Salmon: A Scientific Memoir

by

Jude Isabella
B.A. University of Rhode Island 1985

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of the Requirements for the Degree of

Master of Arts

in Interdisciplinary Studies

Supervisory Committee

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Abstract

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The reason for this story was to investigate a narrative that is important to the identity of North America's Pacific Northwest Coast – a narrative that revolves around wild salmon, a narrative that always seemed too simple to me, a narrative that gives salmon a mythical status, and yet what does the average person know about this fish other than it floods grocery stores in fall and tastes good. How do we know this fish that supposedly defines the natural world of this place?

I began my research as a science writer, inspired by John Steinbeck's *The Log from the Sea of Cortez,* in which he writes that the best way to achieve reality is by combining narrative with scientific data. So I went looking for a different story from the one most people read about in popular media, a story that's overwhelmingly about conflict: I searched for a narrative that combines the science of what we know about salmon and a story of the scientists who study the fish, either directly or indirectly. I tried to follow Steinbeck's example and include the narrative journeys we take in understanding the world around us, the journeys that rarely make it into scientific journals.

I went on about eight field trips with biology, ecology, and archaeology lab teams from the University of British Columbia and Simon Fraser University in Vancouver, with the Department of Fisheries and Oceans onboard the Canadian Coast Guard Ship the *W.E. Ricker*, and an archaeological crew from the Laich-Kwil-Tach Treaty Society in Campbell River, B.C.

At the same time, I was reading a number of things, including a 1938 dissertation by anthropologist Homer Barnett from the University of Oregon titled *The Nature and Function of the Potlatch*, a 2011 book by economist Ronald Trosper at the University of Arizona, *Resilience, Reciprocity and Ecological Economics*, and works by psychologist Douglas Medin at Northwestern University and anthropologist Scott Atran at the University of Michigan, written over the past two decades, particular paying attention to their writings on taxonomy and folkbiology.

My conclusions surprised me, a little.

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Frontispiece

[Credit: BC Ferries]

The field trips took me to points along the British Columbia coast: the Fraser and Harrison Rivers (diamond), Tla'amin (triangle), Quadra Island, Phillips Arm, Campbell River (square), the Central Coast (circle.) I also travelled onboard a Canadian Coast Guard ship that travelled almost the breadth of the province's coastal waters.

Acknowledgements

A thank you to the following, all of equal importance (and probably not a comprehensive list.) To the scientists (and their graduate students) who allowed me to dog their every step, ask hundreds of questions, and get my hands dirty. In alphabetical order, not importance:

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Chapter 1

***It is usually found that only the little stuffy men object to what is called "popularization," by which they mean writing with a clarity understandable to one not familiar with the tricks and codes of the cult. We have not known a single great scientist who could not discourse freely and interestingly with a child. Can it be that the haters of clarity have nothing to say, have observed nothing, have no clear picture of even their own fields? — John Steinbeck,* The Log from the Sea of Cortez**

The Salmon Doctors

It's drizzly, cold, and muddy, and a folding table on the south bank of the Harrison River is no place to perform open-heart surgery. Tim Clark has just begun. He quickly focuses on his delicate patient, who is sucking in anesthetics through a tube down the throat. Clark stares at the body and his tongue sticks out in concentration as he leans over. The patient's flesh is slippery, but he slices deftly into the chest cavity. In minutes, he has stitched up the wound and handed off the patient to be taken away, slightly groggy but still kicking.

Next please.

The van full of medical supplies behind Clark — gauze, forceps, gloves — is a MASH unit without a war. To the sockeye salmon resting on the operating table (a Rubbermaid container) the process must seem more like an alien abduction than surgery. Clark is no alien, though he is Australian. His purpose is to insert a data logger into the cavity behind the gills and near the fish's heart. A tiny computer will continuously record heart rate and temperature once the fish is released back to the Harrison River and makes its final sprint to Weaver Creek, the natal stream where this population of sockeye will spawn before dying. Each surgery takes 10 to 15 minutes, depending on the fish's sex; male salmon have thicker ventral tissue and need fewer stitches to close the opening.

Clark and the rest of the scientists arrived early that morning, in the cold mist of sunrise. Swaddled in fleece, raingear, and chest waders, they set up tents, tables, scalpels and tubes, then waited for the fish. The fishers, men from the Sts'Ailes First Nation's fishery program, are running the beach seine to catch patients for Clark and his colleagues, and it's high drama to watch them pull it off. They fix one end to a truck on shore, the other to a motorboat that zooms across the river and loops back to shore, snaring the catch. From dawn until about 4 p.m., they'll deploy the seine net eight times, catching fewer salmon as the rain stops, the sun shines, the day warms, and the fish sink deeper into cooler water. The scientists have partnered with the Sts'Ailes fishers for the past six years, the fishers taking DNA samples for their own fisheries program, the scientists inserting monitors. In most ways, the operation feels a lot like a traditional fish camp — except that the salmon give up their bodies for data, not food.

Knowing nothing of seining, I jumped in with everyone else to help pull in the netfuls of salmon. Being on the small side, I was the weak link in the tug-of-war. The fish slapped my legs, thrashing and catching their teeth in the netting. Standing there in the midst of them gives a sense of how powerful salmon need to be to swim against the river's current. It was easier to help Clark and a couple of graduate students make the transfer to the operating room's waiting area, scooping salmon in hand-held nets and wading through the water to plop them into a pen. I stood in the water and wrote down tag numbers as they evaluated each fish, plucking off a scale to send to a Department of Fisheries and Oceans temporary lab at Weaver Creek.

Sockeye populations can be identified by scale patterns viewed under a microscope. Within an hour of sending the first catch, the lab, set up just for this purpose, called Clark to tell him that 11 out of the 25 were Weavers; the rest were Harrison River fish. The distinction matters. Clark's study compares fish physiology between salmon species and populations within the sockeye species. The focus of this study was Weaver sockeye, not the more plentiful Harrison River fish. Clark pulled on his surgical gloves to start cutting. Humans have known, through observation in the ancient past and through experimental science today, that the more salmon runs there are, the healthier the species is overall. Whatever challenges salmon face — climate change, disease, industrial pollution, overfishing, hatchery production, fish farms — they will ultimately evolve or go extinct depending on their diversity. Yet, scientists are forced to prove over and over again, in deepening detail that a species is doomed without population diversity especially as the climate changes and water warms. The work these scientists do shows the fine, unseen differences between sockeye populations. It should be simple. But it isn't simple because our relationship with sockeye is overwhelmingly about money. There is nothing simple about money.

The 150-metre stretch of land along the Harrison River where these scientists conduct fieldwork belongs to the Sts'Ailes First Nation and is called simply "The Park." Roughly five kilometres from the Fraser River, it's one of the most productive fish habitats in the Fraser Valley.

All five Pacific salmon (pink, chum, Chinook, coho, and sockeye) species swim these waters, traditionally running from June to March. Even today, after years of commercial fishing, logging, and industrial pollution, the ecosystem erupts with life. The fish attract loads of birds. In the next couple of weeks The Park will swarm with teals and other ducks[redacted] adding that over the past six or seven years cormorants have made a big splash in the area gobbling any fish that fits into their bills, including a two-pound trout. An occasional sea lion has been glimpsed trolling The Park having travelled 150 kilometres from the sea.

The riverside heart surgery is one of many indepth sockeye studies. Fish biologists Scott Hinch and Tony Farrell at the University of British Columbia in Vancouver and Steve Cooke at Carleton University in Ottawa manage most of them. Lift the lid on their research and it's like picking up a patio stone and seeing a colony of ants at work, all frantically moving toward individual goals that converge on a single purpose: to understand the physiology of salmon in excruciating detail. No function seems to go unnoticed, from heart rates and temperature tolerance to aging.

A few strides away from Clark's station, one of the younger team members stands under a tent and eviscerates dead sockeye, plucking out brains and hearts. Samantha (Sam) Wilson flash freezes the organs in liquid nitrogen and stores them in a cooler to be couriered overnight to Ontario. Wilson, an undergraduate student at Carleton University is intrigued by a question of colour. She wants to know if brighter-coloured salmon age more slowly than dull-coloured salmon. A salmon's bright coloured skin comes from carotenoids (antioxidants) from the food they eat. It's possible that brighter–coloured salmon (with higher antioxidant capacity) are better at preventing aging and survive longer on spawning grounds. If so, do they pass this antioxidant capacity to their offspring? The question arose from studies showing that birds with bright-coloured beaks tend to have higher antioxidant capacity than birds with dulled-coloured beaks.

Wilson expertly cuts into a fish brought to the operating table by Graham Raby, who is charged with giving Wilson fresh kill. Raby, a graduate student at Carleton, evaluates Fraser Boxes and fish bags. The Fraser Boxes are plywood boxes through which freshwater runs to revive fish nabbed as bycatch (non-targeted fish caught in the net) by commercial fishers — the boxes are painted black to soothe the fish — and the fish bags are essentially black duffle bags with mesh at each end. The bags are a low-tech method for reviving fish caught by sport fishers, something they're not required to use, yet. When Raby is done reviving the fish (he makes notes on whether they do revive) he bonks them on the head and brings them to Wilson for her study. The salmon is slippery and strong enough to launch a heavy lid off the Fraser Box, so Raby has weighted the boxes with large rocks. Holding down a sockeye and administering a deadly blow on the first swing is tough. Raby is quick and efficient though. He disappears down a short trail that leads to the river and the Fraser Boxes to continue his work.

For the past 10 years this group has focused mostly on stress physiology and the effects of temperature, particularly of warming waters. The conclusion, so far, is what one might expect: Fish that experience high temperatures naturally are better at coping with stressors under high temperatures. Fish that experience cooler temperatures naturally cope less well with stressors when rivers warm. It's a bit like comparing Vancouverites on 30˚C days with little humidity to visiting Torontonians. The Vancouverites are wilting, while the Torontonians are delighted to have escaped the heat back home. Although it's not exactly the same. We warm-blooded humans can handle it even if we don't like it. Cold-blooded salmon can't.

Erika Eliason, who does similar fish physiology work to Clark's, is at the DFO lab at Cultus Lake, about an hour-drive east of Vancouver. She sits on an old couch in a bungalow the students share as they spend long summer days on fish studies. Close to the house, freshwater pools dot a fenced, concrete area. Chasers, graduate students, take turns using their arms to churn the waters of a pool where an adult sockeye swims, having been caught from the lower Fraser River just a few days previously. To chase fish, you need a stopwatch, kneepads, and lots of energy, particularly if it's a hot day. Four women flail their arms in a pool as another watches, a stopwatch in one hand and a clipboard in the other, and calls out encouragement. After three minutes of chasing, the fish is held in the air to simulate what happens when it's caught. The stressed fish are then placed in other pools at temperatures ranging from an ideal 16˚C to a worrisome 21˚C and their stress levels are monitored. The group will do this for 120 fish. Like the fieldwork, a couple of questions are in play: how well do stressed fish recover, does temperature matter to recovery? And does handling them reverse the aging process, making them less likely to reach their spawning grounds?

Eliason is cruising toward the conclusion of her PhD and is there to help fellow students with whatever needs doing, like chasing fish or teaching fish surgery. I had 20 minutes to interview her, which is perfect; it's like sitting through a private TED Talk. Eliason could make an eight-year-old care more about Fraser River fish distinctions than the powers of superheroes.

"These fish are adapted to their environments, which is really interesting in a lot of different ways," Eliason said. "And if you think about it, it's such a narrow part of their lives — only four weeks, three weeks, or two weeks of migrating, but clearly this is a very critical part of their lives."

In general, migrating sockeye suffer when temperatures are above 18˚C. And if things get too warm, some populations are likely to die of heart failure during their heroic journeys to reproduce. Weaver sockeye, which travel a mere 100 kilometres or so to spawn, are the skinny weaklings on the beach compared with Chilko sockeye that travel 650 kilometres to spawn further up the Fraser River.

It took three years for Eliason to figure this out. She spent many evenings inserting catheters into sockeye from various Fraser River populations and taking blood samples as they swam in freshwater pumped into big swimming tunnels made from PVC piping at the Cultus Lake lab. The goal was to compare how well they took up oxygen from the water at rest and while swimming — the "aerobic scope" — to feed their muscles, how well they pumped blood around their bodies, and heart size. As she monitored the fish, she also tweaked the water temperatures.

The names of Eliason's sockeye populations evoke the settlers and First Nations meeting along the Fraser River: Early Stuart, Nechako, Quesnel, Chilko, Lower Adams, Weaver, and Gates. The powers of the populations are as diverse as the people who could wrest a fortune, or not, from the mighty Fraser. The Chilko are the elite athletes of the group, physiological freaks with big hearts, incredible oxygen uptake, and an ability to swim powerfully up to 22˚C, losing steam after that but still moving at 26˚C. They migrate into warm summer waters, then cruise through glacier-fed rivers to spawn. They can handle the cold and heat. Nechako migrate over 800 kilometres, but in water without temperature extremes: Heat the water up to 20-degrees C and they stop swimming. They have the aerobic scope but not the heart of the Chilko. The Weaver, the weakling, has neither. Compared with the mighty Chilko — historically about a quarter of the entire Fraser River sockeye run — Weaver and Nechako would have a tough time adapting to a warmer world.

"We have to recognize that every stock is different," Eliason said, waving her coffee cup in the air. "The same rules aren't going to apply to every population. How is that going to be put into practice when they're all in the river at the same time and you can't see who is who until you look at the DNA?" She shrugged and shook her head.

To avoid catastrophe — a mystery disease, climate change, or both — it helps to view each stock as if it contains the seeds of future diverse populations. It's comforting to know that it can take only 55 years for a salmon population to become reproductively isolated. In other words, split a population into two and within 13 generations they're on diverging genetic roads, widening their genetic heritage. That's only about two human generations. Less comforting is knowing that this happens only under the right conditions: when a population is adapting to a new salmon-friendly environment, not a rapidly changing salmon-hostile environment. To keep evolutionary pace and avoid extinction, a sockeye population needs to be big enough for individual variation too. Larger populations tend to have more internal variability, a good thing for the overall resilience of a species.

Climate change has, of course, shaped all of Earth's fauna, determining which species have gone extinct and which have survived. The human species is no different, but maybe most noticeable in the archaeological record for the nearly two million years the climate has teetered between glacial periods every 40,000 to 100,000 years. From the stout infantfish, the smallest known vertebrate, to the blue whale, the largest, we are subject to the forces of natural selection, in which climate plays a huge role. I asked one population geneticist how he would fix declining sockeye runs and he said, "Probably just fix their habitats and leave them alone."

Unfortunately for salmon, especially the sockeye in the Fraser River watershed, habitat is more than a scientific concern. It's a commodity. The Fraser River is home to over 100 sockeye populations with a commercial worth of over $1 billion annually, on average. Canada's commercial relationship with the fish is older than the scientific relationship. Since the Hudson Bay Company began exporting salted salmon in cedar barrels from Fort Langley on the Fraser River in the 1840s, the numbers of people invested in sockeye has climbed, while sockeye numbers have declined.

Sockeye salmon generally swim up the Fraser River in their fourth year. They lay eggs, die, and in spring the fry emerge. Most head for a lake, probably to avoid predation. When a fry emerges it's only about the length of an inch worm, a perfect snack for a bigger fish. To a young salmon the ocean would hold the same attraction as a buffet does for a growing human adolescent, but sockeye fry must opt for leaner rations. In food-poor lakes they have less to eat, but they're also less likely to end up as lunch. A trade-off — food availability versus predation — and no doubt a good evolutionary move.

To find the lake, fry rely on either the sun's position or polarized light patterns. Put fry in a covered round tank to deny them visual cues as well as odours and water current, rotate the magnetic field with a direct electrical current, and they will navigate by Earth's magnetic field. The sensory-deprived fish head in the direction they normally would to their home lake. One of B.C.'s largest sockeye populations, Chilko River fry, for example, will orient south since they enter Chilko Lake's north end.

Fry have two things to do in the lake: eat and avoid being eaten. The good news for sockeye is that they're usually the most abundant fish feeding on tiny crustaceans. The bad news is that just like the adults that come back to spawn, temperature matters. When food is plentiful, fry grow best at 15˚C. Lower the temperature and it takes longer to digest food. Raise the temperature and the fry's metabolism kicks into high gear so that food barely maintains the fish. If food is less plentiful, the fish needs lower temperatures for best growth.

Of course, sockeye nursery lakes vary in temperature, elevation, and geography and individual populations will vary in their adaptive responses, just as humans do in their varied habitats. Andeans, Tibetans, and Ethiopians living at altitudes above 2,500 metres have three different biological adaptations to oxygen-thin air. The Andeans have more hemoglobin, the oxygen deliverer, in their blood. Andeans can breathe at the same rate as a person living at sea level, yet move more oxygen around the body. Compared with sea level people, Tibetans take more breaths per minute. They also might use another gas, nitric oxide, more efficiently, which widens blood vessels and allows more blood to flow. The Ethiopian adaptation is different but remains a mystery for the moment. Humans that adapted to higher elevations likely did it culturally first, through the use of fire and warm clothing. They had time for biology to catch up. Other animals lack that luxury and salmon have the added complication of living in multiple habitats. They move from freshwater to ocean to freshwater again and have wildly different needs at different life stages. Food, for example, is not a need at all once they start their final migration to spawn but this means they have a lot of eating to do before starting up river. They gain 90 percent of their biomass in the ocean.

Everyone working at the Park already understands that population diversity is a good thing. Yet they're scientists so they continue to amass data to add to our collective knowledge about this particular species. On a wider scale, their studies are about us. By studying the aging process in fish, for example, it tells us something about the human aging process. On a practical level, the science gives fisheries managers much needed information. Maybe, eventually, the data will affect policies. But once they release it, scientists know they have little, if any, control.

"We all know, from the cod collapse on the East Coast, that even some of the best science can be ignored," Hinch told me in as we stood outside the students' summer home at the Cultus Lake lab one afternoon. "I don't think there's any pattern. I think it really depends on the local situation and the people who are involved. History has shown us that in other fisheries small studies can provide really unique information, that if the right people see it and understand it, they can act on it quickly."

Hinch has studied sockeye for almost 20 years and he's still amazed when an elegant study reveals something new. A University of Toronto graduate, Hinch studied warm water fish in Ontario lakes before capitulating to the faunal charisma of salmon and a chance to live in B.C. Hinch might not use the word "capitulate" but as a biologist, he knows that faunal charisma often comes with cash. Even when extinct, faunal charisma can keep an animal alive and funds flowing: what else explains the drive to clone a woolly mammoth?

What Hinch worries about most when it comes to salmon are two horsemen of the environmental apocalypse: warming temperatures and pathogens. The Fraser River is close to 2˚C C warmer than it was just 50 years ago and for cold-blooded salmon, that's a problem.

"Warmer temperatures are going to be a big influence on disease proliferation so I'm very interested and concerned about that angle and we know so little," he said. "The research hasn't been done."

All sorts of circumstances drive pathogens — infectious agents such as viruses, bacteria, fungi, and prions (a cause of the fatal brain disease BSE) — to morph or spread. Crowded fish farms in Chile, for example, hastened the spread of the infectious salmon anaemia virus. And climate change is a big player in pathogen behaviour. So given the almost slam-dunk certainty that Earth will be warmer in our lifetime, what can sockeye expect?

A study by DFO scientist Kristina Miller, and co-authored by Hinch, Farrell, Cooke and other scientists, is a worrisome foreshadowing of things to come. Miller's study exposed a possible disease killing Fraser River sockeye before they get a chance to spawn. Referred to as "salmon leukemia," it is potentially the culprit behind falling salmon numbers over two decades, culminating with the 2009 collapse when only a million fish came back out of an expected 10 million.

Sockeye salmon's immune systems are compromised and it's possibly a virus at play. Scientists don't know how it's transmitted, whether from parents to offspring or fish to fish and whether it's endemic to all fish or only to salmon. They're not sure if it's related to climate change or the role of other stressors. What they do know is if a fish has the signature of this possible virus, the fish is most vulnerable to sickness when morphing itself physiologically to make the switch from saltwater to freshwater. The possible virus could be the driver behind a fatal behaviour change: late-run sockeye that migrate in early autumn when temperatures are cooler have developed a timing issue. Since about 1996, they've been migrating anywhere from three to eight weeks earlier than historically normal making them more vulnerable to the disease under study. Late-run salmon that show up early to spawning grounds are more likely to die before they can reproduce.

A doctoral student co-supervised by Hinch and Miller might soon yield answers about the possible virus. He is analyzing data on the cellular response of artificially heated sockeye and pink salmon. Some of the sockeye in the study have the possible viral signature. Any temperature-related disease progression may be detectable in them.

Rising temperature have already been blamed for the *Ichthyophonus* parasite that, since the 1980s, has been infecting and killing Yukon River Chinook salmon. The river is almost six-degrees C warmer than it was over 30 years ago. "Ich" (appropriately pronounced "ick") was thought to be a fungus at first and the state of Alaska dragged its feet in addressing the problem. It took independent research to convince Alaskan fisheries officials that in warm years Ich was infecting almost half the Yukon River female Chinooks. Peak infection was in 2003-2004. Infection and disease has steadily declined, to 4 percent. But Yukon River Chinook numbers have declined too — by 60 percent, from 268,537 in 2003 to just 107,000 this year.

Not all Chinook are likely equally susceptible to Ich. Lab tests showed some B.C. Chinook populations might be less susceptible than Yukon River Chinook. In Washington State's Puget Sound, the Chinook have very low levels of Ich, even though they feed on heavily infected herring. They'll also resist infection from a Yukon River parasite if introduced. Without population diversity, Chinook might not fend off the disease. It fits into the idea of the "portfolio effect" as described by University of Washington scientists last year. They took over 50 years worth of research on sockeye salmon from Bristol Bay, Alaska — the largest sockeye fishery — and showed that the genetic diversity of its sockeye populations gave the fishery stability. Just as a diverse financial portfolio ensures financial stability as markets go up and down, a diverse genetic portfolio gives the biological system stability.

Like most places fished today in B.C., The Park is within a traditional use area of First Nations. The aboriginal peoples fished here for thousands of years. They're known, in recent centuries, as the Coast Salish, a group bound by language and culture in communities stretching from the Lower Mainland to Vancouver Island and Washington State. The Sts'ailes, the fishers that run the beach seine for the studies, are Coast Salish. Archaeologists have found settlements on both banks of the Harrison River and on mid-river islands, all built within 50 metres of the river or sloughs. Settlement dates remain unclear but it’s safe to say human occupation of the Park is ancient.

Humans have lived along the rugged, fjord-riddled coast of B.C. for at least 11,000 years. They’ve corralled fish to their doom with nettle fibre nets, stones traps, and wooden weirs. The evidence is there, from California to Alaska, even on rivers and streams that no longer host salmon runs. (Remnants of a wooden weir were still visible in the 1970s at Morris Creek, a few kilometres upstream from The Park.) Archaeologists believe that the size of the runs of salmon was less important to early peoples than was access to many populations, big and small. It’s possible that the clues to sustainable management lie in the past.

Unearthing answers will take cooperation between scientific disciplines — a real challenge when it comes to combining biology and anthropology. They generally tend to have different mindsets. For biologists to infer a conclusion — for example, with studies about the effect of fish farms have on wild salmon — makes them suspect as scientists. In some cases it’s okay but there is danger, the mantra being: correlation is not causation.

Anthropologists, on the other hand, are a bit more comfortable with inferences, likely because all sorts of scientists will use anthropological and archaeological data to come to wild conclusions about humanity in general. A number of studies focused on societal collapse is often treated as conclusive evidence that as a species we are incapable of conservation. There’s also a feedback loop at play. Faced with a fact, such as the disappearance of big mammals at the beginning of the Holocene in North America, the spotlight on the human role can be relentless. And egos become tied up with theories, making some theories more powerful than others, especially when the proponent is powerful.

Charles Darwin's breakthrough — evolution by natural selection — gave biology the grammar to move forward as a science. It also gave cultural anthropologists grammar, and a headache for the last 150 years. Both biology and culture help to explain human behaviour, and the challenge remains in keeping them complementary and separate. We're all the same, and we're all different — and that's the starting point. As a species we have the same biological needs, how we meet them will differ. For most of the 20th century biologists, ecologists, and archaeologists have mostly found evidence of past environmental destruction not evidence of conservation but until recently, we didn't really know what it might look like.

At 4 p.m. the buzz of activity is muted at The Park. The fishers are packing their gear and the catch at the lab tents is dwindling. A warm breeze carries a sweet, hay-like smell from the grassy riverbank to overlay the odour of blood wafting from Wilson's fish morgue. She has placed 28 salmon brains in vials today, for transport and later study. I imagine a FedEx delivery to the wrong doorstep, someone expecting smoked wild sockeye fillets, not teeny, raw fish brains.

At the surgery table, Clark continues at a feverish pace. "It's a girl," he calls out at one point incising a belly with quick strokes. The data logger he inserts into fish is encased in

the same silicone used in biomedical implants for humans. Clark often adapts the tools of medical doctors for his fish studies. At the Cultus Lake lab, he has a meter originally intended to measure hemoglobin levels in human blood, which he recalibrated for fish blood, and he adapted a glucose counter for diabetics to count fish glucose levels.
The implant he has just inserted in the female sockeye will rest against her organs, and the tiny computer inside it will record internal temperature as well as electrical pulses from the heart. Once patched together, she'll go to a temporary pen in the river for a few hours before she's let loose to find her natal stream. Not a single fish of Clark's has died since I arrived. They will live to spawn, and then die.

In a few weeks, Clark will go to Weaver Creek to find his tagged fish to remove the computers. The data should tell him if the Weaver fish look for the cool spots in rivers — thermal refuges —to save energy, and how the fish allocates what energy it has during migration. "No one really knows that," Clark says.

As intimately as these scientists have come to know sockeye, knowing them prehistorically falls into a different domain, archaeology. Yet what comes out of both ways of knowing turns out to be the same — without diversity and adaptation systems fail.

Chapter 2

It is not enough to say that we cannot know or judge because all the information is not in. The process of gathering knowledge does not lead to knowing. A child's world spreads only a little beyond his understanding while that of a great scientist thrusts outward immeasurably. An answer is invariably the parent of a great family of new questions. So we draw worlds and fit them like tracings against the world about us, and crumple them when we find they do not fit and draw new ones.
***— John Steinbeck,* The Log from the Sea of Cortez**

Noble Savage? Or maybe they were merely savvy managers

If Dee Cullon had lived in the nineteenth century -- and if she'd been a man -- she might have lit out for the territories as a Coureur des Bois or ship's navigator, braving wind, ice and mud to gather furs, compass points, and stories to tell. Cullon, a slender, delicate-boned 37-year-old anthropologist, gets to spend about much of her time these days slogging around forbidding terrain on the west coast of Canada. Her tools, though, are a good bit more sophisticated than the sextant or theodolite of the early explorers.

"I use Google Earth a lot," Cullon says. "I zoom in and look at the estuaries because, for whatever reason, the photos are taken in summer . . . and during the days with very low tides." For the past six years, Cullon has been searching for fish traps, hopefully ancient fish traps that will tell her something about the people who made them and something about their environment. It takes her years to sift from her data the clues she seeks to social, legal, and ecological puzzles. But gathering the data is a simple matter of slogging through wet and cold — like a Coureur des Bois.

"Do you know what you're looking for?" she asks me on a raw August morning at

Menzies Bay, my first day out with her team. She asks it kindly, head cocked and eyebrows raised, as though welcoming a bewildered kindergartner to the first day of school.

"No idea."

We are looking, it turns out, for the round tops of wooden stakes, darker than the sand and roughly the diameter of a coffee mug. As waters move, they bury all kinds of evidence. But they also erode sand and mud, exposing evidence. Some years, Cullon's team finds signs of elaborate fishing ventures almost everywhere they visit: jumbled stones and stakes, lines of stones and stakes, stone traps alone, wooden stakes alone. I assume the head-down stance of the archaeologist, eyes on the ground, walking, walking, walking.

[redacted] another cheerfully long-suffering outdoors-woman, shorter than Cullon, hails us to her square of beach, where she has found one, then two more, stakes, all in a row. [redacted] around the stakes, measuring diameters and distances and planting a tiny red surveyors' flag, which reminds me, for some reason, of Henry VII: ". . . and I will see that the English flag is planted in this distant land."

It is not, of course, for Henry VII that Cullon [redacted] labour, but rather for the Laich-Kwil-Tach Treaty Group, who want to learn all they can about fish weirs and traps in traditional territories of the Kwiakah, Xwemalhkwu, and We Wai Kum First Nations. What kind of wood are the stakes? How many are there? What's the shape? Do they overlap with historical data? What kind of fish did they trap? How old are they? To whom did they belong?

For the tribes, it's partly a matter of law: The weirs are "fences" below the tide line, and a fence traditionally signifies ownership in British common law, a potential trump card for coastal First Nations wrestling over territorial claims with the government. [redacted]

[redacted]

[redacted]

If nothing else, the traps prove the tribes' deep ties to the land.

Cullon does a GPS reading and makes notes on the Menzies-Bay stakes. The heavy hand of industrialization has hit this area hard, and she is glad to find any signs of ancient fishing. The beach is packed flat and looks scraped. Menzies Bay was a log yard for much of the last century, with camps, a railroad, and steam-run equipment sprawling along the shores and into the forest. One of the largest known human-made explosions on the planet tore off the top of Ripple Rock, just around the point, in Seymour Narrows, in 1958, because, lurking close beneath the surface, the rock had ripped into more than a hundred hapless boats. A couple of wood pilings still poke out of the water from a pier dating to Menzies Bay's busy industrial era, but all that's left of it is a single log sorting and wood chipping facility near town.

Legal questions aside, ancient fish traps and weirs are cryptic guides to much older ways of relating to the coast. For generations of natives — for thousands of years — the fisheries were a complex, integrated solution to meal planning. The people of the First Nations, sophisticated scholars of the coastline, dedicated themselves to harnessing protein from the ocean to feed as many people as possible, for as long as possible, with as little effort as possible. Today's menu planning is complicated, like a Rube Goldberg contraption of interconnecting stovepipes that siphons fish to individuals with competing interests: industrial fishers, commercial fishers, sport fishers, subsistence fishers, separate parts never forming a whole.

As part of her work, Cullon has been asking native elders where they used to fish, hunt, and pick berries — and where the old villages were, and the old burial sites. She has been creating, more or less, a narrative map of the land- and seascapes. That information, compiled in a traditional- use study for the Treaty Group and cross-checked with marine charts and Google Earth, helps Cullon and a colleague, archaeologist Heather Pratt, pinpoint sites to search for ancient fish traps.

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Part of what draws archaeologists to the field, long before they specialize, is the notion that all humans need the same things, and that across the globe they often go about acquiring stuff like food in similar ways. Fish traps turn up practically everywhere you find andromous fish — such as salmon and herring — which migrate from the sea to spawn in rivers or close to shore — or their opposites, catadromous fish — mostly eels — that swim from lakes and rivers to spawn at sea. The Thames River's medieval fish weirs, the Maori people's eel weirs in New Zealand, the Amazon's ancient 500-square-kilometre weir in Baures, the Passaic River's pre-Colombian weirs in heavily urbanized New Jersey, various European weirs dating to 8,000 years ago — all these display similar ingenuity for the gathering of similar dinners.

The Pacific Coast of North America is no different. How the weirs were used depended on the fish, the materials available, the broader environment, and the human culture. But from California to Alaska, fish traps lined the ocean shores for thousands of years, and their remains are easy to find — provided you know what to look for. One may be stone, one wood, one a wall, one a fence. Like the fisheries complex in Amazonia, the people of the Northwest Coast — including British Columbia — domesticated the landscape intensively. In Tla'amin territory, for example, archaeologists have found stone fish traps interspersed with clam gardens. Just as gardeners of domesticated plants accede to the whims of their mini-ecosystems, moving around whatever is growing poorly — blueberry bushes, peonies — until they find the spot where the plant thrives, so must the ancient peoples have moved their fish traps until they found the sweet spot. The more experience you have with the land or water, the better your garden or harvest of seafood.

In North America, weirs have given us many place names. "Toronto" is likely a variant of the Iroquois word for a fish weir at Mnjikaning: "taronto." Mnjikaing itself means "at the fence;" thousands of the now endangered American eels were trapped for almost 5,000 years at the Mnjikaing fence. A variation of Mnjikaning, "Michigan," lends its name to the state.

The abundant productive capacity of the old weirs is referenced in such sneering colonial documents as the 1827-1830 journals of Fort Langley, the Hudson Bay Company fort in British Columbia. Shortly after the fort was built on the Fraser River, the Company's chief factor wrote that the "lazy Indians" couldn't be bothered to hunt beaver for pelts. The darn salmon was so plentiful that the aboriginals hardly needed to work. The colonials may not have understood that the bounty of the weirs was a work in progress that had begun thousands of years earlier. But after derogating the natives, they apparently learned to recognize a good thing. The work of Fort Langley morphed quickly from trading fur to trading salmon.

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The day after my inaugural stake-walk at Menzies Bay, a hired boat takes us to Phillips Arm, a remote estuary some 200 kilometres northwest of Vancouver, to look for either stone walls or wooden stakes. The estuary is an enormous mud flat. From the rocky beach, scars of the heavy-duty logging of the last century are hidden behind a second growth of trees and no one would know that gold was mined nearby. Both of these get-rich-quick industries altered fish habitats forever. Yet in the milky light of early morning, the estuary looks pristine.

The mud slurps and sucks at our legs as we walk — to the top of our knees at times — until we reach firmer ground at the middle of the estuary. It doesn't take long to find the tops of wooden stakes, laced in seaweed, poking up from the tidal flat. No troweling necessary; the estuary is not packed flat like the scarred Menzies Bay. Heather Pratt, the other archeologist, is tall, her light brown ponytail pokes through the back of a baseball cap, a red bandana tied around her neck. She crouches to pick seaweed off a stake. Beyond her, gulls float in a tidal pool. They're uncharacteristically silent — almost regal — without French fries or other human leavings to fight over.

It's chilly, and the mist mutes the voices of the crew as they work at removing four stakes of the dozens of stakes for dating and to identifying the tree species. The team looks like Lilliputians extracting teeth from a giant, salivating mouth. It's hard work, and they grunt and struggle, ladling up muck, over and over as it's sucked back down the hole almost as quickly as it comes out. [redacted] and crew member Rhy MacMillan, know each as students at the Vancouver Island University anthropology program, and they pull together with the stolid equanimity of draft horses — until the first stake erupts from the mud, and they whoop like children on a fun ride. Another three stakes come out along with the sun, and I wander over to watch the crew's surveyor, Ken MacPhail, his glasses giving him a professorial air, sandy-hair and fair skin weathered from years spent outdoors.

I've been wondering about the plunger-shaped protrusion from his backpack. It's the antenna of a roving GPS Total Station, it turns out. MacPhail is there to electronically record and map the exact position of the stakes, if they disappear from view again, the GPS recording will direct future researchers back to the site. The data is later fed into a computer program to generate a map of the weir. This non-tactile method saves hours for archaeologists who traditionally worked with tape measures, compasses, and prisms.

Whether high- or low-tech, maps reveal patterns, and patterns reveal human engineering.

As at Menzies Bay, the early indigenous people at Phillips Arm developed weirs to lead fish from their watery habitat to human plates — and their fishing continued uninterrupted for thousands of years. The weirs coaxed, rather than ripped, food from the shore. Estuaries like Phillips Arm, where ocean tides tumble into river mouths, ease smolts — salmon kids — into sea life. Some species and populations are soon ready for the salty ocean, and for them, the estuary is only a quick stop on the way to a proper meal. Others stay for months to bulk up; a bigger juvenile has a better chance to survive in the open ocean. Some use the estuary to adjust to the saltiness of the sea, in a less abrupt version of a newborn baby's struggle to gasp air into fluid-filled lungs. They linger in the mixed waters, moving up and down a few metres, adjusting.

As recently as a few hundred years ago, Phillips Arm, like many estuaries, was a gentler home to smolts. Forests perched on the coastline regularly sloughed off mature wood and debris that splashed into the water, creating a structurally complex habitat for small fish to forage and escape predators. The waters were turbid, creating a protective smokescreen for the vulnerable smolts to escape such sharp-eyed foes as trout, sculpins, blue herons and older salmon. The kids played their lethal game of tag in the equivalent of a little park playground with a jungle gym, rather than an open field in which the biggest and fastest tend to dominate.

I leave the techies and return to the mud-grubbers and their freshly harvested stakes. We each sling one over a shoulder to take back for dating and sampling. They're about a metre long and waterlogged, thicker than a walking stick and heavier than baseballs bats.

The wood might be hemlock, cedar, or pine. The fish traps from Phillips Arm probably date to about 2,000 years ago, Cullon thinks, as do those from three other nearby sites, including the Nanaimo estuary, which Cullon found dense with traps — solid wood posts made of hemlock stakes with cedar slats strung between. That time period — about the time of the birth of Jesus in Nazareth — is key in West Coast archaeology, because, as in the Middle East, lots of things were changing, populations were bigger, houses were bigger, people stored more food. Why exactly this happens is tough to answer, except that the society that emerged by at least 2,000 years ago was probably the same one encountered by Europeans a few hundred years ago.

We head toward the river mouth, [redacted]

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Through the fractured lens of tidal relics, Cullon's team is scrutinizing long-ago meal-gathering practices, but their research bears on the future of the coastal fisheries. Traps and their fish remains tell archaeologists something about resilience, the idea that communities protected themselves from perniciousness of Mother Nature. The fact that trap technology was so ubiquitous for so long, that the people modified a template to suit a locality, is a testament to the wisdom of intimately living with and managing a local resource.

Traps illustrate the human capacity for thinking in the long term: they allow for selective fishing and for the passage of fish to spawning grounds. In the old days, the Phillips Arm salmon got to reproduce in large enough quantities to sustain their population, and people got to eat for generations. As diverse habitats and diverse fish species changed, the traps adjusted with them**.** Today we tend to use a technology until there are no fish left, think cod and factory ships.

But it's easy to say too many people went after the resource with too efficient a technology, driven by a market economy. That's too easy. It also let's us off the hook — no one can wave a magic wand and make six billion people disappear. Besides, it's unethical. Sometimes it pays to look more closely at one particular problem, like how few Chinook return to the Phillips River and can that be changed?

All five species of salmon come back to spawn and die here. In a few weeks time, in September, about 300,000 pinks, the most abundant and smallest of Pacific salmon, swarm the Phillips estuary. Yet only a few hundred Chinook (called spring or king in the United States — Canada officially changed the name in 1965) come. If you're going to call yourself the Salmon Capital of the World, that's not good enough.

Since the 1980s, the Gilliard Pass Fisheries Association, a non-profit salmon enhancement organization, has taken about 15 percent of the Chinook run, aiming to harvest 200,000 eggs to rear in hatcheries. Once the fish in the hatcheries reach smolt stage, they're released into the Phillips estuary and about six kilometres upstream in Phillips Lake. But like most hatchery-raised Chinook in British Columbia, the survival of hatchery-raised Phillips Arm Chinook is crushingly low, less than one percent. The explanation for such poor numbers flows back to genetics.

The Chinook populations, like sockeye populations, are tremendously diverse. Even contemplating smolt size is like looking at a ballroom full of women from around the world and coming up with some kind of average. Some populations have statuesque, robust smolts, a Venus Williams, while others are slender and gracile, a Lady Gaga. A grown female has anywhere from 2,000 to 17,000 eggs to deposit; Phillips Chinook tend to produce a respectable 5,000. More important is the question of how long they stay in freshwater, if at all. Ocean-type Chinook leave freshwater for the salty sea immediately, though they will linger in the estuary. Stream-type Chinook stay in fresh water for one, two, sometimes three years. During their residence, the stream-types are up for a fight and flaunt colourful fins; their growth seems to be tied to the light cycle. While ocean-types initially grow faster, stream-types are bigger at the moment when they enter the ocean. Their destinations are different too. Stream-types head for the central North Pacific Ocean and return in spring and summer, while ocean-types migrate along the coast and return later, mostly in summer and fall. Cross the two, and the stream-type genes play second fiddle to the ocean-type genes.

The point is that each has adapted to a different ecological niche, and one bold difference is displayed at the 55th parallel, above that line, the Chinook are almost all stream-types, below, scientists think ocean-types dominate and efforts to enhance Chinook habitat has relied on raising ocean-type fish. But is it that simple, a line in the sand?

[copy break]

We walk the Phillips estuary toward the sea, [redacted] as always, far ahead. When we hit the river, we turn and head inland, toward a side channel. From ahead of me, someone lets out a whoop — a stake juts out of a dry stream bed, a lone sentinel waiting for our team to relieve him of a centuries long duty. But no, he's not alone: more stakes cling to the riverbank. Did they support a platform for spearing fish as they headed upstream to spawn? [redacted] Macmillan head further upstream, heads down, scouting. Pratt, Cullon, and MacPhail catch up with the rest of us, lugging their high-tech map-makers. But we should leave soon: The tide is coming in fast. Cullon notes the number of stakes and takes a quick GPS reading. We call back [redacted] and Macmillan: it's more than time to leave.

Running is out of the question. Clumps of seagrass, probably an accidental import, trip up even [redacted] and by the time we find more solid footing, the water is gushing into the estuary, knee-high. [redacted] MacMillan, and [redacted] bound across the onrushing tide; [redacted] turns back to offer help when he realizes he's outpaced the other two, the rest of us are rushing to keep up. I find myself balancing on my left foot, water at thigh level, desperate to keep from plunging the cameras on my back into the tidal flow. I stretch to reach my right foot and pull a sandal back on over a thick, sopping wet, wool sock. By the time I straighten up and regain my balance, the three fleet men have disappeared around the point. [redacted]. I hold my backpack above my head and edge closer to her. We pause and look at each other. [redacted] We turn toward the steep bank along with the other three, and one by one scramble for high ground, passing off our stakes and giving each other a hand out of the water. I had no idea archaeology could be so thrilling.

"[redacted]

[redacted]. The ripe berries are gone by early August, but that thought doesn't give me much comfort; grizzlies also munch on green leafy plants and roots. We are all gripping waterlogged stakes, no use as climbing poles, and our full packs catch in the undergrowth. I'd like to think it was the expensive, cumbersome gear that slowed our group in the rushing tide of the estuary. But even without our loads, we probably couldn't have kept up with the others. I imagine those three lucky souls lolling in the sun as we struggle. [redacted] We look, in vain, for a path.

"I have never had this happen before," Cullon says, bemused. She radios the boat operator to try a new pick-up point. Not possible: The skipper is afraid of running aground. We take turns leading the way, pushing aside brush careful not to let it whip back in someone else's face, tripping on the understory thick with salal, climbing over tree trunks stay as close to the water as possible, passing stakes back and forth. The bluff is high and steep, messy with undergrowth and downed trees; one slip and I'd tumble down to the water, if not stopped painfully by a tree branch. After almost two hours, we figure out a place where the boat can pick us up and lurch within view of it. A huge cedar log stretches across the forest floor between us and a possible path down a lower stretch of cliff. I'm in the lead, and the only thing to do is climb over the log. I stretch over it, arms too short to place the stake on the other side. I drop the stake, figuring to pick it up once I've hoisted myself over the log. The stake rolls. And rolls. And rolls. I scramble over the log in time to see it bound down the bluff and break into two pieces. One by one, the group slides over the log. They bunch up behind me, silent.

Oops.

Cullon picks up the pieces of the 2,000-year-old relic. “You know what,” she says. “It happens.” She smiles. “These traps are everywhere.”

We’re exhausted by the time we meet the guys — and the boat — at the point. We take turns boosting each other to the deck, Cullon last. She hands up her backpack and reaches for Pratt’s hand. The boat shifts, Pratt steps back to gain balance, their hands slip apart, and Cullon lands in the mud and water.

“Sorry!” Pratt shouts.

Cullon laughs, and splashes aboard for a cold ride home [redacted]

[copy break]

On day three of my fieldwork inauguration, we’re at Deepwater Bay on Quadra Island, tramping down a creek, feeling skunked, seeing only steel cables from logging years; they run the length of the stream, like phone lines to nowhere. Mid-morning, after walking for more than three hours, we find ourselves back at the beach, and dutifully walk transects, though we’ve already crisscrossed the sand many times. It seems odd not to find stakes. Deepwater Bay is known to host plentiful sockeye on their way to the Fraser River. In the 20th century, canneries operated a commercial trap at the Seymour Narrows, where the fish waited for the tide to change before heading upriver.

[redacted] he finds two more stakes quickly, and someone starts singing: "May the circle, be unbroken...." We end up flagging a big trap -- 43 stakes in a curving line -- most thanks to Wilson's gumboots. The little red flags flutter in the breeze.

"I like seeing all those flags," Cullon says. Pratt laughs. "That's because you're so controlling."

"Hey," Cullon says, "if I weren't so controlling, we wouldn't be out here." Cullon is meticulous, recording data, organizing her team, and planning. The report she files later is exhaustive and about as much work as a doctoral thesis.

As we perch on a jumble of big grey rocks, waiting for the boat, [redacted] and Cullon segue from discussing British royalty, particularly King Henry VIII and his obsession with sons, to musing about traps. I mention the stone weirs I read about on the Central Coast, one that stretches maybe 100 metres, so obviously used to catch mountains of fish to feed a large population. That's a lot of heavy rocks, a lot of wood to carve into stakes and slam into the ground.

"They would have had a lot of fish," Pratt says. "Everyone must have worked, the entire village." We stare silently at the ocean for a few moments. It rises and falls, as if breathing.

Fish weirs have probably been around since the Paleolithic — the Stone Age — capturing the bounty of the ocean shore. The technology wasn’t always used benignly or in balance, especially in medieval times. In the mid-1300s, fishers in the Alps paid an archbishop 27,000 white fish and eight lake trout annually for the right to catch more, and wiped out a population of whitefish in a generation. In general, when a social order changes and economic interests compete, fish weirs become a problem for lawmakers. The Magna Carta of 1215 banned all inland traps in Britain, and medieval noblemen in Europe routinely destroyed peasant traps. Industry silted, dammed, and polluted rivers and streams, and as seafaring technology advanced, fishers hauled their catch from the open ocean instead of the shores. In Britain, parliament moved to protect the property of the landed gentry (including fish) in 1861 by banning all fish traps not in use before the Magna Carta.

Upon arriving in the Pacific Northwest, colonists assumed that the vast amount of fish being trapped illustrated the abundance of the region — but also that fish traps overexploited the resource. They used either perspective to get what they wanted. The area was in an upswing of productivity — it was an all-you-can-eat buffet for sea lions, sea otters, salmon, herring, zooplankton and humans. What the colonists didn’t know is that the ecosystem, fed by what scientists now call the “chaotic” North Pacific, is notorious for its pendulum swings of abundance and scarcity. If an animal is to survive in the North Pacific, it has to adapt to chaos.

The colonists, understanding neither the newly “discovered” societies nor the North Pacific habitats, failed to realize that aboriginal trap management had sustained a healthy fishery in a chaotic environment for thousands of years. Or maybe they simply didn’t care. The Canadian government banned First Nations fish traps in the late 19th century;

there was no room for the older social order and economic system.

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Catching salmon is the heart of the economy in Campbell River and why the Gilliard Pass Fisheries Association works so hard to keep the salmon coming back, and why they've finally decided to try something new. Maybe that simple line in the sand does not exist when it comes to types of Chinook. After decades of disappointing Chinook runs they enlisted help from the most vocal Chinook salmon breeder on the coast. Carol Schmitt.

In spring, I drive to Omega Hatcheries, a private hatchery on Central Lake on Vancouver Island, owned and operated by Schmitt. Again, if it was the 19th century and Schmitt was a man — a gentleman — she'd be writing elegant letters about her fish experiments to fellow naturalists, exposing a voracious appetite for knowledge and a keen intellect. Schmitt is in her mid-50s. But spend more than an hour with her and the years melt away, revealing the natural scientist inherent in 10- year-olds and a girl who of course rescued stranded salmon fry at her childhood home close by.

Schmitt is convinced that the reason Chinook enhancement fails is because hatcheries pump out ocean-type fish, accelerating growth by stuffing them with food, coddling them in water warmer than their natural environment, and releasing them as smolts too soon, after only eight months before their immune system can fight off fatal ocean viruses. If the Chinook smolts find themselves in the estuary when they're small and vulnerable, they're more likely to lose a game of tag with a predator, or encounter a virus they can't fend off.

Schmitt, a graduate of British Columbia Institute of Technology's two-year fisheries technician program, has worked with fish for over 30 years. A few years ago, she began to change her Chinook rearing conditions. She sits in front of a computer at her mobile home, a minute walk from the hatchery pools, guiding me through her reams of data.

"You want to see the smolts," she says, rising, grabbing a baseball cap, tucking her long blonde hair inside, closing the buttons on a flannel jacket, she leads us out the door. The smolts are Phillips smolts. Schmitt was hired by the Gilliard Pass Fisheries Association to raise stream-type Chinook. It's an experiment the Association and Schmitt hope works — the Association because they'd like more Chinook, and Schmitt because she likes fish and her ideas will be vindicated.

"Call it adaptive management," she says as we walk from building to building, stopping in one to grab a bucket of feed and a scoop. "I think you have to look at individual Chinook [populations] and their environments." Schmitt tries to mimic the stream conditions faced by Chinook smolts, colder water, less food, slower growing conditions. "If something isn't working, I ask myself, 'What can I change?' I can't control the ocean, I can't control the climate, I can only control how I raise the fish."

If the stream-type and ocean-type juvenile life histories are not genetically based, but rather reflect environmental conditions experienced during early juvenile rearing in freshwater, Schmitt has a good point. And the Association and federal government hatcheries have released the wrong fish for decades.

Schmitt cannot resist showing me everything on the way to the pool of Phillips smolts: salmon, salmon, more salmon, and novel fish others pass on to her, knowing Schmitt will observe and experiment — albino coho, blonde rainbow trout, and sturgeon. “I think I qualify as an official fish geek,” she says, before turning to a tank and greeting the fish.

We meander among a dozen or so round, white covered pools, a slice of the roofs open so Schmitt can feed the different salmon smolts. One of the pools holds the Phillips brood. When Schmitt approaches, the fish swarm closer to the opening, like thousands of teeny puppies sensing someone with treats in her pocket. Scooping the feed, Schmitt calls out, “Here you go,” and flings it over the surface as equitably as possible. Dinnertime is loud. The sounds of thousands of smolts feeding is a lot like a herring spawn, little silver bodies arch out of the water, curving their bodies this way and that, flicking tails.

In a few weeks Schmitt will take these fish via truck to Phillips. It will take a few years to find out if she’s right, like most long term ecological research. Though lacking a PhD, after decades of raising fish, this hatchery owner has kept her mind open, playing with ideas and fish, using inductive reasoning skills to understand her environment. Inductive means creating general principles by starting with many specific instances. Generalities are not true all the time, so simply reasoning this way is flawed. It’s the reason scientists turn to deductive reasoning — starting with a limited number of simple statements or assumptions, more complex statements can be built up from the more basic ones. By teaming with the Association, Schmitt might get a chance to prove, deductively, that she’s right.

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Months after our excursions in quest of fish traps, Cullon sent me her report. I now know that the stakes we slung over our shoulders for the circuitous trudge out of Phillips Arm were hacked from balsam trees 2,000 years ago. And with that date it dawns on me that a case could be made that the fish traps and weirs on the coast are legal. If the Magna Carta states traps built and in use before the 13th century are grandfathered into the law, and Canada's west coast was claimed by Britain by the end of the 18th century, well, it seems those "fences" should have been honoured by the Crown.

But it also illustrates that people only see what they want to see — an Eden, where the living was easy. It's no secret today that the indigenous people worked the land- and seascapes, it's figuring out how they did it successfully for so long that has archaeologists looking back through a different lens, looking for chances to redraw this ancient world, impossible without the ecologists.

Chapter 3

The true biologist deals with life, with teeming boisterous life, and learns something from it, learns that the first rule of life is living.

Everything ate everything else with a furious exuberance.

— John Steinbeck, The Log from the Sea of Cortez

Everything Eats Everything Else: Salmon in the Rainforest

A silver, tin can of a vessel comes chugging toward the dock, a funny little boat that would look more at home in a bathtub than the fickle waters of B.C.'s Central Coast. It skirts the wing of a floatplane tied to the dock, and as it comes closer I can see two young scientists squeezed into the wheelhouse at the very back, both wearing sunglasses. No name graces the boat so in an effort to make conversation I ask John Reynolds, an ecologist from Simon Fraser University, what the boat called. "*The Tickler*," he answers.

I burst out laughing. Reynolds grabs a rope as the boat bumps alongside the dock, and he shrugs, laughs, and says, "I have no idea. You know, kids." He did not name the boat. The graduate students in the boat, Noel Swain and Jeanette Bruce, are part of the Reynolds' Lab, a group of graduate students and post-docs studying wild salmon ecology. From spring through to fall, scientists fan out across 50 watersheds on the Central Coast, 700 kilometres north of Vancouver, mostly in territory of the Heiltsuk First Nation, teasing apart the salmon food web, a web woven at the end of the last ice age.

The Tickler has just enough room for Reynolds and I, suited up in survival jackets, to sit on a cold, metal bench in front of the wheelhouse. We're off to the Lab's HQ, an old cannery on Denny Island a 10-minute boat ride from the government dock in Bella Bella, a reserve on Campbell Island.

The water we skip across to Denny Island, is part of the Inside Passage, a marine highway for BC Ferries and other shipping traffic between Port Hardy, at the northern tip of Vancouver Island, and Prince Rupert. To most travellers the scene is only a spectacular backdrop to a holiday snap taken on a cruise to Alaska or a place to pass through, a one-dimensional view, a single frame in a long and ongoing movie.

I'll come back again and again to the Central Coast, a stretch of coastline that's a bull's eye in the middle of a lush, wet coastal eco-region that runs from southeastern Alaska to northern California. It is a landscape in constant, if slow, motion. It teeters and totters in a tectonic rhythm, sinking or rising in response to how glaciers alternately compressed and retreated from it during the last ice age. As much as it's a geographic linchpin, I come to think of it as a metaphoric linchpin in this particular salmon story.

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Noel Swain, one of the grad students, pulls *The Tickler* alongside a dock, a blue building, the old cannery, looms above. We shoulder our packs and head up the gangplank to unload. The day is sunny with time enough to visit one of Reynolds' streams about a 15-minute boat ride away, at a place called Gullchucks.

Reynolds' work is complex and simple at the same time. From a purely theoretical standpoint, he's trying to get at a key concept in ecology — how does salmon affect the population and diets of its consumers, is it a mega-dietary supplement for Pacific wrens, freshwater sculpins, salmonberries? Because the fish overwhelm a nutrient limited system once a year, the evidence of their impact should be plain to see. And it is, but only when Reynolds gets the complex part right — designing elegant experiments to uncover just how deeply salmon are integrated into their coastal surroundings.

His studies focus on population densities of different animals and plants along salmon spawning streams, compared with non-salmon spawning streams, and analyzing those same plants and animals for salmon's signature dietary contribution —nitrogen levels gleaned through isotopic analysis. Since 2006, the Reynolds' Lab has helped create a more detailed image of coastal B.C.'s ecosystem.

"We count pink and chum basically," says Reynolds over the roar of *The Tickler*'s engine and the wind. "If we see coho we'll count them but we see very few of those. They come later. Besides, they're very secretive, hard to find. We see the odd carcass now and then. Most of our systems don't have sockeye. To have sockeye, you have to have a large lake that they can get to because the young spend a year in a lake. We have some lakes but fish can't get to them. We see the odd stray now and then but they're not really part of our story. There are sockeye streams here but not ones that we've worked on. And we don't run into Chinook either."

Right now it's the start of spawning season for chum and pink salmon and in another week more students will arrive to walk streams and count fish. When we arrive at Gullchuks, Swain drops us close to shore, consults a tide chart and then steers *The Tickler* away, anchoring the boat in deeper water, then he climbs into an orange kayak to paddle back and join us. Wearing chest waders and boots, we walk towards the forest, pausing at the stream's mouth to look at a stone arc maybe 100 metres long, a permanent whale's mouth on the beach, the tide flushing out, leaving behind nothing today. It's the remnant of a trap, the first stone trap I've seen. A raven swoops overhead, coming to rest in a Douglas fir tree. Traditionally a "trickster" in coastal First Nations' stories, raven is mischievous, and, like humans, equal parts foolish and smart. In some stories from the Pacific Northwest, the world can thank raven for disturbing the force that keeps the ocean level, resulting in a tide twice a day, and food flooding in to the people, human and non-human. The tide brings in salmon that get stuck behind rock walls for humans, and the phytoplankton washes into the intertidal zone feeding clams and mussels, which in turn feed the crabs.

We schlep a little further upstream in chest waders and boots. I find three wooden stakes peeping out of the mud along bank, waving over the biologists to show them and explain what they are.

“Has anyone rebuilt a fish trap to see exactly how they work?” Reynolds asks, pausing to look at the stake. He’s surprised when I tell him, not that I know of, and that it’s technically illegal.

Swain starts looking for salmon while Reynolds quizzes the other grad student, Jeanette Bruce, on the plant life, intoning a rhyme at the start of the journey, as we clump through sedge: “Sedges have edges, rushes are round, grasses are hollow right up from the ground.” Swain, surefooted after a second season scrambling through the temperate rainforest for 12-hour stretches at a time, leads the way. Reynolds is on his heels and Bruce and I (our first day in the field) hurry after them, each of us barely avoiding the mortification of slipping into the cold water.

Swain and Bruce are East Coast exports — New Brunswick and Newfoundland, respectively — and though in their 20s, the disappearance of the cod fishery is part of their psyche. Bruce recounts tales of her friends leaving The Rock for work in the Alberta oil sands, and Swain’s father is one of many eastern DFO fisheries scientists who discovered politics often trumps science when it comes to fisheries policy.

“What’s this?” Reynolds asks Bruce, fingering a feathery plant that looks soft enough for a pillow.

“Lanky moss,” Bruce answers without hesitation, though she stumbles over some of the other mosses. Reynolds continues to point out plants and trees as we walk, Bruce answers: Amabilis fir, Douglas fir, salmonberry, huckleberry.

We scramble across the stream, and loop back to shore, finding another stone trap, its lower, crumbling walls suggesting an older time frame for this one. We pause again, wondering what it would take to rebuild a trap, and watch early arrivals to their natal stream, pink salmon. Today we’ll count one coho and 512 pinks.

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Of Pacific salmon, pinks are the puniest, averaging about five pounds, and they have the shortest life cycle, a scant two years. In the Fraser River their migration peaks during odd years. But on the Central Coast — again, something of a linchpin — they return in abundance even and odd years to over 130 streams and rivers in the region, though even-year pinks edge out odd-year among monitored streams.

This short life history means they likely can adapt more quickly to environmental changes. They’re like colonizer species, alder trees that shoot up in a clear cut before anything else. They also have a few other advantages that should help them deal with change, and yet, they are the least enjoyed salmon, the one called “cat food” by people a couple generations ago.

Pink salmon leave their freshwater homes right away, so they're less affected by habitat degradation in freshwater. They can migrate through fast moving water when they have to — they're better swimmers than sockeye, although fishers will argue that point — and they can stand heat better than other salmon species. Pinks might even prefer the warmer water. In general, larger, older salmon are found in colder waters and smaller, younger salmon in warmer waters. In lab studies Japanese scientists found the bigger the fish, the increased preference for colder waters, but compared with sockeye of the same size, pink were fine with a little heat, while sockeye wilted. Pink can take a little heat but something else comes with a moderately warm ocean — favourable conditions for the survival and growth of most sub-Arctic zooplankton species. In other words, a seafood buffet for pinks.

Russian studies that measure copepod biomass in the Bering Sea found that warming ocean water enhances ecosystem productivity from the lower trophic levels (toward the bottom of the food web), particularly planktonic crustaceans (pinks eat a lot of pteropods, a planktonic sea snail), which play a significant role in the pink salmon diet. And records from Russia note that during cooler periods — the 1950s and 1960s — regional pink stocks in Russia were low. In 2009, the year sockeye failed so spectacularly, pinks showed up en masse.

And here's the other rub to other species, pinks are some of the first salmon to enter the ocean, they get to the table first and stuff their faces. They spawn in the lower parts of rivers, and within weeks they're off to the races. If a warmer ocean shifts production of food earlier, pinks will chow down before their cousins. Oh, and then as if they don't need another evolutionary boost, they're terrible at finding their natal streams.

Because they're more likely to get lost, maturing pink salmon redistribute themselves and their genes between spawning regions. Fish that show up in some other population's stream are called strays and they're crucial to strengthening, or even re-establishing, a salmon population. The most dramatic example of how influential stray salmon can be occurred after Mount St. Helens erupted in May 1980. Any offspring that spawned in the Toutle River the previous fall died. Strays from that population would have been the only ones to leave a genetic legacy. Another reason to protect all salmon spawning streams — one population might end up re-populating more vulnerable watersheds.

[copy break]

When we emerge from the bush, the sun is lower, the stream banks glow orange, tree branches black against a blue sky, and the boat seems a lot closer than it was.

Swain turns to me, a blush creeping up his face. "You're not going to write about this are you?"

The Tickler is beached.

Unable to read a tide chart myself, there's no way I'll tease him. But Reynolds does, good-naturedly, easing off a bit only when Swain remembers the Fig Newtons he stowed in the cabin and Reynolds starts nibbling on a cookie.

We have a couple of hours to kill until the tide comes up. Time enough for Reynolds to explain what he does here on the Central Coast.

"Surprisingly what I haven't done is won a Darwin Award yet," the scientist says, as we stroll over to the fish trap, now fully exposed, and he describes the time he found himself dragging garbage bags full of dead salmon through the forest and up mountainsides. "You have to stop sometimes and wonder what it is you're doing exactly."

In this case it was part of major study he began with a doctoral student at the time, Morgan Hocking. A few years earlier, with a team of about 10 researchers, academics and members of the Heiltsuk First Nation, Reynolds and Hocking attempted to quantify just how much salmon feed the ecosystem by counting the salmon returning to 50 streams, surveying streams (a laborious, tedious, and time consuming process I'll find out on a later trip) doing an inventory of plants in the watershed, and taking plant samples back to the lab to search for the signature salmon lends its consumer, Nitrogen^{15} (15N). Reynolds and Hocking dragged garbage bags of salmon through the forest to mimic how bears, wolves, and other creatures drag their nutrient rich prey through the understory, sprinkling food around for the green sedentary species lurking in the forest.

From the salmon jostling for position and scouring the stream bottom, to the larger animals that hunt or scavenge the fish, the effect on watersheds like the Central Coast is like having one very generous benefactor continually funding certain charitable organizations, the currency being nitrogen.

"You wouldn't guess [the system was nitrogen limited] to look at how lush the growth is," Reynolds says as we walk the rocky beach, pausing every now and then to listen to a bird call. He can identify them all — in this case what he calls the high-pitched roller coaster call of the Pacific wren, and the most common year-round resident in these woods. "But that lushness is because they're sucking up all the nutrients they can get. A lot of these plants can grow year round and to sustain that it means a lot of these soils are going to be depleted in nitrogen. There is some export of nutrients into the estuary and into the sea, a certain amount out, but there's quite a lot in. Sometimes," he says, waving to the trees in front of us, most standing, some leaning against others, others now deadwood stretching across water, hovering above spawning pinks, "these logs or branches look like clotheslines with dead salmon hanging from them. It's incredible. And obviously that's going to keep the nutrients around a lot longer than if they're just going straight down some steep sided canyon with very little obstructions."

The garbage bag study eventually showed that by looking at the vegetation — up to 35 metres from a stream — it was clear most of the time which streams were spawning salmon streams and which were not. Nitrogen-hogging Salmonberry — it has salmon-coloured flowers — thrives in salmon spawning watersheds. So does stink currant. Wild blueberries do not. And, counter-intuitively, non-salmon streams hosted more plant diversity than salmon streams. Yet, another study running at the same time found an increase in bird diversity and density during the summer around streams with large salmon runs, with some runs numbering over 100,000 fish. Another student is narrowing the bird focus down to Pacific wren, and it appears that when the wrens nest on salmon streams it boosts their population. Reynolds points out that what these ecology studies do is show connections most observers tend to be unaware of — like the soundscape. If Pacific wrens can thank salmon for their density and reproductive success that means even the sounds of the forest would change without salmon.

Water laps into the trap. Aside from the chill, we're standing within a travel magazine cover: the water reflects streaks of purple, orange, and blue from the disappearing sun, *The Tickler*, a silhouette, perks up, water slapping its sides.

The sky is black, the stars suspended over our heads, a mobile of inverted phosphorescence, when Swain flips a switch, *The Tickler* groans, sputters, then cooperates and we head back to the cannery. We arrive around 10 p.m. and after a quick meal we scatters to our beds; tomorrow we start early.

[copy break]

We have about five or six streams to hit today. Around 7:30, lunches and extra clothes packed, we head to the boat. Bruce takes the wheel this time. A turn of a key and the familiar sound of a moaning old man, followed by a cough, tells us *The Tickler* will start, just give it a few seconds. We're headed for Roscoe Inlet about 45 minutes or so away. Rain clouds gather. But as we get closer, the sun shines and Roscoe Bay glitters. Again, it's so clear the bay reflects an upside down world so real, flipping an image would make no difference. Snow clings to the mountains in the distance, but before us the shore is mostly green with tinges of oranges and yellows from leaves and rocks and stumps and logs. Once we get closer and Bruce cuts the engine, the sound of rushing water overwhelms everything else, except for an occasional punctuated splash from a salmon jumping. We hop out, Swain anchors the boat, giving us a wave and a shake of his head and mumbles something, something about never, ever beaching a boat again.

Just at that moment a chum salmon leaps up and over a log and right onto the beach. Oops. From the human perspective it always seems weird when an animal miscalculates — what did this salmon see or not see? Smell or not smell? Was the sun in its eyes? Reynolds scoops up the fish, a spawning male chum, recognized by its vertical purple blotches and fierce, dog-like teeth that give the species its nickname, dog salmon. He carries it back to the stream's mouth, holding the fish's tail as it wriggles in the water. Once its rescuer lets go the salmon hurtles itself along the same course toward the beach. And leaps. Reynolds picks up the fish again and carries it further into the middle of the stream. Citing Darwin, evolution, and human interference, Bruce and I tell him he's subverting the course of nature with his interference.

“Sure,” he says, wiping his hands on the sleeves of his t-shirt, tucked into his chest waders. “But around here it’s really impossible to divorce humans from the system anyway, they are part of the system completely and they have been, we know, for over 10,000 years. Right?”

Swain rejoins us as we watch the chum, back in the water, glistening in the sun, jockeying for position — the moment these fish have waited for their whole lives comes down to being quicker, more aggressive, and wily enough to drive off the competitors from depositing eggs in the best spot or fertilizing those eggs. Or being rescued by a biologist after making a wrong turn. Reynolds chats a bit about ecological baselines and how, in restoring ecosystems, deciding the baseline can be an arbitrary exercise.

Westerners are most comfortable with written records, and even looking back to pre-European contact depends on a point in time, how we read the archaeological record, and what exactly we’re looking for. Unlike salmon some resources inextricably linked with the first peoples — cedar, for example — only pop up as a native species itself about 5,000 years ago.

Still, in contrast to other parts of the continent, which witnessed numerous advances, retreats and replacements of populations, the line from earliest settlers to present-day First Nations in the Pacific Northwest is likely unbroken. Through oral histories it’s fair to assume that until the 19^{th} century, no later arrivals pushed aside or replaced the first people. Yes, some New World colonizers moved on, to people North and South America, but others stayed. Over time the climate changed, the landscape changed, and the culture changed, but home has been home for humans and salmon since the glaciers receded.

“You don’t have to look around very hard to see that the people were here and catching a lot of fish for a long long time,” Reynolds says. “You have wonder if they co-evolved, in fact…that’s a lot of generations of fish to be taken by a lot of generations of people.”

Ancient fishers here caught all five species but after European contact something changed — the hierarchical value of the species. There is no question that a fresh caught sockeye or Chinook is tasty, but take away the modern market and people value a fish like chum for the same reason we disdain and pay so little for it — it’s low in fat. Yet chum salmon’s size (it’s the second largest of the five species), and its relative leanness make it a perfect fish for smoking and keeping on the Central Coast.

Of the 250 documented fish traps on the Central Coast, the 40 studied by Heiltsuk archaeologist Elroy White, another SFU alum, were remembered mostly as traps for chum, not sockeye as everyone — including the younger members of the Heiltsuk community— used to think. When the archaeologist interviewed community elders he kept leading them back to talking about sockeye, confused that they were so focused on chum, until he could see past the cultural bias — sockeye rules! — he grew up with as a boy. To find a fresh chum staring at you behind glass in a grocery store is nearly impossible, it’s always in pieces, canned, or jerky in airport gift shops. As a freshly caught dinner, you have to own a rod, and know how to use it, and where to go, or know someone who does.

The four of us watch a female chum digging a redd (a nest), facing upstream, turned on her side, curving her body as she sweeps her tail into the stream bottom. Habitat and species will drive some differences, but generally speaking, when female salmon come back to spawn this is what they do. In the wild, it's easiest to follow chum spawning behaviour because at this most important moment of their lives, their colouring is the most dramatic of the salmon species. (Although, in general, the further north a salmon lives, the more striking its colouring during spawning.)

Looking at the chum in front of us, I search for a satellite male — the one in drag, a subordinate male that morphs his colour to resemble a female to attract less aggression. He's stealthy. Satellite males hang back, away from the alpha male, and then zip in to fertilize the eggs just as they're released, before any other fish can stop him.

To protect his own position, the alpha male flanks the female, fighting off other males, ramming into them and biting or locking jaws. Alpha males can swim in drag too, if they need to. Scientists know this because in the 1970s Canadian scientist Kees Groot placed male chum in an aquarium, allowing satellite and alpha males to form pairs, then he attacked the alpha males with a broomstick handle — within seconds the alphas' bar patterns switched to the horizontal patterns of a female. Once the attack stopped, the alpha male would nip a subordinate male and gain back his stripes. Later observations at Weaver Creek spawning channel in B.C.'s interior further confirmed Groot's findings.

Females — identified through a dark horizontal bar that run the length of its body — fight females for choice spots, and they fight off the lesser males, the ones they find unattractive, less manly, more metrosexual than macho. The one that looks a lot like them. A female wants an alpha mate, an Arnold Schwarzenegger, a prime male specimen with bold vertical stripes that enhances its bulk. And, apparently a feminine appearance — the slimming horizontal stripe and more dainty dog teeth — attracts males, signaling to them to hold off on the aggression.

To find the undersea equivalent of The Best Nest, females nose along a stream's gravelly bottom, testing the gravel: too much silt and sand will smother the eggs. She also looks for calmer water and a spot hidden from other females. Depending on the species, females dig anywhere from two to seven nests, cone-shaped hollows, about a foot deep, give or take a five or 20 centimetres. Studies on coho females show a correlation between depth and body size, bigger females have the muscle and power to dig deeper nests, an advantage. Shallower nests are more vulnerable to gravel disturbances, whether human-induced, weather induced, or even from other marauding females. Early arrivals might get to the best nest sites first, but later arrivals will dig up their competitor's nests, easier if the earlier arrival is no longer around to defend her nest. Females are just as ruthless and stealthy as males — it is, after all, a dog salmon eat dog salmon world.

Dig a little deeper and the beauty of biological adaptation always seems to surface: early arrivals also tend to be older and bigger fish, which presumably can dig deeper too. While chum fry head straight to sea like pink, unlike pink they stay in marine waters for anywhere from three to six years. Biologists studying the Kuskokwim River system in Alaska, found that most returning chum were five years old, and overwhelmingly earlier rather than later arrivals.

We're mesmerized watching fish splash around, their dorsal fins, backs, and sometimes tails peeking out of water that's less than knee-high deep. We've hardly moved beyond the shoreline; pink and salmon spawn in the lower reaches of streams. Swain points out a couple of pinks, noticeable by the humped backs the males develop during spawning season, which is why they're imaginatively also called "humpies." Pink males form nest groups around one female, with their positions hierarchically organized biggest to smallest, the biggest male with the biggest hump hangs closest to the female, aggressively guarding his access, although he tends to be more aggressive to fish outside the nest group. And even though all pinks are two years old at this point, the males can differ widely in size, but like the chum, the lesser males will dash in when they see an opportunity.

We move on, peeking upstream, greeted by the timeless sounds of rushing water, wind ruffling through trees, birds calling.

[copy break]

A golden eagle flies overhead as we board *The Tickler*. Swain turns the boat south so we can check out Rainbow, another stream that is refreshingly hard to find on a map. In such a connected world, it's almost weird to find no reference on Google Maps to this spot. We stay onboard, gazing at the water, a glassy surface, the only ripples made by the boat. Trees and rock run straight into the water on either side of us. We move on, past islands, here and there a cedar trunk tilts outward, the figurehead for a stationary boat full of trees. Rain clouds gather.

The next stream, Quartcha, is a boggy freshwater outlet. We hike, find some juvenile coho, and pause to fiddle with the radios to make sure they work. Standing in a thicket of sedge, we unwrap turkey sandwiches for lunch, turning up collars or hoods as water droplets coalesce in the air, not quite falling down as much as swirling around us. Then it's off to Ripley, a non-salmon creek.

A waterfall at the beginning of the creek stops salmon cold. It's Reynolds's "control" stream, where he could test the idea of salmon feeding plants. Between them, Reynolds and Hocking hauled five garbage bags — with a tendency to drip fluids — at a time. They struggled up and down through the brush, dense tangles of ferns, devil's club, fir trees, berries, moss-covered logs, carrying dead weight of dead salmon, taking turns holding three instead of two bags. When they came to a log, one scientist would station himself on the other side and the other handed over the bags one at a time. This is grizzly bear territory. Something we are well aware of today as we scramble over downed trees and boulders, along a path barely visible through the brush. Earlier in the day a bear had ambled up on the same path, a bear that ate a lot of berries, maybe too many berries, if that's possible.

“I think this bear might have a gastrointestinal problem,” says Swain, after we passed the fourth or fifth huge pile of scat within a few metres, whole berries still visible.

From Ripley, it was off to Clatse, a stream that traditionally has one of the larger salmon returns for the area. As *The Tickler* chugs along we pass a floating log, 11 gulls perched in a line, sentinels watching us sail past. Reynolds points out the sweet little gulls with stylish pink legs and black smudges behind their eyes

. “Bonaparte’s gulls,” he says, then motions to the bigger ones, California gulls, their snot-coloured legs holding up their stockier bodies, with plumage more typically gull-like. *The Tickler* slows down and we glide into estuary of Clatse River. Swain drops us off then anchors the boat. We hike. It’s so green. After an hour or so, we head back to the shore, three of us walking to a point where Swain can pick us up after he paddles out to the boat. Reynolds says they saw wolves on this point a couple of years ago.

I forget to jot down how many fish are here today. To go looking for numbers in scientific literature is not that hard these days but still daunting when it comes to salmon. The amount of literature on these fish is a universe unto itself, expanding, racing out to infinity with no contraction in sight. Salmon feed an entire coastal rainforest ecosystem and a scientific knowledge ecosystem. The difference is that the scientific ecosystem is a human construct, imbalanced by competing perspectives, desires, needs. The Canadian Department of Fisheries and Oceans, for example, doesn’t monitor many of the streams on the Central Coast on an ongoing basis. Chum are, after all, a low value species. They know chum have visited 119 streams on the Central Coast since counts started in 1950. Some streams will have been counted most years, but some perhaps only once. Size matters. A bigger system gets counted. Smaller systems do not. Clatse, a productive stream, happens to be one of the streams DFO monitors more consistently — this year 7,500 chum will come back and only 16 pinks.

By only monitoring stronger runs, smaller streams run the danger of becoming what scientists call "ghost" streams — ignored, without anyone to notice whether they need enhancement. Odd considering on the Central Coast the smaller spawning streams dwarf the number of larger systems, and probably deposit the most nutrients into the forest from the sea. Reynolds' program, which runs in partnership with the Heiltsuk Integrated Resource Management Department, has led to more than twice as many streams being counted each year, information they share with the DFO.

It's almost as if Reynolds did an end-run around the salmon hierarchy by looking at what chum and pink feed on — an ecosystem that includes bears and wolves — and not the fish itself.

I think scientists lament this but they need funding and they need to publish. Writing grant applications is salesmanship. Even Charles Darwin admitted that he was lucky to be an English gentleman with cash to burn. He might have still written *The Origin of Species*, but maybe he wouldn't have had to time to write an influential book on soil science: *The Formation of Vegetable Mould through the Action of Worms, with Observations on their Habits* (or *Worms*.)

And yet with all this knowledge, as biased as it might be, the average person knows so little about salmon. Maybe the average British Columbian knows how to cook a salmon, but look at the flesh for a clue that it's farmed and not wild? No. Know that chum salmon sometimes eat jellyfish and physiologically their guts are structured differently than other salmon? No. If we're Salmon People in the Pacific Northwest, we're pathetic Salmon People. It seems tragic that chum, which had a great year in 2012 thanks to salmon enhancement programs in B.C., are like ugly Victorian brides, only desirable with big dowries.

Chum are one big dowry, they're naturally the most abundant of salmon in the Pacific. And like pinks, they're also heavily produced in Japanese hatcheries and released into the ocean. And they're definitely becoming more desirable, three chum fisheries in B.C. — none on the Central Coast — were declared sustainable by the Marine Stewardship Council in early 2013, which should boost its status in the marketplace. Still, though this fish spends most of its life in marine waters, when it comes time to join a DFO scientist who studies ocean going salmon, chum are not in the spotlight, the hierarchy of salmon prevails.

Chapter 4

And the young biologists tearing off pieces of their subject, tatters of the life forms, like sharks tearing out hunks of a dead horse, looking at them, tossing them away. This is neither a good nor a bad method; it is simply the one of our time. We can look with longing back to Charles Darwin, staring into the water over the side of a sailing ship, but for us to attempt to imitate that procedure would be romantic and silly. To take a sailing boat, to fight tide and wind, to move 400 miles on a horse when we could take a plane, would be not only ridiculous but ineffective. — John Steinbeck, **The Log from the Sea of Cortez**

The Biological Black Box

The mahogany deck is the first thing I notice when walking onboard the *Ricker* — officially the Canadian Coast Guard Ship *W.E. Ricker.* I could stand here forever, I think, not knowing until later that standing on a deck for hours, days, and weeks is hard work, like pushing against a leg press all day. For deckhands and fishers, the exotic wood is an uncommon luxury, warmer than metal, easier on the feet, and fishnets last longer when they slip across its smooth, hard surface.

I'm with the High Seas Salmon Group, headed by Department of Fisheries and Oceans scientist Marc Trudel. The group's job? To chase juvenile salmon around the Pacific Ocean and figure out how life is going for them. *The Ricker* will take me as close as I'll get to what biologists call the Black Box period of the salmon life cycle, the place where salmon spend most of their lives, the open ocean, a habitat hidden from humans, a period they spend eating, from one to seven years, depending on the species. They're the Takeru Kobayashis, the competitive eaters, of the marine environment. Salmon stuff their faces with copepods, squid, shrimp, herring, instead of hot dogs, Twinkies, or meatballs, as much fish food as possible before the bell dings and it's time to stop cold and head home for their once-in-a-lifetime prize, the chance to reproduce.

We leave from Canada's federal Department of Fisheries and Oceans' Pacific Biological Station (DFO-PBS) in Nanaimo, a small city on the east coast of Vancouver Island, opposite Vancouver on the mainland. Trudel wastes no time beginning his survey as we pull out of dock at 9 a.m., heading north on an overcast fall day, clouds thinning out to reveal our geologic companion for the 10-day trip, the snow-capped Coast Mountains, a 1,600 kilometre long mountain range running from southeast Alaska to the Fraser River.

A boisterous bark of laughter announces Trudel's presence in a room. The French-Canadian scientist's somewhat tough guy image — shaved head, goatee, barrel chest — belies a playful, friendly bear of a man. Someone with the disposition of a good doctor, a career choice he tossed aside after a fateful encounter 20 years ago when he fell in love with fish. His current research sounds simple: are the fish that grow fastest better equipped to survive winter? And if so, can DFO better predict salmon returns based on those measurements?

"I try and understand why salmon come back big in some years, and in some years they don't," he says. We're sitting in the mess, the ship already heading north. The puzzle Trudel pieces together is huge — the big picture that shows the relationship between ocean environment and salmon survival.

Trudel and his crew spend three to four weeks at a time, three times a year, slavishly following a routine, visiting the same 250 to 300 data points, at the same time of day — long-term environmental monitoring and data-gathering that rarely catapults a scientist onto the cover of *Scientific American*. And really, by the time I'm on this trip, I see the process for what it is: an echo of our normal relationship with the planet, slavishly tracking our environment to see if it will support us.

Sampling the ocean daily, the scientists onboard the *Ricker* perform a well-choreographed dance to the tune of groaning cables, rattling chains, splashing water, the slap of fish on a steel table below deck. And, oh yes, bongos. Or, as the captain chimes in over a lunchtime explanation in the mess: CTD, bongos, fish. CTD, bongos, fish. CTD, bongos, fish. From dawn to dusk.

About 65 kilometres north of Nanaimo near Lasqueti Island in the Georgia Strait, the dance begins with the CTD array, the way scientists measure the ocean's conductivity, temperature, and depth. The cue is a grinding sound, a winch lowering an array that includes a Niskin bottle, one of many technological innovations that confirms something else about marine biological fieldwork; it supports a very particular economy, one that relies on ocean engineers, ingenuity, and solutions not always transferrable to daily problems. Where Moon exploration gave us the handheld cordless mini-vacuum (the DustBuster), ocean exploration (inventor Shale Niskin actually) gave us these ingenious bottles, open at each end with stoppers connected by an elastic cord. When the bottle is at an ocean depth a scientist wants sampled, a weight travels the cable to hit a release mechanism attached to the elastic cord, closing each end of the bottle. Violently. No commercial crossover here as a bathtub toy.

Measuring conductivity is exactly what it sounds like: how well the ocean (at a given point) conducts electricity. High conductivity means higher salinity, low conductivity means low salinity. Salinity levels plus "T" (temperature) tell scientists something about seawater density, a driving force of major ocean currents. The deeper a Niskin bottle goes, the higher the salinity should be. Simple temperature readings also say something about warming or cooling trends. And at 10 metres deep, where phytoplankton concentrate, chlorophyll levels in the water sample give a snapshot of ocean biomass: the more chlorophyll, the more phytoplankton, the more zooplankton, the more fish.

The CTD is back onboard and the bongos go. On deck rests two connected cylinders, resembling a giant-sized pair of…bongos. Mesh attached to each bongo flows, cone-shaped, to two small white buckets with screened holes. Attached at the top to a cable, the bongos are swung out behind the boat and towed for 10 minutes to collect the Happy Meals of the juvenile salmon world, euphausiids (krill) and copepods, tiny crustaceans with a big impact. Freshwater or salt, deep ocean trench to streamside litter, copepods are the most numerous multi-celled organism in water communities. And as tempting as it is to make fun of a professional organization with the acronym WAC (World Association of Copepodologists), breathe a sigh of relief that these scientists have our backs; if copepods disappeared tomorrow, we would be in a lot of trouble. The woman on deck wearing a survival jacket, hard hat, and rain pants waiting for the zooplankton catch is not, however, a copepodologist. Mary Thiess is a statistician.

Thiess hoses the white buckets with saltwater. She detaches them, places them in bigger buckets, and hauls them toward the ship's forecastle, next to a closet-sized lab that opens onto the deck. She dumps one bucket's contents into a canning jar laced with formalin and borax for preservation. Later on a technician will identify the preserved plankton species. To the eye, the most visible creatures are the big-eyed sea monkeys, the krill.

Through progressively smaller meshes, Thiess screens the buckets contents three times, cold water washing over her fingers, fingers she keeps limber by sitting in the mess between data points crocheting hats. The ocean is cold here year round. So is the air on this November day. Thiess puts the catch from each screen in a separate Ziploc bag, jotting down a label with a Sharpie. I'm not sure what scientists did before the invention of Ziploc bags and Sharpies, the remains of which will probably replace projectile points in the future archaeological record.

The life in the plastic baggies will be ground and run through isotope analysis for Carbon^{13} (13C) and 15N signatures: carbon levels say something about where zooplankton, like copepods, do most of their dining, on the ocean floor where they sink to at night, or on planktonic algae closer to the surface. Nitrogen levels tell scientists where organisms rest in the food chain. Each 3.4 percent increase of nitrogen measured is a step up on the food chain, a position that can vary for omnivores like copepods (and humans) and a fluctuation of 15N over a long-term study periods can tell researchers something about changes in the food web.

While Thiess screens, the Coast Guard crew — mostly former fishers from the East and West coasts — readies the trawl net. For half an hour at varying depths (surface, 15 metres, and 30 metres) the *Ricker* tows a 32 metre-wide, 15 metre-long net, with the goal of netting juvenile salmon. In the Strait of Georgia, lots of fish are within the 15 to 30 metre strata because the habitat is relatively narrow compared with the west side of Vancouver Island where the fish can spread out, an underwater version of urban sprawl, Calgary compared with Montreal.

For the finale, Trudel and Yeongha Jung weigh, count, and sometimes take pieces of the caught fish, a brief or extended exercise depending on the time, day, and net depth. It's my favourite part of the routine. Over the course of 10 days I'll learn to identify the juveniles of the five salmon species, and I'll also learn to equate the smell of fresh cucumber with whitebait smelt, painfully understand that plunging my hand into a plastic laundry basket full of deceptively harmless forage fish is a bad idea, and come to see spiny lumpsuckers as damn cute. It's fun mucking about with all kinds of fish, all of them are fascinating.

So why do salmon get all the glory? And why do some salmon get more glory than others, why do sockeye and Chinook vie for the top spot, followed by coho, with chum and pink a distant tie for third. Right. Money, for the most part. In pure commercial terms, sockeye is the billion dollar industry, and to be fair there are more sockeye in the world than Chinook and coho, and sockeye tend to flood grocery stores in fall. As for eating preferences, in surveys consumers say they prefer wild sockeye or Chinook to other salmon. Taste, however, is bound with fashion; lobsters were once poor people food. Although when I ask scientists which is their favourite salmon, most of them almost start to drool when they put "freshly caught Chinook" and "barbecue" in the same sentence.

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Late afternoon, sitting in the mess, drinking tea and eating cookies, I ask Trudel which salmon species is his favourite to eat. He surprises me.

"Coho," he says. "They're more consistent, taste-wise, I think. Sockeye depends on the run. The fish that have long migrations have to be fat. Those are the tasty ones. Or the tastiest. The ones that have a short migration usually tend to have a whole lot less fat and they're not as tasty. They're still very good, don't get me wrong. But in terms of consistency of taste and quality, I see that all the time in coho salmon."

By five p.m. we near Cape Mudge on Quadra Island, home of the We Wai Kai First Nation, part of the Laich-kwil-tach. An anthropologist recorded their creation story about a hundred years ago. Translations are always suspect, it's plausible the teller purposely misled the anthropologist, or the English language is inadequate for the task, or the anthropologist misled himself because he tried to squeeze an unfamiliar narrative into a beginning, middle, and end, the narrative arc of his own culture. But, in the story, the best part is when Raven finds himself at war with the salmon people, who in turn summon the other fish people, from smelts to killer whales. After some kind of mash up, Raven throws salmon, eulachon, and others from his canoe to different rivers where the fish people ultimately make their homes. These “fish” (whether fish or sea mammals) have homes and personhood, a metaphor for what in scientific terms is an animal’s “life history,” the strategies it uses to stay alive long enough to reproduce, the way sockeye fry prefer lakes, the way Chinook fry vary in how much time they spend in freshwater, or the way coho fry prefer a stream’s back eddies.

The coho, a salmon on a three-year spawning cycle, I see onboard the *Ricker* have another year to go before their mighty journey to reproduce. When Trudel explains coho, the fish is always explained in relation to the other salmon species, similar to way we explain different human cultures in relation to each other. Coho and Chinook roam the ocean eating bigger prey — anchovy, herring, sardine, pollock, sand lance and smelt — than other salmon species. A just-caught juvenile coho smells fresh, for example, while a Chinook smells fishy. Chinook have black gums, coho have white gums and a black tongue.

By 8 a.m. the next day the *Ricker* plows through the waters near Calvert Island. At about 2:30 we pass Namu, an archaeological site and old cannery town, and at the junction of Fitz Hugh Sound and Burke Channel. This area was probably habitable as early as 13,500 years ago when the sea was lower. What today is Queen Charlotte Sound, to the north and west, was a coastal plain of lakes and streams where a living could be made. The earliest archaeological evidence dates human settlements here to about 11,000 years ago, salmon bones mixed in with stone tools and other artifacts.

When not in the lab learning about fish, I stand on deck watching Theiss, chat with scientists and crew in the mess, or wander to the bridge to look through binoculars, rarely seeing much more than trees, snow capped mountains, sheer rock faces, waterfalls.

When we land fish, I hurry to the lab. At this moment three Chinook and two chum land in the belly of the boat for processing, and not much else. A lumpsucker and sturgeon poacher recover together in a bucket. Trudel will eventually write a paper on fish assemblages they have caught over the years, which, as the days go by, is a lot of forage fish, squid, and jellyfish. One net dumps 29 kilograms of white bait smelt into the hold. We find a pollock in one load of smelt and Trudel does a quick calculation after weighing and counting the bycatch. “There was a one in 2,361 chance of finding a pollock in that load of smelt,” he says. We sift through the slivers of smelt looking for more pollock but only find a few herring.

The salmon we place on trays to be labeled, measured, and weighed. Jung punches a hole from the Chinook’s gill for DNA sampling (the sample goes into a plastic vial with a label) and shows me how to extract the otoliths, the ear bones: snap the head back from the gills, grab scissors and snip into the head near the brain, hit the wrong place and blood spurts, which makes it harder to find the shiny white bones, the otoliths. With a pair of long tweezers it's possible to pluck out the otoliths. A week later, and I'm good enough to look forward to dinner parties where I can show off my skill, provided a big fish is on the menu.

About the size of little white rice grains, otoliths record a fish's age and the number of days it has spent in the marine environment. Otoliths develop circular rings daily, telling a narrative of how fast the fish grows in the first few months in ocean. A spot marks eventful moments: hatching, when a fish enters freshwater, when they enter the ocean.

"We were proposing to look at the marine environment rings," Trudel says, as I snip a head. "The more space, the faster it's growing. Like trees, but on a daily basis. So we were thinking we can measure that and come up with a growth rate. Finally we're starting to do this."

The next haul is six chum, four pinks, and one sockeye. The sockeye are usually more north this time of year, Trudel says, placing three fish on a tray: a chum, a pink, and a sockeye, lifting each of fish's gills to expose the gill rakers — pink salmon have fine gill rakers, a chum's are more spaced apart, and sockeye's are fine and long. Juvenile salmon are particulate feeders, their jaws come down and act like a vacuum, sucking their prey right out of the water and into their mouths. "So why the different gill rakers?" Trudel asks out loud, moving to the scale to weigh the fish.

This telling apart, describing salmon, assigning it a family, genus, species in the Western science sense, began in the late 18th century. Salmon originally meant the Atlantic species (*Salmo salar*), native to the North Atlantic and Arctic Ocean above Western Europe. A German taxonomist, physician Johan Julius Walbaum who worked for the Russian Imperial Court, was the first to scientifically describe Pacific salmon, in 1792, though he had never seen one, not unusual for taxonomists at the time who either read descriptions and looked at drawings, or studied dead specimens sent from explorers or other naturalists. (Walbaum was also the first scientist to wear sheep intestine gloves to prevent the spread of infection.) Naming varieties and species includes a bit of art in the science, and Darwin was preoccupied with the problem in *The Origin of Species*. Sometimes the vague descriptions must be the result of plucking specimens from an environment clear across the world, out of context, relying on the notes someone else made. When Trudel finds a fish in the mix that he can't describe, he reaches for a worn paperback book, *Pacific Fishes of Canada*, a standard identification book that also provides the codes he writes down to identify fish species. Or, more often, experience trumps books and he dashes up to the upper deck and asks one of the former fishers to come down and have a look. Genetics has changed taxonomy, reaching far into the past to map connections.

A DNA sample is taken from the sockeye. Earlier Jung had filled "box number three" with DNA samples of Chinook, bringing the number of DNA samples for that fish to 300 since this season's research began about a month ago. Bits of coho will also be sent to a lab in Vancouver for analysis. No such deep study is wasted on chum, or pink. Each DNA sample costs Trudel $20 and he's admirably frugal: DNA sequencing machines are calibrated and sometimes out-of-whack machines spew out wrong sequences, so the scientist sends out blind copies to test the lab. Since 1998 the scientists have analyzed over 6,000 sockeye and over 6,000 Chinook. Only a few stocks of sockeye are tagged: Cultus Lake sockeye from the Fraser River system and two others from the Columbia River system, the Wenatchee and Redfish. The DNA analysis confirms the tag adding a baseline sequence of DNA for the fish. Cultus and Wenatchee are matched right 100 percent of the time. But for Redfish salmon the accuracy only reaches 85 percent, three out of 20 fish are classified wrong, which means they need more samples and a better baseline.

Though Trudel is a federal government fisheries biologist, like all research scientists he scrounges for funding, putting together a mish mash of cash from the Natural Science and Engineering Research Council, the Bonneville Dam Corporation, whatever funders will climb onboard. He too can be hit hard by an economic meltdown. In 2008, the same year the housing bubble popped, hammering global financial markets, Trudel had applied for funding to develop a technique to better assess how many Chinook and sockeye salmon will return in any given year: an equation for growth rate.

“My first model was for coho,” Trudel says, sitting in a desk chair in a small room off the fish lab. Freezers line the other side of the corridor. We’re between fishing points. “If you can figure out how fast they grow in a finite amount of time, you can predict coho returns. You just have to know how many smolts leave the system.” The only counting of coho that goes on is at Carnation Creek and Robertson Creek, a hatchery, on Vancouver

Island close to Carol Schmitt's hatchery. As immense as the territory salmon traverse in the ocean, the B.C. salmon world of humans is small.

To create his model, the Trudel plotted seven data points from 1998 to 2004 on a graph. On the X-axis was coho growth, on the Y was coho survival. The faster the fish grew, the more likely it would survive, swimming through the winter, inhaling food. In 2005, Trudel noted marine growth was poor. "There were fewer large, fat copepods and warmer water temperatures, which also brought warm water predators on the coast," Trudel says. The 2005 juveniles he caught would head back to their natal rivers in 2006, a year that Trudel forecast as having poor returns. He was right.

"I like to use the phrase – we're going outside the known universe – something I picked up from the captain of the *Ricker*," Trudel says, his voice booming over the engine's din. "I thought that was a powerful sentence, because the model is constrained by what we see. We don't know what the upper limit is [for coho]. In 2005, we were probably close to the lower limit."

That lower limit being about half a percent of the fish in those streams surviving that year. Although, as Trudel points out, the lowest could be zero percent, which would mean a wiped out run.

The *Ricker* cruises as far north as the top of Haida Gwaii in the Dixon Entrance, just south of Alaska. Fog wreaths the ship, our airborne companions, seagulls, materialize next to the ship, then fade, replaced by another. By 7:15 am the CTD goes, when it's drawn back up the sound is in time with the seagulls' wing beats. We catch no fish when the net goes out.

After lunch it picks up, we catch a 4.2 kilogram Chinook and one small coho. Another catch brings in a black bass. And later, with Haida Gwaii a shadow in the distance, the seabed only about 70 metres below, Thiess reports she's not catching much in the bongos. The nets deliver herring and a lot of smelt, big smelts — two-third of a ruler length — the kind that tastes good over a fire after the heads are whacked off and the guts removed. Or so I'm told. After handling thousands of smelts, I still have no idea what they taste like.

Another day passes and we're at the mouth of the Nass River, on our way to port in Prince Rupert. The last few hauls of fish bring up mostly squid, 91 in the last net. After 10 days I can look at juvenile salmon placed on a tray and identify the species. Ten days. What does someone know after a lifetime?

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As detailed as the science is onboard the *Ricker*, it's as murky as the view at the tip of Haida Gwaii. Every once in a while a sliver of information materializes but not all the variables that are needed to see the whole picture. Studying ocean going salmon will always be opaque compared to studying them in rivers and streams, to experiencing their habitat.

Which is why, in spring, when the chance comes to get a little closer to coho, the most elusive of the salmon species, comes along I take it, climbing onboard a much smaller boat than the *Ricker* and a shorter journey — to Namu from nearby Calvert Island. I'm back on the Central Coast with a different group of biologists working from the Hakai Beach Institute, a privately funded research centre on Calvert Island.

In May, most of the coho have fled the streams around Namu and we're looking for them not far from the dock. Atlas plunges hand-held nets from the side in search of juvenile salmon of any species. Hauling up a dripping net full of fish, we immediately put them in a cooler, then package them in Ziploc bags to be analyzed later in the lab. Scientists are obsessed with what salmon eat, and Atlas wants to know what these fish, mostly sockeye, but coho too, scarf back on their way out to sea. These coho meandering around Namu will, unlike the other salmon species, hug the coast a little more during the marine phase of their lives.

"This place is a good place to make a living for a juvenile fish, there's even some juvenile herring in here," he says, turning over the coho he holds in his hands to show off the black spots on its back, something a sockeye lacks. Atlas points out the coho's long anal and dorsal fins, another feature that marks it as distinct from its cousins, probably an adaptation to the slow moving water they prefer when young.

We tie up at a floating dock. Namu was traditionally known to indigenous people as Na'wamu or Ma'awas. Europeans turned it into a cannery town in the late 1890s, the population eventually swelling with thousands of workers, but once the salmon were gone in the 1980s, so were the people, except for three elderly people today who make a living by setting up a party float with picnic tables, a fire pit and gift shop for visiting cruising boats in summer, and sea cucumber and urchin fishers in fall. Overnighters pay a $0.75-a-foot docking fee that hasn't changed in eight years. They grow fruit and vegetables, peaches and kiwi, spinach and chives, in a greenhouse.

This was once a humming settlement, with a nursing station, machine shop and forge, radio shop, store, restaurant, post office, school, and dormitories. It was all left behind when the last operator, B.C. Packers, closed the doors and walked away from Namu.

The faint smell of fish oil lingers amidst the intact buildings, some rented by local lodges to overwinter boats. The store is still "stocked" with magazines, engine v-belts hung along one wall, shelves of paint and spark plugs, fluorescent light tubes, pallets of tartar sauce, mayonnaise, and jam — the last a sweet lure for marauding martens, resident weasels smart enough to break open the jars and feast. The store had a liquor license until 1995. Even spark plugs for a Model T.

We walk through the ghost town, past alder saplings coaxed into shapes — a heart in one instance — to a broken boardwalk that leads to the lake and canoes tucked into the bushes. Climbing into the canoes, we push off and set a quick pace gliding across the placid surface five kilometres across the lake to a cold, clear salmon spawning stream. Beside the mouth of a creek we swing our legs over the gunwale, into the water, sinking into the muck, then we haul the canoes onto land. An air horn hangs from a branch on shore. We hike along the stream clutching clipboards, tape measures, quadrangles, and other measuring paraphernalia, following our leader, biologist Will Atlas, jumping a little as he blasts out “Hey bear!” every so often. Grizzly bears don’t like surprises.

Many streams tumble into Namu Lake. At this one we assess the habitat, measuring the tree canopy, stream width, the size of rocks on the streambed, depth, and other data. It’s tedious work and impressive that Morgan Hocking surveyed 50 streams this way to find out that salmon streams feed salmonberry and other plants. After a couple of hours alternately standing still and passing through slender rays of sun as we waltz a few metres to the next data point, we finish and hike closer to the stream mouth to warm up under a clear blue sky and eat our sandwiches. Atlas beckons me and saunters toward the stream edge a few metres away. He crouches down and points out little fish swimming near the exposed roots of a tree, amidst a tumble of leaves, ferns, sticks, moss-covered tree trunks, and branches dripping needles into the flowing water, the burbling more playful than the audio predictability of a fake fountain.

“Coho like to hang out in these eddies, the water flows more slowly and they have some cover,” he says, edging closer to show me the handful of juvenile fish, fish I hadn’t paid much attention too when in the field with Reynolds. But I didn’t know how much harder it would be see coho.

Coho prefer freshwater streams with low gradients and slow moving water, leaving them more vulnerable to dry summers and autumns. Without much precipitation, their smaller, shallower homes dry out first. Risky. So what's the trade off? Less competition from other salmon species, and a place to hide amongst woody debris and overhanging plant life, stuffing their faces for a year or so before they migrate to sea. One of B.C.'s most beloved naturalists, fly fisher and writer Roderick Haig-Brown, writing in 1959, called coho the most aggressive feeders of all the salmon in their pre-migrant stage.

A few metres more and the stream joins the lake, coursing through a mudflat of sedges. Deep paw marks, visible between strands of the edgy green stalks, tell us a bear visited recently. Coho are often associated with small streams like this one — a "ghost" stream — a creek with no formal name, its importance muted by its remote location, thick vegetation, a diverse population of mighty bears, wolves, eagles and the quieter, cryptic rough-skinned newts, banana slugs, lichen moths that communicate without words.

The one thing that scientists forget — with their numbers, graphs, and language — even as they have sought these experiences within a world that communicates through different channels, is that this world affects them, changes them, and steers them. Fisheries biologists really do start thinking like a fish. Ecologists start to think like animals and plants. They try and translate this world for the rest of us, but it's a world best understood by living it. Why are nature shows endlessly consumed on the Internet and television? It's a proxy for living in those worlds, for thinking like a shark, or an elephant, or a grizzly bear. And archaeologists and anthropologists weave it altogether, adding the human element: where did we fit in, before we planted ourselves so firmly outside the natural realm?

Chapter 5

They seemed to live on remembered things, to be so related to the seashore and the rocky hills and the loneliness that they are these things. To ask about the country is like asking about themselves. "How many toes have you?" "What, toes? Let's see — of course, ten. I have known them all my life, I never thought to count them. Of course it will rain tonight, I don't know why. Something in me tells me I will rain tonight. Of course, I am the whole thing, now that I think about it. I ought know when I will rain."
— John Steinbeck, **The Log from the Sea of Cortez**

Life, Anthropology, and Everything

"You go where it hasn't been tilled, and you just don't get as many," the boat driver says as he speeds us to Waiatt Bay, at the northern end of Quadra Island, accessible only by boat or by foot from another bay to the west. "If you work the beach all the time, you get more clams."

Anne Salomon, an experimental ecologist at Simon Fraser University, nods. She glances at a chart on her iPhone, looks out the windows, and keeps up a patter of questions for the 50-plus-year-old boat driver, Ed, an island resident since he was 10, though he's quick to point out he's still not a "local." Salomon is intrigued by what he just said.

"So, you think tilling the beach mimics clam habitat?" she asks, her smile widening.

"I would think so," he says.

"You and I have the same hypothesis," says Salomon, as we go skim through an area called Salmon Narrows, where, Ed says, there used to be a fish farm directly in the path of migrating salmon. “They moved the farm, but still, I don’t think the blueback coho are coming back.”

I’m back on Quadra Island, this time with a team of ecologists and archaeologists. After spending so much time in salmon-central, it’s easy to see this team as the scientific equivalent of the Rebel Alliance attempting to explode the Death Star, in this case the Pacific coast’s salmon-centric universe. Their work will likely reinvent the historical narrative — it took more than seasonal salmon runs to feed villages up and down the coast, it took cultivating the entire seascape and the adjacent land. The past world was much richer and more diverse than most people suspect.

Salomon is here to launch a project testing whether clam gardens — an ancient mariculture technique — were effective. Did they really nurture the growth of clams?

Archaeologist Dana Lepofsky roped in Salomon when the young scientist arrived at SFU to establish her own lab, handing over an irresistible project to an experimental ecologist. Salomon was skeptical when Lepofsky and geomorophologist John Harper, who first identified the clam gardens as human made in 1996, showed her some clam gardens on the other side of Georgia Strait from where we are now. “I was rolling my eyes behind their backs,” Salomon says. Harper caught her. So he gave Salomon a map and urged her off to Quadra’s classic clam garden bays, Waiatt and nearby Kanish. “I was not convinced and then I paddled into Kanish Bay," she says. "My jaw dropped. Within 20 minutes I saw at least six perfect, obvious clam gardens."

Salomon and Kristin Rowell, an ecologist at the University of Washington, designed the experiment — the first of its kind. The design involves concrete cinder blocks. I never thought hauling concrete cinder blocks onto a boat, then from a boat to a rocky outcrop, from a rocky outcrop to a beachside camp, from camp to a canoe, and from a canoe to another beach would be part of a scientific experiment. (But then again, who in their right mind hauls garbage bags full of dead salmon around grizzly habitat?) At least it's not raining when we get to Waiatt Bay and Ed drops off us, two canoes, four tents, loads of gear, and the cinder blocks.

Graduate student Amy Groesbeck, undergraduate Brooke Davis, Salomon, and I lug backpacks, coolers, tents, lifejackets, rope, tarps, Rubbermaid containers, sieves, and cinder blocks, to a clearing next to a creek, water burbling past a wrecked trailer and a shack struggling to remain upright, despite the tangle of vegetation pulling it down. The canoes we lower into the water and paddle a few metres to the beach. If we hurry — racing the tide, again — we'll have just enough time to visit a clam garden across the bay and plant some native little neck clams.

"By effectively creating an intertidal terrace, akin to a rice paddy that floods with every tidal exchange, we think that clam gardens extend the shore at the tidal height where clams thrive the most," Salomon says, as we load the canoes with a couple of buckets full of rebar, spades, zipties, Sharpies, clams, sieves, and cinderblocks. "Specifically, the optimal tidal height where clams grow the fastest and live the longest."

It appears that various indigenous coastal cultures sustainably cultivated clams in the intertidal zone for at least 2,000 years, until the settler population changed traditional fisheries practices. At the end of winter, when people waited for the herring, then the salmon, and other foods, they could always stroll down to the beach for fresh clams.

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I once asked a representative of the Nez Perce band in Idaho — a band with close ties to the Interior Salish, and one that has been working for decades to restore one of the most battered salmon runs in the Northwest, the Chinook run on the Snake River — if part of the modern problem with salmon was this slavish devotion to the species as something so much more significant that any other. The answer [redacted] was yes.

In the Northwest, First Peoples traditionally had a number of First Food ceremonies, depending on the environment: for deer, duck, berries, and significantly salmon. Keeping a community fed was a complex, social enterprise, [redacted]. An environmental lawyer, listening to the question, interjected that designating an animal as a keystone species — the hub of a wheel, to which other species are attached — is an umbrella strategy, designed to maximize protection of a habitat. Does it really work? That status fails to acknowledge the fish as a part of a human community, with humans being a keystone species, as intertwined with the ecosystem as salmon. The human imprint on the landscape, sketchy though it might be — witness Cullon's attempts to map the material remains of a hardy, ancient fishery —reveals how the cultures here evolved.

One of the older sites in B.C., Glenrose Cannery sits on the Fraser River and dates to over 8,000 years ago. The finds at Glenrose suggests small groups of people that roved across the landscape, seasonal locavores, eating what was available and moving around to find it. Currently 20 kilometers from the sea, the Glenrose riverbank is littered with firecracked rocks and artifacts slowly washing away into the current. Archaeologists first excavated Glenrose in the 1970s. What they found was a menu heavy on bay mussels, other shellfish, salmon, and smaller fish. Deer and elk were important for them too.

At some point — the date is highly debatable — things change when people had an option: eat it fresh and move on, or store it and stay. They chose to stay. In southeast Alaska, people stored food for at least 4,000 years ago, while on British Columbia's central coast, the archaeological record says at minimum 7,000 years ago. On the lower Fraser River, the change is noted about 5,500 years ago, roughly when sea levels settle down closer to what they are today.

The population grew. Permanent housing was built, trade networks developed, along with social hierarchies. More distinct cultures emerged. At this point, the coastal world looked like what the Russian, English, and Spanish explorers encountered by the late 18th

century — an ecologically diverse landscape occupied by complex cultural communities consisting of six major language groups; from north to south, the Tlingit, the Haida, the Tsimshian, the Kwakwaka'wakw, the Nuu-chal-nuth (to which the Heiltsuk language belongs), and the Coast Salish. They had strong ties to the marine world, salmon runs were important to all, yet each group responded differently to the challenges of their unique environments.

The stormy, mercurial weather of isolated Haida Gwaii led to a culture that had to grapple with large expanses of rough ocean. Known as expert navigators, and hearty fishers, they paddled their large cedar war canoes as far as Washington State for raiding expeditions. The open waters on Vancouver Island's wild west coast gave the Nuu-chal-nuth the opportunity to hunt whales while nearby protected inlets offered salmon and shellfish.

The Club Med of these environments is where I am right now, the traditional territory of the Coast Salish that dates, at least linguistically, to 3,000 years ago.

When European settlement comes, the Coast Salish bore the brunt of the change since their environment has the mildest climate and the most accessible resources. Where early Europeans saw uncultivated land, the Coast Salish saw a family-owned resource of semi-cultivated patches of bulbs, berries, and shoots. Where Europeans saw rocky beaches stuffed with clams, First Nations saw family-owned fish traps and clam gardens. Where Europeans saw only red gold — salmon runs — First Nations saw a diverse fishery, family owned with controlled access to the wealth, and regulated distribution. Socially designed resource management is not an anomaly, it's the looking for it that has been the anomaly, until recently. Risky places to live seems to beget caution on the part of human cultures.

On Fijian islands, like Kadavu, only two generations ago fishers boated to local coral reef to feed their families. By the 1970s the fishing trips took longer and longer because the reef fish became harder to find. During this time, villages had abandoned an old system of no fishing zones called *tabu*, instituted by the community. Captain Cook heard the use of the word when visiting Tonga in the 1770s and it has been a part of the English language, as taboo, ever since. *Tabu* areas provided a reliable refuge for the fish and a chance to increase in size and number. About 15 years ago, a Fijian marine biologist from Kadavu convinced the community to try a couple of *tabu* areas. Within five years fish populations increased, along with predators like sharks and humphead wrasse, convincing other villages to create community-controlled no fishing zones as well, and today they number over 200.

In Hawaii, historical accounts and ethnographic studies suggest pre-European contact, Hawaiian communities had a complex set of rules that saw reefs regularly closed to fishing, strict regulations on fishing gear, and restrictions on eating vulnerable species (based on something as potentially unfair as gender and age, but still). There is also archaeological evidence that they built extensive fish ponds stocked with juvenile mullet and milkfish as insurance against famine. Given that Hawaii is at the mercy of tsunamis, floods, hurricanes and droughts, and the population likely peaked at 250,000 before European settlers arrived, they required sophisticated risk management strategies.

In the Pacific Northwest depending on salmon was always a risky venture. Runs will come and go, some will fail for obvious reasons — again, think about Mount St. Helen's eruption, wiping out the salmon runs of nearby streams. But runs also fail for reasons mysterious, such as the 800-year absence of sockeye from an Alaskan lake 2,000 years ago. Scientists recorded the failure by analyzing lake sediments and could find no catastrophic event as an explanation. For 40 human generations that run was gone. Alaskan aboriginals were likely busy pondering how to overcome the loss of an important food source when Jesus of Nazareth revolutionized religion in the Middle East.

Place yourself in the past and it's easy to reason that if even the strongest of salmon runs was a precarious thing, it would be in your best interest to make sure you had multiple food sources and salmon runs to access, there were no ghost streams. Every beach, every watershed, every run was important. No salmon run would be too small, too insignificant. And some territories would be richer than others, and if that wealth was salmon, a food that sticks to the ribs and preserves well, it might be prudent to make friends with the neighbours. Or raid them. Or push them out.

This is no idealized land without evil. It's about culturally adapting to a chaotic environment, to an insecure food supply. Earthquakes rumble, volcanoes burst, fish runs fail, disease kills, there are social inequalities, wars, and slaves are taken. The First Nations bands in the Laich-Kwil-Tach Treaty Society were warring with the K'ómoks

(Comox) to the south when the Europeans arrived in the 18th century. The K'ómoks eventually retreated and gave up territory. Hostilities ended with a marriage between the groups.

Intermarriage was one of the ways the Coast Salish and other tribes gained access to richer salmon runs. People from Vancouver Island with ties to Fraser River clans would regularly travel to fish the Fraser and its tributaries in summer. Complex social and fishing rules were in place. The geographically fortunate Sts'ailes did not have to leave their territory around the Harrison River to visit relatives, they had to enforce a code: a selective fishing model on themselves, neighbours, relatives alike. Food, after all, was wealth.

So here we are, the four of us, sitting on a beach, the remnants of wealth investment before us, a clam garden — a rock barrier and a small cleared beach. We sort almost 200 clams into piles of similar sizes, then label, weigh, and record numbers in a notebook. Davis and Groesbeck jump into a green canoe to plant clams at a clam garden nearby and Salomon and I tackle the one before us. We carry over to the garden six rigid mesh bag, 15 clams inside each, six pieces of rebar, a cinderblock, rope, flagging tape, and spades for digging. One mesh bag is planted subtidally, tied to the cinderblock to keep it in place. The other we space up the beach, at different points in the intertidal zone. Each bag is buried flat, a handbreadth below the surface, and ziptied to the rebar we pound into the beach with a rock. Two beaches down, nine to go.

That night, after we eat a meal of curried vegetables and rice, we sort more clams, file a rough patch on each shell for tags, then weigh, and record each one until it gets too dark. We wake up early, and do it all over again. Except it's raining. For a couple of hours Salomon and I huddle in her tent, while the two students huddle in Groesbeck's. We dry off clams with our wool socks, placing them on a black wool sweater; they look like white chocolates nestled in a box. We quickly deplete a roll of orange tags, tags Salomon used while studying in New Zealand a few years ago, too expensive at $150 a roll to leave behind.

"You know," Salomon says, carefully weighing a clam on a digital scale. "Here we are a group of women, processing clams. If we were here a few hundred years ago, we'd be doing the same thing in a way. We're really just mimicking the past."

Yes, each lab works something like a fish camp, yet when Salomon says it, a bolt of clarity seems to have hit the tent — a scientific lab is an apparition of the past, a reincarnation of traditional ecological knowledge and research, when humans had to read their local environments to live. For lack of a better word, these scientists are neo-indigenous, living this world, thinking beyond their own experience.

Reading the environment means starting with a vocabulary and categories. Past anthropological research has suggested that all societies created a vocabulary and categories, that taxonomy is hardwired. We organize organisms in similar ways across cultures, useful as a means of inductive reasoning when we come upon an unfamiliar habitat. We need cognitive tools to deal with novel places.

Yet, practical knowledge of nature — the ability to categorize the world around us in a way that creates a cognitive map of ecological relationships, relationships that include humans — is all but gone in the general population of educated, industrialized societies, except for the scientists I've followed in the field, or what anthropologists would call "folk" biologists, in this story the Sts'ailes fishers, the ex-fishers aboard the *Ricker*, Carol Schmitt, and Ed. The ecologist sitting across from me in this tent can read this environment better than me, partly because she grew up on the B.C. coast, but more importantly she spent years in formal educational settings in different parts of the world, eventually applying what she learned to the natural world. Like the other scientists I followed, Salomon also gathers knowledge from the folk biologists.

Anthropological research has drawn parallels between indigenous knowledge holders and biological "experts" in North America, people with at least 20 years experience in their occupations. Place a North American formally-educated ornithologist, or an experienced birder, in Itza' territory in Guatemala and they can order the world around them in similar fashion to the Itza', a Mayan culture that relies on the surrounding rainforest for their livelihood. From studies, it can also be assumed that to place an Itza' in Central Park, they can order the natural world in similar fashion to the North American expert, and far better than the average New Yorker, whose grasp of either environment is rudimentary. The Itza' also have a better grasp on ecological relationships (explaining relationships as reciprocal between plants and animals) within the rainforest than the two other communities they share territory with, Ladinos (Spanish-speaking, mixed indigenous and European descent) and Q'eqchi' (immigrant Maya from the highlands, herded there by the Spanish colonialists a couple hundred years ago). The Itza' have lived their world for generations.

Without these scientific labs and folkbiologists — indigenous or settler — we would be doomed about right now in our history.

The four of us spend the afternoon canoeing and seeding three more gardens. One site has an extensive rock wall that rises about a metre straight out of the water and forms a long flat cleared beach, perfect clam habitat. Another telltale sign of good clam habitat is shell hash, layers of broken shell left behind on a beach, and it might be another clam-friendly management tool. Based on studies of oysters, scientists think the shell hash sends chemical messages to juvenile clams that say something like "Live here, plenty of food!"

Over two days we plant 450 juvenile clams at five beaches. We would plant more, but it's time to meet up with the archaeologists surveying Kanish Bay. We pack, the cinder blocks either resting in the subtidal zone or stashed away for the next planting session, and Groesbeck gets in a canoe to retrieve from the bay the live clams she has yet to tag. Placed in a white bucket, a long bright yellow rope attached to the handle and tied to a rock so they wouldn't float away with the tide, they're gone. To tie a bowline knot is not hard. But when you forget the order in which the rabbit is supposed go into its hole, the knot will only be right one out of two times. I lost the clams. Salomon sheds her clothes and dives into the chilly spring waters, too murky to see the yellow rope. The least I can do is donate my dry, clean towel to Salomon as she drags herself out of the ocean shivering, without the clams.

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A hummingbird, its throat a ruby red, buzzes the group of archaeologists and ecologists sprawled on a beach of seashells and sand. Lepofsky looks up at the sound of whirring wings. “Come see me,” she says, holding out her arms to show off her purple jacket and matching nail polish. “Look what I’m wearing.”

But the curious bird levitates up and away as the 10 scientists and graduate students stop chatting about herring, anchovies, and clams, long enough to see a sign of summer tease them with a brief appearance. The past week of fieldwork has been mostly rainy and cold.

We’re sitting on a beach that’s really a midden on a small island in Kanish Bay, nicknamed Shell Island. Our red, orange, blue, and brown tents crown the hill above us. Sunshine illuminates the thick layer of white shell bits. Salomon sits on the beach, legs stretched out, leaning back on her elbows, listening to Lepofsky talk about the overall vision of the project, then asks a question: when a relatively non-typical species pops up in the archaeological record, let’s say anchovy, how do we know it’s not traded?

“Now it’s a bit funny, I think to ask the question in the first place,” Lepofsky says, sifting shells through her hand as she answers. “People don’t ask that question about salmon, I don’t think they ask that about herring, but they’re asking that question about other species because they’re recently extirpated. So the ecological baseline has totally shifted and the onus is on — well, this is me being defensive around people not recognizing the diversity in the past. Definitely a lot of trade happened. I think the record, though, will always be swamped by local consumption.”

The key is figuring out where people lived, what they ate, and how and when they fished. Because of its sheer abundance, salmon tends to overwhelm the archaeological record. But evidence is piling up that the little fishes — herring, eulachon, anchovies — went a long way to feeding entire villages. Add to the mix clams, waterfowl, and fish roe, and the ancient maritime economy was a managed and diverse biological buffet. Salmon was important, but its proportion on the plate might be inflated.

The hummingbird is a good sign: the sun shines and the water is calm. The ecologists leave to dig clams; archaeologists drag canoes and kayaks from the beach to the water for a reconnaissance mission.

An osprey wheels and hovers overhead as the group pulls the boats to shore at a nearby beach. Lepofsky’s target is two types of sites: shallow and dispersed, where people shucked clams and brought the meat back home, and the more complex settlement sites that likely pre-date the clam gardens. What she hopes to find is a transition in the middens between pre- and post-clam garden. By looking at relative species abundance, age, and size in relation to time, it could tell archaeologists when clam harvesting became more managed and if the technology increased production, in either size or number. This is where the ecologists' work dovetails with the archaeologists.

"If there's a transition, if there is some change in productivity, hopefully that will mirror the results of the hypotheses being generated by the ecology," Lepofsky says. "If that's mirrored in the midden, then we'd be able to date that transition."

The group troops up the beach and is swallowed by cedar and fir trees. They're looking for a settlement midden to sample. To find a midden in a coastal B.C. forest is a breeze since shells often speckle the bottoms of uprooted trees and cling to creek faces, sometimes far from shore. Before long, a graduate student has faced off a ledge and draws the layers on notebook paper before excavating a 20 x 20 centimeter column sample 70 centimeters deep with help from Megan Caldwell, a graduate student who studied the fish traps in Comox Harbour, 50 kilometres or so south. Caldwell runs through the routine with the student before taking off — she needs to be on a ferry and at another site in another First Nation's territory, the Tla'amin, by early morning, when the tide is at its lowest.

"I might not have anything else in my life organized but I know when the tides are," Caldwell jokes.

Before heading to the field, Caldwell spent the winter screening samples taken last year from the beach she's about to visit, Gibsons Beach, which dates as far back as 500 years before present, although other sites on Tla'amin land date beyond 7,500 years.

It takes hours to sift dirt through a two millimeter screen, picking out herring and other fish bones from the debris, and sorting the remains of clam shells, cockles, and sea urchins by the hundreds. Show a tiny fish bone to Caldwell and she usually identifies it in a flash — "cleithrum, probably from a herring. It's part of the pectoral girdle, it sits behind the gills." Caldwell knows herring. In 2008 Caldwell concluded her master's thesis showing that in Comox Harbour herring overwhelms salmon in the faunal record from her sampling areas.

Thousands of wooden stakes pierce the seafloor in Comox Harbour. Archaeologist Nancy Greene has spent a decade mapping over 14,000 stakes. From the radiocarbon dates, it appears the people used the traps continuously for a thousand years, beginning about 1,220 years ago. The chevron- and heart-shaped traps were designed to massively harvest fish by funneling them into woven traps. The heart-shaped trap is 42 meters in diameter. While a fish trap means fish, to figure out the species takes the tedium of screening, which poses another problem for a researcher: size.

It's common to use six-millimeter mesh sized screens, which are too big to catch the bones of herring, anchovy, and eulachon. Even half that size misses the smallest remains. Couple that bias with recent extirpations and invasive species and our view of the ancient and historical environment is skewed. So archaeologists like Lepofsky, and others working nearby, in places like Alaska, Haida Gwaii, Oregon, almost have this unspoken agreement between themselves to redress a past problem of a myopic fixation on salmon, and dig deeper, not necessarily in a physical sense. Something as simple as changing mesh sizes and using nested screens — one millimeter and two millimeter — to compare fish bones recovered, can change the record.

The downside is that decreasing screen size doubles screening time and costs. It's no leap to think that funding availability skews science.

Nova Pierson, another of Lepofsky's graduate students, used the small screens to sift through midden material that dates as far back as 3,000 years from Burrard Inlet, a narrow band of water that separates Vancouver from North Vancouver. A traditional use area of several Coast Salish communities, the inlet is 50 kilometers long. Pierson picked out species no longer found in the ecosystem, such as native oysters and sea urchin. She also found widespread abundance of salmon, herring, and anchovy in similar proportions over the time period and noticed that when the remains of one fish decreased, salmon for instance, one of the other two species' remains increased.

"Because both large and small fish may have been valued, decisions could have been made that took into account the ecosystem as whole," Pierson says, when I track her down and chat with her over the phone from Vancouver. The research lines up with other zooarchaeological data emerging over the past decade or so — the proportion of salmon species compared with other marine species was fairly constant in a time frame that spans 7,500 years.

The picture emerging is one of a culture that avoided relying on one plentiful species. It's almost as if people hedged their bets when it came to food — a risky environment demands caution. Salmon is very present in the record, but it doesn't appear to go through a classic boom/bust overexploitation cycle.

The fact that fish traps and clam gardens were so widespread makes for a compelling argument that past culture played a part in conservation. "If you talk to the elders about these intertidal sites," Lepofsky says, "they don't really think about them as single purpose the way we tend to."

In the 1930s anthropologist Homer Barnett spent time with the Tla'amin, and later wrote about their fishery — fish traps, nets, hooks, and harpoons for salmon, halibut and cod, the prized delicacy of sea mammals, and the clams, which "were everywhere and a never failing source of food." He also witnessed the herring harvest. Two people in a canoe, often a husband and wife, the woman paddling and the man with a herring rake to impale fish. They collected herring by the hundreds or more. For the roe, people submerged branches of Douglas fir, hemlock or red cedar near the shore for herring to deposit their eggs. Tee-sho-shum, one of the Tla'amin's main villages actually translates to "water white with herring roe." Barnett, almost offhandedly, mentions that Tla'amin and two other Salish tribes had no first salmon ceremony.

Lepofsky hunts down copies of Barnett's *The Nature and Function of the Potlatch* as gifts for her graduating students. This 1938 dissertation, awarded by University of Oregon, outlines an economic system almost completely at odds with the industrialized, capitalist system brought with the colonialists. It's not, however, a system alien to the current dominant culture, and it's how, I've learned, scientific labs function.

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Potlatch is an Anglicized version of the original Nuu-chal-nuuth word *pachitle*, a ceremonial feast that redistributed wealth and maintained a healthy ecosystem: the more a community had to give away, the richer the community. The most wealthy had access and rights to exploit natural resources, they also had the responsibility of regulating resources to ensure a steady supply to the community. It was practiced up and down the coast, each community had its own variations, but the core ideal — reciprocity — was the same.

Reading the dissertation, many things stand out, one being that academically, if Barnett is any indication, researching and writing a dissertation was more fun in 1938 than today. *The Nature and Function of the Potlatch* is not painful to read. No slogging through a long genealogy of anthropological writing and then redefining every anthropological term ever found in print. Barnett dips the readers into a world, in this case Coast Salish, where wealth came from the land and sea, the rich were expected to "pay" what they could afford, and the expectation that everyone gave back as much or more than was received. It was a reciprocal economic system where generosity was rewarded.

Caldwell's worked intrigued me and I visit her site at Gibsons Beach, a beach Barnett likely strolled as well. After measuring and mapping traps we get in our cars and drive five minutes to the Tla'amin main village, where we stroll the front "yard," a scientifically impressive archaeological site, sunken fish traps that echo the pre-Colombian-era remains that Caldwell maps at Gibsons. On this sandy beach, stonewalls scallop the shore for a kilometer. The traps still catch salmon and other species in season. A breeze riffles the water, bringing a slight chill to the air, momentarily interfering with the sun's warmth. Twin markers of the relentless march of the outside world frame the site, a pulp and paper mill bellows steam in the distance and a few metres away a church squats on the waterfront.

We walk to the band office where I meet Michelle Washington, the land use planning coordinator for the Sliammon Treaty Society, who has worked with the archaeologists from the beginning. When introducing herself, Washington also gives her traditional name, Siemthlut.

Washington is only 40, young enough that in many families she might have grown up ignorant of Tla'amin traditions, but she was curious about the old ways and spent time with her grandparents as a girl. Over the years she also interviewed lots of elders. One of the things she learned was the interplay of environment and people: stone traps invited in the herring, precisely when salmon stores were low (early spring) and villages needed an influx of fresh food. Animals and people danced an annual cycle together.

"When I was a kid, this time of year was alive, this village was alive," she says, as she placed a number of studies on the table. One was a land use survey she authored. "Everybody had their smokehouse ready, their herring racks ready, the kids were all down the beach, you know little kids just had ice cream buckets, the bigger kids had bigger buckets, because you could go down into the little pond in the intertidal zone and scoop up hundreds of herring in one scoop and run it to your house. That's not that long ago: 1984 was the last year I remember that happening."

But the damage to indigenous fisheries began long before that. Washington explains the system, pausing to press a point that when people stop gathering or cultivating a species — like herring — information is lost forever. Especially when language is also lost. Anthropological writings, like Barnett's, fills in gaps and confirms oral histories though most early researchers failed to see signs of active management, something Washington is keen to make sure becomes part of the historical narrative of the coast. We weren't just lucky, Washington says, our ancestors worked this land. They had relationships, non-human and human.

Higher-class Coast Salish families inherited rights to abundant salmon runs and they consolidated wealth by marrying other elites. "Heh goos" — the head man in the Tl'amin language — made decisions on when and how to fish. Their status was publicly legitimized through the potlatches, where the wealth was given away. The Coast Salish lower-classes had little social mobility and a lot of incentive to cooperate with the wealthy. Soon after potlatches were outlawed in 1885, anthropologist Franz Boas visited the Kwakwaka'wakwa (ancestors of the tribes in the Laich-Kwil-Tach Treaty Society).

The chief told him: "It is a strict law that bids us distribute our property among our friends and neighbours. It is a good law."

Such a good law that scientific labs abide by it too.

A particularly good example is the lab I followed in the field and learned all about sockeye salmon, Scott Hinch's lab at UBC, mostly because his lineage goes back a few more years than the others. Hinch is the "Heh goos" (in science speak, he's the PI, the Principal Investigator) who has access to knowledge, equipment, funds, and other "elite" PIs in the field. Hinch generously shares his access to resources with students. In turn, the students cooperate with Hinch and each other to add to that lab's body of knowledge, which adds to the Hinch Lab's prestige. Successful labs have generous PIs, who beget generous graduate students, who move on to establish their own labs, or work in industry, or government, and keep ties with their old labs (that's the intermarriage part.) This generosity and reciprocity leads to resilience. As long as the knowledge remains valuable, the lab and its prestigious status remain stable. (This is sometimes why scientific theories that need to die might take a long time to do so — they come from a resilient lab. The theory only dies when the investigators die.)

Potlatches not only distributed wealth — a finite natural resource — they also distributed knowledge, which is not a finite resource. But the biggest problem with knowledge is that it sometimes gets lost, especially if it's not written down.

The work on sockeye, Chinook, coho, chum, and pink, and the relationship these fish have with their environments, is a painstaking, expensive, and highly-structure, and the only means of translating the indigenous and community knowledge into science. Science gives language to a way of living in the world that normally requires multiple means of communication, that requires no numbers or words. To know salmon, or any other fish, or shrub, or tree, is most possible by thinking like them and to think like them means knowing them — a circular path trod within any environment full of life. Seceding ourselves from that knowledge is dangerous.

Washington is teary when she talks about knowledge disappearing. This way of living in the world is hard won and not easily retrieved.

"My Granny used to say something that I never quite understood until I got older," Washington explains. "She would look at expensive homes with manicured lawns and say, in our language, 'Oh those poor people, they have no medicines or food in their yard. How are they going to feed themselves and take care of themselves if anything happens?'"