Homing and Straying, Part I

- Do salmon home? Wise men and skeptics in past generations
- Evidence for homing, but not by all
- Straying – why is it important?
- Hypotheses to explain straying and homing
“Sir Francis Bacon observed, the age of a Salmon exceeds not ten years…Much of this has been observed by tying a Ribband or some known Tape or thred, in the tail of some young Salmons, which have been taken in Weirs as they have swimm’d toward the salt water, and then by taking a part of them again with the known mark at the same place at their return from the Sea, which is usually about six moneths after; and the like experiment hath been tried upon young Swallowes, who have after six moneths absence, been observed to return to the same chimney, there to make their nests and habitations for the Summer following: which has inclined many to think, that every Salmon usually returns to the same River to which it was bred.”

Izaak Walton, *The Compleat Angler*. 1653. Bacon lived from 1561 to 1626
“This stream [near Elko, Nevada] is one of the many that form the headwaters of the Columbia River, and to this point, eighteen hundred miles from its mouth, the salt-water salmon come in myriads to spawn…From these facts we may infer that the instinct of location is probably sufficient to attract a colony of fishes as far inland as the headwaters of the longest river, whenever their home has been once established there.”

Milner (1876) noted “[t]he generally accepted fact in the habits of anadromous fishes that they are disposed to return to almost the exact locality where they passed their embryonic and earlier stages of growth… Observations of the shad brought to the large markets show considerable differences in the physiognomy and general contour of those from different rivers. The suggestion is natural that they are distinct and separate colonies of the same species, and thus slight characteristics are perpetuated because they breed in-and-in and do not mix with those of other rivers.”

A.G. Huntsman, the skeptic, believed that salmon did not venture far out to sea but stayed near the mouth of the river. He also believed that salmon did not return home from distant locations.

He challenged scientists to show him an example of a salmon tagged as a juvenile in freshwater, caught at a distant location at sea, and then caught again at the location where it was first tagged.

31,359 Atlantic salmon smolts were marked in the Northeast Margaree River, Cape Breton, Nova Scotia in the spring of 1938.

One was caught at Bonavista, off the east coast of Newfoundland (at least 550 miles away) on June 17, 1940, marked, and released.

This fish was recaptured in the Northeast Margaree River on September 21, 1940.
Are the adults that enter a river or lake the same ones that left there years earlier?

Approach: Mark all the smolts leaving a small lake in the lower Fraser River system, where the vast majority of smolts would be from other lakes farther upriver.

Cultus Lake
The return of adult sockeye salmon to Cultus Lake after all the smolts were marked

| Marking smolts | Return | | | |
|---|---|---|---|
| | Large | Small |
| | Marked | Unmarked* | Unmarked** |
| Spring 1931 | 365,265 | Fall 1933 | 2856 | 17 | 409 |
| | | | | (0.6%) | |
| Spring 1936 | 497,598 | Fall 1938 | 8980 | 136 | 4226 |
| | | | | (1.5%) | |

* Possibly strays  
** Presumed to Foerster (1936, 1968)

Foerster (1936, 1968)
Homing and straying between two small streams in coastal California

<table>
<thead>
<tr>
<th>species</th>
<th>Marking site (n)</th>
<th>Waddell (%)</th>
<th>Scott (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coho salmon</td>
<td>Waddell (369)</td>
<td>85.1%</td>
<td>14.9%</td>
</tr>
<tr>
<td></td>
<td>Scott (56)</td>
<td>26.8%</td>
<td>73.2%</td>
</tr>
<tr>
<td>Steelhead trout</td>
<td>Waddell (485)</td>
<td>98.1%</td>
<td>1.9%</td>
</tr>
<tr>
<td></td>
<td>Scott (960)</td>
<td>2.9%</td>
<td>97.1%</td>
</tr>
</tbody>
</table>

Shapovalov and Taft (1954)
How much straying occurs between nearby lakes?

The parasite is prevalent in Owikeno Lake but absent in Long Lake.

*Myxobolous neurobius*, a myxosporan protozoon parasite.
*Henneguya*, another parasite, can help distinguish among three populations, two of which have *Myxobolous*. 

![Image of fish tissue with parasites] 

![Map of lakes and rivers]
Percent of adult sockeye salmon infected with two kinds of parasites, as evidence of homing

<table>
<thead>
<tr>
<th>Region</th>
<th>Lake</th>
<th>Myxobolous</th>
<th>Henneguya</th>
</tr>
</thead>
<tbody>
<tr>
<td>B.C. coast</td>
<td>Long</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Owikeno</td>
<td>98.5</td>
<td></td>
</tr>
<tr>
<td>Vancouver Island</td>
<td>Great Central</td>
<td>3.9</td>
<td>0.6</td>
</tr>
<tr>
<td></td>
<td>Sproat</td>
<td>99.8</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Henderson</td>
<td>98.0</td>
<td>66</td>
</tr>
</tbody>
</table>

Quinn et al. (1987)
Do salmon home to the area within the river where they came from? Steelhead smolts released in the Wilson River, Oregon

<table>
<thead>
<tr>
<th>Area of Release</th>
<th>Area of Recovery</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Upper</td>
</tr>
<tr>
<td>Upper</td>
<td>595</td>
</tr>
<tr>
<td>Middle</td>
<td>202</td>
</tr>
<tr>
<td>Lower</td>
<td>108</td>
</tr>
</tbody>
</table>

Estimated catches, 1964 and 1965 releases

Wagner, H. 1969. TAFS 98: 27-34
Do salmon home to the area within the river where they came from? Sockeye salmon fry released in the Cedar River, Washington

<table>
<thead>
<tr>
<th>Area of Release</th>
<th>Area of Recovery</th>
<th>Mean of annual values, 1997 - 2000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Downstream</td>
<td>Downstream 91%</td>
<td></td>
</tr>
<tr>
<td>Upstream</td>
<td>Upstream 52%</td>
<td></td>
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</tbody>
</table>

Fresh et al. WDFW unpublished report 2002
Use of coded wire microtags vastly expanded our ability to study homing and straying.
Recoveries of Columbia River Chinook salmon reveal complex straying patterns to and from hatcheries

### Release sites

<table>
<thead>
<tr>
<th>Recovery sites</th>
<th>Abernathy</th>
<th>Cowlitz</th>
<th>Kalama</th>
<th>Lewis</th>
<th>Washougal</th>
<th>total</th>
<th>% native</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abernathy</td>
<td>618</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>619</td>
<td>99.8%</td>
</tr>
<tr>
<td>Cowlitz</td>
<td>1</td>
<td>4022</td>
<td>32</td>
<td>48</td>
<td>4</td>
<td>4107</td>
<td>97.9%</td>
</tr>
<tr>
<td>Kalama</td>
<td>60</td>
<td>46</td>
<td>477</td>
<td>54</td>
<td>366</td>
<td>1003</td>
<td>47.6%</td>
</tr>
<tr>
<td>Lewis</td>
<td>0</td>
<td>137</td>
<td>47</td>
<td>1388</td>
<td>212</td>
<td>1784</td>
<td>77.8%</td>
</tr>
<tr>
<td>Washougal</td>
<td>1</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>2794</td>
<td>2798</td>
<td>99.8%</td>
</tr>
<tr>
<td><strong>Total strays</strong></td>
<td><strong>97</strong></td>
<td><strong>198</strong></td>
<td><strong>94</strong></td>
<td><strong>104</strong></td>
<td><strong>640</strong></td>
<td><strong>1133</strong></td>
<td></td>
</tr>
<tr>
<td><strong>% strays</strong></td>
<td>13.6%</td>
<td>4.7%</td>
<td>16.5%</td>
<td>7.5%</td>
<td>18.6%</td>
<td>10.9%</td>
<td></td>
</tr>
</tbody>
</table>
"Face it—we’re lost.”
Why Study Strays?

• Post-glacial dispersal
• Responses to disturbance
• Recovery of populations after removal of barriers
• Interactions between wild and hatchery fish
Muir Glacier/Muir Inlet, Glacier Bay Alaska

On the left is a photograph taken August 13, 1941, by glaciologist William Field; on the right, a photograph taken from the same vantage on August 31, 2004, by geologist Bruce Molnia of the United States Geological Survey (USGS). http://nsidc.org/data/glacier_photo/special_high_res.html
Glacier Bay National Park, Alaska
Increase in pink salmon abundance in Wolf Point Creek, Glacier Bay, Alaska

Milner et al., in prep.

Year

Number of spawners


0 2000 4000 6000 8000 10000 12000 14000

Count = zero

100 1250 3600 7200 11500
The eruption of Mt. St. Helens on May 18, 1980 destroyed all the progeny of salmon from the Toutle River population that homed in 1979. Only strays in that brood year were successful, and colonization was also by strays.
Fish passage facilities at Hell’s Gate, Fraser River
Increase in pink salmon abundance in the upper Fraser River, B.C. after passage was improved at Hell’s Gate

Withler 1982
Restoration of salmon populations in the Elwha River after removal of the dams may hinge on straying. Should we rely on natural re-colonization or transplant fish to the upper reaches?
Homing, straying, and hatchery production

- Most straying studies involve hatchery fish, especially coho and Chinook salmon. Hatchery environments differ from natural ones, so do wild salmon stray as often as hatchery fish? On this very important point, the evidence is limited and equivocal.

- Genetic interactions between wild and hatchery fish, and even accurate enumeration of wild populations, are affected by straying.
Not all hatchery-produced fish that home to the river actually enter the hatchery.

Elk River, Oregon Chinook salmon

Straying of coho salmon between the ORE-AQUA Hatchery and Yaquina Bay tributaries in 1981

- 54235 coho salmon produced by ORE-AQUA’s hatchery returned to Yaquina Bay. 5.8% strayed to tributaries of the bay; the rest returned to the hatchery.
- Those 3158 hatchery-produced strays constituted 74% of the escapement to tributaries, along with 1102 wild coho.
- Those 1102 wild coho returning constituted only 35% of the run; 2022 (65%) entered the hatchery.

Consequently, the hatchery diluted the local gene pool both by outnumbering wild fish on the spawning grounds and by attracting wild fish into the hatchery.

Nicholas and Van Dyke. 1982. ODF&W Info. Report
Proximate and Ultimate Causation in Animal Behavior

• **Proximate:**
  1. Mechanism (how does it work?)
  2. Ontogeny (how does it develop?)

• **Ultimate**
  1. Functional Significance (how does it help the animal survive and successfully reproduce?)
  2. Phylogeny (how did it evolve?)

Why do salmon stray?

**Failure to home**
- Imperfect imprinting
- Memory loss
- Sensory failure
- Signal changed or masked
- Exhaustion

**Decision to stray**
- Tradeoff between homing and spawning site selection

**Genetic strategy**
- Dynamic equilibrium between homing and straying (then, why home?)
**Homing is beneficial because it:**
1) Returns locally adapted fish to suitable habitats
2) Increases the chances of finding a suitable breeding site and mate because habitat quality varies spatially

**Straying is beneficial because it:**
1) Buffers against temporal variation in recruitment
2) Allows colonization of new environments

Hendry et al. 2004
Stream Stability

Less → More

Homing

Straying

Chinook

sockeye

coho

chum

pink
Chinook
sockeye
pink
coho

Complexity of Freshwater Environment

Homing

Straying

Less

More

chum

sockeye

Less

More
How might mechanistic factors affect variation in straying among species?

If coho home with more fidelity than pinks, is it because they spend more time in freshwater and so have more time to learn odors?
Spawning habitats and imprinting opportunities

Intertidal spawning by pink and chum salmon
Southeast Alaska
Coho and stream-type Chinook salmon seem to have much greater homing fidelity than ocean-type Chinook salmon.

Do these patterns result from differences in the duration of time juveniles spend in freshwater? The nature of the parr-smolt transition? Conditions experienced by returning adults? Evolutionary processes?

Older salmon are more prone to stray than younger ones. Evolution or forgetfulness?
Variation in Age at Maturity

- Less
- More

Straying

Homing

- steelhead
- Chinook
- sockeye
- chum
- coho
- pink
### Hypothesized proximate and ultimate causes of homing and straying

<table>
<thead>
<tr>
<th></th>
<th>Homing</th>
<th>Straying</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Proximate</strong></td>
<td>1. River odors: Rock, soil, plants</td>
<td>1. Obstruction</td>
</tr>
<tr>
<td></td>
<td>2. Population specific pheromones</td>
<td>2. Degradation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3. Pheromones</td>
</tr>
<tr>
<td><strong>Ultimate</strong></td>
<td>1. High inter-stream variation</td>
<td>1. Low inter-stream variation</td>
</tr>
<tr>
<td></td>
<td>2. High intra-stream stability</td>
<td>2. Low intra-stream stability</td>
</tr>
</tbody>
</table>

**Proximate (Environmental)**

**Ultimate (Evolutionary)**
Homing of Wild and Hatchery-Reared Lewis River Chinook Salmon

Distribution of returning adults (%)

<table>
<thead>
<tr>
<th>Rearing history</th>
<th>Lewis River</th>
<th>Adjacent rivers</th>
<th>Columbia R. system</th>
<th>Outside Col. R.</th>
</tr>
</thead>
<tbody>
<tr>
<td>River-caught</td>
<td>96.8</td>
<td>&lt;0.1</td>
<td>3.2</td>
<td>0</td>
</tr>
<tr>
<td>River-caught, hatchery-reared</td>
<td>90.7</td>
<td>4.8</td>
<td>4.5</td>
<td>0</td>
</tr>
<tr>
<td>Hatchery spawned and reared</td>
<td>89.7</td>
<td>5.7</td>
<td>4.6</td>
<td>&lt;0.1</td>
</tr>
</tbody>
</table>

McIsaac, D.O. 1990. PhD. Univ. of Washington
Straying of Cowlitz River spring chinook salmon by age of return (1974 -1977)