February 19, 2018

Dear Chairman Josephson, Chairwoman Tarr, and Members of House Resources Committee:

In 2017, Alaskans once again made their opposition to the proposed Pebble Mine abundantly clear when an unprecedented 26,000 comments from around the state poured into the Environmental Protection Agency requesting the Bristol Bay Proposed Determination not be withdrawn. Ultimately, the agency received over a million requests to maintain the strong protections for the salmon-rich region of Alaska.

Last December, Pebble submitted its first Clean Water Act 404 dredge and fill of wetlands permit application to the U.S. Army Corps of Engineers, which kickstarted the federal permitting and environmental review process. Within the initial permit application, which proposes a mine roughly four times the size deemed to be safe by the Environmental Protection Agency, Pebble seeks to develop the first 1.2 billion tons of its nearly 11 billion ton deposit, and set the stage for future expansion into nearby areas. Initial review of the Pebble Partnership's plan makes it abundantly clear that mining Pebble will irrevocably harm salmon and the company has indicated the plan we see today is only phase one of the project.

EPA Administrator Scott Pruitt: "…it is my judgment at this time that **any mining projects in the region likely pose a risk to the abundant natural resources that exist there**. Until we know the full extent of that risk, those natural resources and **world-class fisheries deserve the utmost protection**."

Governor Walker: "…. **we should prioritize the resource that has sustained generations and must continue to do so in perpetuity. "**

In addition to this phase one federal permit application, there are many Pebble-related issues currently at play.

- First Quantum announces potential partnership; states divest
- U.S. EPA reviews comments, announces they will not withdraw the 2014 Proposed Determination.
- Pebble applies for additional exploration and drilling in "MLUP" permit
- Governor Walker and Senator Murkowski: looked to for leadership on Bristol Bay protections

It is clear that now more than ever, that thousands of Alaskans are concerned about the threat posed by the company's newest plan, and they are mobilized. Bristol Bay's future without the Pebble Mine remains bright with a record-setting season in 2017 and banner returns expected once again in the 2018 season. By protecting the clean water and salmon that make Bristol Bay

so special, we can ensure the next generation of Alaskans doesn't have to deal with a long battle against this ill-conceived idea.
The broad coalition of Bristol Bay tribes, commercial fishermen, Alaska Native Corporations, sportsmen and women and hunting and fishing business owners, chefs, jewelers and conservation organizations is asking Alaska leadership at all levels to listen to the widespread opposition to the Pebble Mine proposal and ensure permits for this irresponsible idea are not issued.

Thank you for staying abreast of the proposal that jeopardizes the culture, economy and way of life in Bristol Bay.

Sincerely,

Lindsay Layland, Deputy Director, United Tribes of Bristol Bay:
- Email: llayland@utbb.org

Tom Tilden, Nunamta Aulukestai

Norman Van Vactor, Chief Executive Officer, Bristol Bay Economic Development Corporation
- Email: norm@bbedc.com

Nanci Morris Lyon, owner, Bear Trail Lodge:
- Email: gofish@bristolbay.com

Rick Halford, former Alaska Senate President:
- Email: rhalford@mtaonline.net

The majority of Alaskan residents, including 80% of local residents, and hundreds of businesses oppose Pebble Mine. Alaskans have spoken. The facts are clear. **We are counting on our leaders to listen to Alaskans and protect Bristol Bay's salmon, jobs and way of life.**

PROVIDING OPPORTUNITIES "ACCEPT THE CHALLENGE" BBEDC

Bristol Bay Native Association

NUNAMTA AULUKESTAI CARETAKERS OF THE LAND

ALASKA SPORTSMAN'S BEAR TRAIL LODGE

TROUT UNLIMITED ALASKA

united TRIBES OF BRISTOL BAY

Tikchik Narrows Lodge, Alaska

COMMERCIAL FISHERMEN FOR BRISTOL BAY

ALASKA SPORTSMAN'S LODGE

ROYAL WOLF ALASKA

ALASKA'S ENCHANTED LAKE LODGE

Grizzly Skins OF ALASKA

Anglers Paradise Lodges ALASKA

Bristol Bay Adventures

FRONTIER RIVER GUIDES OF ALASKA

No-See-Um Lodge ALASKA'S FINEST

Alaskas Fishing UNLIMITED

TRACY VEEMS BLUE MOUNTAIN LODGE ALASKA

WOMEN'S FLYFISHING P.O. BOX 243-963 • ANCHORAGE, AK 99524

Bristol Bay ADVENTURES

fishpeople connect celebrate organize

Crystal Creek LODGE

alaskaflyfishingjobs.com

Bristol Bay Lodge ALASKA

Brightwater Alaska

Alaska Fly Anglers

BLUEFLY B&B GUIDE SERVICE

ALASKA ALPINE ADVENTURES

February 13, 2018

Via email and U.S. Mail to:

Philip K. R. Pascall, Chief Executive Officer
First Quantum Minerals Ltd.
14th Floor – 543 Granville Street
Vancouver, BC
Canada V6C 1X8
E-Mail: philip.pascall@fqml.com

Clive Newall, President & Director
First Quantum Minerals Ltd.
14th Floor – 543 Granville Street
Vancouver, BC
Canada V6C 1X8
E-Mail: clive.newall@fqml.com

Re: Bristol Bay, Alaska and the Proposed Pebble Mine

Dear Mr. Pascall and Mr. Newall:

Our organizations collectively represent the interests of fifteen Tribal governments and nine Alaska Native village corporations throughout the Bristol Bay region of southwest Alaska, as well as the interests of Bristol Bay Native Corporation's 10,300 shareholders of Aleut, Eskimo, and Athabascan heritage with ancestral ties to Bristol Bay. In addition, Bristol Bay Economic Development Corporation represents the economic interests and opportunities for the residents of 17-member communities throughout the region. Together, our organizations represent the economic, cultural, and social foundations of Bristol Bay, Alaska, home of the world's most valuable wild salmon fishery.

Our organizations are opposed to the proposed Pebble mine. We are writing to share information about our opposition and to make it very clear that we will resolutely oppose the Pebble Limited Partnership's (PLP) efforts to build this massive gold and copper mine located in an area that is critical to the region's fisheries and fisheries-based economy and way-of-life.

We are disappointed that First Quantum Minerals entered the framework agreement with Northern Dynasty Minerals (NDM) without consulting the people of Bristol Bay and we urge you not to move forward into an option agreement with NDM or PLP for potential entry into the Pebble Limited Partnership. If the Pebble mine is built, critical habitat for the world's greatest wild sockeye salmon fishery will be put at tremendous risk. For this reason, Pebble mine poses unacceptable threat to the communities, economy, and way-of-life of the region. We ask that you accede to our opposition to this project and end your involvement with the proposed Pebble mine, or, short of that, enter into a dialogue with our organizations about the project so that we may more readily share our concerns with you.

Bristol Bay is home to a 130-year-old commercial fishery that supports 14,000 American jobs in Bristol Bay and generates $500 million in direct income annually. Nationally, our fishery supports 20,000 American jobs, and generates over $1.5 billion in annual economic activity. Each summer our commercial and subsistence fishermen harvest a sustainable portion of the more than 50 million salmon returning to the watersheds of Bristol Bay. Our region is also a bucket list destination for hunters and anglers, whose hunting and fishing trips support an additional 850 jobs and add $60 million annually to the region's economy. Simply stated, the people and communities of Bristol Bay economically and culturally depend on the region's fisheries and our organizations will not risk those resources to a large-scale mining project proposed by foreign interests.

For the past decade, our organizations have opposed and strongly advocated against development of the proposed Pebble mine. The proposed mine entails insurmountable obstacles related to its size, type, and location and poses fundamental risks to the salmon fisheries of the region and the economic and subsistence benefits those fisheries provide. These are problems that cannot be engineered or avoided in any meaningful way. In 2010 our organizations and member tribes requested the U.S. Environmental Protection Agency (EPA) undertake a public process to carefully tailor prohibitions on proposed Pebble mine's impacts to Bristol Bay's headwaters. In 2014, after years of study and public process, EPA concluded that the proposed Pebble mine would have "unacceptable adverse impacts" on fish populations and streams and issued proposed restrictions on the development of the proposed mine.

Just last month, in a decision celebrated throughout Bristol Bay and by the Governor of Alaska, EPA announced that it will be keeping its 2014 proposed restrictions in place for the pendency of the federal permitting process. The decision will mean that any mine plan PLP pursues will have to meet a high standard and address the "unacceptable adverse impacts" identified by the agency. In fact, EPA Administrator Scott Pruitt said "It is my judgment at this time that any mining projects in the region likely pose a risk to the abundant natural resources that exist there." This landmark decision and acknowledgment underscores our resolve and commitment to ensure that Bristol Bay is protected for generations to come.

As First Quantum Minerals considers our position and conducts its due diligence, keep in mind that local opposition to the proposed Pebble mine project is unwavering and Pebble is the wrong mine in the wrong place. Our opposition is sincere, science and fact-based, deep, and committed.

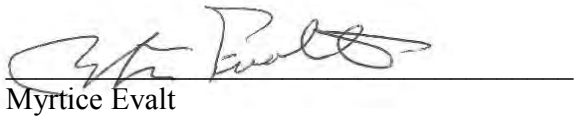
Sincerely,

Jason Metrokin
President/CEO, Bristol Bay Native Corporation
111 West 16th Avenue, Suite 400
Anchorage, AK 99501
Phone: (907) 278-3602

Norm Van Vactor
President/CEO, Bristol Bay Economic Dev't Corp.
PO Box 1464
Dillingham, Alaska 99576
Phone: (907) 842-4370

Robert Heyano
President, United Tribes of Bristol Bay
P.O. Box 1252
Dillingham, AK 99576
Phone: (907) 842-1687

Ralph Andersen
President & CEO, Bristol Bay Native Association
P.O. Box 310
Dillingham, Alaska 99576
Phone: (907) 842-5257



Myrtice Evalt
Interim Executive Director, Nunamta Aulukestai
PO Box 735
Dillingham, AK 99576
Phone: (907) 842-4404

Cc:

Angus Kennedy-Perkins	*Group Mgr. Commercial Projects, First Quantum Minerals Ltd.* angus.kennedy-perkins@fqml.com
Caitlin Glynn-Morris	*Corporate Mgr. Community Relations & Development, First Quantum Minerals Ltd* Caitlin.Glynn-morris@fqml.com

FOR IMMEDIATE RELEASE
Friday, January 26, 2018

CONTACTS:
Austin Baird (Governor Walker), 907-310-9761; Gov.PressOffice@alaska.gov
Tim Clark (Speaker Edgmon), 907-209-9930; Timonthy.Clark@akleg.gov
Norm Van Vactor (BBEDC), 907-843-2508; norm@bbedc.com
Daniel Cheyette (BBNC/BBNA), 907-265-7855; dcheyette@bbnc.net
Alannah Hurley (UTBB), 907-843-1633; ahurley@utbb.org
Myrtice Evalt (Nunamta Aulukestai), 907-360-3325; myrticenoden@yahoo.com

Alaskans Celebrate: EPA Right to Keep Bristol Bay Protections in Place

DILLINGHAM, AK— Alaska Governor Bill Walker, Alaska House Speaker Bryce Edgmon, and organizations representing the Alaska Native community and fishing industries made the following statements after the Environmental Protection Agency announced it would suspend withdrawal of the proposed restrictions for hard rock mining of the Pebble deposit, located in Bristol Bay in southwest Alaska. Last year, the EPA began the process to consider rescinding restrictions first proposed in 2014 that were based on the Bristol Bay Watershed Assessment, which determined mining on the scale of the proposed Pebble Mine would have "unacceptable adverse impacts" on the Bristol Bay watershed. Bristol Bay and its renowned fishery is responsible for half of the wild sockeye salmon caught around the world that sustain the region's indigenous communities, 14,000 fishing jobs, and $1.5 billion in economic activity.

In the announcement, EPA Administrator Scott Pruitt stated:

> "Based on that review, it is my judgment at this time that any mining projects in the region likely pose a risk to the abundant natural resources that exist there. Until we know the full extent of that risk, those natural resources and world-class fisheries deserve the utmost protection. Today's action allows EPA to get the information needed to determine what specific impacts the proposed mining project will have on those critical resources…. However, their permit application must clear a high bar, because EPA believes the risk to Bristol Bay may be unacceptable."

> "Today's action is important for several reasons. First, EPA has serious concerns about the impacts of mining activity in the Bristol Bay Watershed. From public comments to community meetings, stakeholders stressed the importance of balancing a singular mine venture with the risk

to one of the world's largest commercial fisheries. Second, for EPA not to express an environmental position at this stage would be disingenuous."

Alaska Governor Bill Walker:
"I have spoken to Administrator Pruitt about the Pebble Mine Project many times in the past year, and I have shared with him my belief that in the Bristol Bay region we should prioritize the resource that has sustained generations and must continue to do so in perpetuity. I thank the Environmental Protection Agency and the Trump Administration for listening to my input, as well as the input of thousands of Alaskans who oppose rescinding the EPA's Bristol Bay assessment."

Speaker of the Alaska House Representatives Bryce Edgmon:
"EPA's announcement could not be more welcome to the people I serve in Bristol Bay as their state representative. The threat of large-scale mining in the watershed has caused far too much stress for far too long in the region. I commend the EPA for crediting the extensive scientific evaluation that led the agency to this conclusion. This is a landmark decision for Bristol Bay that heartens our resolve to bring this fight to a close and ensure Bristol Bay is protected for generations to come."

Norm Van Vactor, CEO of Bristol Bay Economic Development Corporation:
"Today, Administrator Pruitt and EPA listened to Alaskans and science by keeping in place the proposed protections for Bristol Bay. More than 2,500 Bristol Bay, 26,000 Alaskan, and approximately one million American comments were submitted in support of protections for Bristol Bay during the most recent public comment period on the proposal to withdraw, showing clear and widespread support for restrictions on hard rock mining of the Pebble deposit. Alaskans know the Pebble Mine is the wrong mine in the wrong place because they trust independent science and have spent years publicly debating its cost and benefits. We cannot put at risk the thousands of American fishing jobs supported by Bristol Bay's waters by allowing a foreign-owned company to build a massive mine at the bay's headwaters."

Jason Metrokin, President and CEO of Bristol Bay Native Corporation and Ralph Andersen, President and CEO of Bristol Bay Native Association:
"Administrator Pruitt and the staff at the EPA deserve credit for rightly keeping in place proposed restrictions for mining in Bristol Bay. The Pebble Limited Partnership (PLP) appears determined to build its mine despite years of scientific assessment and thousands of years of traditional knowledge and experience that have made it clear to the people of Bristol Bay that a mine such as Pebble cannot be built without harm to the region's fisheries. Today's decision by EPA is unlikely to end this debate. Nevertheless, the decision will mean that any mine plan PLP pursues will have to meet a high standard and address the 'unacceptable adverse impacts' identified in the Bristol Bay Watershed Assessment and the Proposed Determination. This is a high but fair bar and we continue to urge the EPA and other state and federal regulatory and permitting agencies to closely scrutinize PLP's mining proposal to ensure our region's fisheries are adequately protected. Kudos again to EPA and Administrator Pruitt for not abandoning science, American jobs, and the people and communities of Bristol Bay."

Robert Heyano, President of United Tribes of Bristol Bay:
"Today's announcement marks another milestone for Bristol Bay. It shows us that the power of local people, speaking together in a united voice, can still be heard above the noise of today's partisan politics. The United Tribes of Bristol Bay would like to thank EPA Administrator Scott Pruitt, Regional Administrator Chris Hladick, and the staff at EPA for their work. The fight to protect our watershed from Pebble is far from finished. But, today's decision, and all those who worked so tirelessly to get us here, will be celebrated."

Myrtice Evalt, Interim Executive Director for Nunamta Aulukestai:
"Over and over, Alaskans have spoken. They want our salmon and waterways protected. Americans have spoken. They want EPA to protect places like Bristol Bay. The science has spoken. EPA's own watershed

assessment concluded that the proposed Pebble mine would be catastrophic to our fisheries and communities. Even Pebble's permit application has spoken, confirming that it cannot protect our salmon, our homes, or our way of life. Today EPA has listened. The next step is for EPA to finalize its determination once and for all. Bristol Bay is no place for a mine. Those of us who live here, whose families have lived here for centuries, know that, and we will fight the Pebble project every step of the way."

###

*The **Bristol Bay Economic Development Corporation** exists to promote economic growth and opportunities for Bristol Bay residents through sustainable use of the Bering Sea fisheries.*

***Bristol Bay Native Association** is the regional nonprofit tribal service provider providing social, economic, and educational opportunities to tribal members.*

***Bristol Bay Native Corporation** is a responsible Alaska Native investment corporation dedicated to the mission of "Enriching Our Native Way of Life." Established through the Alaska Native Claims Settlement Act of 1971, BBNC works to protect the land in Bristol Bay, celebrate the legacy of its people, and enhance the lives of its shareholders.*

*The **United Tribes of Bristol Bay** (UTBB) is a tribal consortium representing 15 Bristol Bay tribal governments (that represent over 80 percent of the region's total population) working to protect the Yup'ik, Denai'na, and Alutiiq way of life in Bristol Bay.*

***Nunamta Aulukestai** is a coalition of Alaska Native Village Corporations and tribes in the Bristol Bay region dedicated to protecting the Bristol Bay watershed from unsustainable development.*

THANK YOU

Governor Walker

"I am not supportive of the Pebble Mine."

Governor Bill Walker, October 2017

Dear Governor,

Thank you for standing up for our salmon, jobs and way of life by not supporting the proposed Pebble Mine. For more than a decade we've been living with the uncertainty of the Pebble Mine hanging over our future. We deeply appreciate your strong leadership on this issue and look forward to working with you to put Alaskans firmly in the drivers seat when it comes to determining the healthy and prosperous future we want for Bristol Bay.

Sincerely,

The People of Bristol Bay

PEBBLE MINE

The majority of Alaskan residents, including 80% of local residents, and hundreds of businesses oppose Pebble Mine.

Bristol Bay Native Association

Trout Unlimited Alaska

BBEDC

united

COMMERCIAL FISHERMEN OF BRISTOL BAY

Enchanted Lake Lodge

Bear Trail Lodge

Alaska Sportsman Lodge

Tikchik Narrows

fishpeople

Royal Wolf Alaska

Bristol Bay Lodge

Alaska Alpine Adventures

New partner won’t change Pebble to gold

Author: **Norm Van Vactor**

Published July 20, 2017 in the Anchorage Dispatch News

Right now, a record number of sockeye salmon are flooding into the Nushagak River — returning from their multiyear feeding frenzy in the north Pacific Ocean. Over 1 million salmon were caught in one day alone.

This year is an impressive demonstration of what clean water and healthy habitat can do for Bristol Bay communities and Alaska.

At the same time, Northern Dynasty Minerals, a junior mining company with no mining experience, is searching for an investor to pursue the development of the Pebble mine and has indicated it will announce a new partnership by the end of this month.

If Northern Dynasty secures a partner, it will likely move forward to obtain the permits needed for developing the Pebble mine. While we've heard that promise before, with the recent lawsuit settlement between Pebble and Environmental Protection Agency Administrator Scott Pruitt, Pebble now has a strong incentive to attempt to move into permitting in the next two years.

Most of the permits needed would be granted by the state of Alaska. They also would need a permit from the U.S. Army Corps of Engineers.

[Pebble and Native corporation team up, frustrating mine opponents]

It is clear from the announcement this week that we can no longer fully count on the EPA to finalize the protections that tens of thousands of Alaskans supported. We certainly need to let Pruitt know that withdrawing the proposed determination is absolutely the wrong decision.

But we also cannot afford complacency when it comes to protection of our salmon, and our opposition to Pebble needs to stretch beyond that. We need to let any prospective investor in Pebble know that they will have to deal with tens of thousands of Alaskans who do not want a mine on top of Bristol Bay's salmon rivers.

We need to demand that our leaders, Gov. Bill Walker, Lt. Gov. Byron Mallott, Sens. Lisa Murkowski and Dan Sullivan and Rep. Don Young stand with the majority of state residents to strongly and vocally oppose Pebble.

Over the past decade, as concern has grown about the mine, thousands of Alaskans showed up at public hearings to testify in favor of protecting the salmon, jobs and culture of Bristol Bay from Pebble mine.

Ninety-eight percent of Bristol Bay area people supported protections for Bristol Bay during the 2012 EPA comment period. Eighty-one percent of Bristol Bay Native Corp. shareholders, according to a 2011 poll, and dozens of tribes and village corporations oppose Pebble.

Commercial and sportfishing businesses have spoken up with concerns about Pebble impacting their jobs and income.

During the fall 2014 election, it became abundantly clear that Alaskans across the state oppose this egregious proposal, as people voted by a 2 to 1 margin, including a majority in every district in the state, to pass an initiative that puts an additional hurdle in Pebble's permitting process.

While that is a good step, I think most Alaskans realize we cannot afford to rest until we know Bristol Bay salmon habitat is truly protected.

[Even a smaller Pebble mine, as developer now plans, could face high development hurdles]

Several years ago, local Bristol Bay leaders came together and worked with residents to define a community vision for Bristol Bay. The vision included excellent schools, safe and healthy families, local jobs, access to subsistence resources and a strong voice in determining the future direction of the region.

Sixty-three percent of Bristol Bay residents wanted to see economic growth in business and industries based largely on renewable resources.

These are lofty and admirable goals. It is a vision where Pebble has no place. It is a vision where salmon thrive, and the communities, economies and cultures that depend on them.

Knowing the grit and determination of the people here, I am confident we can attain that vision if given half a chance.

It's time to put in place an Alaska-driven solution to the Pebble problem, which has dragged on for far too long.

Norm Van Vactor *is president and CEO of the Bristol Bay Economic Development Corp.*

Pebble advisers must know the answer is still no

Author: **Ralph Andersen, Rep. Bryce Edgmon, Robert Heyano, Brian Kraft, Myrtice Noden , Robin Samuelson, Norm Van Vactor, Nelli Williams**

Published August 19, 2017 in the Anchorage Dispatch News

To members of the Pebble advisory committee: Thanks, but no thanks.

For those on their first visit to our great state: Welcome to Alaska. As you will see, the seasons are changing and Alaskans everywhere are transitioning from summer into another short fall and long winter.

On Monday, you will gather in downtown Anchorage to discuss how to advance the Pebble mine project. There will be one thing noticeably absent from your meeting though, the people of Bristol Bay.

We will not be attending. It's nothing personal. While you might be new to the issue, the prospect of Northern Dynasty's Pebble project has weighed on our minds since 2001.

Bristol Bay has thought this over for a long time, and we have long since made up our minds: Pebble mine is not welcome here. The discussion is over.

It is an utter waste of your time, and ours, to sit down and discuss how to build a "better" mine in Bristol Bay. That's because our region does not want a Pebble mine in any size, form or configuration.

[Pebble and Native corporation team up, frustrating mine opponents]

If Pebble Limited Partnership truly wanted to listen to the people of Bristol Bay, it would not convene a private meeting hundreds of miles away from the region on the day after moose-hunting season starts.

It would not spend years attacking us in court and in the media. If the Pebble partnership had been listening, it would know we have made our message clear for nearly 17 years: Do not build a mine at the headwaters of our fishery. Period.

We're sure Pebble sold this advisory committee as something socially responsible to do — a new paradigm on how to develop mining projects in rural Alaska. The problem though, is that not only is this committee's agenda predetermined, the idea of an advisory committee is one Pebble has tried before.

In 2007, Northern Dynasty hired the nonprofit Keystone Center to conduct essentially the same task your committee is undertaking now. The Keystone process utterly failed to convince Bristol Bay on Pebble's merits.

Nothing's changed in the intervening years. Your committee can work as hard as it wants, but it cannot fix the essential problem with Pebble: The people of Bristol Bay do not want it.

When Pebble invited us to your meeting, it asked us to comment on anything, including "engineering design, environmental safeguards and technology, alternatives assessments, environmental impacts, project mitigation, socio-economic impacts, and programs to enhance public benefits."

We only have one comment to share: We will never support a Pebble mine in Bristol Bay.

[New partner won't change Pebble to gold]

We do not want to discuss how to mitigate a disaster to our fisheries, or how to "better" engineer a mine in our headwaters. Your committee's mission carries the underlying presumption that the mine will be built. We reject that presumption.

We are not open to a mine, whether it's built all at once or phased in over time. We are not open to a mine that comes with local payouts. Bristol Bay is not open for mining.

The company has made it clear it will not listen to us. But you, as committee members, can. Listen to the voices in the region who have considered the issue carefully.

Listen to the Yup'ik, Denai'na and Alutiiq people who have thrived on this land since time immemorial. Listen to the small vessel captains who, for over 100 years, have sustainably operated a commercial fishery.

Listen to the entrepreneurs and small business owners who drive local economic development and bring visitors from all over the world to experience this incredible place. We all have a vision for a healthy, prosperous future in Bristol Bay.

And that future has no room for the Pebble mine.

Ralph Andersen *is CEO of Bristol Bay Native Association;* ***Rep. Bryce Edgmon****, D-Dillingham, is Speaker of the Alaska House of Representatives;* ***Robert Heyano*** *is president of United Tribes of Bristol Bay;* ***Brian Kraft*** *is president of Katmai Service Providers;* ***Myrtice Noden*** *is executive director of Nunamta Aulukestai;* ***Robin Samuelson*** *is president of Bristol Bay Economic Development Corp.;* ***Norm Van Vactor*** *is CEO of Bristol Bay Economic Development Corp.;* ***Nelli Williams*** *is Alaska director of Trout Unlimited.*

Opinions

Reason already has spoken on Pebble

Author: **Dr. Deborah McLean** | **Opinion**, **Dr. Todd Radenbaugh** | **Opinion**, **Mark Lisac** | **Opinion**
Updated: December 11, 2017 Published December 11, 2017 in Anchorage Dispatch News

The Pebble Limited Partnership recently announced the addition of Mark Hamilton as its executive vice president of external affairs. As the president of the University of Alaska system for 12 years, Hamilton is no stranger to Alaska, particularly those in the academic community. According to the Pebble partnership, Mr. Hamilton will "connect with political, business, community, and Alaska Native leaders throughout the state to better understand their views and consider their advice," on the proposed Pebble mine.

Given his background, why isn't Mr. Hamilton's appointment being met with excitement from many of his colleagues in our community?

Perhaps it is because Mr. Hamilton's rationale for taking the job is contradicted by the overwhelming public opposition and scientific evidence that shows that industrial hard-rock mining would have a significant negative influence on Bristol Bay's ecosystems.

[It's time for a new dialogue on Pebble]

In a press release, Mr. Hamilton said: "I believe in reason. I believe in coming to the table to contest different opinions respectfully and honestly; refusing to hear the evidence that supports opinions contrary to our own signals the rejection of the dialectic and the end of reason. ... I intend to appeal to my fellow Alaskans to rise above that caustic dynamic, and to consider (the Pebble mine) based on its merits — on the facts, rather than on fear."

With all due respect to Mr. Hamilton, Alaskans' opposition to the Pebble mine is based on both scientific data and social merits, as well as a healthy dose of fear for what could happen if open pit mining is allowed in a pristine wilderness where fish sustain both nature and our communities.

This is an aerial view of a work camp in the area of the proposed Pebble mine in Alaska, seen on Tuesday, August 27, 2013. (Bill Roth/ADN archive 2013)

Regional opposition is a product of extensive educational activities presented to the Bristol Bay residents while Mr. Hamilton served the UA system. During his tenure, the university approved activities intended to inform the people of Bristol Bay with unbiased scientific information about the Pebble mine, including its risks and benefits. He had a front-row seat for understanding how a majority of the region developed opinions based on fact and reason.

Our fears about the Pebble mine are further grounded in the findings of a robust scientific process initiated locally and finalized by the U.S. Environmental Protection Agency. In fact, its Bristol Bay Watershed Assessment relied on data and analysis from scientists and economists, many from the university Mr. Hamilton once led.

The only thing that has changed in the nearly four years since the watershed assessment was finalized is the newly appointed EPA administration in Washington, D.C., that has breathed new life into the Pebble project. As we have seen during the recent comment period concerning the EPA's withdrawal of the Assessment's proposed restrictions, the opposition to the Pebble mine in Alaska and the Lower 48 remains alive, well, and growing. Over 80 percent of the region's residents oppose the mine, and 65 percent of Alaska voters supported the Bristol Bay Forever ballot initiative.

With the possible exception of the Arctic National Wildlife Refuge, no other proposed Alaska resource development project has been the subject of as much debate as the Pebble project. The fact that Pebble is such a known commodity in Alaska makes

Mr. Hamilton's stated role with the company so perplexing. In many ways, Mr. Hamilton seeks a dialogue and conversation that has already occurred over many years. A man who is no stranger to science and reason is jumping on board with a project that science and reason have already deemed too risky and costly.

[Pebble has no place in Alaska's future]

This type of approach is par for the course for the Pebble partnership, which has long sought to move the argument beyond science and into the realm of political influence and illusion. In October, it was revealed that the EPA decided to begin the process of withdrawing its mining restrictions in Bristol Bay just hours after Pebble CEO Tom Collier met with EPA Administrator Scott Pruitt. Career staffers with relevant scientific and policy backgrounds were not given the opportunity to brief Administrator Pruitt about their extensive work in Bristol Bay.

This recent EPA decision followed a multiyear legal process in which Pebble sought to discredit both the science and scientists underpinning the EPA Watershed Assessment. These are not the actions of a company that intends to have an open and honest dialogue with the people its actions would affect.

We want to take Mr. Hamilton's stated role at face value. But history and reason are our guides in understanding that the Pebble Limited Partnership's only goal is to cultivate investors and permit a massive mine — no matter the social and environmental risks.

Reason is the power of the mind to think, understand and form judgments by a process of logic. Our judgment about the risks of the Pebble mine have been settled using the best science, logic and policy prescription. We hope Mr. Hamilton soon reaches a similar conclusion.

Dr. Deborah McLean is recently retired from the University of Alaska system. She served the people of the Bristol Bay region for 25 years, with the last 15 years as the director of the Bristol Bay campus. Dr. Todd Radenbaugh is an environmental scientist and educator currently living in Bristol Bay, with international and interdisciplinary experience in the fields of geology, ecology, geography, and environmental policy. Mark Lisac is a 34-year resident of Bristol Bay and a retired federal fishery biologist.

People of Bristol Bay will never trade fish for gold

Author: **Alannah Hurley** | **Opinion** Updated: June 22, 2017 Published June 22, 2017

Two important annual events are kicking off this Friday. In Bristol Bay, Alaska, it's salmon season. Smokehouses will start filling up with strips of fresh king salmon. Fishermen will be delivering totes full of sockeye to tenders. Families will be gathering at sites all along the river banks, as they have done for generations, in order to not only feed their loved ones but also to feed their spirit as indigenous peoples.

Here in Vancouver, British Columbia, a Bristol Bay-related event is also set to begin. This Friday, Northern Dynasty Minerals hosts its annual shareholders meeting. But whereas back home we are celebrating the return of our greatest natural resource, this Vancouver gathering is focused on what non-renewable resources can be taken from Bristol Bay. The major topic of discussion? Moving forward with the Pebble mine, a copper and gold deposit the company describes as "world class," and which ranks among the world's largest undeveloped mineral deposits. This deposit also happens to be located under the natural wetlands that form the headwaters of Bristol Bay's two economic engines: the Kvichak and Nushagak rivers. Together, these river systems are responsible for 51 percent of the world's commercially harvested sockeye salmon.

At this year's shareholders meeting, Northern Dynasty Minerals wants to achieve one thing: convince current and potential investors that Bristol Bay is open and ready for mining.

To those same current and potential Northern Dynasty investors: I'm here to tell you — it's not. Northern Dynasty has pitched the Pebble project in one form or another since 2001. During those 16 years Bristol Bay's position has been unwavering: Fish first, Pebble never. That will never change.

This year, Northern Dynasty will try to convince the investment community that the tide has turned back home and Bristol Bay's residents are coming around to the notion of the Pebble mine. For example, the company will point to its new "advisory committee" meant to guide developers toward building a safer, more responsible Pebble mine. This is nothing new. In fact, it's a replay from years past when Northern Dynasty hired the Keystone Center to conduct essentially the same task as the current advisory committee. The Keystone Center's process was widely panned in Alaska, and it utterly failed to convince Bristol Bay on the merits of Pebble. Despite the advisory committee's new membership and new title, it cannot fix the essential problem with the Pebble mine: The people of Bristol Bay do not want it.

Northern Dynasty will tout its recent legal settlement with the U.S. Environmental Protection Agency as a big win, and as the signal that green lights are ahead for the Pebble mine. Don't be fooled by the rhetoric. The settlement Northern Dynasty is touting as a victory now requires the company to meet strict timelines for moving into environmental review under the U.S. National Environmental Policy Act. We welcome the idea that Northern Dynasty — a company that has stalled on filing mine permits for over a decade — is finally having its feet held to the fire. They say they have a world-class mine plan. Well, it's time for them to show their cards.

The Alaska Department of Fish and Game forecasts that 41.47 million sockeye salmon will return to Bristol Bay's rivers this year. That staggering number does not include the thousands more chinook and coho that will likewise make their way back to the streams of their birth. The same streams that overlay the Pebble deposit.

For the people of Bristol Bay, that's all this is about. Native people have made their way on this land since time immemorial. Small boat captains have sustainably operated a commercial fishery here for more than 100 years. Bristol Bay's salmon have fed the world. They are a natural resource unlike any other: They have the power to regenerate themselves, year after year. Ad infinitum. But that is only possible if we make the right management decisions today. A Pebble mine, big or small, cannot co- exist with our fishery. Pebble will always be the wrong mine, in the wrong place. And the people of Bristol Bay will never trade our fish for gold.

Alannah Hurley is a lifelong Bristol Bay resident and executive director of the United Tribes of Bristol Bay. UTBB is a tribal consortium representing 14 tribes (over 80 percent of the total population of Bristol Bay) working to protect the Bristol Bay watershed that sustains the Yup'ik, Denai'na and Alutiq way of life.

The New York Times | https://nyti.ms/2i5RCCa

SundayReview | OPINION

A Gold Rush in Salmon Country

By BRENDAN JONES NOV. 24, 2017

SITKA, Alaska — It is almost winter again here. The days shorten and the furrows of the volcano that looms over our town steadily fill with snow. At night my daughters and I watch northern lights dance green across a mountain ridge as we wait for our salmon to thaw for dinner. In the courts there is a case in which the defendant, a fisherman, claims his cloth measuring tape constricted in the cold, causing him to mismeasure his halibut. In another case a fisherman blames his freezer for shrinking a king salmon. Alaska state troopers disagree. Life continues apace.

When I'm not working on our tugboat, I fish with Eric Jordan, a second-generation troller whose parents, like those of so many seasoned fishermen around here, fought for Alaskan statehood so salmon could be better managed. We work the winter line, stretching between Cape Edgecumbe Light and Point Woodhouse. The salmon, chromatic shifts of light prowling the kelp forests, have slowed down by this time of year. Smoked, canned, stacked in the freezer like cordwood, their pumpkin-orange meat sustains us, as it has sustained the Tlingit community on this island for 10,000 years.

The other day, during a slow stretch on the boat, Eric brought up the issue of Pebble Mine. "It makes you want to give up hope, doesn't it?" he asked.

He was talking about renewed efforts to build a mine at the headwaters of one of the world's last wild salmon nurseries, at Bristol Bay in southwestern Alaska. Northern Dynasty Minerals, a Canadian company that wants to construct the mine, estimates that 100 million ounces of gold rest beneath the native spawning grounds.

In 2014, after three years of study and millions of public comments of protest, the Environmental Protection Agency concluded that Pebble Mine would commit "irreversible" damage to the wetlands, resulting in "complete loss of fish habitat due to elimination, dewatering and fragmentation of streams, wetlands and other aquatic resources." The fishery was too valuable to risk and too difficult to mine.

Alaskans had come out overwhelmingly against the measure, a rare example of consensus in a proudly opinionated state. Even the Republican senator Ted Stevens, a staunch supporter of mines, said that this was "the wrong mine in the wrong place." Investors pulled out and stock prices of Northern Dynasty fell. Slowly, bumper stickers around town denouncing the mine disappeared.

Then Donald Trump, a man in love with all things gold, came along.

On May 1, Scott Pruitt, the new administrator of the E.P.A., met with Tom Collier, the head of the Pebble Mine project, for breakfast. Later that same morning, Mr. Pruitt ordered the E.P.A. regulations scrapped, telling the company it could proceed with permitting. And like that, the mine was back in play.

Northern Dynasty Minerals originally proposed detonating millions of pounds of explosives to open a pit the size of Seattle, which would make Pebble Mine the largest manufactured hole in the world. This time around, the company speaks of a smaller mine. But once drilling begins, permits are easily amended. What mine in the history of the world has ever left gold in the ground? The company also proposes that the mine's toxic wastewater be kept in a reservoir protected by an earthen dam — in one of North America's most active earthquake zones.

All this bodes ill for salmon. In the continental United States, Atlantic salmon, once teeming in New England and Canada, have all but disappeared, and are now considered an endangered species. In 2015 fish biologists went into a tizzy after a mere handful of salmon set up nests in the Connecticut River.

On the West Coast, the Columbia River, known for its king salmon, and the Snake River in Idaho — where in the 19th century, salmon were so copious that locals had to beat them off with a stick before their horses would cross — have lost wild salmon because of dams and agricultural development. In the Puget Sound and in the San Francisco Bay, the same thing has happened.

Outside the United States the picture is no less bleak. That water mill that van Gogh painted so beautifully? One of the reasons the Netherlands lost its salmon. The trendy Canal S.-Martin in Paris? It was once the Ourcq River, a tributary of the Marne River — which, like the Seine, hosted abundant salmon runs. Power plants in Denmark and fish farms in Norway have disrupted wild stocks. In Scotland, Ireland, Canada — the list continues.

Alaska has remained the exception. Written into our state Constitution is a mandate to maintain a sustainable fishery, and the Alaska Department of Fish and Game has done well by it. We have outlawed fish farms and closely monitor escapement — the number of fish that make it back to their home streams to spawn. This conservative approach has led to bumper salmon runs in Bristol Bay, where, since 1884, the total cumulative catch in the area has been two billion fish. It took 95 years to catch the first billion, and just 38 years to catch the second. This year was record-breaking for sockeye returns.

Meanwhile, fishing and tourism combine to sustain some 14,000 jobs in the area. Northern Dynasty says Pebble Mine will create 1,000. If making America great again means bringing back jobs, then Bristol Bay is already doing just fine.

In Alaska, salmon give us food and work. But they also give us something harder to quantify. We welcome the fish each summer as they build their nests at headwaters. We breathe in their scent as they decay along the riverbanks. They permeate our lives. As they say on the island, the fish are in the trees.

My daughters, girls built of salmon.

Brendan Jones is a commercial fisherman and the author of the novel “The Alaskan Laundry.”

Follow The New York Times Opinion section on Facebook and Twitter (@NYTopinion), and sign up for the Opinion Today newsletter.

A version of this op-ed appears in print on November 26, 2017, on Page SR10 of the New York edition with the headline: A Gold Rush in Salmon Country.

OPINION

An American Industry Could Be Cut Adrift – And Our Jobs Are on the Line

BY **STEVEN BROOKS** , **WARNER LEW** & **RONN GRIFFIN**
February 8, 2018

Think of an American legacy industry that generates billions of dollars in economic activity and creates thousands of jobs – all based on a renewable natural resource that's essentially free. An industry that sustains thousands of American families and has been doing so for generations.

Does that sound like an industry you'd want to destroy? That's the question for Environmental Protection Agency Administrator Scott Pruitt to answer.

The industry we are describing is the Bristol Bay wild salmon fishery, one of the most awe-inspiring fish runs on the globe, and one of the most vibrant natural resources belonging to the American public. Last summer, almost 60 million sockeye salmon returned to spawn in the headwaters of Bristol Bay – almost half of the world's total. The harvested portion of this spectacular resource generates $1.5 billion in economic activity every year, and directly supports more than 14,000 American jobs — jobs like ours, and our combined workforces of over a thousand people. We are part of a long chain of hard working Americans catching, processing, transporting selling Bristol Bay salmon, and supporting this economic engine.

If a pristine watershed in Alaska seems remote, rest assured that many of those jobs are spread throughout the lower 48. Bristol Bay fishermen hail from more than 39 states, creating a value chain as long as the continent – and beyond.

The jobs that depend on Bristol Bay's salmon fishery are as diverse by industry as they are by state. These include tradesmen who build and repair boats and equipment; fishing boat captains and crew; seafarers transporting fresh fish to processing plants; thousands of fish processors; shipping companies transporting our fish by air, land and sea; storage facilities that receive and distribute the product; and retail distributors, markets and restaurants that ultimately deliver the product to consumers. The Bristol Bay fishery provides revenue, jobs and a valuable food source to our nation.

All of this value depends on the quality and health of the headwaters of Bristol Bay. And all of that is threatened by a foreign company that wants to develop a gold and copper mine in those headwaters, a location that will irreparably damage the two most productive sockeye salmon rivers in the world. The project is called Pebble Mine.

Why is this project even being considered? Our president made it clear that he prioritizes American jobs, not foreign companies. Northern Dynasty Minerals is a Canadian company that wants to operate on U.S. soil to extract gold and copper

to ship overseas and sell on the global market. All the profit would be theirs, and all the risk would be ours.

Alaska Gov. Bill Walker (I) has said he does not support the mine, and the people of Alaska have fought Pebble Mine every step of the way. By a strong majority — more than 65 percent in every precinct — Alaskans passed a ballot initiative in 2014 that protects the Bristol Bay watershed from large-scale sulfide mining like the proposed Pebble Mine. Local opposition is even stronger: More than 80 percent of Bristol Bay residents and 85 percent of commercial fishermen oppose the Pebble Mine.

Yet within hours of meeting with the CEO of the Pebble Limited Partnership, Pruitt ordered his agency to withdraw protections for the watershed proposed by the previous administration after years of scientific study. Almost immediately the Pebble Mine project regained momentum — foreign backers have now submitted permit applications and acquired additional funding.

In a welcome reversal last month, the EPA announced its intention to leave the original proposed protections in place for the time being, noting that Bristol Bay's "natural resources and world-class fisheries deserve the utmost protection." This is good news for those of us whose livelihoods depend on Bristol Bay's natural resources, and we thank Mr. Pruitt. But now the EPA must finalize those protections and put the Pebble Mine project out of its misery for good.

Pebble Mine is a bad project in the worst place, risking a great American natural resource while favoring foreign interests over many thousands of American families' livelihoods. Mr. Pruitt, let us keep our jobs — and please do yours. Protect Bristol Bay.

Steven Brooks is the president at the Seattle Marine and Fishing Supply Co. Warner Lew is the fleet manager for Western Alaska, Icicle Seafoods. Ronn Griffin has been a Bristol Bay fisherman and boat captain for 34 years.

Morning Consult welcomes op-ed submissions on policy, politics and business strategy in our coverage areas. Updated submission guidelines can be found here.

ENERGY

POLITICS 12/12/2017 09:08 pm ET

EPA Leaders From Past GOP Administrations Slam Proposed Pebble Mine In Alaska

"The record is clear: The Pebble Mine is fundamentally flawed — it's the wrong mine in the wrong place."

By Nick Visser

ENVIRONMENTAL PROTECTION AGENCY VIA REUTERS

Environmentalists have warned the proposed Pebble Mine could devastate the sockeye salmon industry near Alaska's Bristol Bay.

Three former administrators of the Environmental Protection Agency slammed a proposal to open a gold and copper mine in the heart of an Alaska salmon fishery, saying the project could devastate natural ecosystems and imperil a multibillion-dollar industry.

William Ruckelshaus, William Reilly and Christine Todd Whitman — all former heads of the EPA under Republican presidents — joined former Secretary of the Interior Bruce Babbitt in signing a letter published in The Washington Post on Tuesday. In the letter, they voiced their opposition to the controversial Pebble Mine near Alaska's Bristol Bay.

"The question of whether to build a massive open pit copper and gold mine in the heart of the planet's largest wild sockeye salmon fishery has a simple answer," the authors write. "The Pebble Mine is the wrong mine in absolutely the wrong place, and the answer is no."

Environmental, tribal and business groups also signed on to the missive, including the Natural Resources Defense Council, the United Tribes of Bristol Bay and Commercial Fishermen for Bristol Bay.

The EPA, now under the stewardship of Scott Pruitt, moved to reverse an Obama-era decision to block the mine in May after executives of the Pebble Limited Partnership, the developer of the project, sued the government.

At the time, the executives praised Pruitt for his "commitment to the rule of law" and said they would move to file a new application for a permit to proceed with the mine, according to The New York Times.

The EPA in July also moved to withdraw a former determination made under the Clean Water Act that would have imposed restrictions on the site.

The Hill notes that a lengthy permitting process won't see a mine in Bristol Bay for years. But an amenable Trump administration — which has done little to protect the environment over the past year — has activists and local fishermen worried about one of the

“We oppose the Trump Administration’s efforts to sweep nearly a decade of science and Clean Water Act review under the rug,” Tuesday’s letter says. “The record is clear: The Pebble Mine is fundamentally flawed — it’s the wrong mine in the wrong place.”

“Protect the greatest salmon fishery on the planet,” the authors conclude. “Protect Alaskans and the Bristol Bay watershed.”

Read the full letter below.

PROTECT BRISTOL BAY

Visit **www.sportsmansalliance4ak.org**, **www.savebristolbay.org**, and **www.renewableresourcescoalition.org** to learn more and get involved.

PROTECTING BRISTOL BAY

Tiffany & Co. applauds the U.S. Environmental Protection Agency's decision to leave in place proposed restrictions protecting the Bristol Bay watershed in Alaska, recognizing that any mining projects in this pristine environment not only risk its beauty, but the abundant natural resources that exist there.

Tiffany & Co. has long been a vocal opponent of the proposed Pebble Mine, believing it poses a dire threat to the remarkable Bristol Bay ecosystem, and the world's most productive salmon fishery it sustains.

It is a belief widely shared by Alaskans, commercial and sport fishermen, Bristol Bay residents, and even many of our fellow jewelers whose livelihoods depend on mining. Our 180 years of experience sourcing precious metals and gemstones tells us there are certain places where mining should simply never occur.

Alaska's Bristol Bay is one such place.

TIFFANY & CO.

ECONOMIC VALUE OF BRISTOL BAY

A National Treasure

Bristol Bay is the world's most valuable wild salmon fishery. It supplies 50% of the world's wild sockeye salmon. Harvesting, processing, and retailing Bristol Bay salmon generates $1.5 billion in annual economic activity across the United States.

Locally, the Bristol Bay salmon fishery supports 14,000 full and part time jobs. Nationally, the Bristol Bay salmon industry supports nearly 20,000 permanent jobs and $500 million in direct annual income.

ECONOMIC IMPACTS OF THE BRISTOL BAY SALMON INDUSTRY IN 2010

ANNUAL AVERAGE EMPLOYMENT	OUTPUT VALUE: $1.5 BILLION	INCOME: $500 MILLION
FISHING & PROCESSING IN BRISTOL BAY		
12,000 seasonal jobs	$390 million	$140 million
SHIPPING, SECONDARY PROCESSING & RETAILING AFTER BRISTOL BAY		
1,000 jobs	$110 million	$40 million
MULTIPLIER IMPACTS IN OTHER INDUSTRIES		
6,800 jobs	$970 million	$320 million

Source: Institute of Social and Economic Research, University of Alaska Anchorage

While in Bristol Bay, sportsmen spend millions and contribute to the employment of lodge owners, guides, pilots, and other staff. Hunting and fishing trips support an additional 850 jobs and add $60 million to the region's economy.

EPA CONFIRMED THE ENORMOUS ECONOMIC VALUE OF THE BRISTOL BAY WATERSHED

In studying the Bristol Bay watershed, EPA highlighted that the Bristol Bay watershed supports several sustainable and robust economic sectors such as:

- commercial, sport, and subsistence fishing
- sport and subsistence hunting
- non-consumptive recreation (e.g. wildlife viewing and tourism)

From these sectors, according to the EPA, **the ecological resources of the Bristol Bay watershed generated nearly $480 million in direct economic expenditures and sales in 2009,** and provided in-region employment for over 14,000 full-and part-time workers.

www.epa.gov/bristolbay/about-bristol-bay

EPA's proposed restrictions help protect Bristol Bay's incredible fisheries and the thousands of jobs that those fisheries support.

FOR MORE INFORMATION CONTACT:

Daniel L. Cheyette
Bristol Bay Native Corporation
(907) 278-3602 // dcheyette@bbnc.net

Carmell Engebretson
Bristol Bay Native Corporation
(907) 278-3602 // cengebretson@bbnc.net

Bristol Bay NATIVE CORPORATION

The Economic Importance of the Bristol Bay Salmon Industry

prepared for the

Bristol Bay Regional Seafood Development Association

by

Gunnar Knapp
Mouhcine Guetttabi
Scott Goldsmith

Institute of Social and Economic Research
University of Alaska Anchorage / 3211 Providence Drive / Anchorage, AK 99508
907-786-7710 / www.iser.uaa.alaska.edu/

April 2013

THE ECONOMIC IMPORTANCE OF THE BRISTOL BAY SALMON INDUSTRY

EXECUTIVE SUMMARY

By any measure, the Bristol Bay sockeye salmon fishery is very large and valuable. It is the world's most valuable wild salmon fishery, and typically supplies almost half of the world's wild sockeye salmon. In 2010, harvesting, processing, and retailing Bristol Bay salmon and the multiplier effects of these activities **created $1.5 billion** in output or sales value across the United States.

In 2010, Bristol Bay salmon fishermen harvested 29 million sockeye salmon worth $165 million in direct harvest value alone. That represented 31% of the total Alaska salmon harvest value, and was greater than the total value of fish harvests in 41 states. Salmon processing in Bristol Bay increased the value by $225 million, for a total first wholesale value after processing of $390 million. The total value of Bristol Bay salmon product exports in 2010 was about $250 million, or about 6% of the total value of all U.S. seafood exports.

In 2010, the Bristol Bay sockeye salmon fishery supported 12,000 fishing and processing jobs during the summer salmon fishing season. Measuring these as year-round jobs, and adding jobs created in other industries, the Bristol Bay salmon fishery created the equivalent of almost 10,000 year-round American jobs across the country, and brought Americans $500 million in income. For every dollar of direct output value created in Bristol Bay fishing and processing, more than two additional dollars of output value are created in other industries, as payments from the Bristol Bay fishery ripple through the economy. These payments create almost three jobs for every direct job in Bristol Bay fishing and processing.

United States domestic consumption of Bristol Bay frozen sockeye salmon products has been growing over time as a result of sustained and effective marketing by the industry, new product development and other factors. This growth is likely to continue over time, which will result in even greater output value figures for the industry's economic impacts across the U.S.

The economic importance of the Bristol Bay salmon industry extends far beyond Alaska, particularly to the West Coast states of Washington, Oregon and California.

- About one-third of Bristol Bay fishermen and two-thirds of Bristol Bay processing workers live in West Coast states.
- Almost all major Bristol Bay processing companies are based in Seattle.
- Most of the supplies and services used in fishing and processing are purchased in Washington state.
- Significant secondary processing of Bristol Bay salmon products occurs in Washington and Oregon.

Bristol Bay fishing boats

The economic importance of the Bristol Bay salmon industry goes well beyond the value, jobs, and income created by the fishing and processing which happens in Bristol Bay. More value, jobs and income are created in *downstream industries* as

Bristol Bay salmon are shipped to other states, undergo further processing, and are sold in stores and restaurants across the United States. Still more jobs, income and value are created in other industries through *multiplier impacts* as Bristol Bay fishermen and processors and downstream industries purchase supplies and services, and as their employees spend their income.

Economic Impacts of the Bristol Bay Salmon Industry in 2010

Annual average employment: 9,800 jobs	Output value: $1.5 billion	Income: $500 million
Fishing & processing in Bristol Bay		
12,000 seasonal jobs (=2,000 annual jobs)	$390 million	$140 million
Shipping, secondary processing & retailing after Bristol Bay		
1,000 jobs	$110 million	$40 million
Multiplier impacts in other industries		
6,800 jobs	$970 million	$320 million

Overview of the Bristol Bay Salmon Industry

Bristol Bay is located in southwestern Alaska. Each year tens of millions of sockeye salmon return to spawn in the major river systems which flow into Bristol Bay. The large lakes of the Bristol Bay region provide habitat for juvenile sockeye salmon during their first year of life.

A Bristol Bay salmon fisherman

For well over a century, Bristol Bay salmon have supported a major salmon fishing and processing industry. Most of the harvest occurs between mid-June and mid-July. At the peak of the fishing season, millions of salmon may be harvested in a single day.

Only holders of limited entry permits (issued by Alaska's state government) and their crew are allowed to fish in Bristol Bay. There are permits for two kinds of fishing gear: drift gillnets (operated from fishing boats) and set gillnets (operated from shore). There are approximately 1,860 drift gillnet permits and approximately 1,000 set net permits. Drift gillnet permits average much higher catches and account for most of the total catch. About one-third of the permit holders are from West Coast states.

Bristol Bay Salmon Industry Permit Holders, by State of Residence, 2010

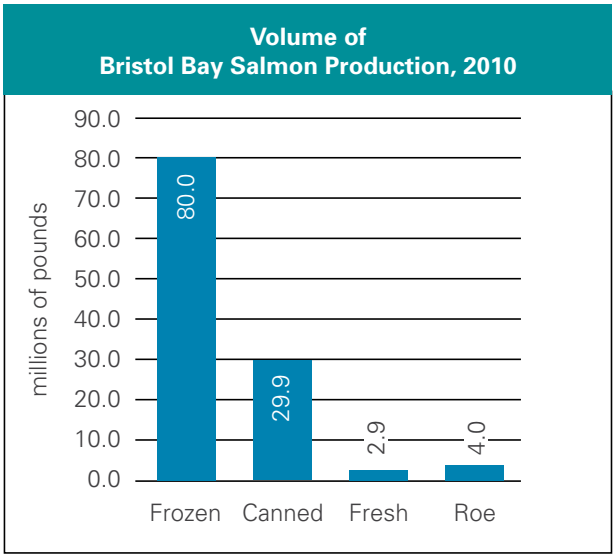
Permit Type	Alaska	Washington	Oregon	California	Other States & Countries	Total
Drift Gillnet	845	642	98	109	156	1,850
Set Gillnet	629	127	38	34	99	927
Total	1,474	769	136	143	255	2,777

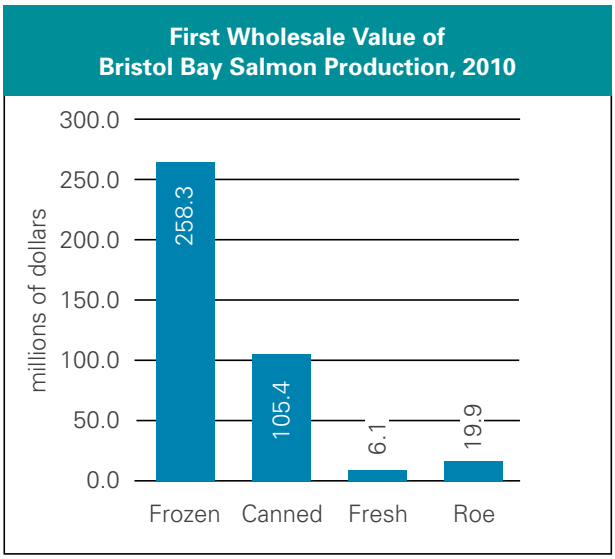
For each permit holder, who is usually a captain, there are typically two to three additional crew members. About 7,000 fishermen fished in Bristol Bay in 2010.

The Bristol Bay salmon harvest is processed by about 10 large processing companies and 20 smaller companies employing about 5,000 processing workers at the peak of the season in both land-based and floating processing operations. Most of the workers are from other states and live in bunkhouse facilities at the processing plants.

Bristol Bay salmon are processed into four major primary products: frozen salmon, canned salmon, fresh salmon, and salmon roe. Frozen salmon includes both headed and gutted (H&G) salmon as well as salmon fillets.

Frozen and canned salmon account for most of the volume and value of Bristol Bay salmon production.

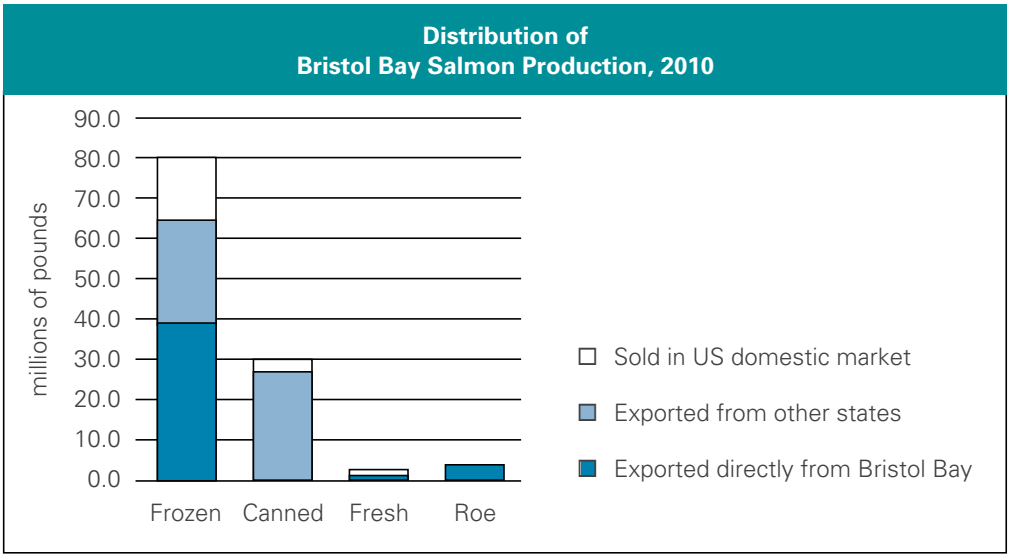




About half of Bristol Bay frozen salmon is exported directly from Bristol Bay, primarily to Japan and China. Most of the remaining frozen salmon is shipped to Washington state where much of it is repackaged and/or reprocessed into secondary products such as fillets, portions and smoked salmon. Some of these products are exported while the rest are sold in the US domestic market.

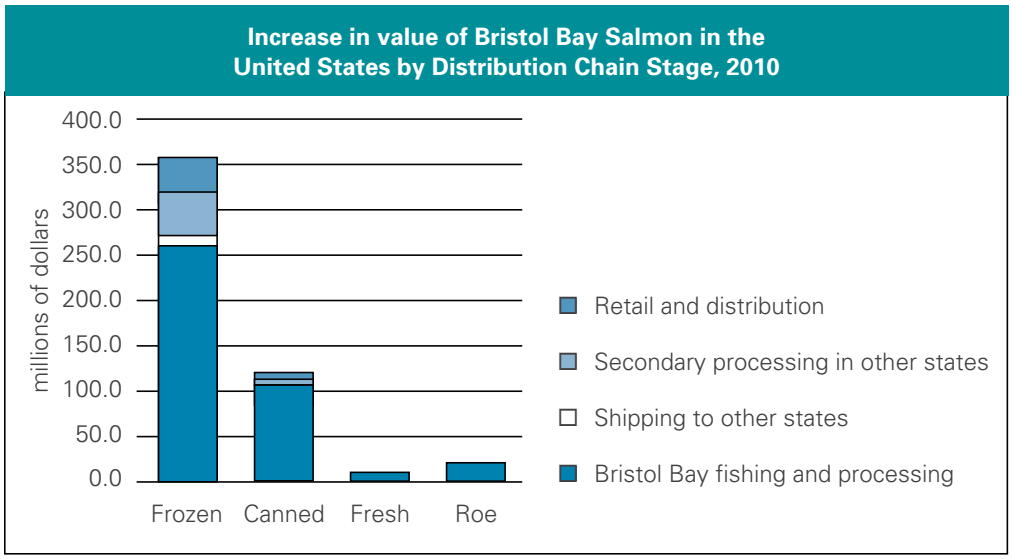
Bristol Bay canned salmon is shipped to warehouses in Washington and Oregon where it is stored, labeled, and sold by processors over the course of the year, mostly to the United Kingdom and other export markets.

The total value of Bristol Bay salmon product exports in 2010 was about $252 million, or about **6% of the total value of all U.S. seafood exports.**



The value of Bristol Bay salmon increases at each stage in the distribution chain. Because a large share is exported, most of the increase in value in the United States occurs in Bristol Bay fishing and processing. About one-fifth of the total increase in value occurs in later stages of the distribution chain.

Containers for shipping Bristol Bay salmon products



Economic Impacts of the Bristol Bay Salmon Industry

Economic impacts of the Bristol Bay salmon industry are the jobs, income and output value created by the fishery—or the jobs, income and output value that would not exist if the industry did not exist. Economic impacts include:

» *Direct economic impacts:* Jobs, income and output value in businesses directly involved in harvesting, processing, and retailing Bristol Bay salmon.

» *Multiplier economic impacts:* Jobs, income and output value created in other industries as Bristol Bay fishermen, processors and downstream industries purchase supplies and services, and as their employees spend their income.

We estimated both direct and indirect economic impacts for three stages of the distribution or value chain for Bristol Bay salmon in the United States:

» Fishing and primary processing in Bristol Bay

» Shipping to other states and secondary processing

» Distribution and retailing (nationwide transportation, wholesaling and retailing of Bristol Bay salmon products in stores and restaurants throughout the United States)[1]

[1] The economic effects of distribution and retailing of Bristol Bay salmon are technically economic contributions rather than economic impacts, because if Bristol Bay salmon did not exist stores would sell other products instead, which would still create jobs, income and output value. Because no data are available for Bristol Bay salmon retail volumes and prices, our estimates of economic contributions for this stage are based on the simple assumption that distribution and retailing increases the value of Bristol Bay salmon products by an average of 50%.

We estimated economic impacts for the United States as well as for Alaska, Washington, Oregon and California in 2010. To estimate economic impacts, we used IMPLAN input-output modeling software which tracks the ripple effects of payments between industries at both the national level as well as within individual states.

Our economic impact estimates do not account for the fact that Bristol Bay salmon fishing and processing helps to cover a significant share of the fixed costs of many Alaska and Pacific Northwest fishermen and processors, or for the economic benefits of Bristol Bay salmon exports in helping to offset the large United States seafood trade deficit. Thus our estimates of the economic importance of the Bristol Bay seafood industry are conservative.

In 2010, almost 12,000 people worked in the Bristol Bay salmon industry during the fishing season, which occurs primarily in June and July. Of these, about 4,400 were Alaska residents, while most of the others were residents of West Coast states.

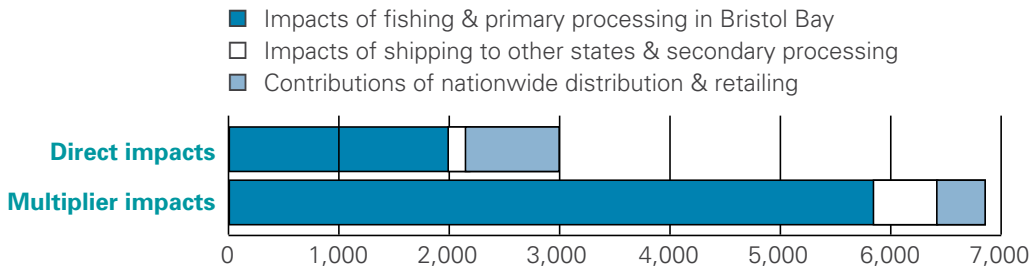
To compare Bristol Bay seasonal jobs lasting about two months with other year-round employment impacts, we converted them to annual average employment by dividing seasonal employment by six. Expressed as annual average employment, in 2010, almost 10,000 American jobs were created in harvesting, processing, and retailing Bristol Bay salmon and through the multiplier effects of these activities.

In 2010, Americans earned $500 million from harvesting, processing, and retailing Bristol Bay salmon and the multiplier effects of these activities.

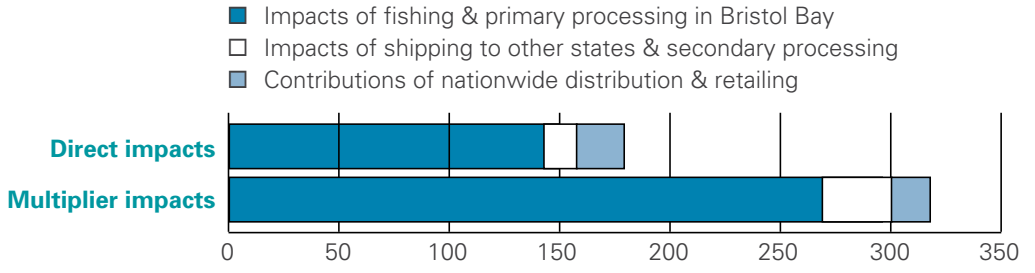
Seasonal Jobs in the Bristol Bay Salmon Industry, by State of Residence, 2010

	Total US	Alaska	Washington	Oregon	California	Other States
Fishing	7,035	3,734	1,948	362	345	646
Processing	4,886	635	1,279	1,781	208	983
Total	11,921	4,369	3,227	2,143	553	1,629

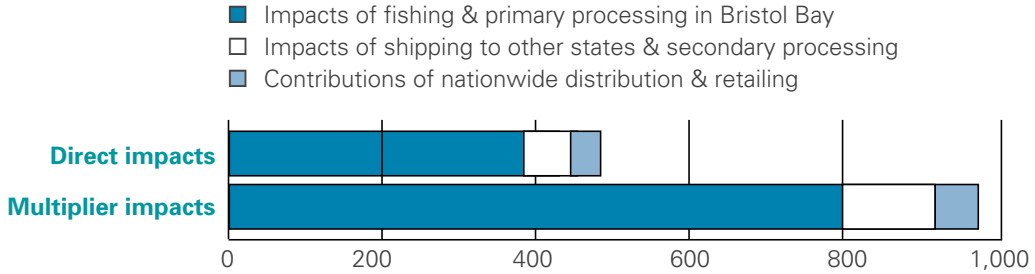
Employment Impacts of the Bristol Bay Salmon Industry, Total US, 2010



Income Impacts of the Bristol Bay Salmon Industry, Total US, 2010



Output Value Impacts of the Bristol Bay Salmon Industry, Total US, 2010



In 2010, $1.5 billion in output value was created in the United States in harvesting, processing, and retailing Bristol Bay salmon and the multiplier effects of these activities.

The tables below provide additional details of our economic impact estimates. A large share of the impacts occur in West Coast states—reflecting the fact that about one-third of Bristol Bay fishermen and two-thirds of Bristol Bay processing workers live in West Coast states; almost all major Bristol Bay processing companies are based in Seattle; most of the supplies and services used in fishing and processing are purchased from Washington; and significant secondary processing of Bristol Bay salmon products occurs in Washington and Oregon.

Employment Impacts of the Bristol Bay Salmon Industry, 2010 (annual average employment)

Impact Driver		Total US	AK	WA	OR	CA	Other States
Fishing and primary processing in Bristol Bay	Direct impacts*	1,987	728	538	92	357	271
	Multiplier impacts	5,852	1,338	2,237	163	249	1,865
	Total impacts	**7,839**	**2,066**	**2,775**	**255**	**606**	**2,137**
Shipping to other states and secondary processing	Direct impacts	191		156	15		
	Multiplier impacts	563		229	24		
	Total impacts	**754**		**385**	**39**		
Total impacts		**8,592**		**3,160**	**294**		
Nationwide distribution and retailing**	Direct contributions	787	Note: Total US may exceed sum of estimates shown for individual states; see report for technical explanation. *Direct employment impacts of fishing and processing in Bristol Bay were calculated by dividing seasonal employment by 6. **Based on conservative assumption that distribution and retailing increases value by 50%.				
	Multiplier contributions	425					
	Total contributions	**1,212**					
Total impacts & contributions		**9,804**					

Income Impacts of the Bristol Bay Salmon Industry, 2010 (millions of dollars)

Impact Driver		Total US	AK	WA	OR	CA	Other States
Fishing and primary processing in Bristol Bay	Direct impacts	144	50	48	8	19	18
	Multiplier impacts	268	62	98	7	12	90
	Total impacts	**412**	**112**	**146**	**15**	**31**	**108**
Shipping to other states and secondary processing	Direct impacts	13		11	1		
	Multiplier impacts	30		12	1		
	Total impacts	**43**		**23**	**2**		
Total impacts		**455**		**169**	**17**		
Nationwide distribution and retailing*	Direct contributions	23	Note: Total US may exceed sum of estimates shown for individual states; see report for technical explanation. *Based on conservative assumption that distribution and retailing increases value by 50%.				
	Multiplier contributions	20					
	Total contributions	**42**					
Total impacts & contributions		**497**					

Output Value Impacts of the Bristol Bay Salmon Industry, 2010 (millions of dollars)							
Impact Driver		Total US	AK	WA	OR	CA	Other States
Fishing and primary processing in Bristol Bay	Direct impacts	390	127	198	13	19	32
	Multiplier impacts	801	161	288	19	37	297
	Total impacts	**1,191**	**288**	**486**	**32**	**56**	**329**
Shipping to other states and secondary processing in WA & OR	Direct impacts	68		56	4		
	Multiplier impacts	111		37	3		
	Total impacts	**179**		**93**	**6**		
Total impacts		**1,370**		**580**	**38**		
Nationwide distribution and retailing*	Direct contributions	46	Note: Total US may exceed sum of estimates shown for individual states; see report for technical explanation. Output value allocated among states based on the residency of fishing and processing workers and business locations. * Based on conservative assumption that distribution and retailing increases value by 50%.				
	Multiplier contributions	61					
	Total contributions	**106**					
Total impacts & contributions		**1,476**					

Conclusions

The Bristol Bay salmon fishery is the world's most valuable wild salmon fishery. It contributes well over $1 billion in value and about 10,000 jobs to the United States economy every year, across multiple industries and states. It has operated continuously for more than 120 years and can continue to provide significant and widespread economic benefits across multiple industries and states for the foreseeable future.

LETTERS

Population diversity and the portfolio effect in an exploited species

Daniel E. Schindler[1], Ray Hilborn[1], Brandon Chasco[1], Christopher P. Boatright[1], Thomas P. Quinn[1], Lauren A. Rogers[1] & Michael S. Webster[2]

One of the most pervasive themes in ecology is that biological diversity stabilizes ecosystem processes and the services they provide to society[1–4], a concept that has become a common argument for biodiversity conservation[5]. Species-rich communities are thought to produce more temporally stable ecosystem services because of the complementary or independent dynamics among species that perform similar ecosystem functions[6]. Such variance dampening within communities is referred to as a portfolio effect[7] and is analogous to the effects of asset diversity on the stability of financial portfolios[8]. In ecology, these arguments have focused on the effects of species diversity on ecosystem stability but have not considered the importance of biologically relevant diversity within individual species[9]. Current rates of population extirpation are probably at least three orders of magnitude higher than species extinction rates[10], so there is a pressing need to clarify how population and life history diversity affect the performance of individual species in providing important ecosystem services. Here we use five decades of data from *Oncorhynchus nerka* (sockeye salmon) in Bristol Bay, Alaska, to provide the first quantification of portfolio effects that derive from population and life history diversity in an important and heavily exploited species. Variability in annual Bristol Bay salmon returns is 2.2 times lower than it would be if the system consisted of a single homogenous population rather than the several hundred discrete populations it currently consists of. Furthermore, if it were a single homogeneous population, such increased variability would lead to ten times more frequent fisheries closures. Portfolio effects are also evident in watershed food webs, where they stabilize and extend predator access to salmon resources. Our results demonstrate the critical importance of maintaining population diversity for stabilizing ecosystem services and securing the economies and livelihoods that depend on them. The reliability of ecosystem services will erode faster than indicated by species loss alone.

The recent focus on ecosystem-based management of renewable resources emphasizes species interactions and how these are affected by human activities within exploited ecosystems. However, there is growing recognition that population diversity within exploited species can contribute to their long-term sustainability and should be incorporated more explicitly into management and conservation schemes[11,12]. For example, it has been argued[11] that population diversity reduced the temporal variability of sockeye salmon fisheries in Bristol Bay because of complementary dynamics in different components of the stock complex. Similar phenomena are now appreciated qualitatively in other marine ecosystems[12]. However, at present there are neither quantitative estimates of the strength of portfolio effects produced by population and life history diversity in exploited species, nor an objective assessment of the benefits of population diversity to human economies and ecosystem services in general.

From 1950 to 2008, sockeye salmon supported the most valuable fisheries in the United States (landed value, US$7,900,000,000), and 63% of the associated revenue came from Bristol Bay (see Supplementary Information for details). The total economic value of this fishery is considerably higher when considering the retail, cultural and recreational value of these fish. Income from sockeye salmon in Bristol Bay is the major source of personal income for most Bristol Bay communities, and landing taxes provide the major funding for local school districts. Thus, the interannual reliability of this fishery has critical and direct consequences for the livelihoods of people in this region.

Population diversity within the stock complex of Bristol Bay sockeye substantially reduces the interannual variability experienced by the commercial fishery, which intercepts sockeye salmon as they enter each of the nine major rivers of this region (Fig. 1a). Each river stock contains tens to hundreds of locally adapted populations distributed among tributaries and lakes (Fig. 1b and Supplementary Fig. 1). This remarkable diversity in sockeye reflects their ability to thrive in a wide range of habitat conditions, the reproductive isolation of populations by precise homing to natal spawning sites, and their capacity for microevolution[13]. Thus, the Bristol Bay sockeye fishery integrates across substantial population diversity both within and among watersheds.

Annual sockeye returns to the Bristol Bay stock complex were considerably less variable (coefficient of variation (standard deviation divided by mean), CV = 55%) than those observed for individual rivers (average CV = 77%; Fig. 1c) for 1962–2008. Annual returns to individual populations spawning in streams of the Wood River system, where long-term detailed population assessments are available (Fig. 1b), were more variable (average CV = 95%) than both the aggregate of these streams (CV = 67%) and the total returns to the Wood River (CV = 60%; Fig. 1c). Thus, annual sockeye returns become increasingly more stable across the complexity hierarchy ranging from individual spawning populations to stocks associated with the watersheds of major rivers and, eventually, to the regional stock complex of Bristol Bay.

The degree of temporal covariation among portfolio assets controls the strength of portfolio effects[8,14]; the buffering effects of asset diversity on variability of the aggregate portfolio become weaker as asset dynamics become more synchronous. Analysis of the covariation among river stocks and among stream populations (that is, the analogues of assets in an investment portfolio) showed that annual sockeye returns were only weakly synchronous (and some negatively correlated) both within and among the watersheds of Bristol Bay. This lack of synchrony among populations of Bristol Bay sockeye occurred despite many commonalities in their migration corridors, nursery habitats and seasonal timing of migrations between freshwater and marine environments. Furthermore, strong shifts in climatic conditions

[1]School of Aquatic and Fishery Sciences, University of Washington, Box 355020, Seattle, Washington 98195-5020, USA. [2]The Gordon and Betty Moore Foundation, 1661 Page Mill Road, Palo Alto, California 94304, USA.

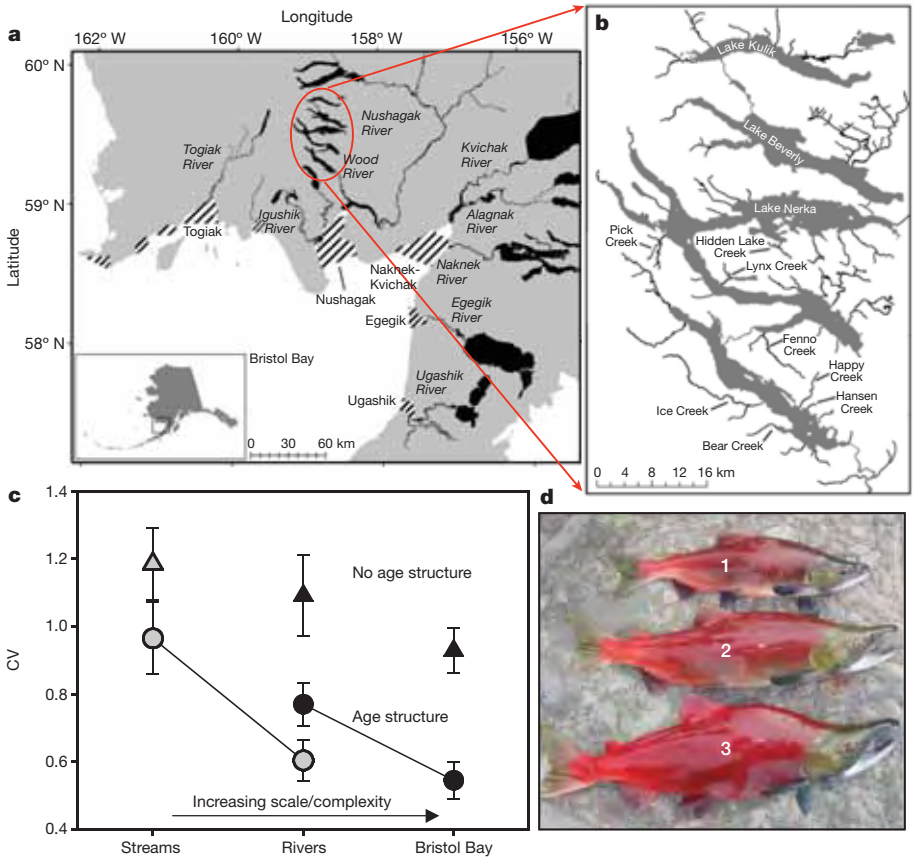


Figure 1 | Bristol Bay sockeye habitat and associated change in variability of returns at different spatial scales and levels of life history aggregation. **a**, Map of Bristol Bay, southwest Alaska. Sockeye salmon nursery lakes are shown in solid black. Fishing districts associated with major rivers are highlighted as striped areas. **b**, Map of the Wood River system showing streams supporting anadromous salmon populations. **c**, Interannual variability in total returns to sockeye populations and stocks at three spatial scales and two levels of life history aggregation. Grey symbols are for the Wood River, highlighting the watershed for which continuous long-term data on stream populations (1962–2007, $n = 8$) exist. Black symbols are for rivers (including the Wood River, $n = 8$) and the Bristol Bay aggregate (1958–2008). Circles show average variabilities for populations and stocks with their observed age composition, and triangles show average variabilities for the dominant age classes at each spatial scale. Error bars, 1 s.e. **d**, Three age classes of reproductively mature male sockeye salmon from the Wood River that have spent one, two or three years at sea, as indicated.

of the North Pacific Ocean during the past century[15,16] should also have induced synchrony in the population dynamics of the stock complex, but had little effect (Supplementary Fig. 2). Thus, the portfolio effects observed in Bristol Bay sockeye, both among major rivers and within individual watersheds, are derived from the weakly synchronous population dynamics among the components of this stock complex. If portfolio components in Bristol Bay fluctuated fully independently of one another, the expected CV would be only marginally lower (42% for rivers, 38% for Wood River tributary populations) than is currently observed (55% for rivers, 67% for tributary populations).

Life history diversity further buffers the variability of the sockeye stock complex. Most Bristol Bay sockeye spend one to two years rearing in fresh water and one to three years in the ocean as they complete their life cycles (Fig. 1d). This staggered age structure reduces variation in recruitment because it reduces the probability that all individuals in a cohort of siblings will encounter unfavourable environmental conditions over the course of the life cycle. To assess the effect of age structure diversity on variability, we compared the CV of total annual returns (above) with the CV observed within the two dominant age classes at each level of spatial aggregation considered earlier (Supplementary Fig. 3). The CVs of the dominant age classes in stream populations, river stocks and the Bristol Bay stock complex were respectively 44%, 42% and 69% higher than the variabilities observed at these spatial scales for the diversified population age structure (Fig. 1c). In sum, if the dynamics of Bristol Bay sockeye returns were characterized by the most simplified spatial and life history portfolio (that is, dominant age classes in the average stream population), they would be about 2.2 times more temporally variable (CV = 119%) than is currently observed for the Bristol Bay stock complex with its full complement of population and life history diversity.

To illustrate the value to commercial fisheries of population and life history diversity in Bristol Bay sockeye, we considered alternative hypothetical stocks characterized by the same long-term average return (30,000,000 fish) but with different interannual CVs. Furthermore, we assumed that fishery management would resemble the current system, in which the management goal is to allow approximately 10,000,000 fish onto the spawning grounds per year; returns in excess of 10,000,000 are harvested, and no fishing is allowed in years when fewer than 10,000,000 sockeye return. Given the current variability of the Bristol Bay stock complex, this picture translates into a complete fishery closure less than four times per century (Fig. 2). If Bristol Bay sockeye lacked the dampening effects population and life history diversity provide, complete fishery closures would occur every two to three years (Fig. 2). Thus, the net result of losing population and life history diversity could be a tenfold increase in the frequency of fishery closures, generating considerable hardship for people who rely on consistent annual returns for their livelihoods. A full assessment of the economic implications of such increased interannual variability resulting from loss of population and life history diversity would be valuable, but the necessary livelihood and economic data are lacking at present.

In addition to sustaining a valuable marine fishery, sockeye also support a diverse array of well-documented ecosystem processes and services in the watersheds where they spawn[17,18] (Supplementary

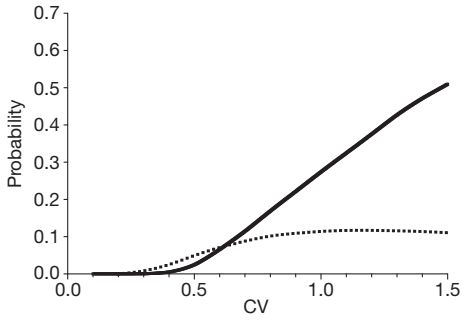


Figure 2 | Effect of interannual variability on the probability of fishery closures or capacity-swamping returns. Probability of total annual return being less than 10,000,000 (solid line) or greater than 60,000,000 (dotted line) as a function of the coefficient of variation in the overall distribution of returns. No fishing is allowed when total returns are less than about 10,000,000. Returns in excess of 60,000,000 swamp the capacity of the fishing fleet and processing industry to capture their allocation of the resource. Stock abundances were assumed to be characterized by log-normal distributions. Current Bristol Bay returns have a CV of about 0.55 and the simplest component of the stock dynamics is about 1.2.

Information). Sockeye release substantial quantities of productivity-limiting nutrients following their post-spawning death[19], and are the dominant food source for a community of mobile predators and scavengers in freshwater and terrestrial ecosystems. These species perform important ecosystem functions such as dispersing salmon-derived nutrients from spawning sites to the broader landscape[20,21]. Like commercial fisheries, many of these consumers are mobile and can capitalize on spatial variation in sockeye resources associated with the dynamics of individual populations within each river system. Using data on the number of spawning fish observed on the spawning grounds (the 'escapement'), the average CV observed for streams was 82% whereas that for their aggregate was 46% and that for the entire Wood River was 50%. Thus, consumers able to capitalize on high-density sockeye populations experience substantially less interannual variation in salmon resources than they would if they focused on individual stream populations or if population dynamics within the stock were highly synchronous.

The life history diversity observed in the seasonal timing of migration and spawning among populations further enhances many ecosystem services by extending the seasonal availability of salmon resources to the fishery and watershed food webs (Fig. 3). For example, in a typical commercial fishing season 90% of the catch is taken in about 16 days, yet the midpoints of sockeye migration to the respective fishing districts vary over a range of about 13 days (Fig. 3a). This variation in migration timing allows the fishing fleet to assess relative abundance of sockeye among districts and redirect effort to capture fish from multiple districts within a season. If seasonal migration timing were more synchronous among rivers, the window of opportunity to capture sockeye would be more constrained and the capture and processing fleet more easily saturated at the peak of the run. Seasonal access to sockeye by mobile predators is similarly extended because of staggered spawn timing among tributary and lake populations (Fig. 3b and Supplementary Fig. 3). Most sockeye populations are vulnerable to predators and scavengers in individual spawning habitats for approximately one month each year. However, salmon are present for over 2.5 months in spawning habitats throughout the Wood River watershed (Fig. 3b), owing to variation in the spawn timing among populations. Thus, watershed consumers of salmon and the ecosystem services they provide (for example trout fishing and wildlife viewing) also benefit from the variation in spawn timing, which represents one of many dimensions of life history variation in this species[13].

Although most large-scale fisheries probably integrate across considerable intraspecific diversity in a manner similar to that described here, this 'stock structure' is usually ignored by management focused

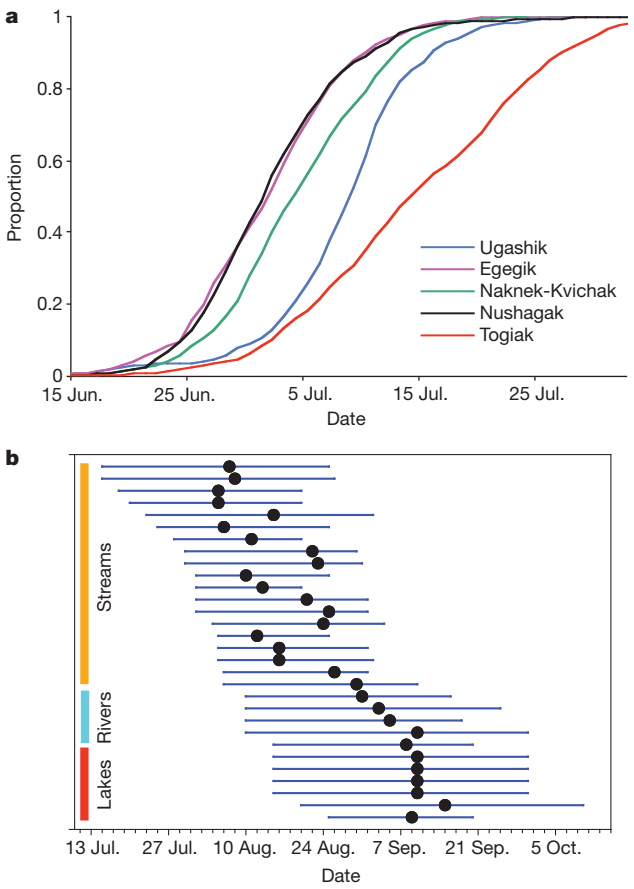


Figure 3 | Annual run timing to fishing districts and streams. a, Cumulative returns (catch plus escapement) to each of the major fishing districts in Bristol Bay for 2000–2007. The Bristol Bay fishery can currently process about 2,000,000 fish per day; on days with total returns above this level, the industry cannot capture their allocation of the resource. Between 1978 and 2007, the daily catch plus escapement was >2,000,000 fish on about seven days per season, on average. However, if all the fish had arrived at the fishing grounds with exactly the same timing, as determined by the distribution observed in any single fishing district in a given year, the length of the peak fishing season would have been reduced on average by 20% (range, 8–34%). **b**, Comparison of the dates of occupancy (dot, peak; line, occupancy period) in spawning habitats where sockeye salmon are available to predators and scavengers for 30 populations in the Wood River system (Supplementary Fig. 1).

on numerically dominant stock components[12]. Variation in the population dynamics of Bristol Bay sockeye is easy to monitor because of spatial separation among stock components resulting from the homing tendencies within populations. However, similar population diversity, although more cryptic, may exist and be equally important in other species[22], a possibility supported by the growing recognition of homing tendencies in marine and freshwater fish stocks[23,24]. There is no reason to believe that population and life history diversity are any less important in other aquatic or terrestrial species that are focuses of exploitation or conservation.

The portfolio effects in the Bristol Bay sockeye stock complex are a characteristic of a landscape with a largely undisturbed habitat, natural hydrologic regimes and neither invasive species nor artificial propagation of salmon in hatcheries, combined with sustainable fishery exploitation. In contrast, in the southern end of their range, Pacific salmon populations have declined substantially owing to the cumulative impacts of heavy exploitation, habitat loss, climate change, hatchery dependence and hydropower development. Recent assessments show that 29% of 1,400 populations of Pacific salmon in the US Pacific Northwest and California have been extirpated since European contact[25]. What is underappreciated is that extant stocks in highly

affected watersheds have also lost some of the stabilizing portfolio effects that we observe in Bristol Bay[26,27].

Although ecosystem management schemes commonly map the habitat requirements of individual species, it is rare to consider the heterogeneity and disturbance regimes that maintain population and life history diversity in ecosystems. In the case of fisheries management, minimizing the homogenizing effects of hatcheries on genetic diversity and protection of weak stocks from overharvesting in mixed stock fisheries will be required to maintain the diversity that stabilizes variance in returns. Without this broader framework for conserving the roles of individual species, the resilience biodiversity provides to ecosystems[28] will deteriorate well before individual species are extirpated.

METHODS SUMMARY

Annual sockeye escapements to rivers were enumerated visually from towers on each of the Bristol Bay rivers by the Alaska Department of Fish and Game[29]. Age composition of sockeye was estimated by subsampling approximately 50,000 fish from the fisheries and the escapement towers in each year. Total returns to each river were calculated as the sum of fisheries catch and the escapement to the spawning grounds. In fishing districts that capture fish from neighbouring rivers, age composition comparisons between the fishery catch and the escapement towers was used to assign harvested fish to the total annual return to each river[29]. Stream-spawning populations of sockeye salmon in the Wood River system were monitored by two to four people who surveyed the entire extent of habitat suitable for sockeye spawning at least once per year at the peak of spawning activity. Otoliths were sampled annually from up to 220 fish from each steam to determine the age composition of the escapement. The total stream production for eight streams was calculated by accounting for the age- and year-specific vulnerabilities to the fishery and then adding estimated fishery interceptions back to the stream-spawning populations on the basis of the stream age composition in each year[30]. Interannual variability was calculated as the CV for all situations considered.

Full Methods and any associated references are available in the online version of the paper at www.nature.com/nature.

Received 21 October 2009; accepted 24 March 2010.

1. MacArthur, R. H. Fluctuations of animal populations, and a measure of community stability. *Ecology* **36,** 533–536 (1955).
2. Elton, C. S. *The Ecology of Invasions by Animals and Plants* (Chapman & Hall, 1958).
3. Hooper, D. U. *et al.* Effects of biodiversity on ecosystem functioning: a consensus of current knowledge. *Ecol. Monogr.* **75,** 3–35 (2005).
4. Chapin, F. S. *et al.* Consequences of changing biodiversity. *Nature* **405,** 234–242 (2000).
5. Duffy, J. E. Why biodiversity is important to the functioning of real-world ecosystems. *Front. Ecol. Environ* **7,** 437–444 (2009).
6. Tilman, D. Biodiversity: population versus ecosystem stability. *Ecology* **77,** 350–363 (1996).
7. Figge, F. Bio-folio: applying portfolio theory to biodiversity. *Biodivers. Conserv.* **13,** 827–849 (2004).
8. Markowitz, H. Portfolio selection. *J. Finance* **7,** 77–91 (1952).
9. Luck, G. W., Daily, G. C. & Ehrlich, P. R. Population diversity and ecosystem services. *Trends Ecol. Evol.* **18,** 331–336 (2003).
10. Hughes, J. B., Daily, G. C. & Ehrlich, P. R. Population diversity: its extent and extinction. *Science* **278,** 689–692 (1997).
11. Hilborn, R., Quinn, T. P., Schindler, D. E. & Rogers, D. E. Biocomplexity and fisheries sustainability. *Proc. Natl Acad. Sci. USA* **100,** 6564–6568 (2003).
12. Hutchinson, W. F. The dangers of ignoring stock complexity in fishery management: the case of the North Sea cod. *Biol. Lett.* **4,** 693–695 (2008).
13. Quinn, T. P. *The Behavior and Ecology of Pacific Salmon and Trout* (Univ. Washington Press, 2005).
14. Doak, D. F. *et al.* The statistical inevitability of stability-diversity relationships in community ecology. *Am. Nat.* **151,** 264–276 (1998).
15. Mantua, N. J. & Hare, S. R. The Pacific decadal oscillation. *J. Oceanogr.* **58,** 35–44 (2002).
16. Schindler, D. E. *et al.* Climate change, ecosystem impacts, and management for Pacific salmon. *Fisheries* **33,** 502–506 (2008).
17. Gende, S. M., Edwards, R. T., Willson, M. F. & Wipfli, M. S. Pacific salmon in aquatic and terrestrial ecosystems. *Bioscience* **52,** 917–928 (2002).
18. Naiman, R. J., Bilby, R. E., Schindler, D. E. & Helfield, J. M. Pacific salmon, nutrients, and the dynamics of freshwater and riparian ecosystems. *Ecosystems (NY, Print)* **5,** 399–417 (2002).
19. Schindler, D. E., Leavitt, P. R., Brock, C. S., Johnson, S. P. & Quay, P. D. Marine-derived nutrients, commercial fisheries, and production of salmon and lake algae in Alaska. *Ecology* **86,** 3225–3231 (2005).
20. Helfield, J. M., &. Naiman, R. J. Keystone interactions: salmon and bear in riparian forests of Alaska. *Ecosystems (NY, Print)* **9,** 167–180 (2006).
21. Payne, L. X. & Moore, J. M. Mobile scavengers create hotspots of freshwater productivity. *Oikos* **115,** 69–80 (2006).
22. Olsen, E. M. *et al.* Small-scale biocomplexity in coastal Atlantic cod supporting a Darwinian perspective on fisheries management. *Evol. Appl.* **1,** 524–533 (2008).
23. Dixson, D. L. *et al.* Coral reef fish smell leaves to find island homes. *Proc. R. Soc. Lond. B* **275,** 2831–2839 (2008).
24. Rooker, J. R. *et al.* Natal homing and connectivity in Atlantic bluefin tuna populations. *Science* **322,** 742–744 (2008).
25. Gustafson, R. G. *et al.* Pacific salmon extinctions: quantifying lost and remaining diversity. *Conserv. Biol.* **21,** 1009–1020 (2007).
26. Lindley, S. T. *et al. What Caused the Sacramento River Fall Chinook Stock Collapse?* Pre-publication report (Pacific Fishery Management Council, 2009); available at ⟨http://swr.nmfs.noaa.gov/media/salmondeclinereport.pdf⟩.
27. Moore, J. W., McClure, M., Rogers, L. A. & Schindler, D. E. Synchronization and portfolio performance of threatened salmon. *Conserv. Lett.* doi:10.1111/j.1755-263X.2010.00119.x (in the press).
28. Folke, C. *et al.* Regime shifts, resilience, and biodiversity in ecosystem management. *Annu. Rev. Ecol. Syst.* **35,** 557–581 (2004).
29. West, F. W. & Fair, L. F. *Abundance, Age, Sex, and Size Statistics for Pacific Salmon in Bristol Bay, 2003.* Fishery Data Series No. 06–47 (Alaska Department of Fish and Game, 2006).
30. Rogers, L. A. & Schindler, D. E. Asynchrony in population dynamics in sockeye salmon of southwest Alaska. *Oikos* **117,** 1578–1586 (2008).

Supplementary Information is linked to the online version of the paper at www.nature.com/nature.

Acknowledgements We thank the Gordon and Betty Moore Foundation, the US National Science Foundation, the University of Washington, the Alaska salmon processing industry and the H. Mason Keeler Professorship for support for this work. N. Baron, L. Neeley and S. Sethi provided feedback and comments on the manuscript, and P. Lisi and G. Holtgrieve helped prepare the figures.

Author Contributions D.E.S. designed and coordinated the project; R.H., B.C. and L.A.R contributed to the analyses; M.S.W. helped design the project; and all authors contributed to the writing.

Author Information Reprints and permissions information is available at www.nature.com/reprints. The authors declare no competing financial interests. Readers are welcome to comment on the online version of this article at www.nature.com/nature. Correspondence and requests for materials should be addressed to D.E.S. (deschind@u.washington.edu).

METHODS

River escapements were estimated by visual counts from towers located on either side of each of the Bristol Bay rivers by the Alaska Department of Fish and Game[29]. Migrating sockeye were counted for 20 min each hour, split equally between the two sides of each river, and these figures were extrapolated into daily escapement estimates. Nine major rivers contribute to the Bristol Bay fishery. For the analyses in this paper, we have not included the populations in the Nushagak River, as these have only been enumerated for the past two decades. Ages (numbers of years in fresh water and in the ocean) of fish were determined by visual examination of scales or otoliths sampled in the escapement and in the fishery catches.

Stream-spawning populations of sockeye salmon have been monitored by the University of Washington since 1956 throughout the Wood River system. Stream surveys were conducted by two to four people who walked the entire extent of habitat suitable for sockeye spawning at least once per year at the peak of spawning activity, counting the live and dead sockeye. Otoliths were sampled annually from up to 220 fish from each steam to determine the age composition of the returns. The total stream production for eight streams was calculated by accounting for the age- and year-specific vulnerabilities to the fishery on the basis of samples collected in the fishery, and then adding estimated fishery interceptions back to the stream-spawning populations on the basis of the stream age composition in each year[30].

The interannual variability in total returns to Bristol Bay was compared with the variability observed in the total returns to each of the major rivers. The variability in the annual returns to each of the eight streams in the Wood River for which we had detailed age composition data, which could be used to apportion fishery catches to total annual returns, was compared to the inter-annual variability observed in total returns to the Wood River system as a whole. When considering services provided by sockeye in freshwater ecosystems, we assessed variability only for sockeye abundance in the spawning grounds for the eight stream populations (that is, not including fishery interceptions).

We calculated covariations among the numbers of sockeye that returned to each of the rivers or streams (Supplementary Fig. 2) as the Pearson correlation among all pairwise combinations of stocks or populations with a minimum of ten years of concurrent data. Because the time series were often positively auto-correlated, we used the method of ref. 31 to adjust the degrees of freedom in tests of significance for each pairwise correlation. Tests of statistical significance were two-tailed, with $\alpha = 0.05$.

31. Pyper, B. J. & Peterman, R. M. Comparison of methods to account for autocorrelation in correlation analyses of fish data. *Can. J. Fish. Aquat. Sci.* **55**, 2127–2140 (1998).