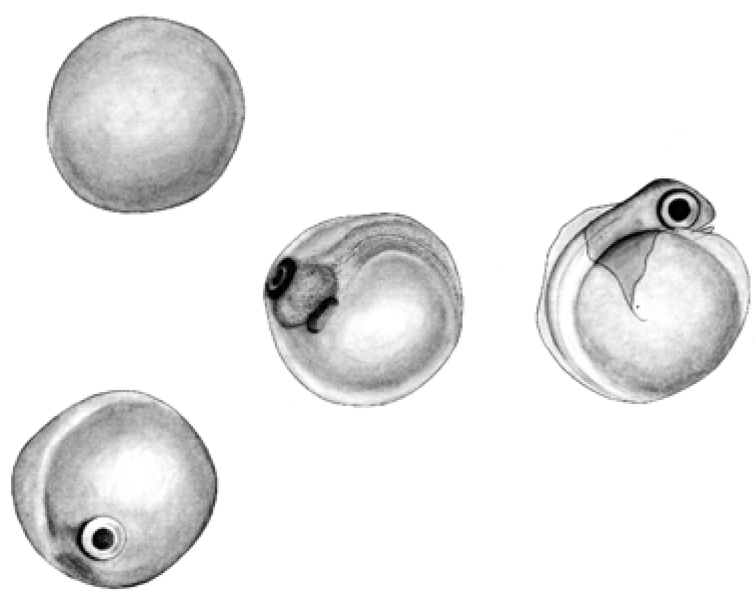


Illustration: Karen Uldall-Ekman

Salmon and ATUs [math/simulation]

Materials:

- Math blocks or pennies (optional)
- Handouts

Time Required:
Approximately 60 minutes

Level of Conceptual Difficulty:
Simple to moderate

Evidence for Assessment:
Review the charts the students make to ensure that the students can identify various stages in the life of plants and animals, including salmon.

INTRODUCTION

- Ask students to suggest reasons for birds sitting on their eggs before they hatch. Explain that a bird's body provides heat, which eggs need to develop. In many species, including birds and fish, the amount of heat that eggs receive is the most important factor in determining when the eggs will hatch. The amount of heat is measured in units called accumulated thermal units (ATUs). Each species needs a different number of ATUs (about 450 ATU's for coho salmon; about 777 for chicken eggs at 70% relative humidity). While birds get most of the ATUs they need from their mother's body, salmon get the ATUs they need from the water that flows past them.

SIMULATION

- Explain that, in the simulation which follows, each student represents a redd with 2,500 coho salmon eggs in a stream. The eggs must receive 450 ATUs to hatch, but if they receive more than 18 or less than 2 ATUs in a day, they will die. Events taking place around them in their environment may also cause the eggs to die. Using the table on page 12, have the class calculate the ATUs received by their salmon eggs.

  Note: You may wish to calculate a few examples with the class. With younger students, you may prefer to have them manipulate tokens such as math blocks or pennies representing the ATUs the eggs receive. Ensure that the students understand that the ATUs suggested below are examples for the purpose of the simulation only, although they represent what could happen in an actual setting.

- Read the daily temperature from the chart (page 10) to the class. Have each student note the temperature in a notebook, then calculate the ATUs the eggs in the redd receive.

☞ Periodically ask the class to calculate the number of days until the eggs hatch if the temperature continues at that day's temperature. Students can use the formula:

$$\frac{450 - \text{ATUs to date}}{\text{current day's temperature}}$$

☞ Ask the class to predict when eyes will appear in the egg if they normally appear at 220 ATUs.
Prediction-Day 30

☞ Randomly add some events that affect the survival of the redds. Ensure that about 10 percent survive to hatch.

Events could include:

- ✓ ***Rainbow trout discover redds and eat some eggs. One of every 10 redds is lost.***
- ✓ ***Disease hits some redds and kills some eggs. Two of every 10 redds are lost.***
- ✓ ***Off-road vehicles drive through the stream, crushing some eggs. One of every 20 redds is lost.***
- ✓ ***Construction or logging upstream releases silt into the stream, preventing oxygen from reaching the eggs. Two of every 10 redds are lost.***
- ✓ ***Small streams freeze solid, which destroys eggs. One of every 10 redds is lost.***
- ✓ ***High rainfall floods the stream and washes away the gravel and some eggs. One of every 10 redds is lost.***
- ✓ ***Car oil seeps into the stream and poisons the water. One of every 20 redds is lost.***
- ✓ ***People remove stream-side vegetation, raising the temperature to 20ºC and killing juvenile salmon in the stream. Three of every 10 redds are lost.***
- ✓ ***Dogs playing in the stream dig up redds. One of every 20 redds is lost.***

☞ Option: Have students determine scientific ways of maximizing the eggs' chances of hatching on a given date.
Control the temperature to a level between 2°C and 14°C (36°F and 57°F) so the eggs receive 450 ATUs on the given date.

☞ Option: Have students calculate the average ATUs the eggs received per day (9) and use graph paper to graph the daily variations.

DISCUSSION

☞ Discuss with the class the observations they drew from the data. If necessary, prompt them with questions, such as:

- How consistent was the temperature?

  It varied from 4ºC to 14ºC (39º-57ºF), changing 0ºC to 3ºC per day.
- When the temperature changed, what happened to the projected hatch out day?

  Higher temperatures made it sooner; lower temperatures made it later.
- What events had the most impact on salmon survival?

  Logging, construction and disease

☞ Option: Have students use data such as those in the table to create a computer simulation game or a desktop game that represents the development of an egg and its chances of survival.

RESEARCH

☞ Have students measure the water temperature of a nearby salmon stream daily or weekly. A chart like the one on page 12 can help students estimate when eyes will appear in the eggs, when the eggs will hatch, etc.

☞ Conduct the research until the fry emerge from the gravel. Observe to see if fry have emerged. How accurate were the students' estimates of the emergence date? Ask the students what factors other than temperature may affect emergence.

Day	Temp C°	ATUs	Days to hatch*	Notes
Day 1	8	8	55	Eggs laid, very sensitive.
Day 2	8	16	54	
Day 3	8	24	53	
Day 4	9	33	46	
Day 5	9	42	45	
Day 6	10	52	40	
Day 7	9	61	43	
Day 8	8	69	48	
Day 9	8	77	47	
Day 10	9	86	40	
Day 11	8	94	45	
Day 12	7	101	50	
Day 13	6	107	57	
Day 14	5	112	68	
Day 15	6	118	55	
Day 16	5	123	65	
Day 17	4	127	81	Low temperature warning.
Day 18	4	131	80	
Day 19	5	136	63	
Day 20	5	141	62	
Day 21	6	147	51	
Day 22	7	154	42	
Day 23	8	162	36	
Day 24	8	170	35	
Day 25	9	179	30	
Day 26	9	188	29	
Day 27	9	197	28	
Day 28	9	206	27	
Day 29	10	216	23	
Day 30	10	226	22	Eyes become visible.
Day 31	11	237	19	
Day 32	11	248	18	
Day 33	12	260	16	
Day 34	12	272	15	
Day 35	13	285	13	
Day 36	13	298	12	
Day 37	14	312	10	
Day 38	13	325	10	
Day 39	14	339	8	
Day 40	13	352	8	
Day 41	12	364	7	
Day 42	12	376	6	
Day 43	11	387	6	
Day 44	10	397	5	
Day 45	11	408	4	
Day 46	10	418	3	
Day 47	8	426	3	
Day 48	7	433	2	
Day 49	7	440	1	
Day 50	10	450	0	Hatch out.

* If current day's temperature continues until hatch out.

SALMON EGGS

WRAP-UP

REVIEW

- ☞ Materials: chart paper and markers.
- ☞ Have students draw and label the things a salmon egg needs for a healthy environment.
  A redd made of rocks and gravel; cold, clean water; air in the stream or lake water; vegetation on the stream bank.
- ☞ Explain that these elements make a safe home for a salmon egg, and that a baby salmon will hatch when it has finished growing inside the egg.

EVIDENCE FOR SKEIN ASSESSMENT

- ☞ Have students make a list or Venn diagram of overlapping circles (model the procedure, if necessary) comparing the size, shape, color, and parts of a chicken egg and a salmon egg.
- ☞ Have students make a model or picture of a redd in a stream, and use it to explain in a conference or using an audio recording how a redd protects salmon eggs.
- ☞ Have students make a web or write a sentence listing ways that a salmon egg is different from a chicken egg.
- ☞ Have students complete a stem sentence such as "I used to think … about salmon eggs but now I know that …" or "One thing I learned about salmon eggs is that …"
- ☞ Have students add their materials to their salmon science notebook and write a sentence explaining what they learned.

LANGUAGE AND ARTS INTEGRATION

- ☞ Have students bring in small rocks that they can place in the salmon incubation tank, and demonstrate how they are cleaned and boiled to prevent them from contaminating the tank.
- ☞ Have students research the temperature needs of developing salmon eggs by interviewing students in an older class who are raising eggs in an incubation tank.
- ☞ Have students incubate frog, snail, butterfly, or chicken eggs and compare their development with that of salmon eggs.
- ☞ Have students construct large hollow eggs by covering balloons with papier mâché, then make a hole in the egg, and make sock puppets of growing salmon or other animals to place inside the eggs.

HOME CONNECTIONS

- ☞ Have students describe a redd to their parents or caregiver and compare it to their own home.

SALMON EGGS

WRAP-UP

EXTENSION ACTIVITIES

- ☞ If your school has a classroom incubation tank, have students observe the eggs from the spawner when they are placed in the tank.

- ☞ If students are raising salmon in an incubation tank, have them calculate the number of ATUs the eggs receive daily and project the hatching date.

- ☞ Have students test and compare the physical and chemical characteristics of water from salmon streams in their local watershed and discuss its suitability for salmon eggs.

- ☞ Have students research what happens to wastes that enter the local sewage and stormwater drainage systems.

- ☞ Have students collect information on water quality in the following skeins to defend a position in favor of or against a project, such as a water diversion or sewage outflow, that would affect water conditions in a salmon spawning stream.

SUGGESTIONS FOR ASSESSMENT

- ☞ Have students write a letter to governmental or nongovernmental organizations describing the impact of pollutants on salmon and other organisms, and recommending steps the organization could take to protect salmon and their habitat.

- ☞ Monitor student discussions of the class' habitat mural and life cycle chart to ensure that the students can identify the needs of salmon eggs, their habitat and threats.

- ☞ Monitor the discussion as students make and present their lists in the review activity to ensure that they can use factual information from the activities to support an opinion about salmon eggs.

- ☞ Have students write quiz questions about salmon eggs on one side of an index card and answers on the other. Have them quiz each other by asking the questions or using a Jeopardy-style format by giving the answers and asking for a question.

- ☞ Have students add their notes, experiment observations, and other materials to a salmon science notebook.

HOME AND COMMUNITY CONNECTIONS

- ☞ Have students describe to an adult practical steps they could take at home to reduce liquid pollutants and explain why the steps are useful.

- ☞ Suggest that the class begin a project to improve damaged salmon streams by arranging to place suitable gravel in appropriate locations where salmon can use it to bury their eggs.