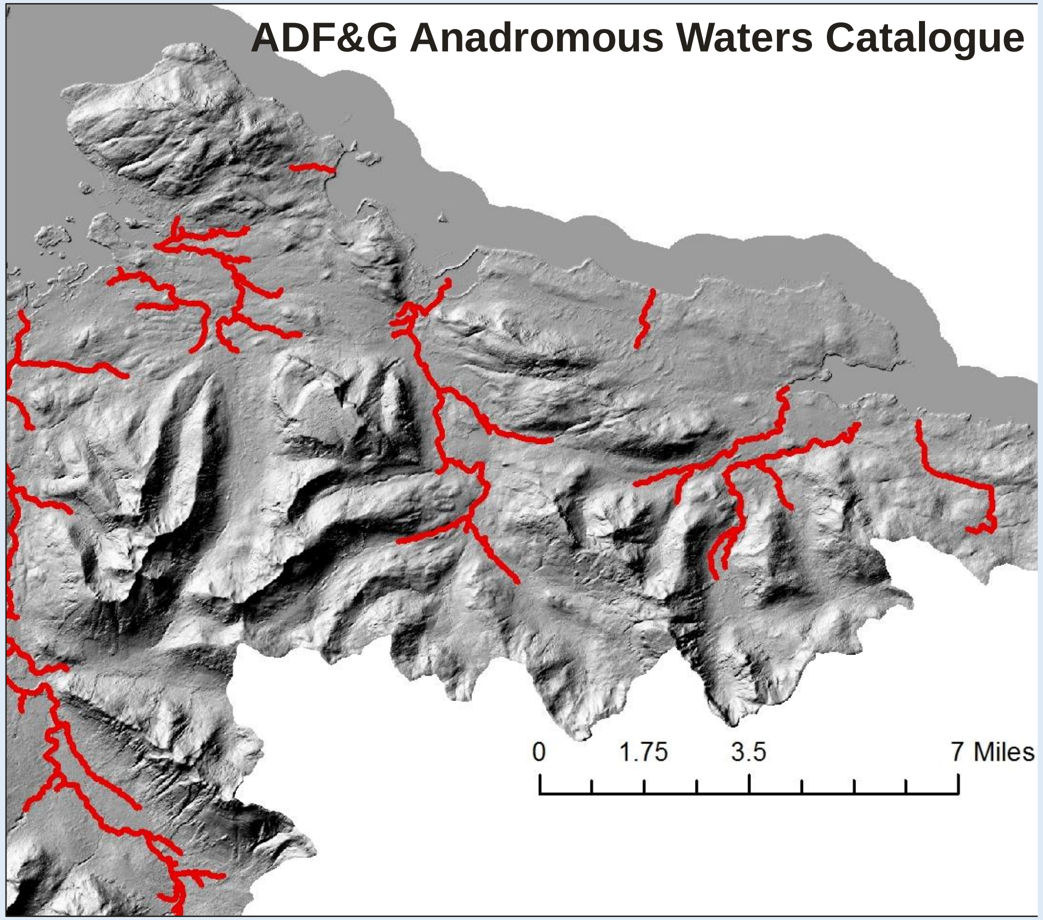
How Can We Safeguard Salmon If We Don’t Know Where They Live?

A Crowdfunding Solution to Modernize Identification and Mapping of Salmon Habitats across the Trans-Boundary region

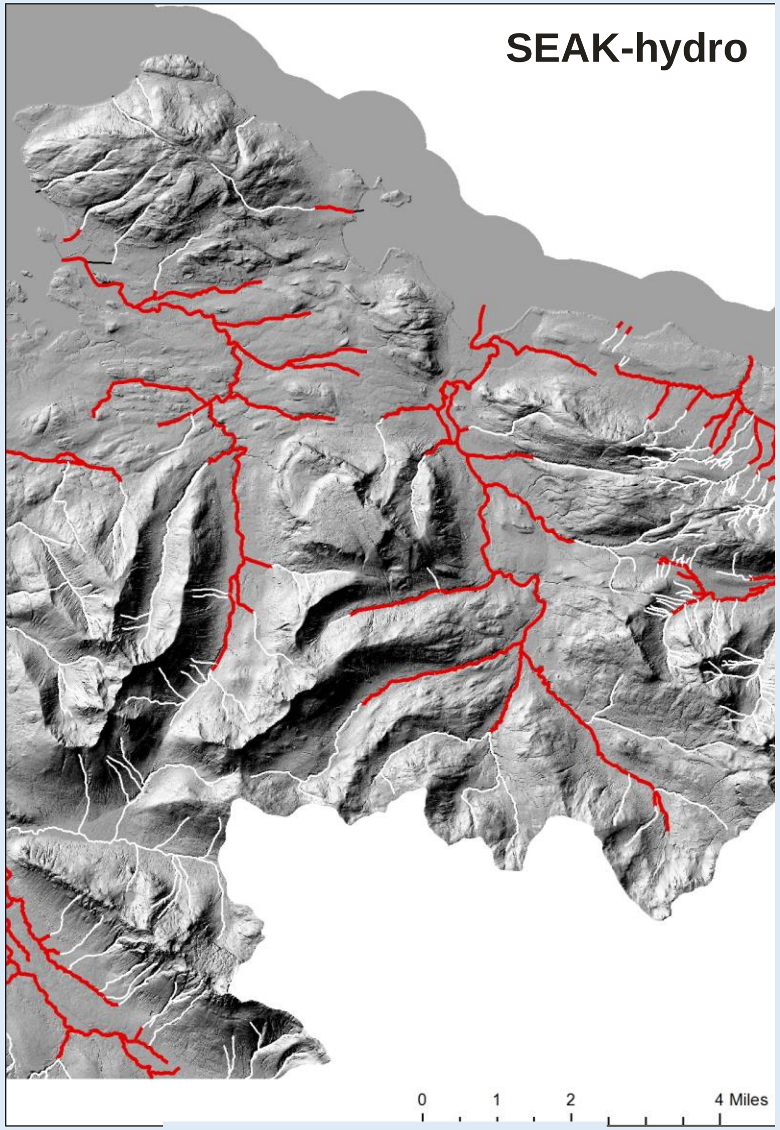
Terrain Works

We investigate how well the locations and abundance of salmon habitats can be known in southeast Alaska and in coastal British Columbia, using an area of northern Chichigof Island as a demonstration.

We can start with available maps that show where salmon habitats are located



Drainage density salmon streams: 0.26 km km $^{-2}$



Drainage d

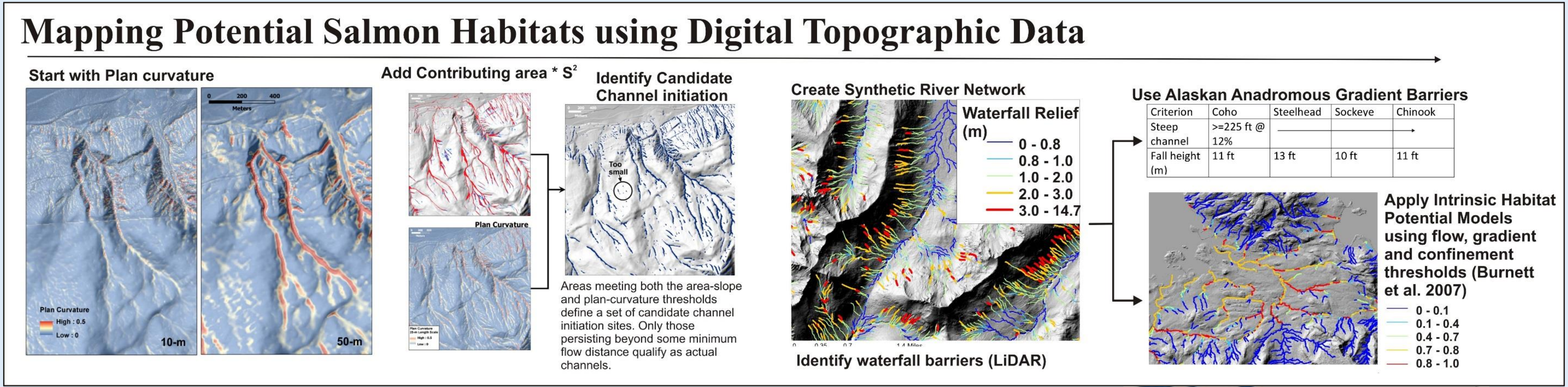
Salmon streams: 0.39 km km^{-2}

Salmon streams: 0.44 km km $^{-2}$

1:63,500-100,000 NHD cartographic stream layer

Note the use of densities (km km^{-2}) that allow us to compare stream networks and salmon stream length across the different data products

Next, we can delineate channels and salmon habitats using existing digital topographic data.



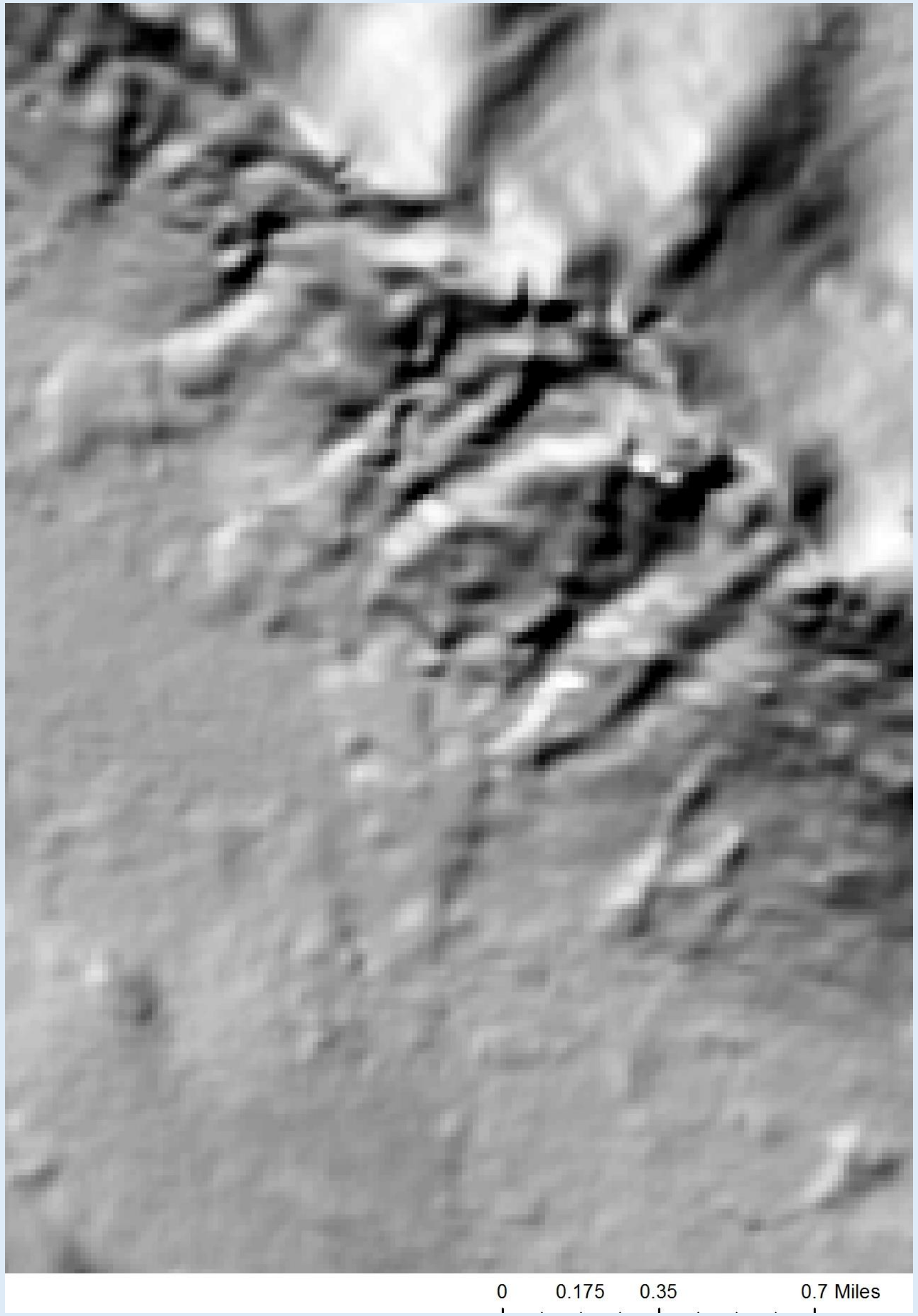
Project Pilot Area, approximately 750 km^2 with 1 m LiDAR digital elevation model (DEM)

We can map salmon habitats using digital elevation models (DEMs) by identifying channel gradient thresholds and by applying salmon models. The extent and accuracy of predicting salmon habitats are strongly influenced by the resolution of DEMs.

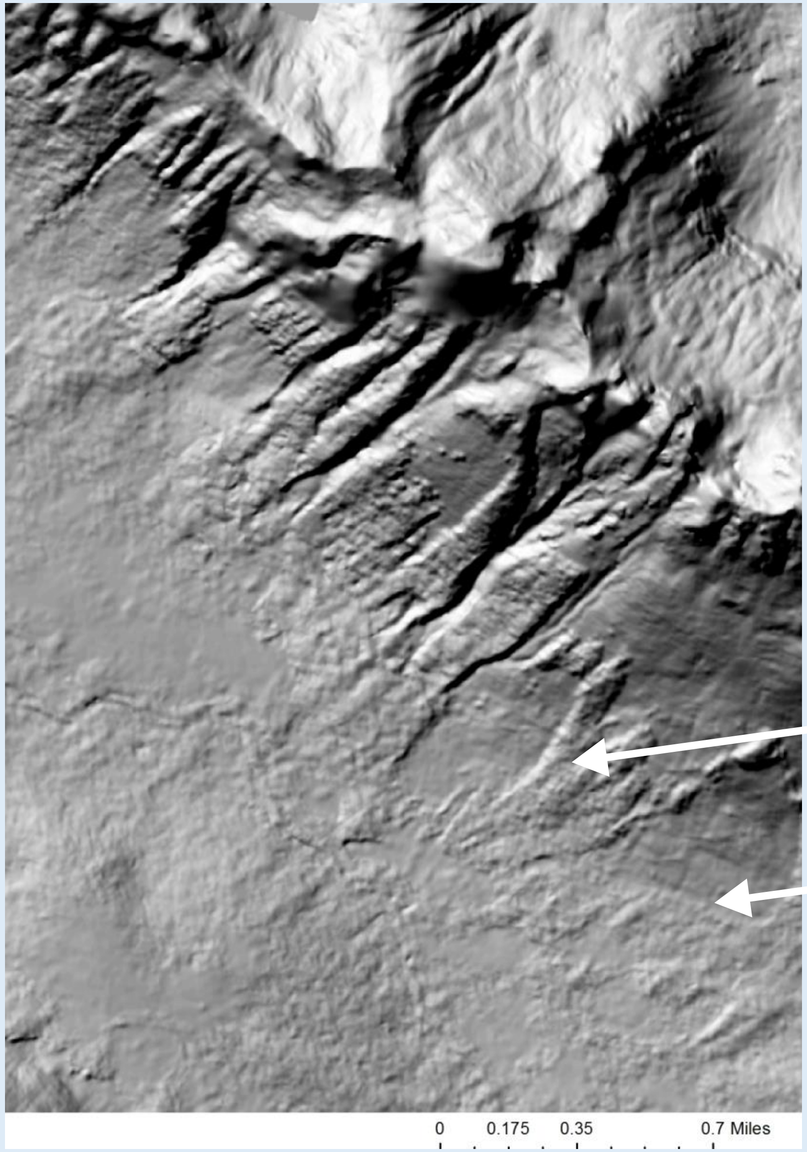
Here we examine the ability of four DEM resolutions: in southeast Alaska (20m, IfSAR 5m and 1m LiDAR) and in British Columbia (17m). We compare those salmon maps to salmon extent in existing cartographic map products including SEAK-Hydro, ADF&G Anadromous Waters Catalog and B.C. Provincial stream layer.

Existing topographic data in southeast Alaska

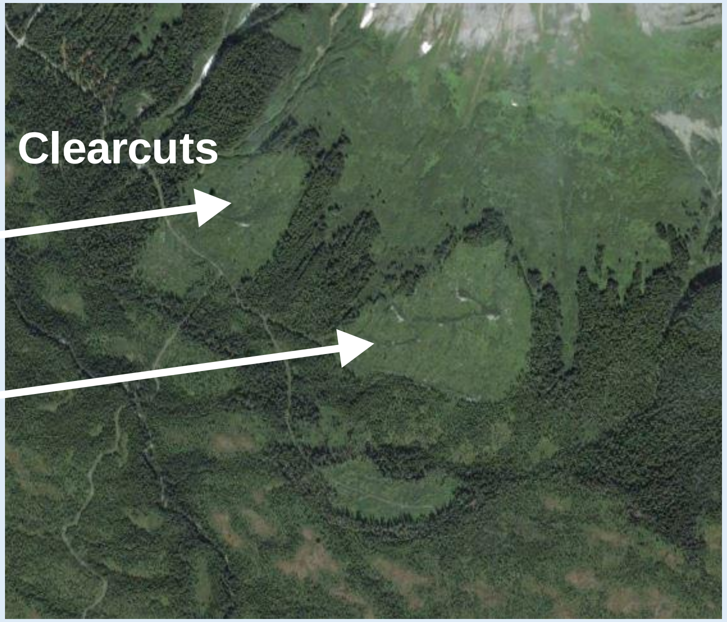
USFS 20m



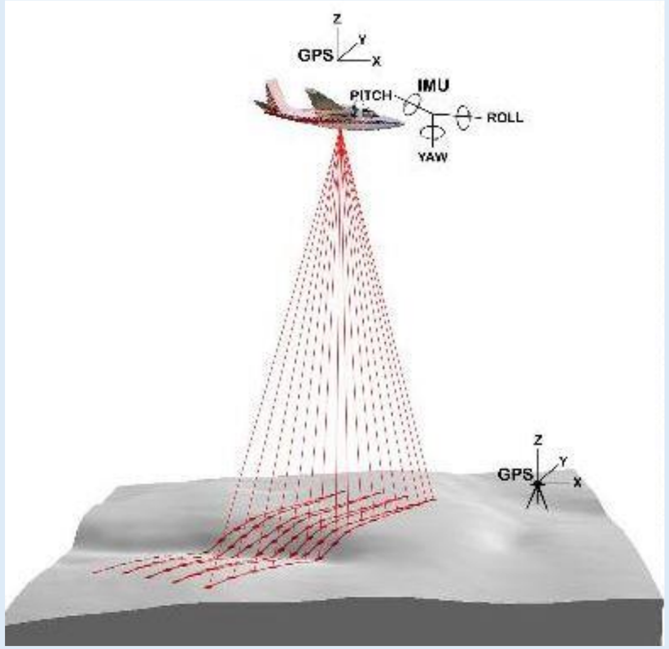
IfSAR 5m



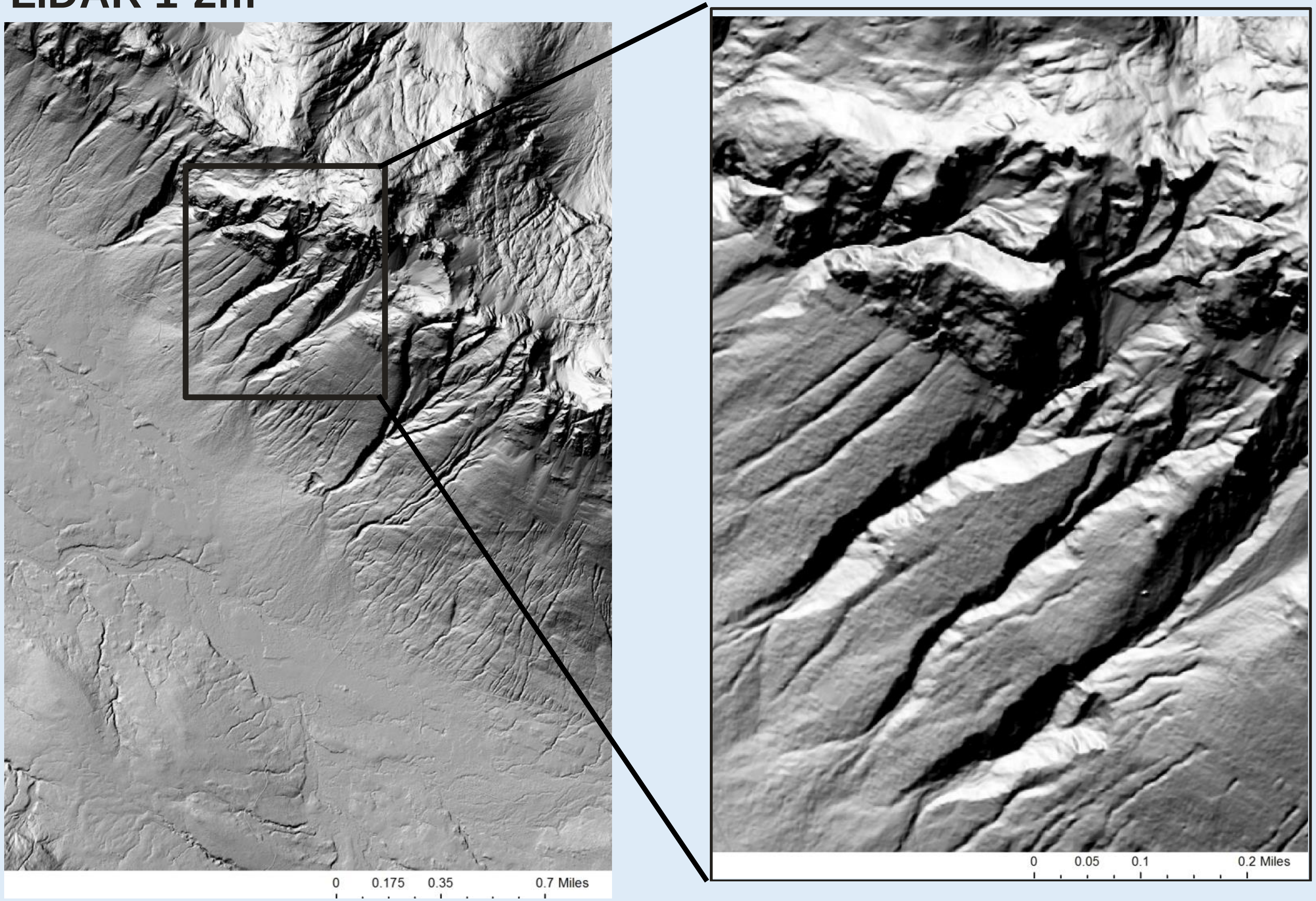
The IfSAR 5m DEM is effected by variation in vegetation heights making it unsuitable to map river networks or salmon habitats



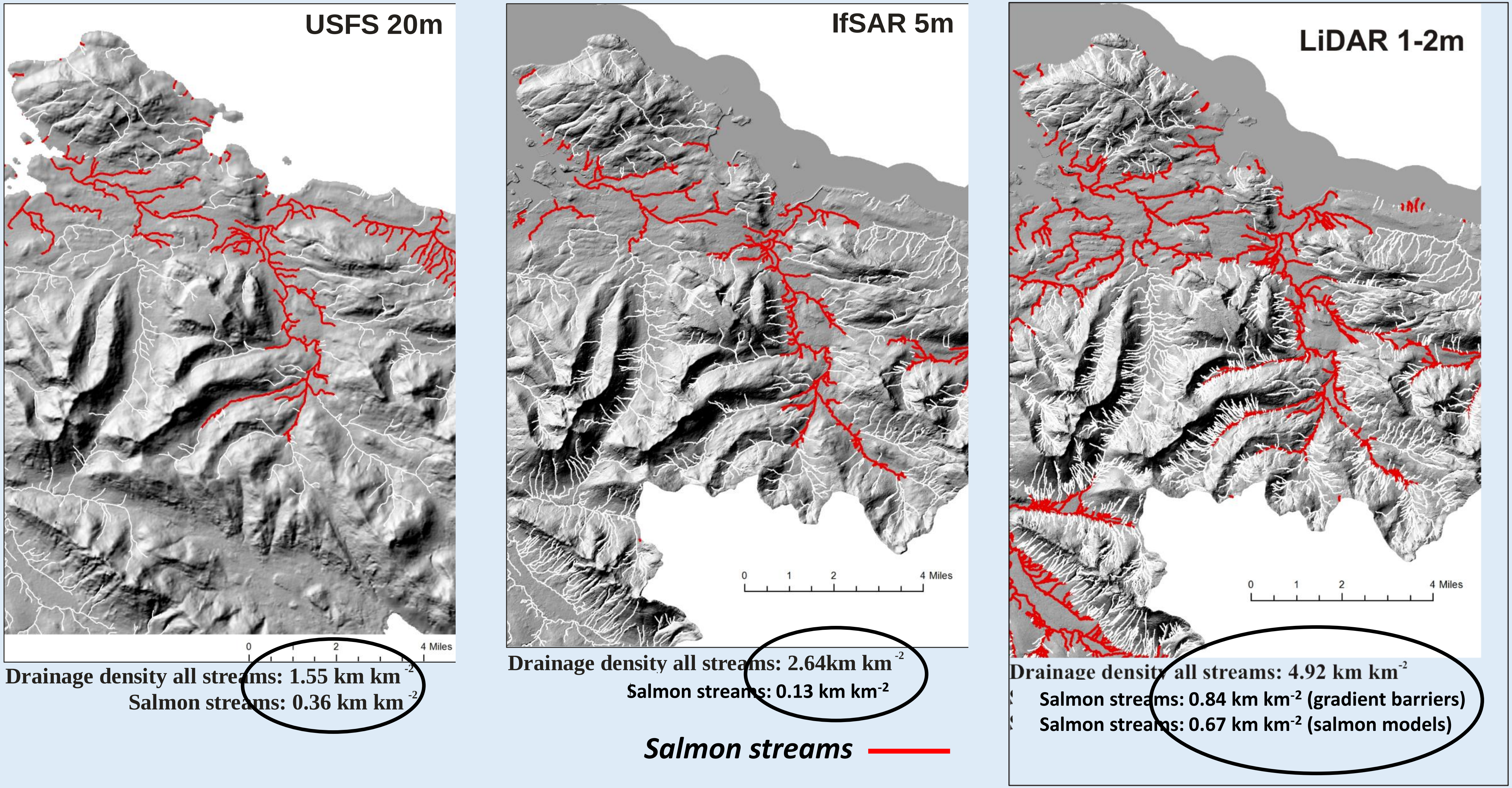
Modern airborne mapping technology (called LiDAR) can create very high resolution digital topography from which complete as possible river networks and mapping of all potential salmon habitats can be accomplished.



LiDAR 1-2m



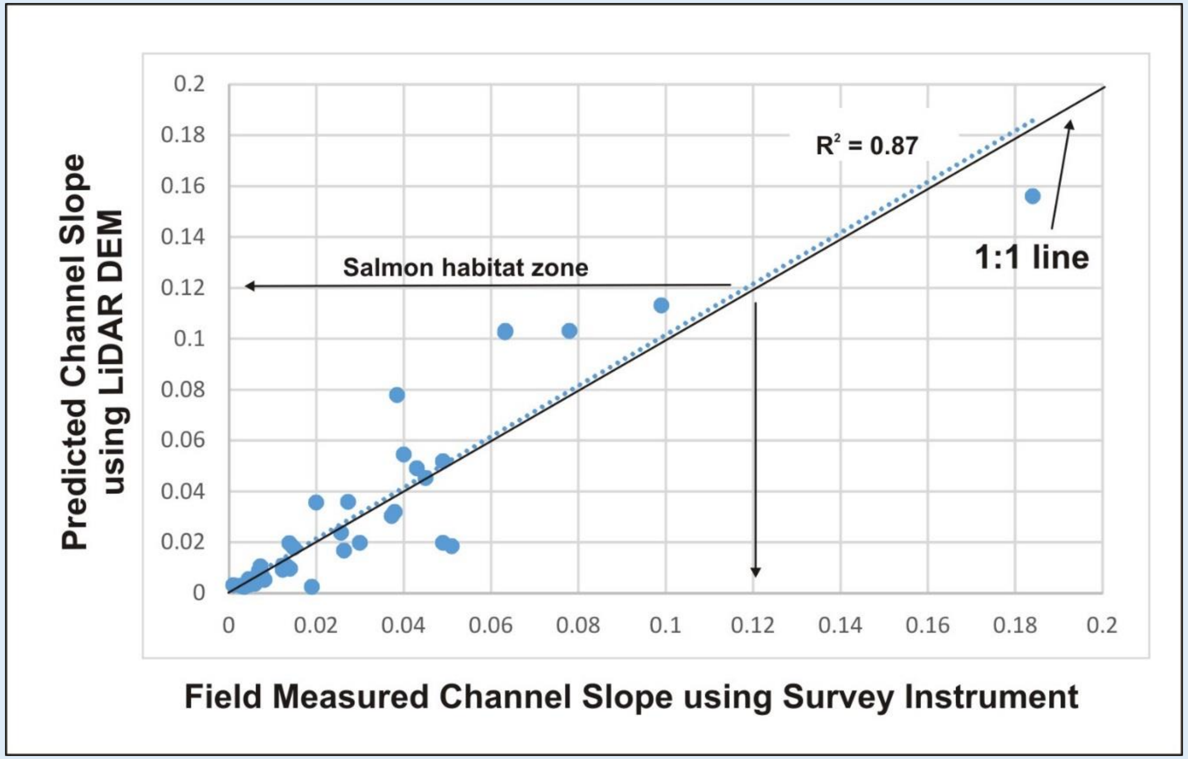
North Chichigof Island
Southeast Alaska



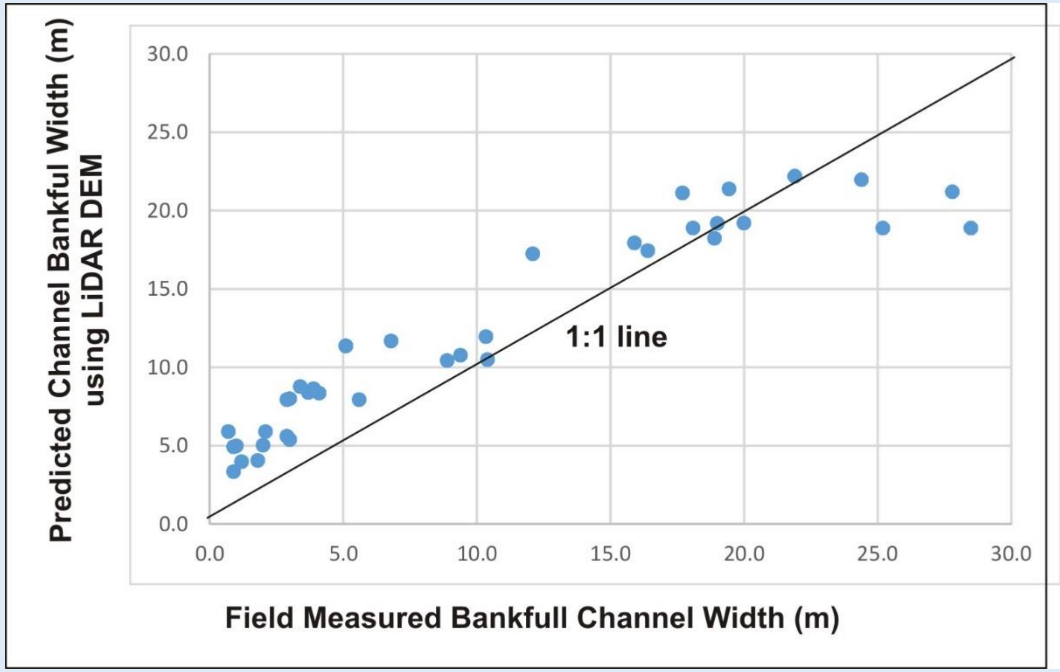
This image shows how the various DEM resolutions support, or not, the delineation of stream and river networks and salmon habitats. Note the differences in the densities of all streams and salmon streams; LiDAR produces the best river networks with the highest densities, including for potential salmon streams.

How Accurate is LiDAR for Predicting Channel Attributes Relevant to Gradient Barriers and Salmon Habitat Modeling?

Field data were collected in the Hoonah study area (at 43 sites) including channel gradient (using a survey station), channel bankfull width, bankfull depth and floodplain width.



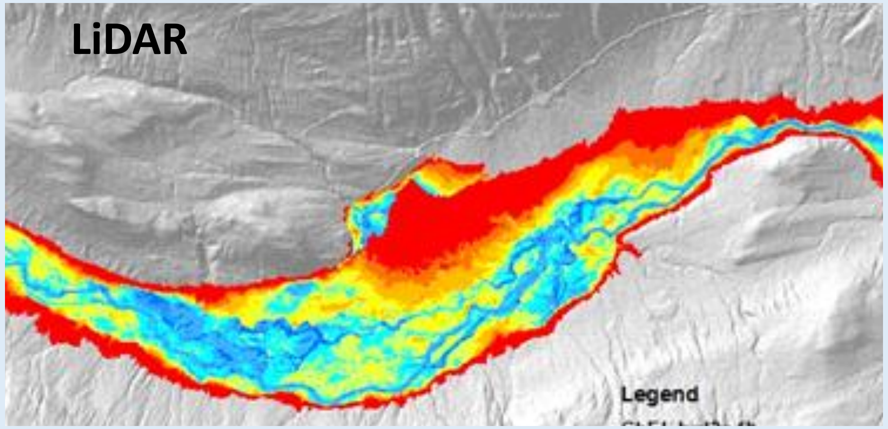
Channel gradient, the principle variable in predicting salmon gradient barriers and in salmon intrinsic habitat potential modeling, was very accurately predicted using LiDAR.

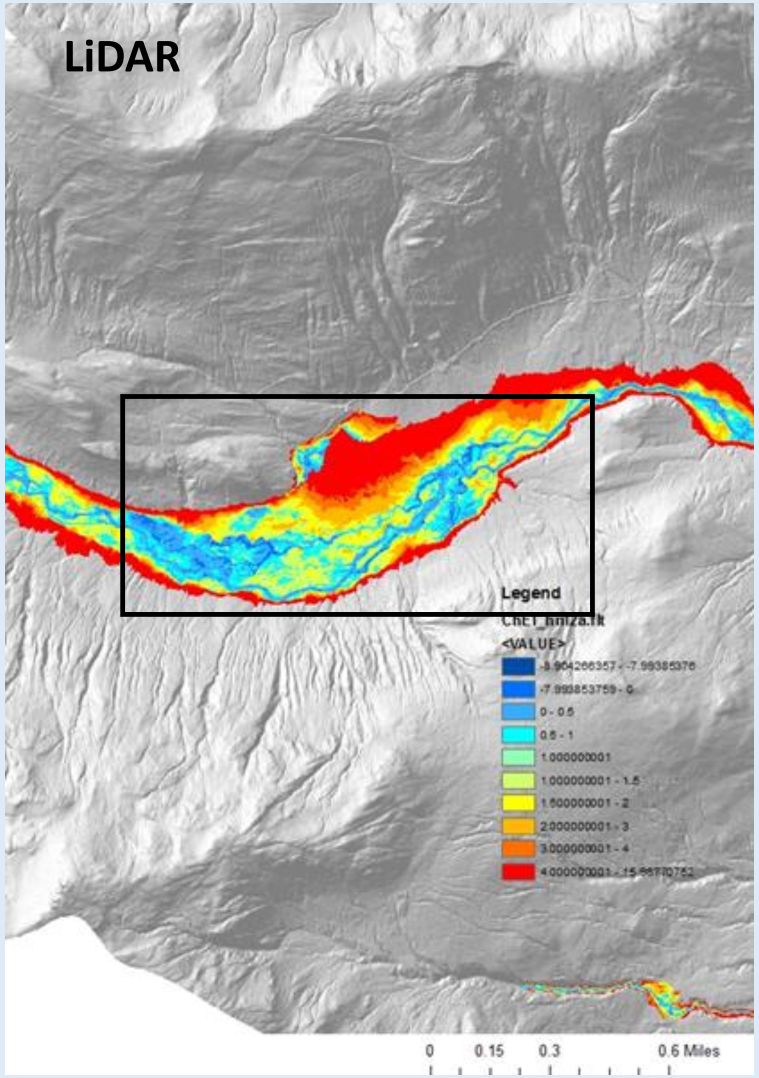


Bankfull channel width is an important component of salmon habitat models and it is used in calculating channel confinement, as floodplain width divided by channel width. Channel width is predicted using a regression equation based on 1,000 data points across SE AK. The model preformed very well.

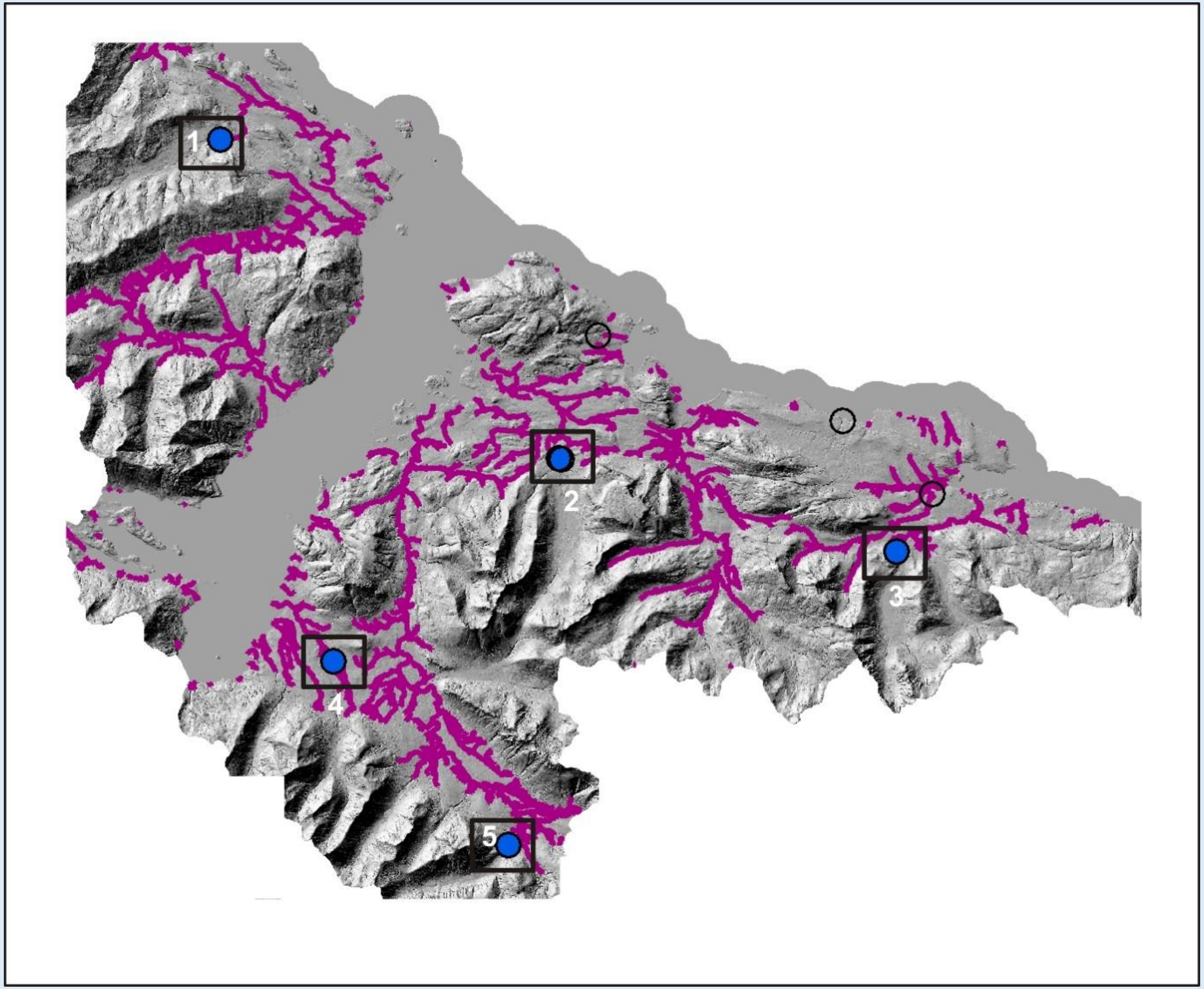
How Accurate is LiDAR for Predicting Channel Attributes Relevant to Gradient Barriers and Salmon Habitat Modeling?

Field data were collected in the Hoonah study area (at 43 sites) including channel gradient (using a survey station), channel bankfull width, bankfull depth and floodplain width.



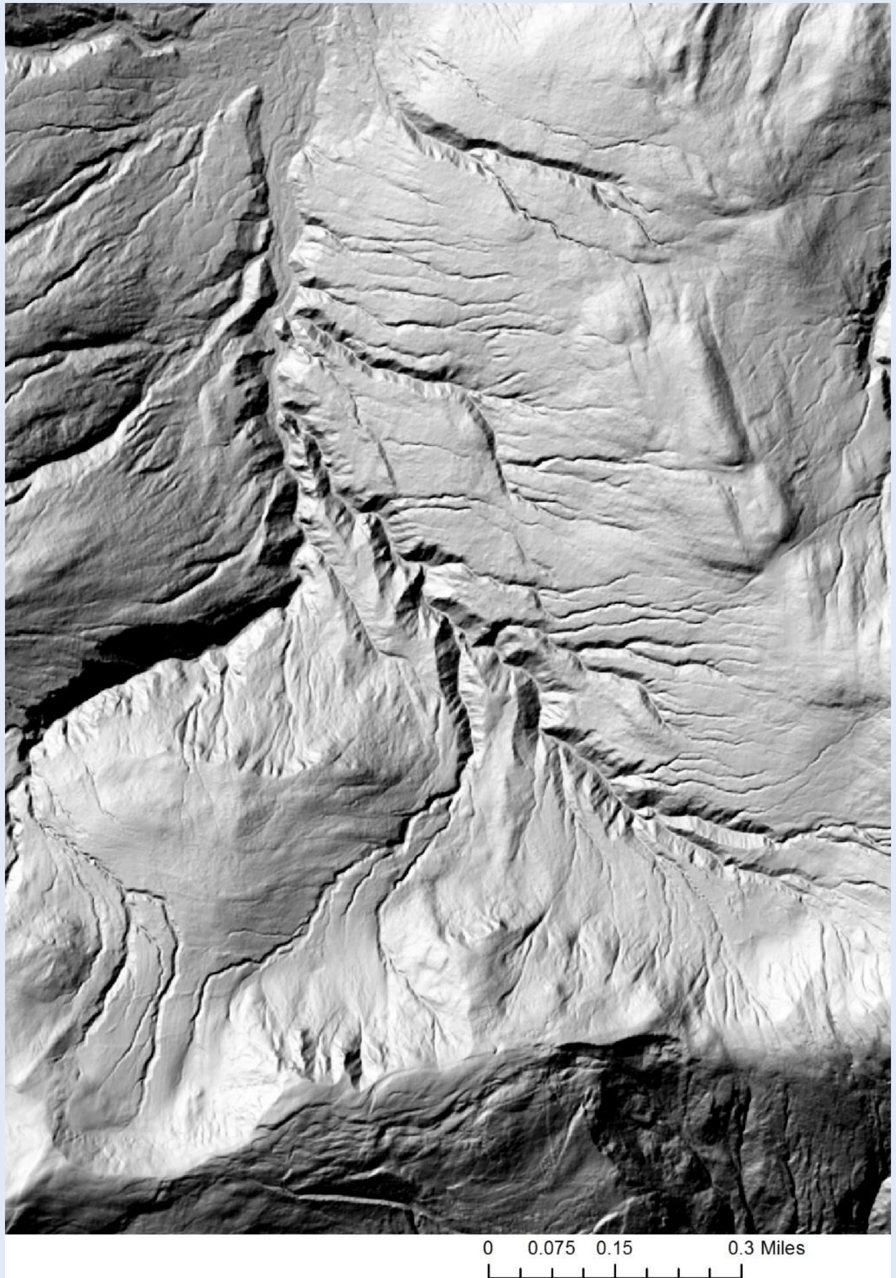


Mapping valley floor elevations and floodplains using LiDAR is highly accurate, thus predictions of channel confinement (valley width/channel width) in the salmon models is also considered accurate.

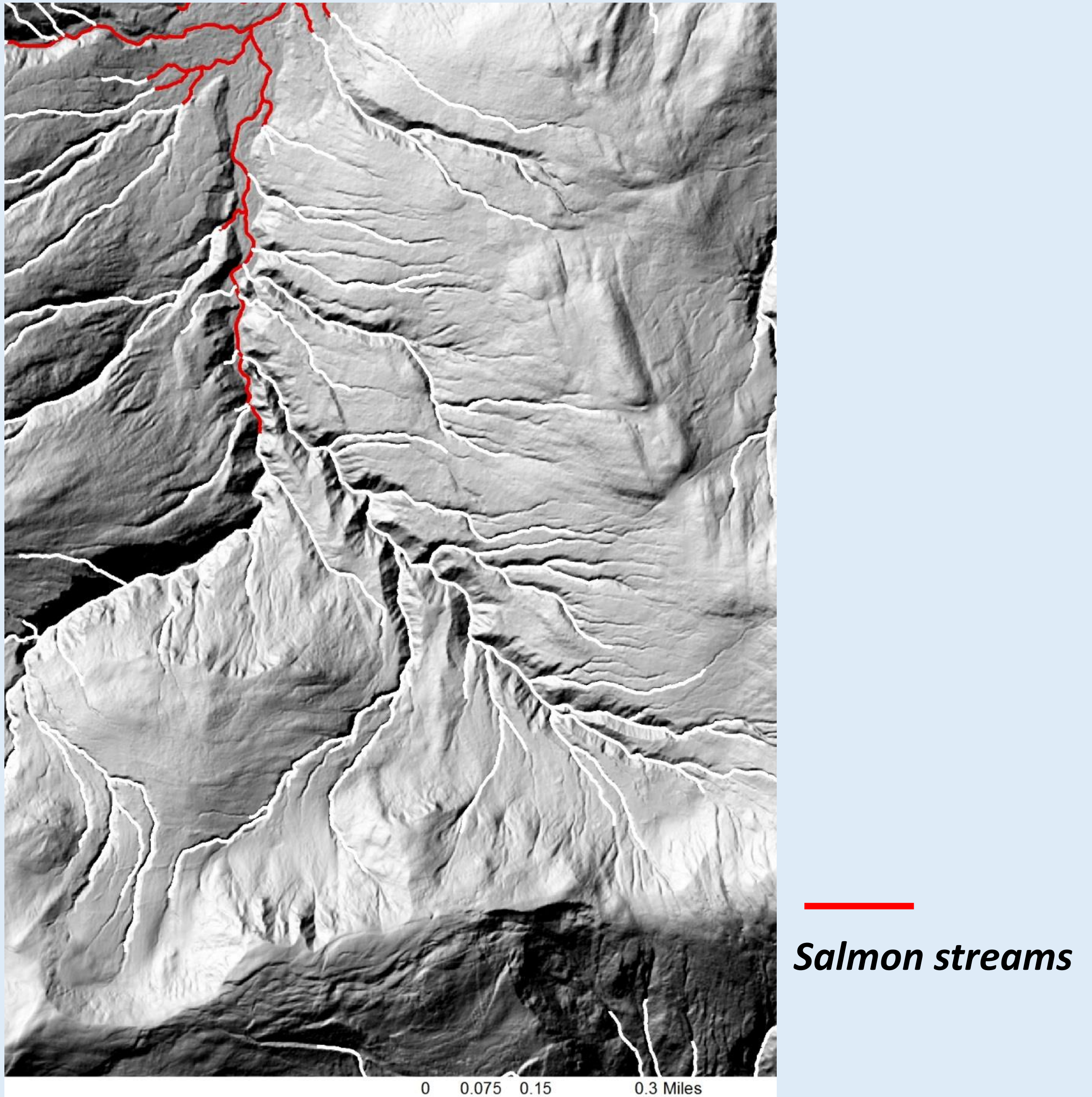


In addition, NetMap was able to detect 4 of 5 mapped waterfalls (in the SEAK-Hydro layer) > 3m using the LiDAR DEM; only waterfall #4 was not detected leading to a 1.5 km overestimation of salmon habitat.

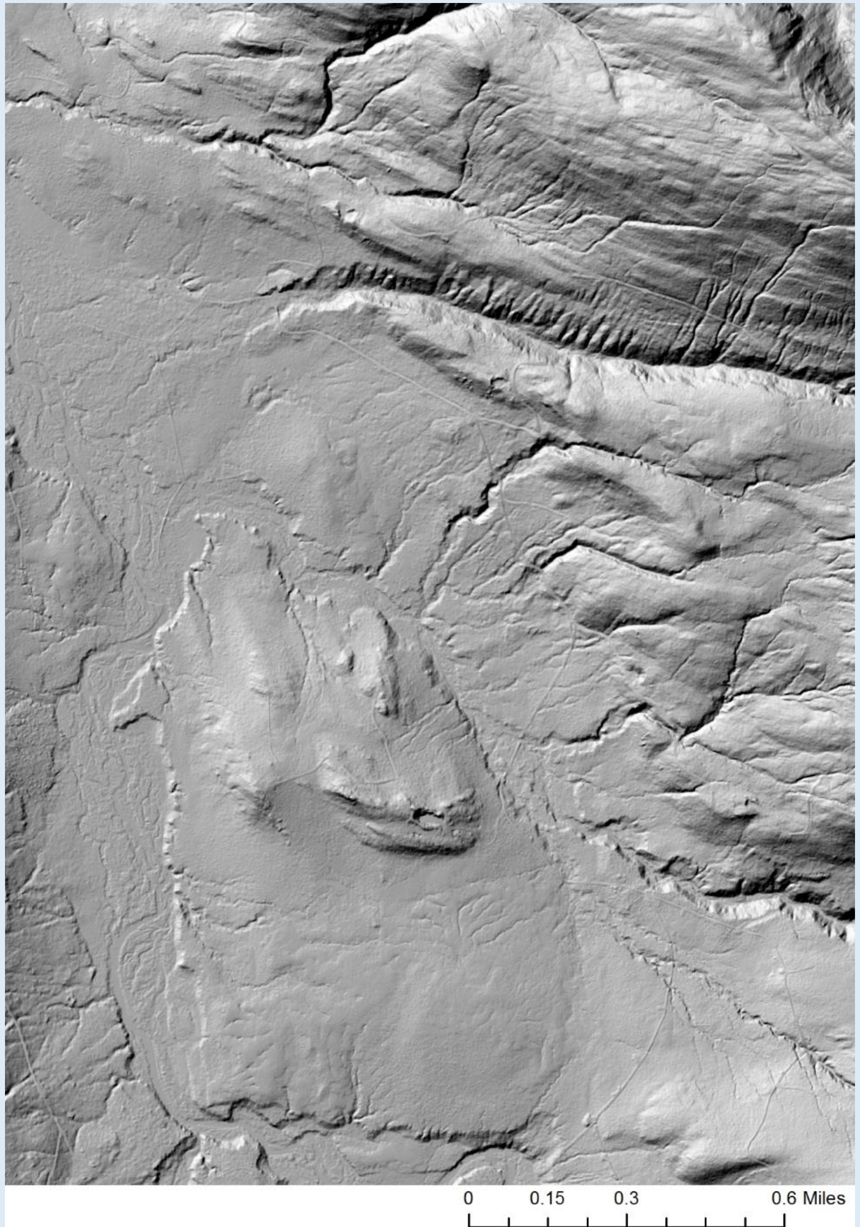
Using LiDAR, the topography related to stream channels is well represented in steeper areas



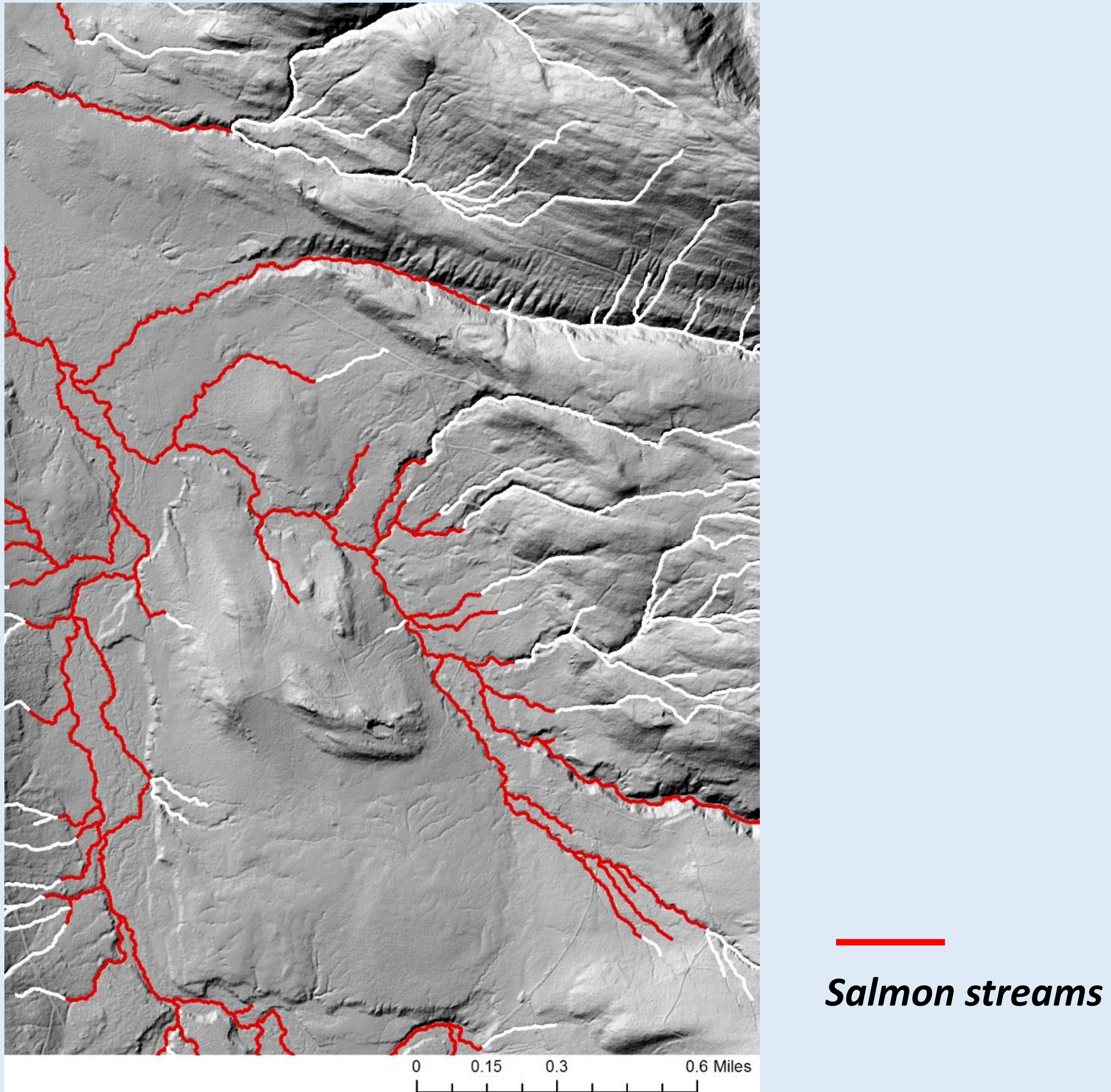
Indicating that channels are being accurately delineated (in this example, not all first order or ephemeral channels are even mapped)



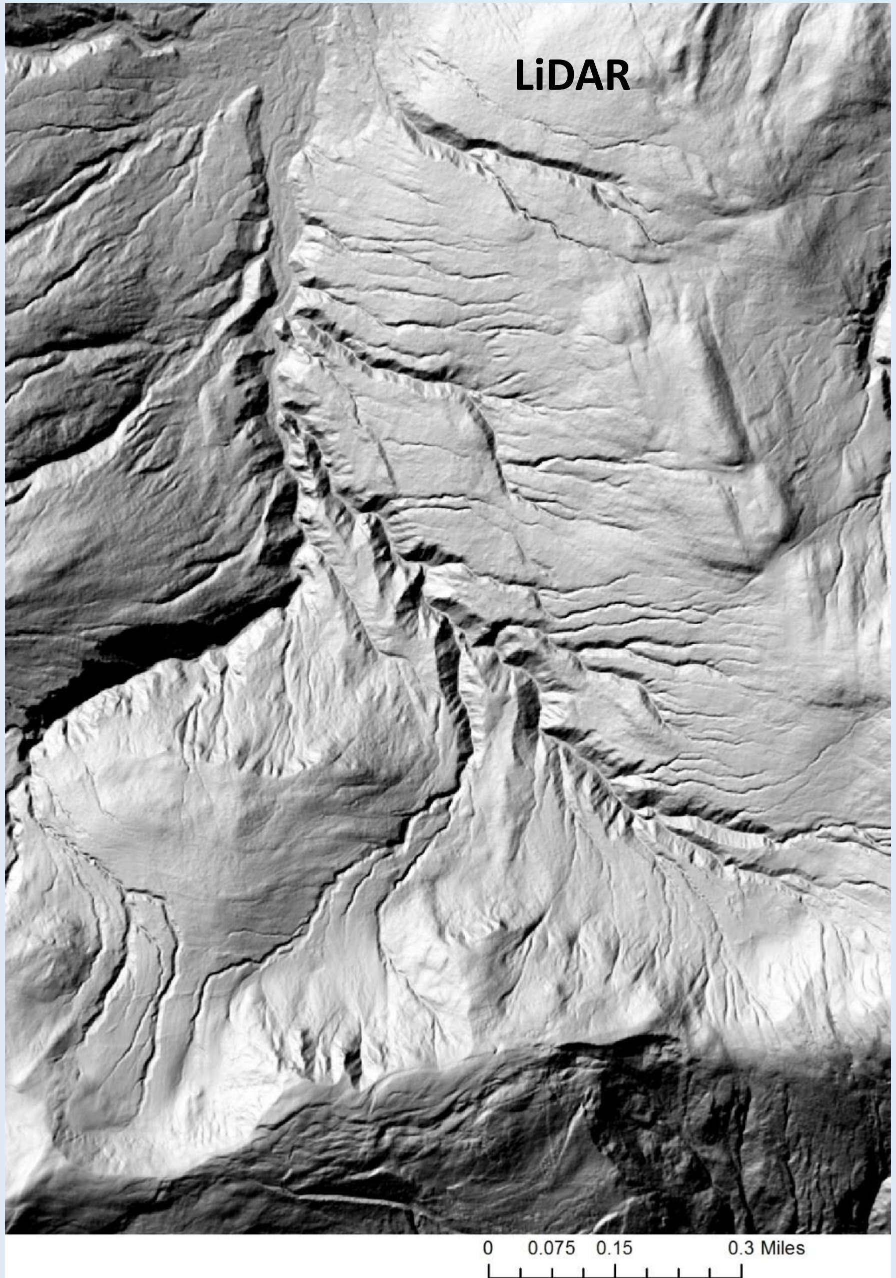
Using LiDAR, even in lower gradient areas, the topography related to stream channels is well represented



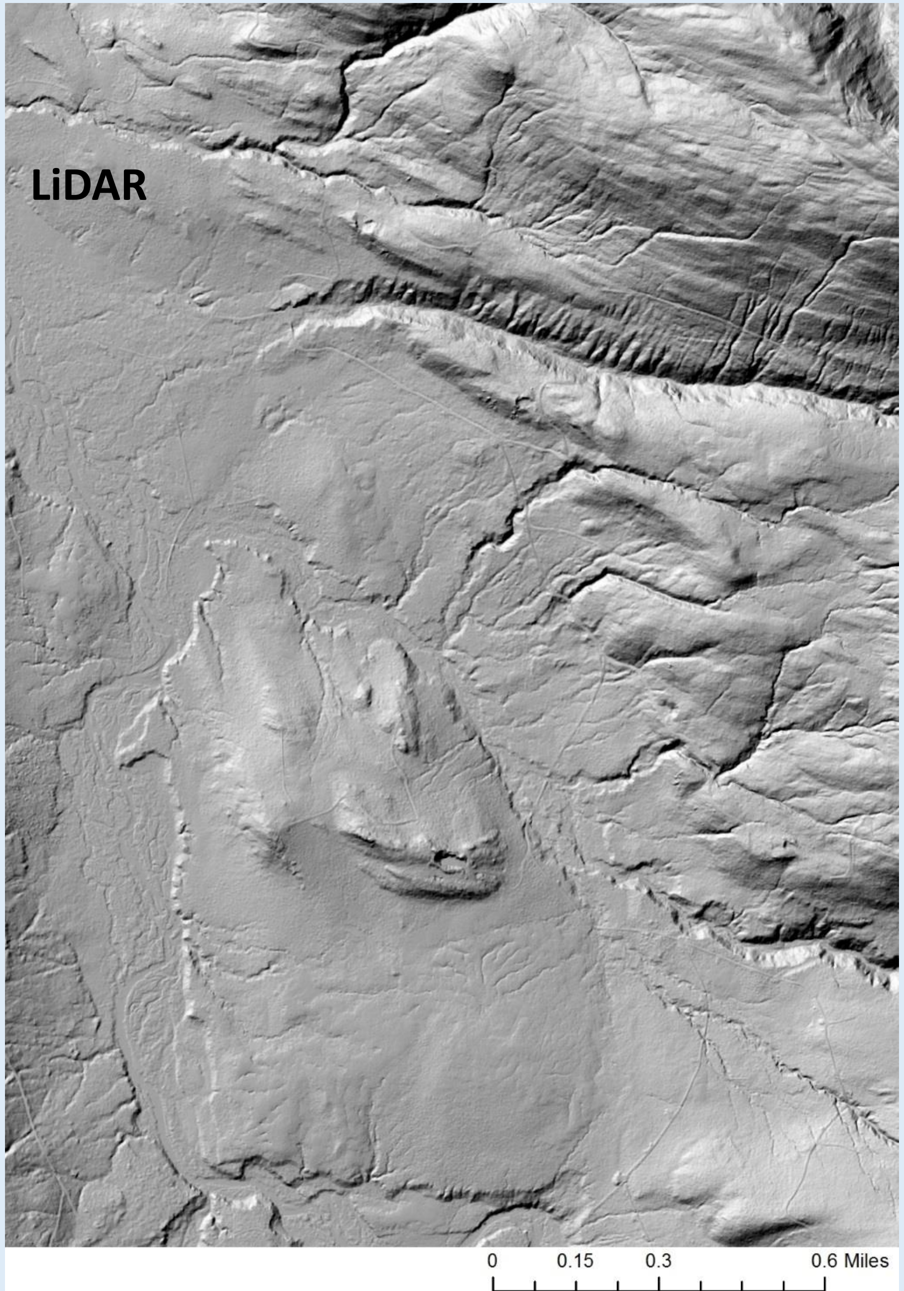
Indicating that channels are being accurately delineated

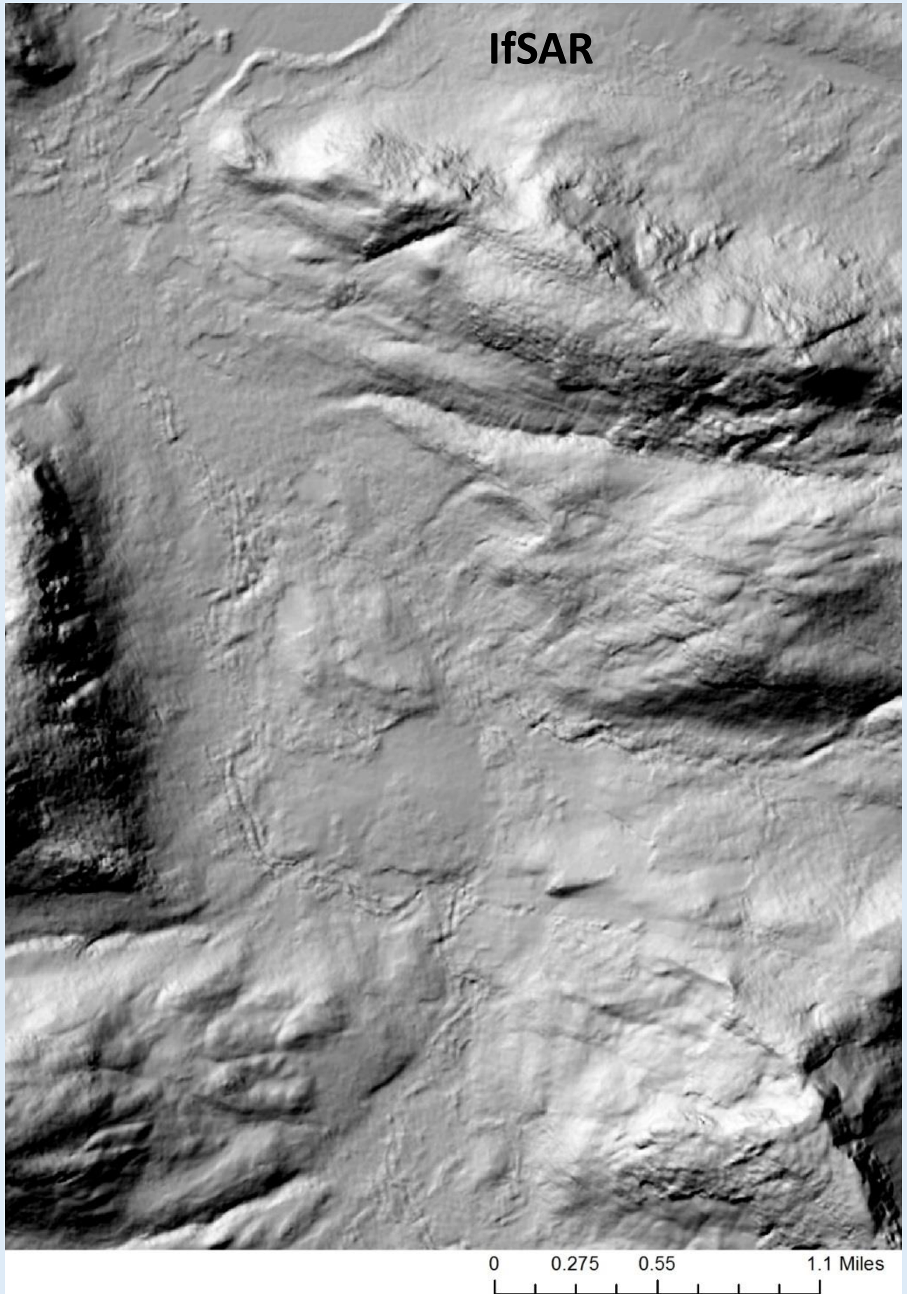


Compare topographic detail required to delineate streams (LiDAR vs IfSAR)

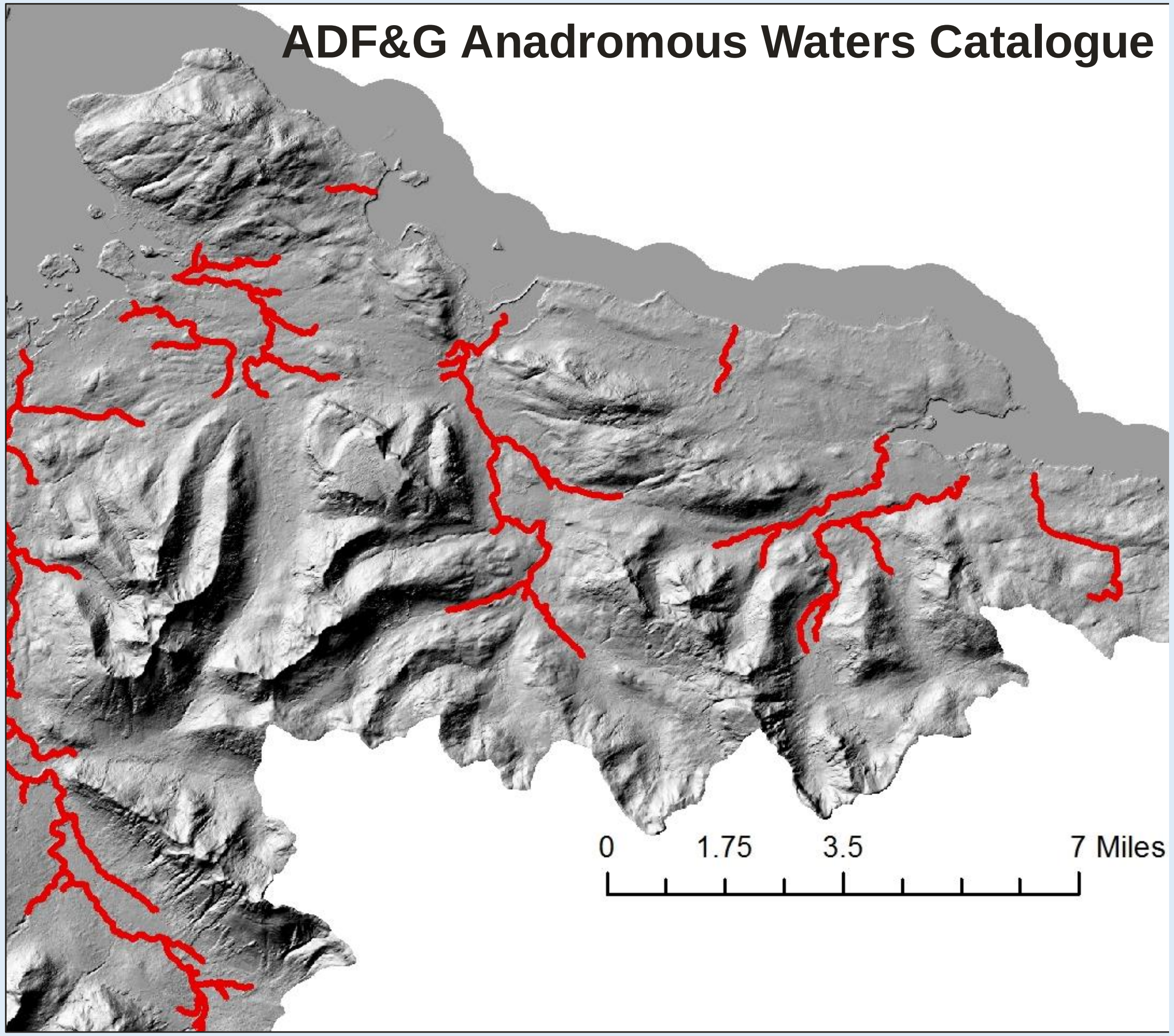


Compare topographic detail required to delineate streams (LiDAR vs IfSAR)

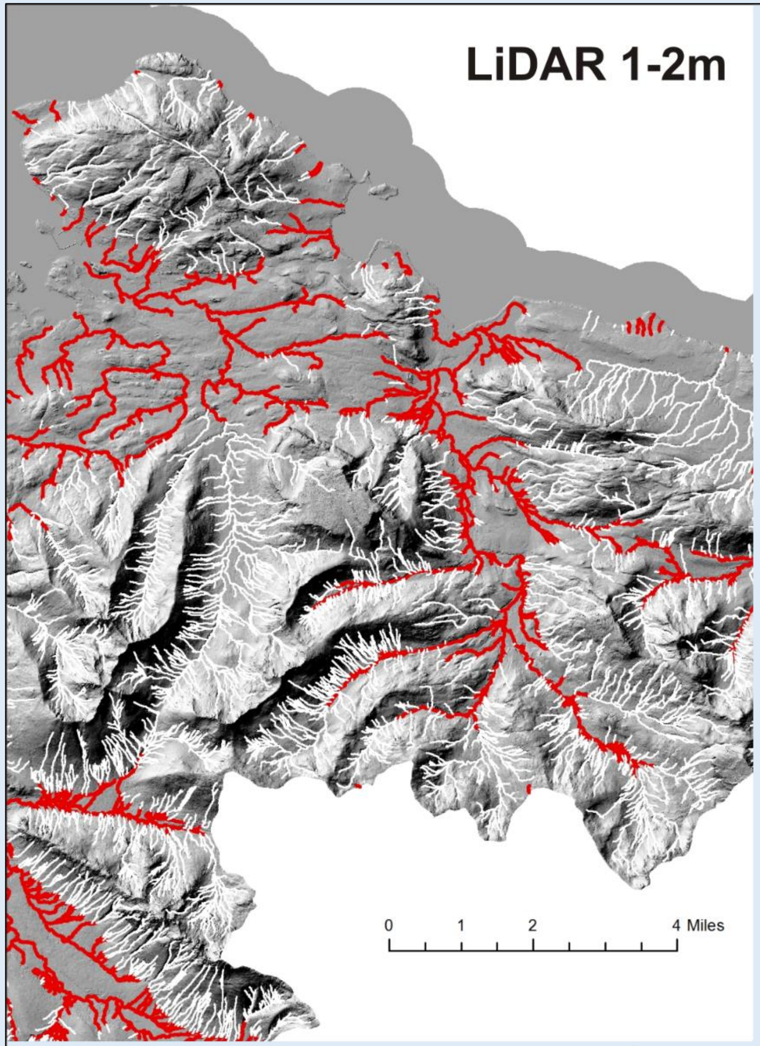




Compare the ADF&G AWC salmon extent with that predicted using the LIDAR DEM: AWC has 250% fewer potential salmon streams (based on length)



Drainage density salmon streams: 0.26 km km $^{-2}$



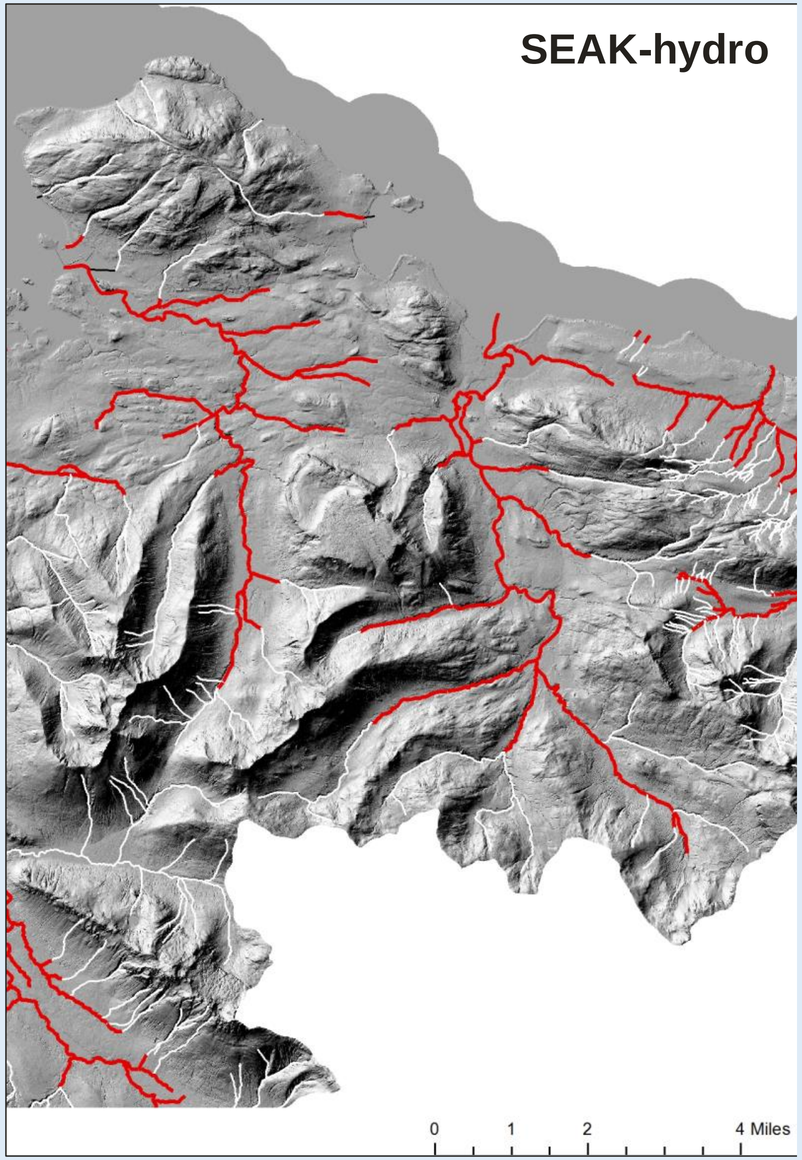
Drainage density all streams: 4.92 km km $^{-2}$

Salmon streams: 0.84 km km $^{-2}$ (gradient barriers)

Salmon streams: 0.67 km km $^{-2}$ (salmon models)

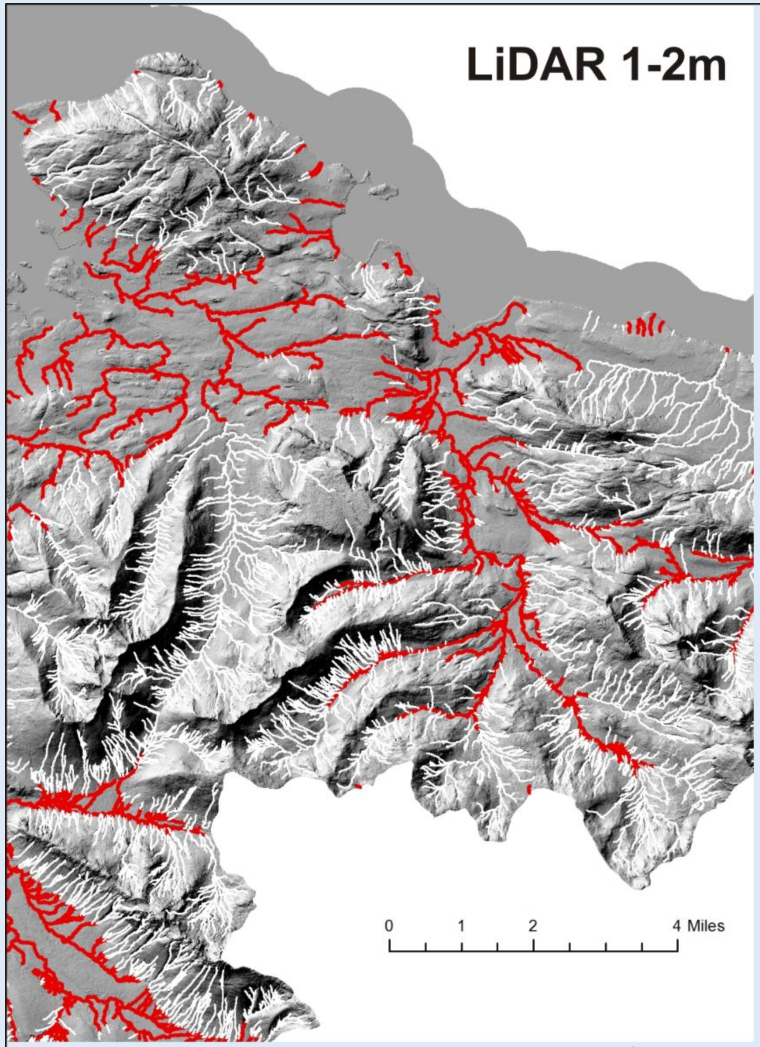
Salmon streams

Compare the SEAK-hydro (Tongass NF) salmon extent with that predicted using the LIDAR DEM: SEAK has about 140% fewer potential salmon streams (based on length)



Drainage density all streams: 1.39 km km $^{-2}$

Salmon streams: 0.44 km km $^{-2}$



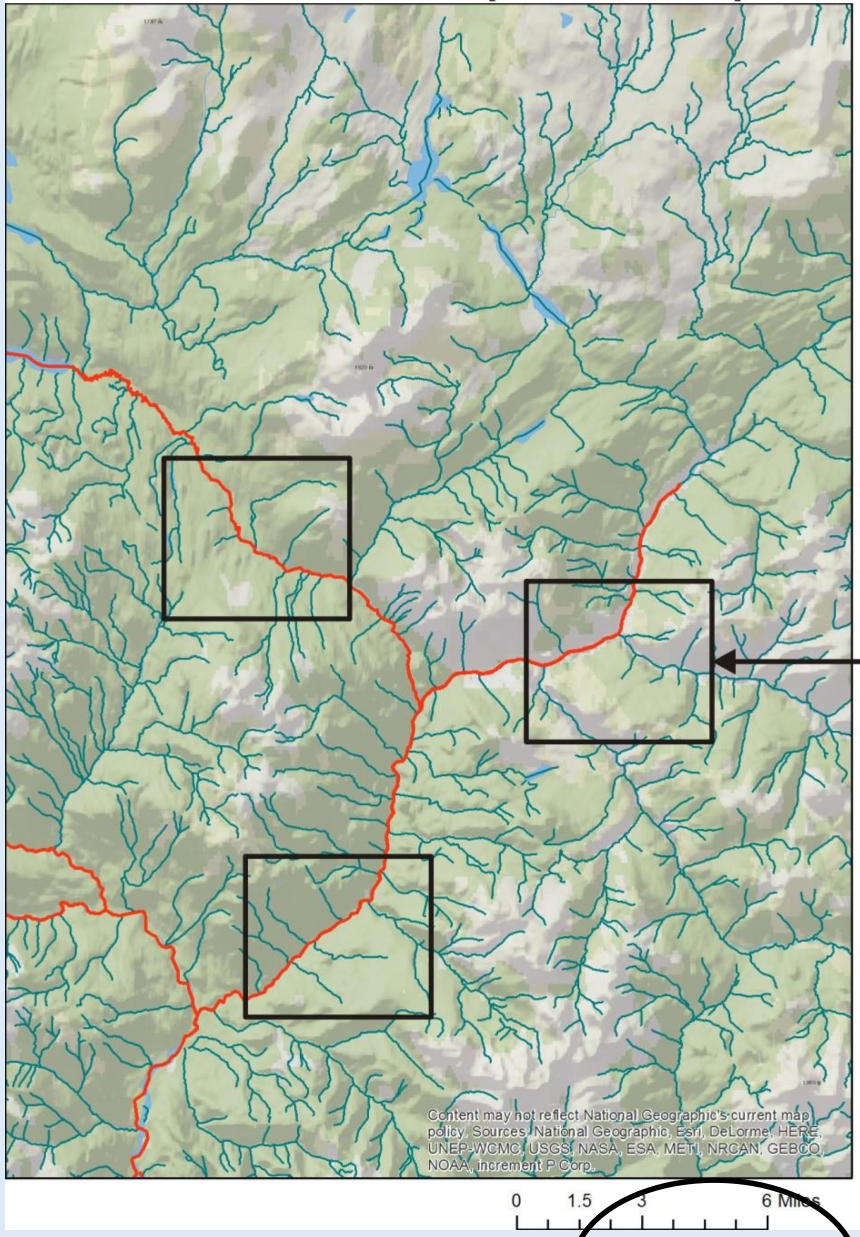
Drainage density all streams: 4.92 km km $^{-2}$

Salmon streams: 0.84 km km $^{-2}$ (gradient barriers)

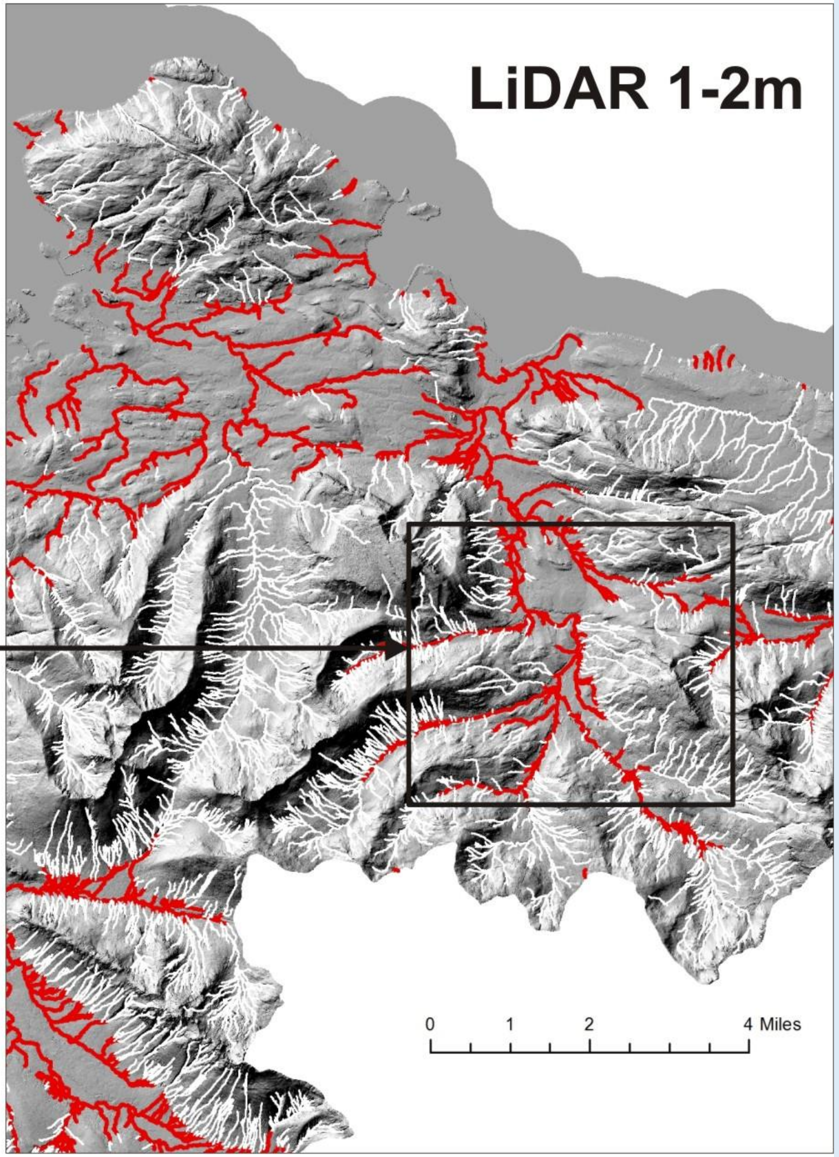
Salmon streams: 0.67 km km $^{-2}$ (salmon models)

Salmon streams

B.C. All streams (1:50,000)



Drainage density all streams: 1.37 km km^{-2}



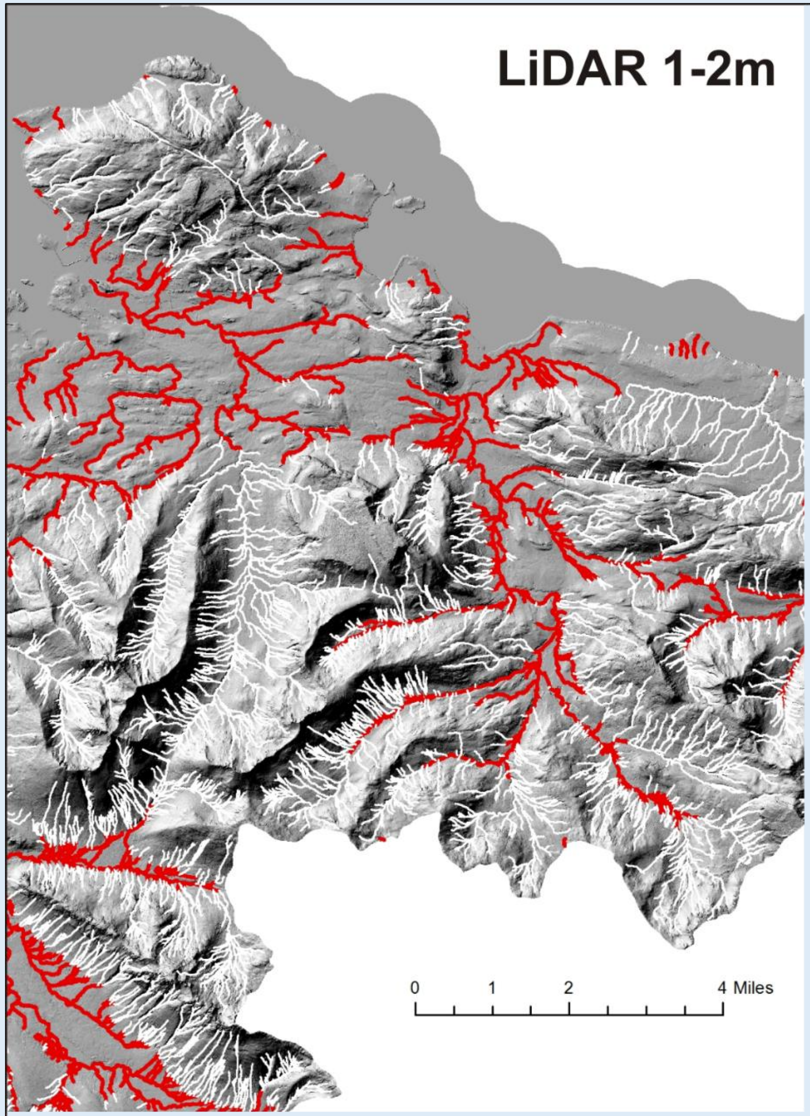
Drainage density all streams: 4.92 km km^{-2}

Let's check out what is available in B. C. coastal watersheds.

Note that the boxes in the two images are of the same scale; the streams in the box on the right indicates how many streams are missing in the B.C. trans-boundary area; the B.C. streams (Provincial hydrography) have about 260% less stream length compared to the LiDAR).

B.C. Fish Streams

Drainage density all streams: 1.37 km km^{-2}
Salmon streams: 0.22 km km^{-2}

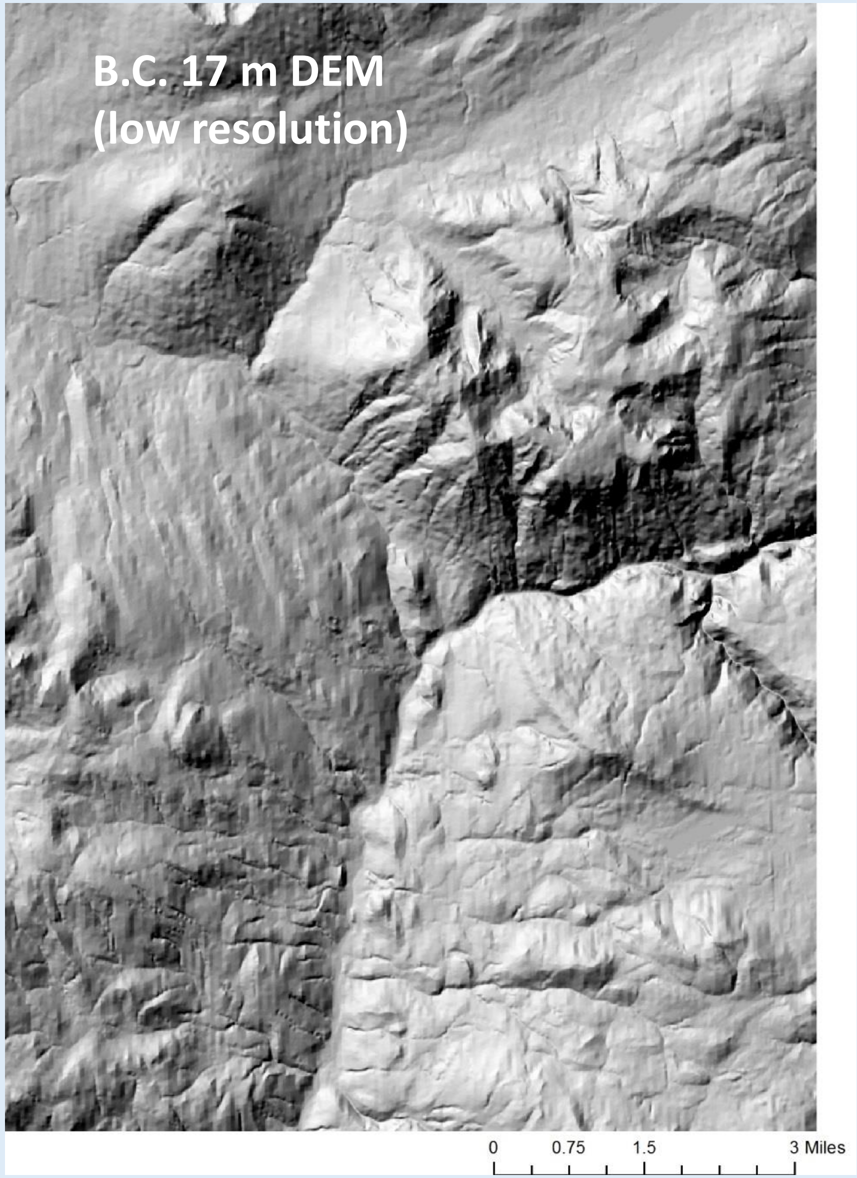


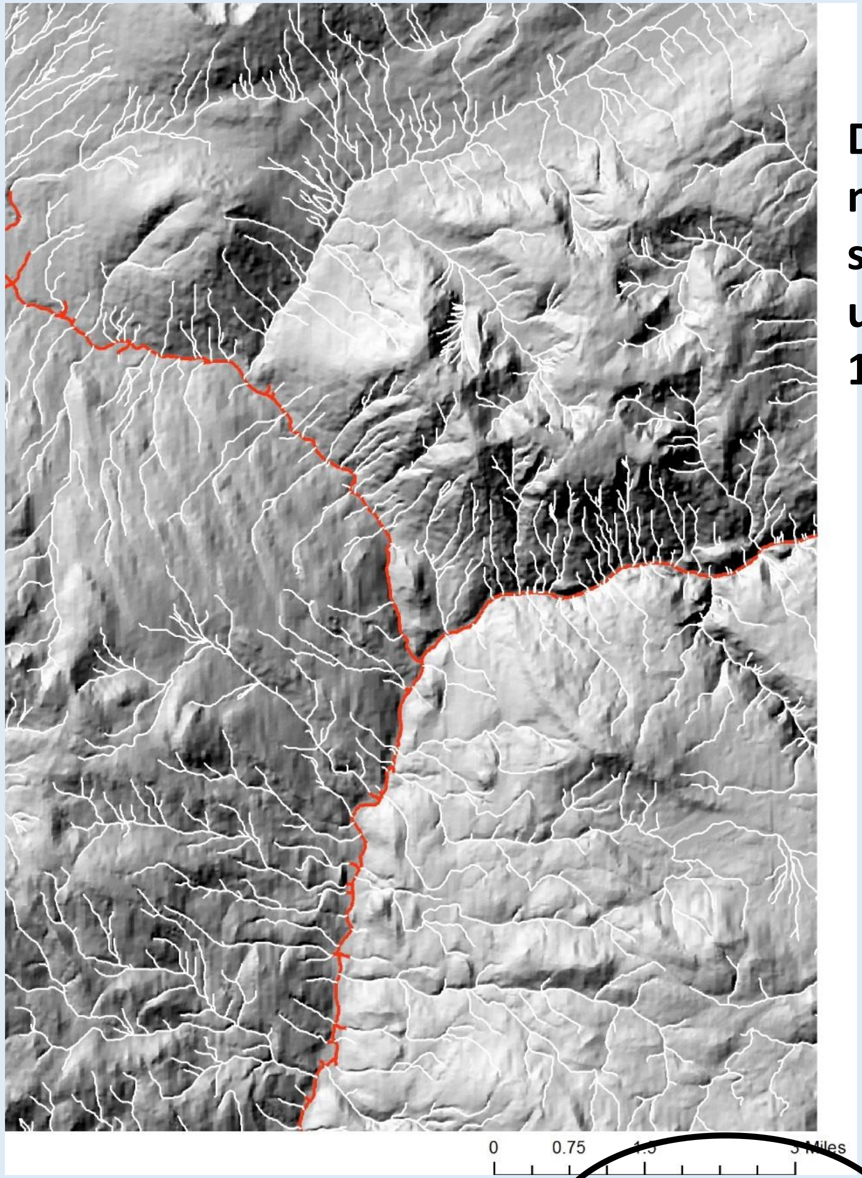
Drainage density all streams: 4.92 km km^{-2}

Salmon streams: 0.84 km km^{-2} (gradient barriers)
Salmon streams: 0.67 km km^{-2} (salmon models)

Note that the B.C. fish streams (includes salmon) on the left has a density of 0.22 km km^{-2}, compared to the potential salmon stream density using LiDAR (0.84-0.67 km km^{-2}); this strongly suggests that salmon streams in B.C. might be underestimated (in length) by as much as 300% (and if modeling potential salmon habitat using the B.C. 17m DEM by as much as 180 to 500%.

Can we delineate more complete stream networks and salmon habitat in B.C. using the available 17m DEM across the coastal watersheds?





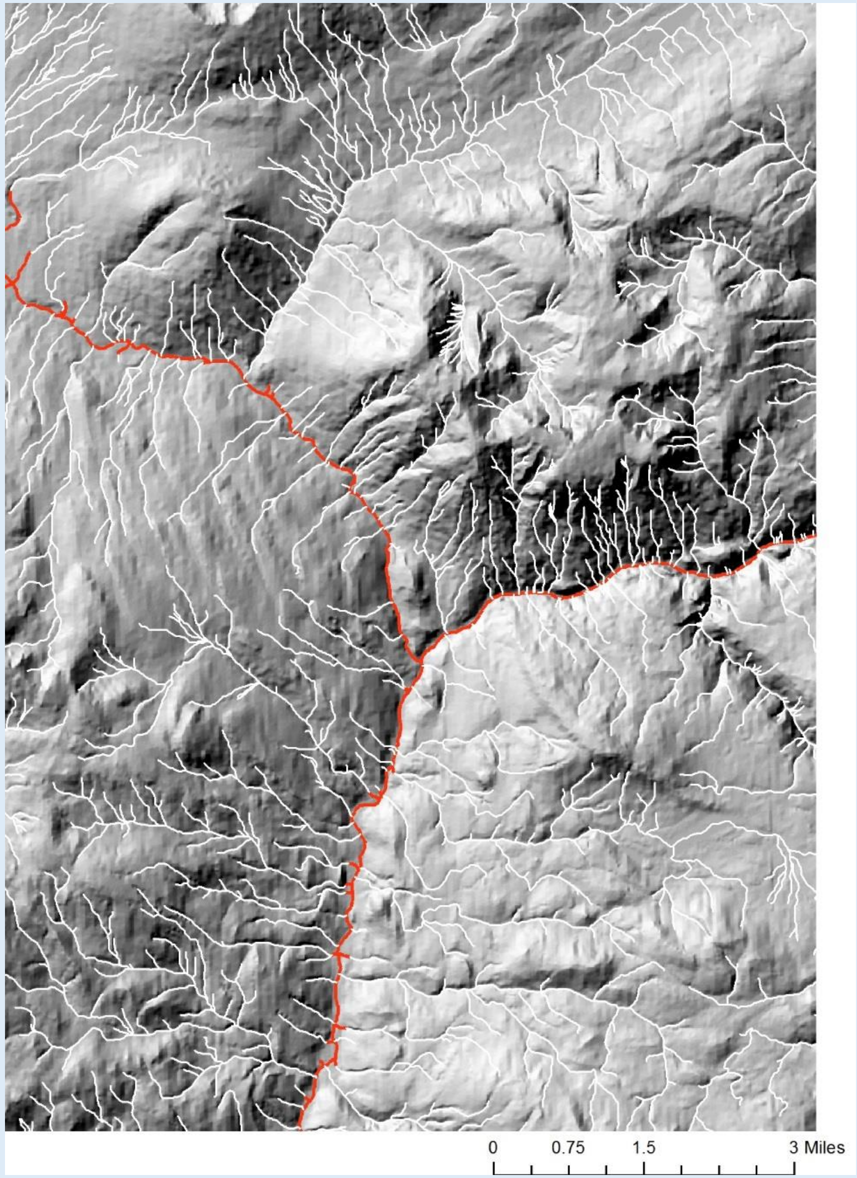
Derived stream network and salmon streams using the B.C. 17m DEM

Salmon streams

Drainage density all streams: 2.85 km km^{-2}

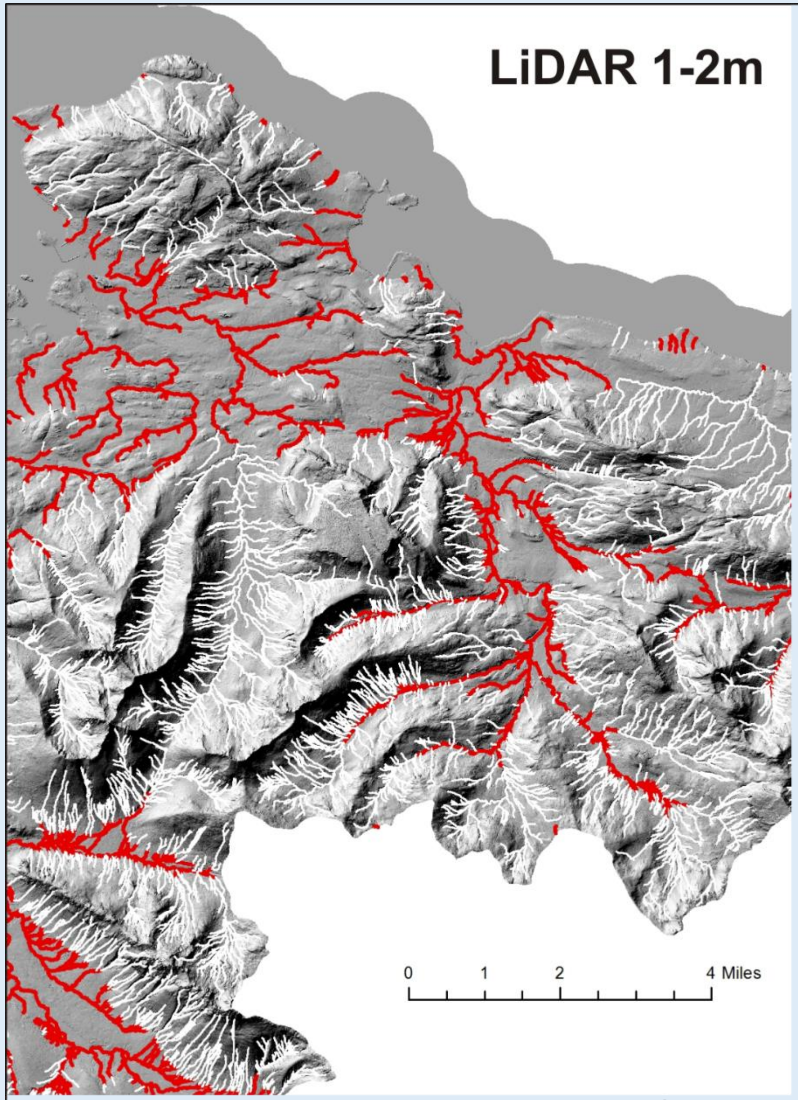
Fish streams: 0.29 km km^{-2}

Compare the derived stream network using B.C. 17m DEM with streams using a 1-2m LiDAR DEM



Drainage density all streams: 2.85 km km^{-2}

Fish streams: 0.29 km km^{-2} ←



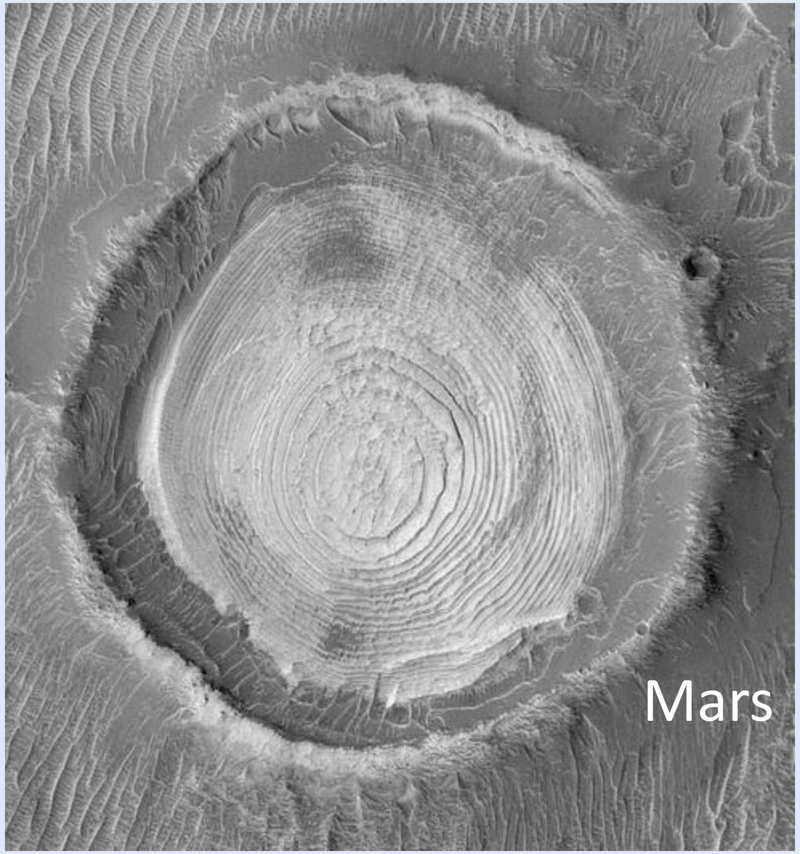
Drainage density all streams: 4.92 km km^{-2}

Salmon streams: 0.84 km km^{-2} (gradient barriers) ←

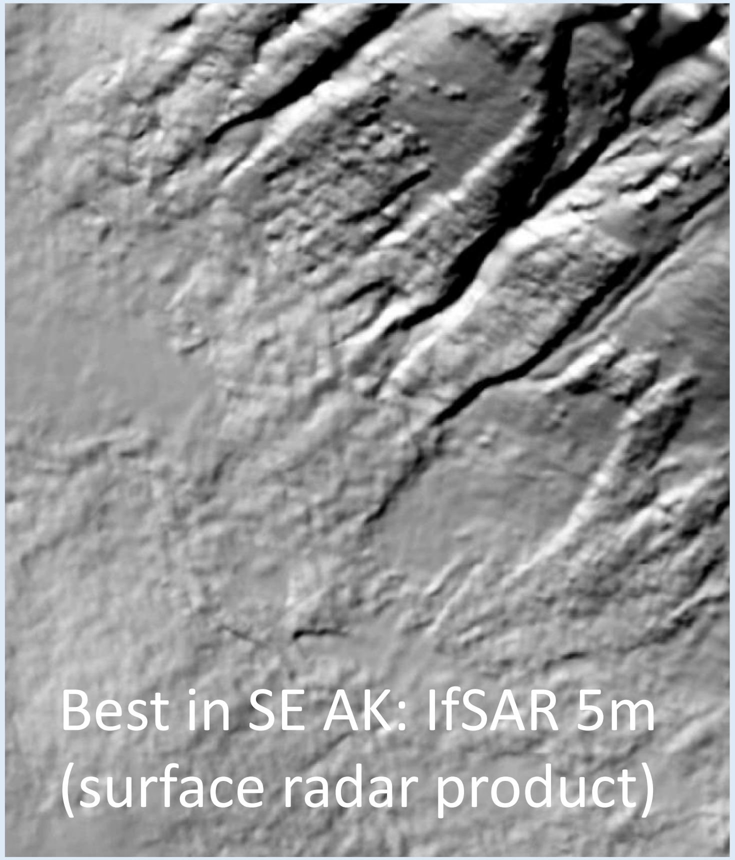
Salmon streams: 0.67 km km^{-2} (salmon models) ←

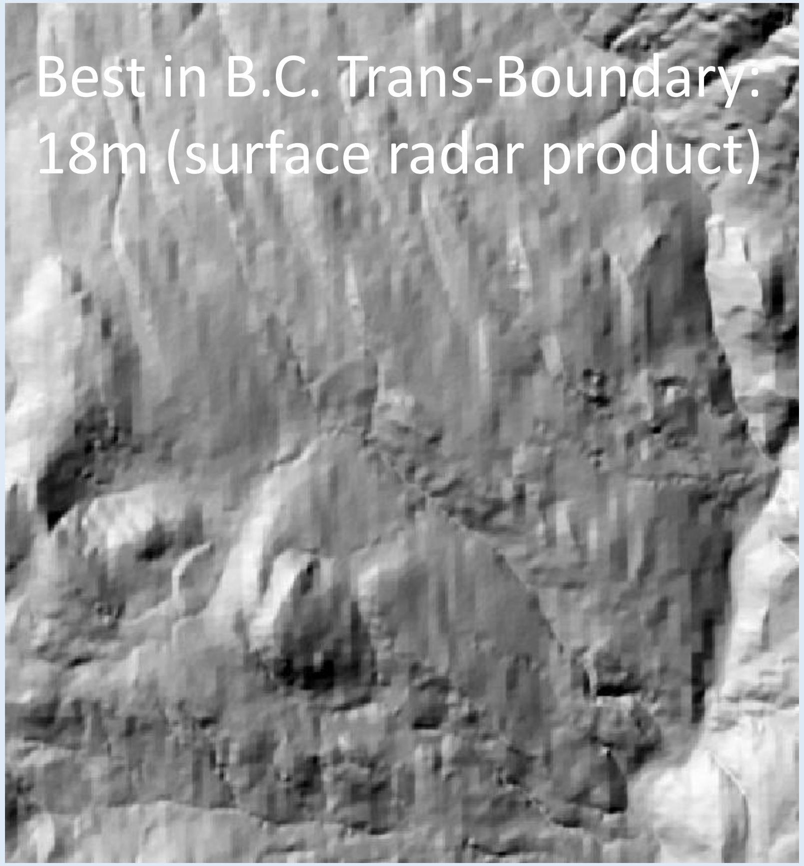
Salmon streams

Mars have better digital elevation models and maps than the U.S.–Canadian Trans Boundary Region?



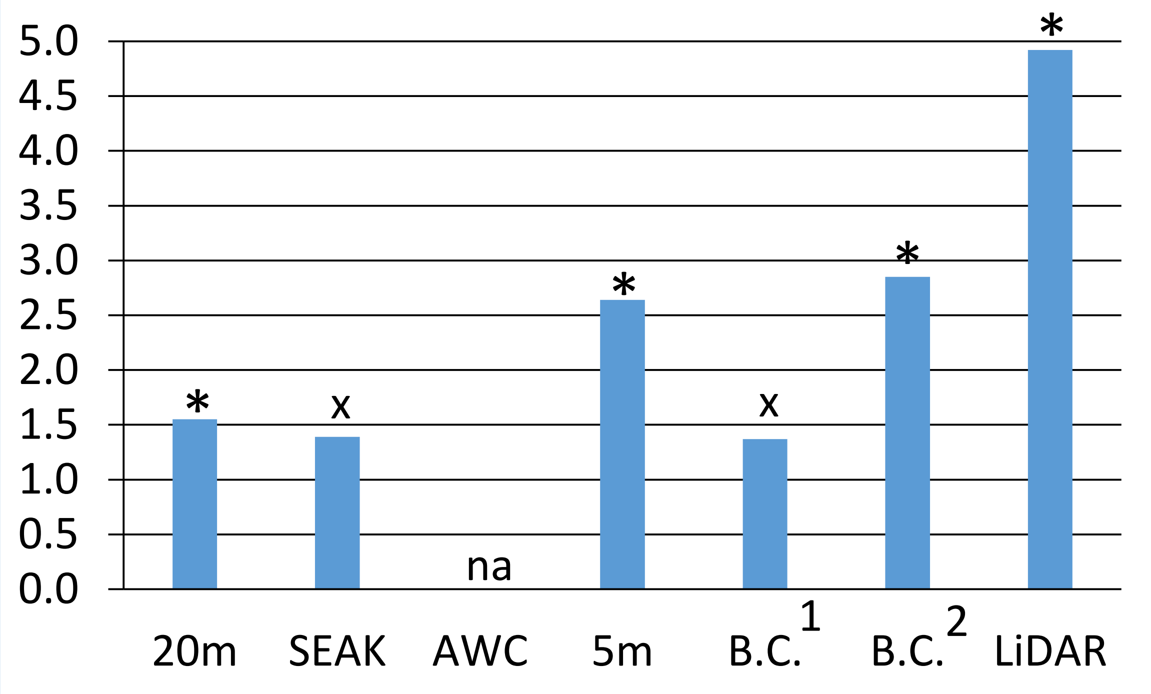
Remember the “Schiaparelli Crater” in “The Martian”



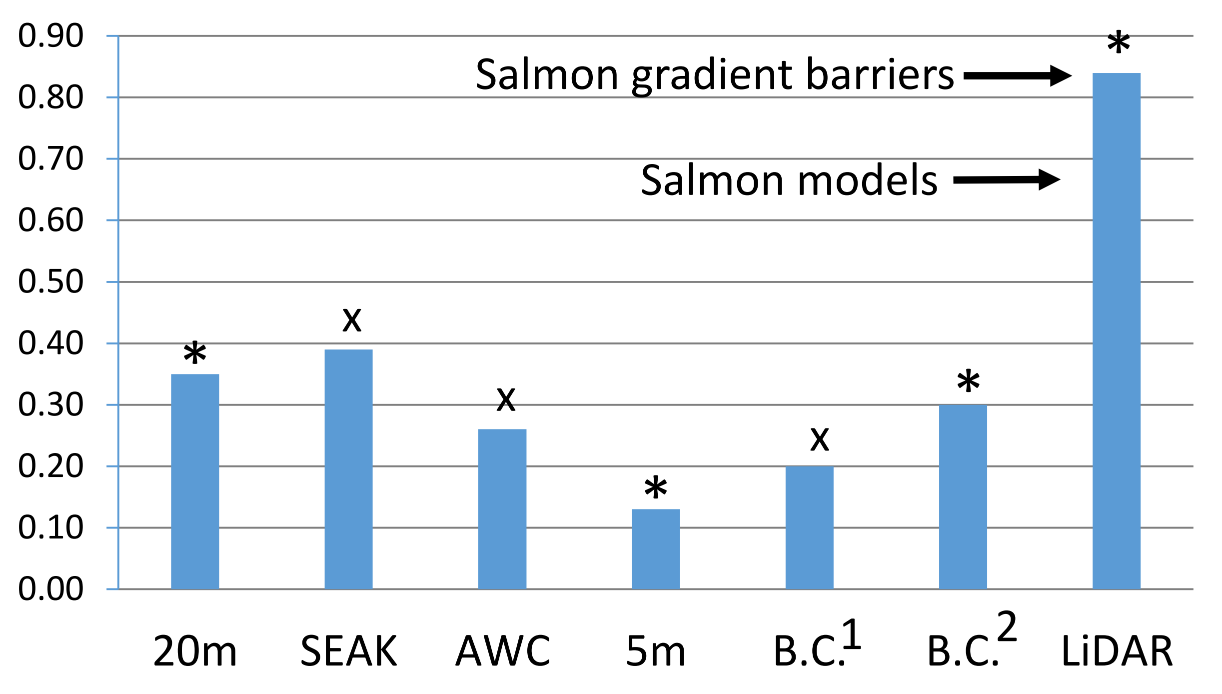


Data Analysis: Contrast the abundance of all streams and salmon streams only across existing data products and DEMs

Abundance of all streams by density (km km^{-2})



Salmon stream abundance by density (km km^{-2})



* Stream networks derived from DEMs

x Cartographic stream layers (existing map products)

Histograms showing the relative differences in mapped streams (all) and salmon habitats only.

* Potential salmon streams, predicted using synthetic river networks derived from DEMs and by gradient barriers and models

B.C. = British Columbia (Stikine, Taku, & Unuk Rivers)

B.C.[1] = B.C. 1:50,000 Provincial stream layer

B.C.[2] = Streams derived from B.C. 18m DEM

Table 1. Comparison (numeric differences) of existing and modeled streams and salmon habitats (based on existing data products and DEMs) with LiDAR (1-2m) derived streams and salmon habitats using gradient barriers and salmon habitat modeling.

Locations and Data Layers	All streams (km km^{-2})	All streams difference from LiDAR (km km^{-2})	Salmon Streams-gradient barrier	Salmon streams barrier difference from LiDAR (km km^{-2})	Salmon stream modeling	Salmon stream modeling difference from LiDAR (km km^{-2})
Southeast Alaska						
ADF&G AWC	--	--	0.26 (field valid)	0.58	--	0.41
USFS 20m	1.5	3.4	0.35	0.49	0.3	0.37
SEAK-Hydro	1.4	3.5	0.39	0.45	--	
IfSAR 5 m	2.6	2.3	0.13	0.71	.10	0.57
LiDAR	4.9	--	0.84	--	0.67	--
B.C.						
Provincial Stream Layer	1.4	3.5	0.2 (attribute in fish layer)	.64	--	--
17m BC DEM	2.85	2.1	0.3	.54	0.11	0.56

Table 2. Comparison (percent differences) of existing and modeled streams and salmon habitats (based on existing data products and DEMs) with LiDAR (1-2m) derived streams and salmon habitats using gradient barriers and salmon habitat modeling. Anything over 100% means that more than half or more of the length of salmon streams are not identified or mapped.

Locations and Data Layers	All streams (km km-2)	Difference percent from LiDAR (km km^{-2})	Salmon Streams- gradient barrier	Salmon barrier difference percent from LiDAR (km km^{-2})	Salmon, modeling	Salmon modeling difference percent from LiDAR (km km^{-2})
Southeast Alaska						
ADF&G AWC	--	--	0.26 (field valid)	-220%	--	-160%
USFS 20m	1.5	-226%	0.35	-140%	0.3	-125%
SEAK-Hydro	1.4	-250%	0.39	-115%	--	
IfSAR 5 m	2.6	-88%	0.13	-540%	.10	-570%
LiDAR	4.9	--	0.84	--	0.67	--
B.C.						
Provincial Stream Layer	1.4	-250%	0.2 (attribute in fish layer)	-320%	--	--
17m BC DEM	2.85	-72%	0.3	-180%	0.11	-500%

Table 3. Estimated missing stream length from current map products and from models using existing DEMs across southeast Alaska (77,000 km^2, 30,000 mi^2) and in coastal B.C. watersheds (100,000 km^2, 39,000 mi^2), and combined (177,000 km^2, 68,000 mi^2).

Location	All Streams – Current maps/data products	All Streams – Modeled Existing DEMs (not done)	Salmon Streams – Current data products	Salmon Streams – Modeled using existing DEMs (not done)
Southeast Alaska	270,000 km[1] (165,000 miles)	177,000 km[2] (110,000 miles)	34,650 km[3] (21,530 miles)	28,490 km[4] (17,700 miles)
B. C.	350,000 km (217,000 miles)	210,000 km (106,000 miles)	64,000 km (39,700 miles)	56,000 km (34,800 miles)
Entire US-Canada Trans-Boundary	620,000 km (384,000 miles)	387,000 km (240,000 miles)	98,650 km (62,000 miles)	84,500 km (52,505 miles)
Perspective	1.6 x distance to the moon	to the moon	stretch around the earth ~2 times	stretch around the earth 2 times

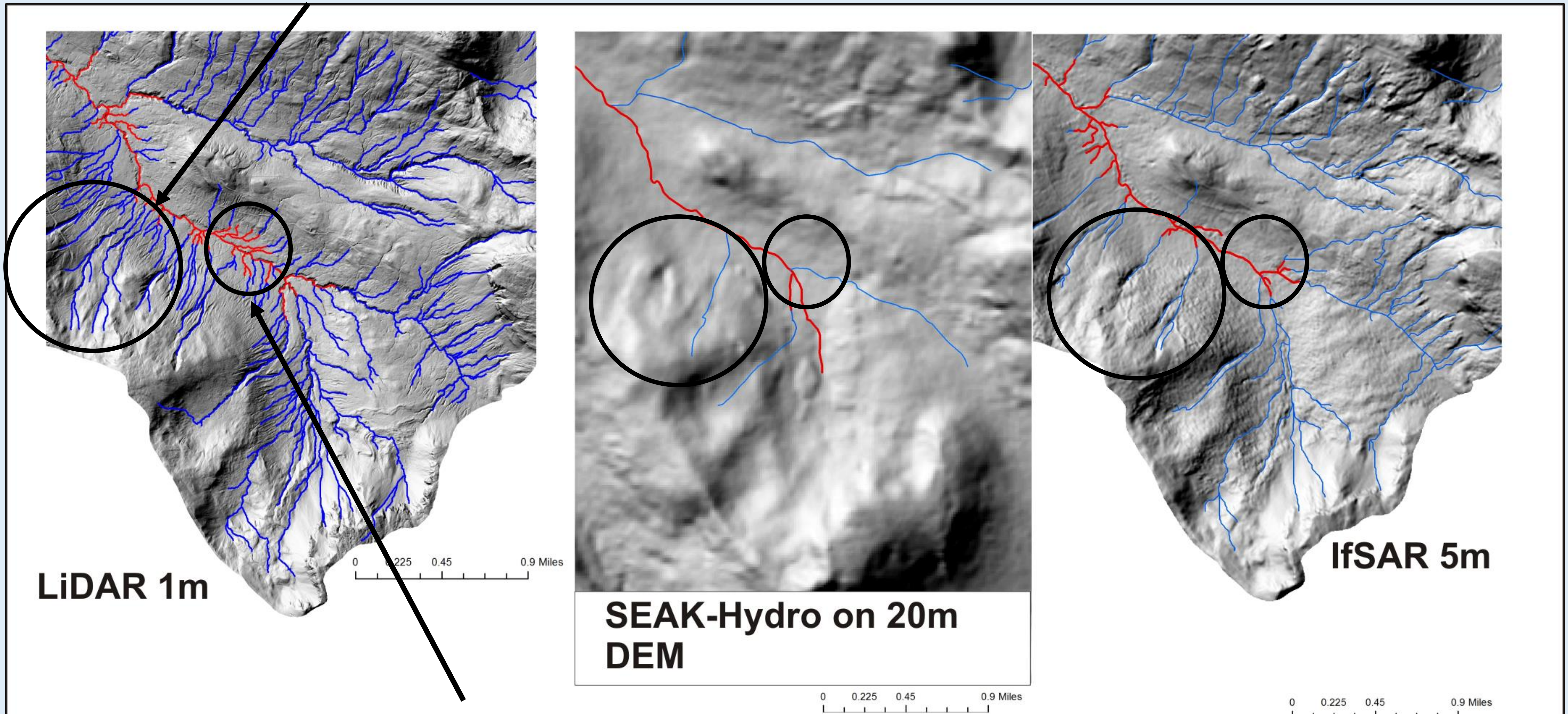
Of course there is uncertainty around these estimates.

But one thing is for sure: there is a very large length of stream channels overall, and salmon habitats specifically, that are not identified on existing maps or that can be derived from existing DEMs

[1] Use SEAK-Hydro
[2] Use IfSAR 5m
[3] Use SEAK-Hydro
[4] Use IfSAR 5m

So, which streams are missing?

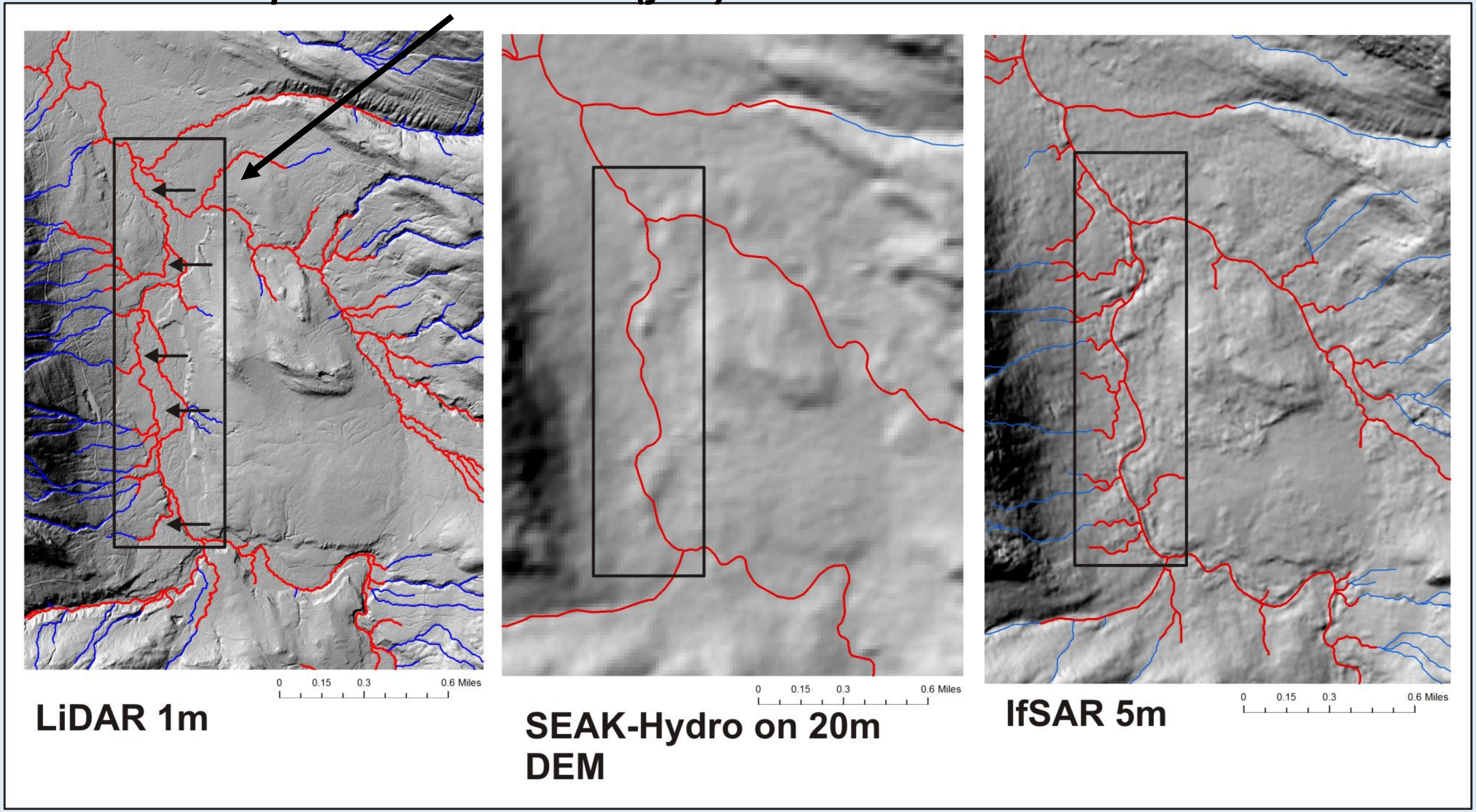
Headwaters (no fish, but creates fish streams at their lower ends)



Lower ends of headwaters on valley floors (fish)

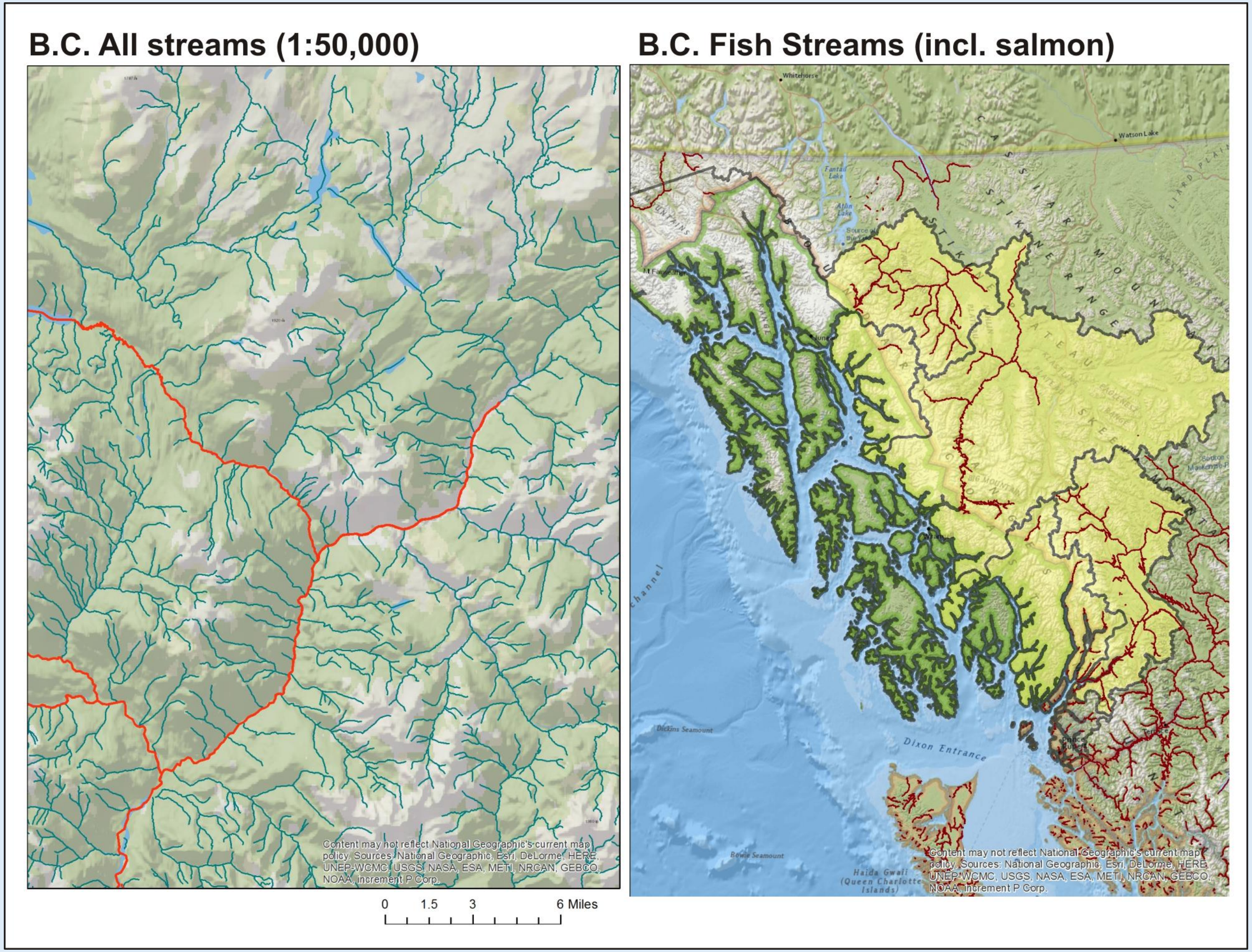
So, which streams are missing?

Floodplain side channels (fish)



So, which streams are missing?

In B.C., the same types of streams are missing as in SE AK; however some of the smaller tributaries may also be missing, and larger fish bearing tributaries as well.



In the trans-boundary region, the predicted length of all missing streams could be as high as 300,000 miles (distance to the moon is 240,000 miles).

The predicted length of missing salmon streams is about 50,000 to 60,000 miles (85,000 to 98,000 kilometers (about 2 times around the world).

Implications

How can federal, state and provincial agencies evaluate potential environmental impacts associated with timber harvest, road building, hydro-development and mining, if they don't even know the accurate locations and abundances of salmon habitats, or river networks in general.

The majority of salmon streams remain undetected, unmapped and thus unprotected in much of the Trans-Boundary area.

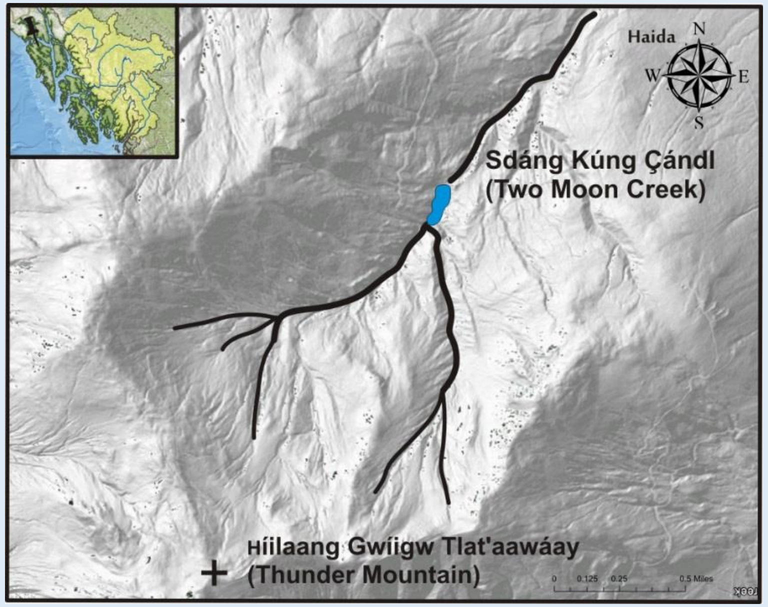
This represents the most basic limitation on science, resource management and conservation.

The delineation of complete river networks and accurate salmon habitat identification will not be achieved in the U.S.-Trans Boundary region until LiDAR DEMs become available.

TerrainWorks is launching a crowdfunding campaign to fund the acquisition of LiDAR DEMs and to create as complete-as-possible river networks and to identify all potential salmon habitats across the 80,000 mi^2 southeast Alaska and coastal B.C. Trans-Boundary landscape. Launch date is early summer 2016.

The LiDAR topographic database will be utilized by, and underpin, research, resource management and conservation by all stakeholders for many decades. Its uses will be extensive.

Add data products will be freely accessible and housed at a location to be determined.



Successful crowdfunding requires supporters to receive rewards.

One unique reward is that supporters would nominate names for the newly discovered and mapped streams (and possibly other currently unnamed geographic features) in the languages of the Native Peoples in SE AK and B.C (Eyak, Haida, Tlingit, Tsimshian, Nisqaa, Gitsan, Tahltan and Tagish).

Place names will be viewable in the online Map Atlas "Salmonidae Geographica" that will also house all of the open source LiDAR products, complete river networks, salmon habitats and other key topographic features (floodplains etc.) (freely available to all).

A journal paper is currently in development that described the analysis, results and interpretations. It will be submitted to Plos One in May 2016.

The Challenge of Mapping Complete River Networks and Potential Salmon Habitats in Southeast Alaska and in Adjoining Canadian Trans-Boundary Watersheds. Benda et al. in prep.

Abstract

The Southeast Alaska region, inclusive of the Alexander Archipelago and the large rivers that extend into British Columbia (Stikine, Taku and Unuk watersheds), constitutes one of the last environmental strongholds for five species of wild Pacific Salmon. To manage resource development and to protect salmon in this trans-boundary region, federal, state and provincial agencies need to know the locations and abundance of salmon habitats accurately. We investigated the feasibility of identifying and mapping complete stream networks, including locations and abundance of salmon habitats in southeast Alaska and northern British Columbia (180,000 km^2). We delineated complete river networks using a range of digital elevation models (DEMs) including 1m LiDAR available in a 740 km^2 pilot area in southeast Alaska, the U.S.F.S. 20m DEM, the newly available 5m IfSAR DEM across southeast Alaska and a 17m DEM available in British Columbia. We applied thresholds of channel steepness, including waterfalls, and salmon habitat models to identify potential salmon habitats in the virtual watersheds. The predicted density ($km\ km^{-2}$) of all streams, and of potential salmon streams, were compared to those within existing map products including the Alaska Department of Fish and Game Anadromous Salmon stream catalogue, the U.S. Forest Service's (Tongass National Forest) 1:63,500 - 100,000 national stream layer, and British Columbia's Provincial 1:50,000 hydrography, including its mapped salmon streams. In the U.S., the predicted LiDAR-derived salmon stream extent is 220% greater than the State of Alaska's salmon stream catalogue, 115% greater than the Tongass National Forest salmon distribution, 140% greater that salmon streams in the 20m DEM, and 540% greater than the derived salmon streams using the newly available IfSAR 5m river networks. In B.C., we infer that LiDAR derived stream networks would be 250% greater in length than the Provincial stream layer. The length of salmon streams would be 320% greater compared to what is contained within existing B.C. map products. We also infer that predicted salmon streams delineated using B.C.'s 17m DEM would be 180% to 500% less than a LiDAR derived salmon stream extent. Based on this analysis we estimate that as much as 600,000 km of all streams, and 85,000 to 98,000 km of salmon streams, remain unidentified and unmapped across the north Pacific trans-boundary ecosystem. How can salmon habitats be protected, including within watersheds with ongoing and proposed timber harvest, road building, hydro-development and mining projects if agencies and others do not know the locations of the majority of salmon habitats? We conclude that delineation of complete river networks and accurate salmon habitat identification will not be achieved in the U.S.–Canadian trans-boundary region until LiDAR DEMs become available.

A Crowdfunding campaign is a solution to acquire LiDAR across the U.S. – Canada Trans Boundary ecosystem; refer to the crowdfunding poster for additional information.

For additional information, contact Dr. Lee Benda @ TerrainWorks
leebenda@terrainworks.com
530 926-1066