SIA Junior: Salmon Survivors

Revised 5/09

Recommended for:
6^{th} – 8^{th} Grade

Alaska Science Performance Standards (Grade Level Expectations)
[6] SA1.1, [7] SA1.1, [7] SE3.1, [8] SA1.1, [8] SA3.1, [8] SC2.2, [8] SF1.1-SF3.1

Nutshell
Students will learn that salmon reared in an artificial environment and wild-bred salmon face different survival challenges throughout their life cycles. They will learn that despite the survival differences, there are economic factors that influence decisions about managing Alaska's salmon populations.

Concepts
- Hatchery salmon are less adapted to survival once released, and can become even less adapted through time.
- Wild salmon are better adapted to their environment, and can adapt to changes in the environment (given sufficient time).
- Salmon management must take economics (e.g., people's livelihood, tourism) into account when making decisions affecting salmon populations.

Objectives
Students will be able to:
- Identify three factors that favor survival of hatchery salmon and three factors that favor survival of wild salmon.
- Support the argument that hatcheries can have negative impacts on wild salmon
- Support the argument that hatcheries have a place in Alaska's fisheries

Materials
- PowerPoint presentation (Note that there are two PowerPoint presentations. One has only a blank Characteristics table in it, while the Characteristics table in the other version will have the responses filled in as you click through it. Use the former if the presentation screen is a magnetic white board, otherwise use the latter)
- Characteristics Worksheets (one per group)
- Characteristics cards (only if the presentation screen is a magnetic white board)
- Crime Scene Investigation Evidence Folders

Lesson Outline

10 min.	Hatchery vs natural environment discussion
10 min.	Sorting characteristics activity
20 min.	CSI-style investigation
5 min.	Trade-offs discussion
5 min.	Closing

Background

Terminology

ADF&G: Alaska Department of Fish and Game

Alevin: a newly-hatched salmon that still has a yolk sac

Enhancement: efforts applied to a stock of salmon in the form of specific manipulation, such as hatchery augmentation or lake fertilization, to enhance its productivity above the levels that would naturally occur. Enhanced salmon stock includes an introduced stock, where no wild salmon stock had occurred before, or a wild salmon stock undergoing manipulation, but does not include a salmon stock undergoing rehabilitation, which is intended to restore a salmon stock's productivity to a higher natural level. An action is enhancement when it establishes new stock; improves the condition of a stock which is at naturally sustainable productive capacity – and has been for at least five years – by augmenting the stock's naturally sustainable productive levels. Enhancement can occur whatever the condition of the wild stock is judged to be. If a stock is "non-existent" or "healthy," or includes long-term (annual) stocking, the action is by definition enhancement. The restoration of habitat, creation of new habitat, improvement of habitat, opening of access to habitat, and long-term stocking may be designated enhancement when they conform to these guidelines. (Cook Inlet Salmon Enhancement Planning)

Exvessel value: first buyer price paid to the commercial fishermen for their harvest

Fry: young salmon after yolk sac has been absorbed

Homing: returning to the natal stream (where it incubated, hatched, and emerged) to spawn

Kype: a pronounced curvature of the jaws in male salmon

Rehabilitation: efforts applied to a salmon stock to restore it to an otherwise natural level of productivity. It does not include an enhancement, which is intended to augment production above otherwise natural levels. An action is rehabilitation when it seeks to improve the condition of a stock that has been below naturally sustainable productive capacity for at least five years. Rehabilitation can only occur when the subject stock is judged to be of "conservation concern" or "yield concern." If the action is or includes stocking, the stocking must utilize indigenous stocks, and the stocking must be only short-term (start-up) stocking. The restoration of habitat, creation of new habitat, improvement of habitat, opening of access to habitat, and short-term stocking with indigenous stocks may be designated rehabilitation when they conform to these guidelines. (Cook Inlet Salmon Enhancement Planning)

Salmon ranching (=ocean ranching) refers to a process by which indigenous salmon are initially caught and stripped of eggs and milt. The fertilized eggs are then cultured in a hatchery where they will hatch and begin feeding on a feed powder. Mimicking the natural life cycle of a wild salmon, these salmon are then transported from freshwater hatcheries to saltwater fish farms. The juvenile salmon continued to be cultured in saltwater fish farms using net pens to contain the salmon. While in net pens, salmon are fed feed pellets to gain size and strength. Also, by remaining captive in an area suitable for a future commercial fishery, the salmon are “imprinted” to the area where they are temporarily farmed. (*Note: ADF&G recommends a three-week imprinting period*) Imprinted ensures that these cultured salmon return to the same place where they were “born” - similar to natural, wild salmon. Once large enough to successfully compete with wild salmon for food and space, these cultured salmon are released into the ocean to forage for food (referred to as “ranching”). Depending on the species of salmon (Pink, Chum, Coho, Chinook or Sockeye), they will return to their birthplace in two to five years. Upon return, a mixture of wild and ranched salmon are caught by commercial and sports salmon fisherman. Selected salmon are also retained by the source hatchery to be used again for eggs and milt - thus repeating the process. (http://alaskasalmonranching.wordpress.com/what-is-salmon-ranching/)

“Salmon ranching” differs from “salmon farming” in that salmon in a ranching program are released into the wild as smolts, thereby gaining size and weight as a result of foraging in the ocean. In salmon farming, the salmon are kept and fed in pens until large enough to harvest. I suppose the difference could be compared to cattle being bred in captivity and then released to roam the wild west until they’re rounded up and sent to market vs. cattle being raised on a farm and trough-fed until sent to market. There is controversy as to whether or not “ranched” salmon are any more wild than “free-range” cattle.

Under the definitions provided by ADF&G, most salmon ranching would be defined as enhancement.

Smolt: young salmon that has adapted to salt water

Straying: returning to spawn in a stream other than the natal stream

USFWS: United States Fish and Wildlife Service

Wild salmon stock: a stock of salmon that originates in a specific location under natural conditions, including an enhanced or rehabilitated stock if its productivity is augmented by supplemental means such as lake fertilization or rehabilitative stocking. (Cook Inlet Salmon Enhancement Planning)

Hatchery Background

(Evaluating Alaska’s Ocean-Ranching Salmon Hatcheries)

There was a flurry of private hatchery construction in Alaska during the early 1900s, but it was short-lived and with little apparent success. An amendment in 1900 to the Alaska Salmon Fisheries Act required any person, company, or corporation taking salmon for commercial purposes in Alaska waters to establish a hatchery. This amendment was poorly conceived and not stringently enforced. A number of canning companies did construct hatcheries, but they were poorly sited. Water was often of poor quality and quantity, and insufficient numbers of salmon returned to provide eggs for incubation. By 1936, all hatcheries in Alaska had closed.

Only one attempt was made to propagate salmon in Alaska between the 1930s and 1950s, an experimental pink salmon hatchery operated by the USFWS. By then a complete reversal of management philosophy had taken place since the federal government first mandated artificial propagation. A policy of regulating the fisheries replaced that of artificial propagation and remained in effect in Alaska until the 1970s.

In the mid-1970s, commercial salmon harvests in Alaska reached near historic lows (20 to 25 million fish) compared with the very high salmon harvests of the 1930s (100 to 126 million fish). To counteract declining commercial salmon harvests, the state embarked on an ambitious salmon enhancement program. By 1988 ADF&G was operating 16 hatcheries throughout Alaska, which were annually producing more than 300 million juvenile salmon. In 2001 there were 2 state hatcheries, 3 federal hatcheries, and 27 private hatcheries operating in Alaska. The state hatcheries primarily produce salmonid species targeted for sport fisheries. Two of the federal hatcheries are generally used for research and the third is operated by the Metlakatla Indian Community. Private hatchery corporations are permitted to operate salmon hatcheries and recoup their operational costs from the harvest of adult fish. Pink and chum salmon make up the largest proportion of salmon produced in Alaska hatcheries and all come from private hatcheries.

(Comprehensive Salmon Enhancement Plan)

Alaska's hatchery program grew out of depressed fisheries and was predicated on the concept of supplementing or enhancing fisheries, not restoring wild stocks. (*Note: the implication here is that wild stocks do not need assistance or restoring, an assumption that is difficult to assess*)

The policies and laws implemented in Alaska were carefully considered to meet the state's constitutional mandate; for example, an Alaska statute prohibits construction or operation of a hatchery on an anadromous stream.

In Southeast Alaska, hatcheries were generally built in areas where there were minimal runs of wild stocks. Broodstock was obtained only from ADF&G-sanctioned healthy wild stocks located in neighboring systems. (*Note: while this selection of broodstock increases the chances of survival for the hatchery strain, it also allows for genetically-directed straying back to the "neighboring" natal streams acknowledged in this same document: "Some studies have strongly indicated that a genetic component may influence the homing behavior of transplanted Chinook, pink, and coho salmon."*) The goal of the ADF&G genetic policy is to develop an enhancement program while minimizing the potential for genetic impacts on wild stocks to an acceptable level; protection of genetic integrity of wild stocks has always remained the principal objective of the policy. ADF&G clearly believes that although genetic impacts to wild indigenous fish stocks become possible when fish are produced in a hatchery and/or transported to another location for remote release, they stress it is important to recognize that these activities do not automatically imply that genetic impacts on wild stocks will follow.

Risks, particularly overharvest of wild stocks in mixed-stock fisheries, have been reduced by siting facilities where harvests are not heavily mixed and by identifying hatchery-produced fish in mixed (wild and hatchery) harvests so that managers can avoid overexploitation of wild stocks.

Regarding the effect of hatchery-produced salmon on wild stocks through density dependent interactions such as competition for food in the Gulf of Alaska, recent data appear to indicate that when marine survival of hatchery chum salmon is high and large numbers of adults return, it appears these fish are larger. (*Note: this contradicts statements in Evaluating Alaska's Ocean-Ranching Salmon Hatcheries*)

The "best practices" recommended by ADF&G indicate a goal that no hatchery-produced fish remain un-caught, referring to "mop-up harvests," the ability to effectively harvest returning fish as a consideration for hatchery/release site selection, and containment of returning adults to prevent straying.

Currently the Alaska Department of Fish and Game oversees and regulates all state and private sector salmon enhancement and rehabilitation projects. Protection of Alaska's natural salmon stocks requires stringent permitting processes. Geneticists, pathologists, and biologists review all projects prior to the issuance of a permit to operate a salmon ranching facility, transfer eggs or fish, or release any fish into Alaska waters. Pathology, genetic, coded wire tag, and otolith processing laboratories are maintained to provide both diagnostic information to Alaska Department of Fish and Game fishery managers, and in-season and technical expertise to the private sector. (Alaska Salmon Enhancement Program 2008 Annual Report)

In 2008, hatchery operators collected over 1.6 billion salmon eggs and released over 1.4 billion juvenile fish. An estimated 60 million adult salmon of hatchery origin returned. The preliminary total statewide commercial salmon harvest was 146 million fish. There were approximately 133 million salmon harvested in the common property commercial fishery, and an estimated 45 million, or 34%, were produced by the Alaska salmon enhancement program. Enhanced salmon provided an estimated $110 million or 29% of the exvessel value of the statewide common property commercial harvest. The ocean ranching program employs hundreds of Alaskans in seasonal and fulltime jobs. It is considered the largest agricultural industry in Alaska. (Alaska Salmon Enhancement Program 2008 Annual Report)

Over a five year period from 1999 to 2003, the fishing effort associated with the Alaska Department of Fish and Game's (ADF&G) stocking programs contributed between $19.2 million and $49.1 million annually to the Alaska economy and created roughly 330,000 angler days per year. The effect of average resident expenditures on the economy is between $8.0 million and $22.2 million, while the average effect of non-resident expenditures ranges from $11.2 million to $26.9 million.

Issues

(Evaluating Alaska's Ocean-Ranching Salmon Hatcheries)

Salmon have a great deal of biological diversity: within populations, between populations, behaviorally, physiologically, ecologically, and on a molecular level. Some stocks that have no obvious molecular differences may still have substantial ecological differences such as run timing, preferences of substrate or habitat for redd construction and for incubation, intertidal versus upstream spawning, etc.

There are a number of ecological interactions that can take place between hatchery and wild fish. These can take the form of competition for food or space, predation, and negative social interactions when large numbers of hatchery fish are released in areas with small numbers of wild fish. Given the controlled environmental conditions in a hatchery, it is not surprising that fish reared under these conditions are markedly different than their wild counterparts in behavior, morphology, survival, and reproductive ability. Hatchery environments condition fish to respond to food, habitat, others of their own species, and predators differently than do wild fish. Seemingly, the only similarities in hatchery and wild environments for salmonids are the water they're reared in and the amount of daylight they're exposed to during rearing. The table below summarizes the major differences between hatchery and wild salmonids.

Hatchery Salmonid		Wild Salmonid
Larger eggs *More* eggs *Lower* breeding success	***Reproduction***	*Smaller* eggs *Fewer* eggs *Higher* breeding success
Higher survival egg to smolt *Lower* survival smolt to adult	***Survival***	*Lower* survival egg to smolt *Higher* survival smolt to adult
Less variable shape *Duller* color *Smaller* kype	***Morphology***	*More* variable shape *Brighter* color *Larger* kype
Inefficient forager *Higher* aggression *Higher* social density *Lower* territorial fidelity *Congregate* in migration *Surface* habitat preference *Approach* predators	***Behavior***	*Efficient* forager *Lower* aggression *Lower* social density *Higher* territorial fidelity *Disperse* in migration *Bottom* habitat preference *Flee* from predators

Hatchery vs wild salmonid differences

The positive relationship between smolt size and survival of hatchery fish has encouraged hatchery managers to release larger smolts to maximize hatchery returns. A problem arises when hatchery fish are introduced to environments already inhabited by wild salmon. Wild salmon are smaller and have evolved based on the sizes they can achieve given the temperature and nutrient limitations of the natural environment. Two potential negative impacts can result from this hatchery management practice. One is the immediate impact on the ability of wild fish to avoid competition and predation pressures compounded by the presence of abundant, larger hatchery fish [meaning the smaller wild salmon are less able to compete with the larger hatchery fish, and it is more difficult for them to avoid predators if the larger hatchery fish scare or force them away from hiding places]. The other, and perhaps more serious impact, is the long-term selective pressure being exerted on wild fish to accommodate the larger hatchery-raised salmon in the ecosystem.

Coho, sockeye, and Chinook salmon spend 1-5 years (depending on the species) in freshwater before migrating to the ocean, while chum and pink salmon migrate to the ocean immediately upon entering the free-swimming (fry) stage. Consequently, hatchery-reared coho, sockeye, and Chinook salmon are subject to unnatural conditions and subtle environmental changes for a much longer time than chum and pink salmon. Although hatchery rearing increases egg-to-smolt survival, the post-release survival of hatchery salmonids is often lower than wild-reared fish. This is due to both adaptive differences between hatchery and wild populations and to environmental differences between hatchery and natural rearing environments. Poor survival of both hatchery strains in natural environments and wild strains in hatchery environments were found in steelhead trout. In other steelhead studies, naturally spawned and reared hatchery offspring (i.e., the offspring of hatchery-produced steelhead that reproduced in the wild) experienced greater mortality than offspring of wild fish during all three major life-history stages. These studies suggest that adaptive differences occur between hatchery and wild populations in a relatively short time period.

The hatchery-rearing environment can influence the behavior of salmon in several ways:

- Levels of aggression and antagonistic behavior appear to be greater in hatchery populations than in wild populations. This may be due to the higher social density experienced by hatchery populations
- Cultured and naturally-reared salmonids respond differently to habitat. In most cases wild fish use both riffles and pools in streams, while hatchery fish primarily use pool environments.
- Hatchery strains are typically more surface oriented than are wild fish, likely an adaptive response to the practice of providing food at the surface of the water.
- Predation is a major factor affecting the survival of hatchery-reared fish. Hatchery strains of salmonids have increased risk-taking behavior and lowered fright responses compared to wild fish.

Another impact of hatcheries on wild fish involves pre-smolt releases on stream carrying capacity through added competition. Hatchery fish are seldom released in numbers related to the carrying capacity of the receiving stream. The pre-smolt juveniles will compete with their wild counterparts and lower the wild fish success by changing optimum habitat use of the wild fish. [This “changed optimum habitat use of wild fish” may indicated by the more numerous hatchery fish displacing the wild salmon from the more protected (e.g., from high currents, predators, or sun) habitat areas.]

Hatchery practices have altered reproductive behavior by relaxing selection pressure on secondary sexual characteristics (“mate-attracting” characteristics such as body color, and kype size in males) used in breeding competition in the wild, while increasing selection pressure on primary sexual characteristics (such as quantity and quality of eggs). Relaxation of breeding competition led to hatchery coho salmon with less pronounced kypes and breeding colors while developing larger and more numerous eggs than comparable members of the wild stocks. Hatchery male coho allowed to spawn naturally were less aggressive and less active than wild males. Either inadvertently or intentionally, hatcheries often develop strains that spawn at different times than their ancestral stock. The most common practice is to select for early run timing by spawning a disproportionate higher percentage of the early returning fish. If interbreeding between hatchery and wild salmon takes place, the fry may emerge before food sources are abundant and thus suffer higher mortality rates.

A fundamental assumption of hatcheries has been that salmon use only a small fraction of available coastal and ocean forage. Food limitations in these environments were not given serious consideration until salmon began returning at smaller sizes and older ages. This is important evidence of density-dependent growth and it may suggest that the North Pacific is approaching carrying capacity for salmonids. Evidence for a limited ocean carrying capacity comes from negative relationships between numbers of fish and their rates of growth, possibly explaining why fish became smaller during periods of high salmon abundance. (*Note: this contradicts statements in Comprehensive Salmon Enhancement Plan*) There has been a decrease in mean body length, mean weight, ability to reproduce, and an increase in the mean age of matured fish. A decrease in size of the fish may lead to corresponding decreases in energy reserves available for the freshwater migration. Some scientists believe that competition with juveniles of hatchery origin during the marine-rearing phase can prevent the recovery of wild stocks. In contrast to growth, survival does not appear to be as density dependent. Survival of hatchery-produced salmon in Alaska appears to mirror that of wild fish from the area surrounding the hatchery.

Note that many of the concerns expressed in *Evaluating Alaska's Ocean-Ranching Salmon Hatcheries* are based on fresh-water interactions between hatchery salmon and wild salmon. The large majority of Alaska hatcheries are located adjacent to the sea and produce pink and chum salmon that are released directly into marine waters and would therefore have little fresh-water interaction with wild salmon. Concerns regarding coastal and ocean forage are valid regardless of whether salmon are released directly into estuaries or into local rivers. ADF&G's policies also apply primarily to "significant" wild stocks, leaving "insignificant" wild populations open to "contamination" or eventual extirpation by hatchery stock.

In addition to the differences (and resulting issues) between hatchery and wild salmon detailed above, some environmentalists oppose hatchery programs on the grounds that ranched salmon are released into the ocean basin to compete for food with wild salmon, but few of these fish return to streams to fertilize the watersheds. (http://www2.canada.com/courierislander/news/letters/story.html?id=94bc8c68-03d9-4f8b-b356-9bb58c01702e) In fact, it is the goal of most hatcheries that *no* hatchery-produced fish spawn in the wild. Ocean resources are consumed (possibly to the detriment of wild salmon) without those resources being transferred to the nutrient-poor streams once inhabited by wild salmon. Consequently ranching enhances the social and economic importance of salmon without preserving their ecological importance.

There is also concern that referring to Alaska's salmon runs as being "in excellent shape, supporting sustainable, record harvest levels over the past 20 years" (Commercial Fisheries of Alaska) is deceiving the general public into thinking wild Alaskan salmon stocks are flourishing due to a large commercial harvest. (http://www2.canada.com/courierislander/news/letters/story.html?id=94bc8c68-03d9-4f8b-b356-9bb58c01702e) And while touting the excellent shape of Alaska's runs, ADF&G bemoans "increased escapes of farmed Atlantic salmon … [posing] a threat in terms of diseases, competition, and possibly genetic mixing with our wild stock fisheries" (Commercial Fisheries of Alaska) without mention of these same potential threats from the "ocean ranched" salmon produced locally.

Clearly, the statistics will say what you want them to say. ADF&G/ADF&G-sponsored documents stress the separation of hatchery and wild stocks while negating or minimizing the potential impacts of hatchery-stock genetics on wild populations. They also stress fisheries enhancement (i.e., increasing the number of fish available for harvest) while downplaying any potential impact that the hundreds of millions of hatchery fish may be having on the strength of wild runs. Documents such as *Evaluating Alaska's Ocean-Ranching Salmon Hatcheries* stress and minimize the opposite issues.

The Lesson

Hatchery vs natural environment discussion

Take a look at the other students in your class. (***Click to show first slide***) Unless there are twins in the class, no two of you are exactly alike. There are differences in height, weight, hair color, eye color, skin color, face shape, body proportions, and so on. You're all humans, but you all look a bit different. It wouldn't be too hard to look at a picture and find the matching student in the class.

What if the class were made up of three sets of identical octuplets, though? (***Click to show octuplets class***) (*get student responses)* Beside the fact that there would be some boys and some girls, the students would be much harder to tell apart. A picture might allow you to narrow your matches down to two or three students, but you'd probably not be able to do any better than that. Would each set of octuplets be identical? (*no, there'd be some differences, especially in personality*). But the differences would be harder to spot. Even though that class would be made up of humans just like this class, there would be some important differences between the two classes.

In this program you'll learn that there are two "classes" of salmon in Alaska: wild salmon and hatchery salmon. Just like the two classes described earlier, the wild salmon and hatchery salmon differ in some very important ways. Wild salmon are more like a normal, highly variable, classroom, while hatchery salmon have less variety – along the lines of octuplets. We'll look at some of the ways that they're different, how the different populations impact each other, and what the differences mean to their ability to survive. Despite the differences and impacts, both populations have an important role in the ecology and economy of Alaska.

(***Show slide with pictures of salmon eggs and fry in a hatchery and in a stream***). Look at these pictures of a hatchery environment and a wild environment.

Let's identify the differences between the two environments (***click through the slide showing the differences between hatchery and wild environments***):

Pairing: We'll look at two things here: who chooses the mates in each environment, and what are those decisions based on.

(*Ask for responses for the hatchery environment*) In a hatchery, people choose the mates, and they base their decisions on which fish they think will produce the most eggs. This means that many fish will be excluded from reproducing, most likely the smaller fish.

(*Ask for responses for the wild environment*) In the wild, the fish choose their own mates, choosing mates they think will produce the strongest offspring. Their decisions are based on size, color, body shape, and a lot of other factors that we don't know about. In the end, most salmon that reach the spawning grounds actually spawn.

Eggs in…: (*Ask for responses for the hatchery environment*) In a hatchery, the eggs are "laid" in plastic trays.

(*Ask for responses for the wild environment*) In the wild, the eggs are "laid" in the gravel. (*Ask if they know what a salmon "nest" is called: a redd*)

Surviving eggs: (*Ask for responses for the hatchery environment*) Lots!!! (Ask why) The eggs are in a very protected environment and are carefully monitored.

(*Ask for responses for the wild environment*) Not too many. (*Ask why*) The eggs face many dangers including being not being fertilized, being eaten, and being covered with silt.

Fry spacing: (*Ask for responses for the hatchery environment*) As was shown in the previous pictures, the fry live in very crowded conditions while at the hatchery.

(*Ask for responses for the wild environment*) In the wild, there aren't as many fry as in a hatchery because not as many eggs survived, and they have more room to spread out.

Fry feeding: (*Ask for responses for the hatchery environment*) In a hatchery the fish are fed like you'd feed your fish in an aquarium at home, by sprinkling food on the top.

(*Ask for responses for the wild environment*) In the wild, the fry eat macroinvertebrates from the bottom of the stream.

Fry & predators: (*Ask for responses for the hatchery environment*) In a hatchery this tall thing comes to the tank, throws food in, and walks away. (*Demonstrate this* *behavior*) The next day this tall thing comes to the tank, throws food in, and walks away. The next day this tall thing comes to the tank, throws food in, and walks away. The fry get to associate these tall things with food. What happens when they're released and a tall bird comes to the water? The fry approach it expecting it to throw in some food, but they *become* food instead!

(*Ask for responses for the wild environment*) They learn very quickly to be wary of things larger than they are.

In Alaska, most hatchery salmon are intended to increase the number of fish available for catching by commercial, sport, and subsistence fishers. The hatchery salmon are *not* intended to replace wild salmon in the streams, and, in fact, great efforts are made to ensure that hatchery salmon don't end up in the same streams as wild salmon. One of the laws in Alaska is that hatcheries are required to identify the fish that they release. Why would we want to identify the fish? (*in addition to ideas the kids come up with,* ***go through the next slide*** *to provide the following reasons*) We want to know:

- which fish are from a hatchery and which are wild – we don't want the hatchery fish spawning with wild fish (*if the kids ask why, explain that we'll talk about that later*)
- which fish caught by fishermen came from a certain hatchery – so they can show that their hatchery is important
- if wild fish are returning to the hatchery instead of their home stream – so they can get a measure of straying (*ask if they know what straying is: returning to a spawn in a stream other than the one they weren't hatched in*)
- if hatchery fish are returning to nearby streams instead of the hatchery – also so they can get a measure of straying

To obey the law, salmon fry and alevins are "marked" at the hatchery, not only to identify them as coming from *a* hatchery, but as coming from a *particular* hatchery. ***Step through the next slide*** *to show ways juvenile salmon can be marked*:

- A coded wire tag (CWT) is a small piece of wire that has been laser-etched with information that tells which hatchery a fish came from and when that fish was raised at that hatchery. (***click***) The wire is very small, about the length of two fingerprint lines (*have the kids look at their fingerprints to understand how small this is*). Two of these wires would fit side-by-side in the same width as the lead you probably use in your mechanical pencils! (***click***) The coded wire tag is inserted in the snout of some (not all) of the fry at the hatchery).
- (***click***) Because many salmon produce millions of fry, they can't put a coded wire tag in each fry; it would take way too long. To allow them to find the fish with the coded wire tags, they need a way to easily identify which fish were tagged. Well, salmon have a small fin that doesn't really help them swim or survive. The fry that get tags also have their adipose fin clipped. (***click***) If a fisherman catches a fish with its adipose fin clipped, he cuts the off the fish's head and sends it to the Alaska Department of Fish and Game where they dig out the coded wire tag and find out which hatchery the fish came from.
- Scientists have found a way to mark *all* the fish from a hatchery very easily using thermal otolith marking. Thermal has to do with temperature, and the otolith (***click***) is a small "ear

bone" in fish. It's not really a bone, but it's located near the brain in the head of the fish (***click***). The otolith grows with the fish and can gets growth rings on it just like the growth rings in a tree. (***click***) The rings are made by raising the water temperature a few degrees for 24 hours, then lowering it for 24 hours, then raising it for 24 hours and so on. Each time they cycle the temperature they create a ring on the otolith. Later the otolith can be sliced open and looked at under a microscope (***click***) to read the rings on it and find out which hatchery the fish came from. This method allows all salmon from a hatchery to be identified.

Why would Alaska be concerned with allowing hatchery salmon to mix with wild salmon? Think back to the two different classes we talked about earlier. What if in their gym class the students in each class had to climb a six-foot wall? In the "normal" class, most likely some students would be able to climb the wall and others wouldn't, but ultimately you'd end up with at least some students on the other side of the wall. If the octuplets in the other class were all tall, maybe all of them would be able to make it over the wall. But what if they were all short? You could end up with no students on the other side of the wall.

If the next gym test were to sneak through some dark bushes without being seen, then chances are good that at least a few of the kids from the "normal" class would have dark skin and be able to sneak through the bushes. In the octuplets class, again they would either all make it or … not.

At the end of all the tests, you'd probably end up with at least a few kids from the "normal" class making it to the end. Chances are all the kids in the octuplets class would have been stopped at one of the tests.

Studies have shown that wild salmon are like a "normal" class of students ***(show next slide)***. Because the fish differ in so many ways, at least some will be able to pass whatever test is put in front of them (climbing waterfalls, squeezing under fallen logs, swimming quickly past predators, blending in to avoid predators, etc.).

On the other hand the studies have shown that hatchery salmon are more like the octuplets class: there aren't that many differences between the individuals ***(click to show other half of slide)***. There's a good chance that they will either all pass or all fail the tests put in front of them. If they all pass, that's great. If they all fail, that's a disaster!

Scientists are concerned that allowing hatchery and wild salmon to mix will result in the salmon becoming more and more like hatchery salmon over time, losing some of the characteristics that allow for the best chances of survival.

Sorting characteristics activity

Scientists have identified some major differences between hatchery and wild salmon, some of which we've talked about, others that we haven't. They have learned that hatchery and wild salmon have different characteristics that change how well they can survive.

Using what we've been talking about and what you may know about hatcheries and the natural environment, let's see if you can identify the characteristics scientists say are true for most hatchery salmon and the characteristics they say are true for most wild salmon.

(*Distribute Characteristics Worksheets to student groups of four*) On these worksheets you need to identify which of the characteristics would be most true for hatchery salmon and which would be most true for wild salmon. For those characteristics that are most true for hatchery salmon, put an "H" by the characteristic; for those characteristics that are most true for wild salmon, put a "W" by the characteristic. Each pair of characteristics should have one "H" and one "W."

Let me explain one of the entries for you. The last item under "Reproduction" talks about *chance of spawning*. This means that if both hatchery-raised salmon and wild-raised salmon return to a stream to spawn (meaning the hatchery salmon strayed and didn't return to the hatchery), which of the fish would have an easier time actually finding a mate and spawning?

Have them discuss the choices in their groups and come to a consensus as to which characteristics represent those of wild salmon and which characteristics represent those of hatchery salmon. If the Characteristics Cards are being used, randomly distribute them to students as they finish their group discussions.

Either have students bring up the Cards and place them in the appropriate column on the board as you call for them, or call on students to give their answers. With either method, have students ***explain*** *their answers. Discuss areas where there are misconceptions:*

Reproduction
Egg size/number: As a result of natural selection, egg sizes and numbers from wild salmon are widely distributed; some salmon produce a lot of smaller eggs, others produce fewer larger eggs. Hatchery salmon, however, are selected that produce lots of large eggs, giving the hatchery the best chance of producing a lot of salmon.

Chance of spawning: Hatchery male salmon allowed to spawn naturally are less active than wild males, resulting in their being less successful in mating. Scientists aren't really sure why they're less active.

Survival
Egg-to-smolt survival: Fewer wild salmon survive this period due to the abundance of predators during this defenseless portion of their lives. More hatchery salmon survive this period as they are incubated in a protected environment.

Smolt-to-adult survival: More wild salmon survive this period because they have experienced successful foraging and predator avoidance. More hatchery salmon die during this period as they gain the experience the wild salmon already have; they have "adapted" to a hatchery life and must now adapt to a wild life.. Many hatchery salmon also die as a result of trauma during their release. This difference is greatest for salmon species that spend more time rearing in hatchery environments (coho, sockeye, Chinook) than those that do not (chum, pink).

Morphology
Shape: Natural selection results in a large range of body shapes, increasing the population's chances of survival. Larger salmon tend to be selected for hatchery use, resulting in less variation in body shape.

Color/kype: Male salmon with brighter colors and larger kypes tend to be able to "win over" females or chase away competing males easier, resulting in them producing more offspring like themselves. Hatchery salmon are chosen to produce large numbers of large eggs; secondary characteristics such as color and kype don't play a role in their selection and so tend to become less pronounced over time.

Behavior
Foraging: Wild salmon started foraging for food when they became fry (they are referred to as alevins while they still have their yolk sac) and either did well at it or died. Hatchery salmon were fed sufficient amounts of food to ensure fast growth and didn't have to learn to forage until after their smoltification.

Aggression: The high numbers of hatchery salmon always in close proximity to each other and competing for the same food particles thrown on the surface tend to make them more aggressive. Wild salmon actually compete less for a given "piece" of food as fry than do their hatchery counterparts.

Crowding: Wild salmon have a larger "personal space" than hatchery salmon, and don't tend to crowd together. The hatchery environment results in fish being accustomed to close neighbors.

Returning to home stream: Wild salmon tend to stray to non-natal streams less than hatchery fish. This is especially true for salmon species that spend little time rearing in hatchery environments (chum, pink) than those that spend an extended period in the hatchery environment (coho, sockeye, Chinook).

Migration: Just as wild salmon spend less time in very close proximity to other salmon while fry and smolts, they also tend to spread out during migration feeding. The experience of close living sticks with the hatchery salmon as they migrate, resulting in more congregation and less dispersion.

Stream location preference: Having learned that the food is on the bottom of the stream and that there are fewer predators there, wild salmon tend to stick to the bottom of their habitat. Hatchery salmon, having been surface fed as fry, tend to spend more time at the surface of their habitat.

Predators: Having people frequently looking in at them without threatening them, hatchery fish have become accustomed to large predator-type animals being near them and don't tend to flee as readily; indeed, they may view the predator-type animal as a potential supplier of food. Wild salmon don't have these "safe" experiences and are more wary of potential predators. This difference in behavior would be most pronounced shortly after the hatchery salmon are released into the wild; mature salmon would likely show a similar reaction to predators.

Based on the differences between hatchery salmon and wild salmon, briefly discuss in your groups ways that the hatchery salmon can have a negative impact on the wild salmon. Write three reasons on the back of the Characteristics Worksheet. (*Ask for responses. Reasons should include competition for food, space, mates, and areas suitable for redds; mention these if they leave them out*)

CSI-style investigation

You are now going to investigate a crime committed by a notorious salmon gang. The investigators have narrowed the gang to either the "Hatchery Humpies" or the "Harsh Habitat Humpbacks," and your job is to determine which gang it was. During the crime, dozens of gang members were found dead at the scene.

(*Distribute Crime Scene Investigation Evidence Folders to each group*) Contained in the folder are *Crime Scene Investigation Evidence Review* sheets; each of you gets your own *Evidence Review Sheet*. (***Click***) You have four types of evidence available to you: witness statements, otolith images, DNA analyses, and suspect sketches.

Discuss the evidence found in the envelopes in the order indicated on the *Evidence Review* sheets, summarize the evidence on the *Evidence Review* sheets, and make a determination about which group was responsible for the crime.

(***click** to have the names of the two suspect groups alternate*)

Some of the groups will receive envelopes implicating the Hatchery Humpies while other groups will have evidence implicating the Harsh Habitat Humpbacks. When groups are done, review the evidence found in the envelopes with the whole class:

- Otolith photographs – the otoliths of several of the deceased gang members were removed, sectioned (cut in half), examined under a microscope, and photographed. An otolith from the hatchery fish shows the characteristic ring groupings created as the hatchery adjusted its temperature regime, while an otolith from the wild fish shows no clearly defined spacing patterns.

- DNA –While obtaining the otoliths, the forensics staff also did a DNA analysis of the fallen gang members. The DNA samples of the hatchery fish are very similarly distributed, while the DNA samples of the wild fish are more widely distributed.

- Witness statements – several fish hanging around the crime were interviewed and their observations are included in the police report. *Summarize the Hatchery quotes and the Wild quotes*.

- Sketches – the police sketch artists were first on the scene and created sketches of several of the gang members. The profiles of the hatchery fish show clipped adipose fins on some (not all) of the fish, similar body shapes, and less pronounced kypes, while the profiles of the wild fish show unclipped adipose fins, varied body shapes, and more pronounced kypes.

The crime? Leaving the school without permission!

Trade-offs
If wild salmon are better suited to their environment and environmental changes than hatchery salmon, if hatchery salmon can threaten wild populations, and if the ocean can only support a certain number of fish before the fish are affected, why do we have hatcheries at all?

Briefly discuss in your groups reasons why Alaska has salmon hatcheries. Write three reasons on the back of the Characteristics Worksheet. (*Ask for responses. Reasons should include the economy (commercial fisheries and the tourism associated with sport fisheries), recreation (sport fisheries), and culture (subsistence fisheries); mention these if they leave them out.*)

Closing Discussion
Ask kids to volunteer three factors that favor survival of hatchery salmon and three factors that favor survival of wild salmon; three ways that hatcheries can have negative impacts on wild salmon; and three reasons that hatcheries are important to Alaskans.

Optional Activities
TBA

Research Ties
TBA

Resources
TBA

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Association and three representing ADF&G (both the Division of Commercial Fisheries and the Division of Sport Fish).

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