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Science FINDINGS

INSIDE

"Science affects the way we think together."
Lewis Thomas

If You Built It, Did They Come? Evaluating the Effects of Stream Restoration on Fish Populations

Engineered logjams such as this one on Washington's Entiat River form pools that serve as rearing habitat for young salmon and steelhead. Researchers have developed new methods for evaluating the effectiveness of stream restoration projects throughout a river basin.

IN SUMMARY

Salmon and steelhead habitat restoration projects in the Pacific Northwest have frequently relied on the use of engineered logjams—logs that are cabled together and placed in rivers to create pools where young salmon can live and grow in their first year before migrating to the ocean. Monitoring programs that rely on fish counts have shown that these human-made pools function as intended by providing a healthy habitat for juvenile fish.

But do the logjams affect stream habitat beyond the areas of the pools? Could they benefit entire river reaches?

Carlos Polivka, a research fishery biologist with the USDA Forest Service's Pacific Northwest Research Station, studied the upper and lower basins of Washington's Entiat River to find out.

Many habitat restoration projects involving engineered logjams are installed along the Entiat River. Polivka and his research team conducted snorkel surveys of roughly 5 miles of river, covering 13 individual reaches. They found that the pools created by these logjams did attract young salmon and not at the expense of other parts of the river where no restoration projects had been installed—the rearing capacity of broad sections of river was enhanced.

The research can be applied when planning habitat restoration projects and provides conceptual and empirical tools for more rigorous monitoring programs to assess the outcomes of the projects.

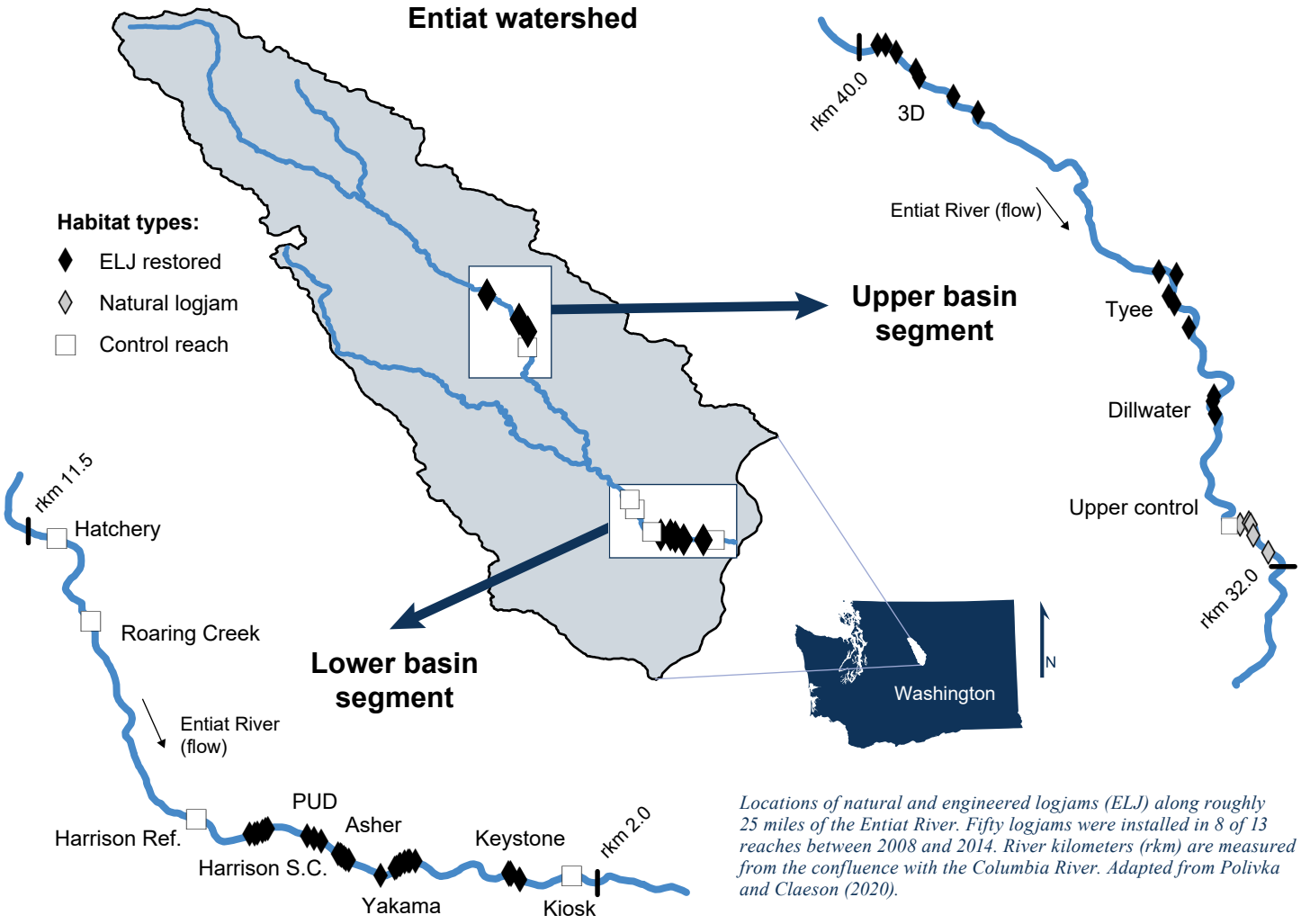
"If we knew what it was we were doing, it would not be called research, would it?"

—Albert Einstein

Salmon and steelhead (*Oncorhynchus* sp.) populations in the Pacific Northwest are declining. Their need for both freshwater and ocean habitat at different life stages makes the fish vulnerable to degraded habitat at any point along the way. Rivers and streams that have been altered by human activities take a particularly heavy toll on juvenile salmon, which rely on pools of cool, slower moving water to live and grow during their first year of life before they migrate to the ocean.

Tens of millions of dollars have been spent over the past several decades to restore freshwater salmon and steelhead habitat, often by using engineered logjams. These structures use logs of different sizes that are either cabled to a riverbank to form pools, or placed mid-channel, altering the streamflow to form more complex habitat. In both cases, the aim is the same: to create more and better places for salmon to grow and live during their crucial first year.

These restoration projects are typically coupled with monitoring programs to assess their efficacy. After the projects are installed, field technicians follow up by counting fish in the areas near the installation.



Locations of natural and engineered logjams (ELJ) along roughly 25 miles of the Entiat River. Fifty logjams were installed in 8 of 13 reaches between 2008 and 2014. River kilometers (rkm) are measured from the confluence with the Columbia River. Adapted from Polivka and Claeson (2020).

Purpose of PNW Science Findings

To provide scientific information to people who make and influence decisions about managing land.

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But do those counts tell the whole story?

Carlos Polivka, a research fishery biologist with the USDA Forest Service's Pacific Northwest (PNW) Research Station in Wenatchee, Washington, didn't think so. He launched a research project near his home territory to uncover the full benefit of these human-made structures.

"Analyses that only use fish counting have led to ambiguous results," he says. "The question I was asking in my research is, are there better methods? Are there better ways of identifying habitat capacity?"

Polivka wanted to find out not only if those projects worked, but—using the most robust metrics available—to show **how** scientists and managers can **know** that they worked. This information is critical for fisheries managers, natural resource agencies, and other sponsors of restoration work to demonstrate whether these projects provide their intended benefit to fish.

"I wanted to develop methodologies rather than just counting fish—methodologies that are not commonly used," he says.

Moreover, he adds that he wanted to be able to assess the effectiveness even when there was no data showing the conditions of fish populations before the logjams were put in place.

Borrowing language from the movie "Field of Dreams," Polivka wanted to answer these questions about the effectiveness of engineered logjams in supporting fish:

If you built it, did they come?

If you built it, and they came, did this show that habitat capacity increased?

And if you built it, and they came, did the fish actually do better there?

Gathering the Data

To answer these questions, Polivka integrated several forms of ecological science, including behavioral ecology, in ways that are seldom used to evaluate habitat restoration. He also developed a conceptual framework and field methodology for distinguishing between increases in habitat capacity for fish and the simple redistribution of fish from poor habitat to better habitat.

Sandy Letzing

Shannon Claeson measures water velocity on the Entiat River as part of her research with Carlos Polivka on the effectiveness of human-made logjams in enhancing salmon and steelhead habitat.

KEY FINDINGS

- Restoration projects increased the habitat capacity of several stream reaches of the Entiat River in Washington state for both Chinook salmon (*Oncorhynchus tshawytscha*) and steelhead (*O. mykiss*).
- The density of salmon populations increased, and individual fish appeared to be more robust in stream reaches with engineered logjams.
- Multiple seasons of fish-count data are necessary to understand how fish abundance varies spatially and over time.
- The spatial scale of the study is critical to determining if habitat restoration led to more fish, and if the restoration measures increased the total capacity of the river or stream for fish, rather than simply redistributing fish from poor habitat to better habitat.

Sandy Letzing

Carlos Polivka, suited up with a mask and snorkel, surveys the presence of subyearling salmon and steelhead at an engineered logjam in the Entiat River, Washington.

The distinction is important. Simple redistribution just means that fish shift from less desirable habitat to more desirable habitat without increasing their actual numbers. Greater habitat capacity means that an entire river reach may support more fish, even if logjams have been installed in only a small portion of the reach.

His research team included Shannon Claeson, an aquatic ecologist with the PNW Research Station. Claeson helped manage the study and had a lead role in analyzing the data.

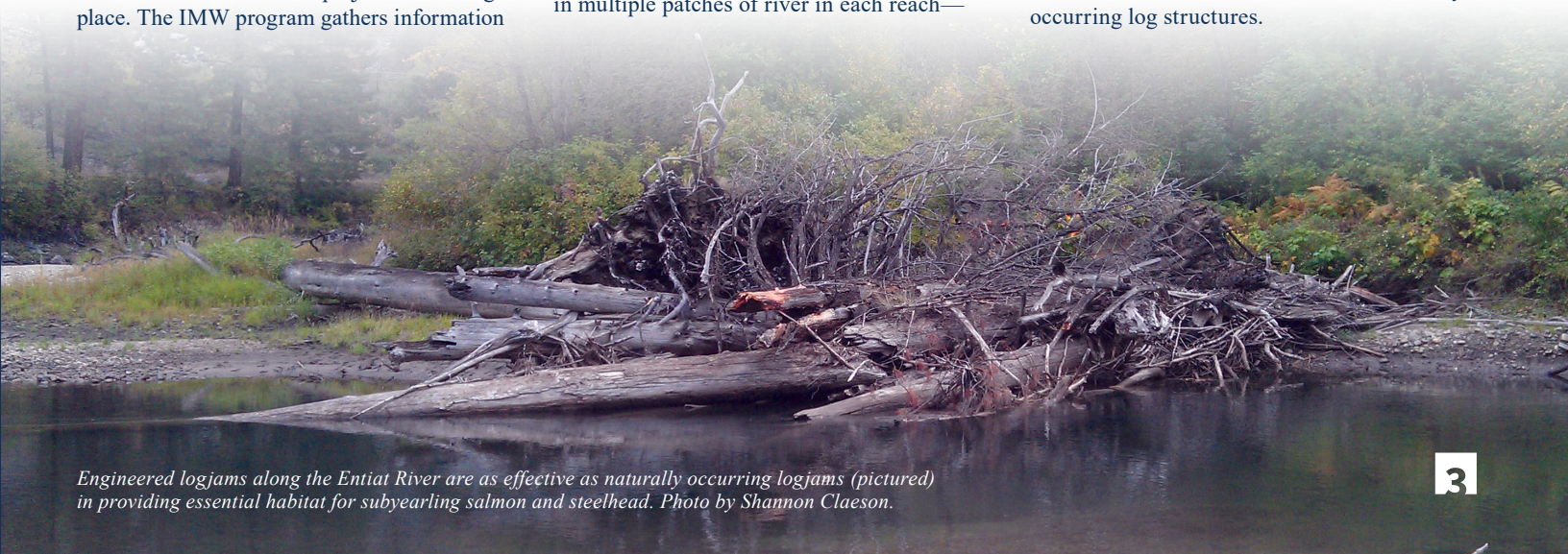
"It's always been assumed that these structures are beneficial to fish habitat in an isolated sense. I was intrigued by Carlos's idea of getting a fuller picture," Claeson says.

Polivka concentrated his work on the Entiat River in eastern Washington, a tributary of the Columbia River, and focused his observations on Chinook salmon (*Oncorhynchus tshawytscha*) and steelhead trout (*O. mykiss)*. From 2008 to 2017, the Entiat was designated as an intensively monitored watershed (IMW), one of 14 in the Pacific Northwest. All these watersheds—managed by multiple agencies—are in areas where restoration projects are taking place. The IMW program gathers information about what works in restoring salmon and steelhead populations so it can be applied elsewhere and help society get the greatest results from its restoration efforts.

Numerous logjams were installed in the upper and lower Entiat basins to create juvenile rearing pools. In all, Polivka and his research team examined roughly 5 miles of river, covering 13 individual reaches. Fifty logjams had been installed in eight of those reaches between 2008 and 2014. The remaining five of those reaches had no treatments.

Donning snorkels, researchers counted fish in multiple patches of river in each reach—mostly slower flowing glides, which are more favorable habitat for salmon and steelhead than faster running riffles. Moving downstream, the snorkelers visually identified and counted all juvenile Chinook salmon and steelhead that they saw in both treated and untreated sections of the river.

From these numbers, they calculated fish densities. They compared the data in three ways: between restored and unrestored habitat in treated reaches; between unrestored habitat in both treated and untreated reaches; and in one section of the river, between restored habitat in treated reaches and areas that had naturally occurring log structures.



Engineered logjams along the Entiat River are as effective as naturally occurring logjams (pictured) in providing essential habitat for subyearling salmon and steelhead. Photo by Shannon Claeson.

Not surprisingly, the data showed that fish density was significantly higher in the pools created by the engineered logjams, compared to unrestored river patches. In the lower Entiat, it showed a nearly threefold greater density of subyearling Chinook salmon compared to the unrestored habitats of the same reaches. The results were more dramatic in the upper Entiat: the density of Chinook salmon subyearling populations was 13 times greater compared to unrestored habitat.

Robust Fish, and More of Them

In answering the first question—"If you built it, did they come?"—Polivka found that, yes, they did. There was a higher density of both Chinook salmon and steelhead in the deep, slow pools created by the engineered logjams compared with untreated habitat in the same river and in other reaches that had no treatment.

Answering the second question—"If you built it, and they came, did habitat capacity increase?"—required Polivka to look beyond just the pools created by the logjams. This was important because, while the logjams provide a nurturing environment for the fish that use them, long-term population growth requires an overall increase in rearing capacity of the entire river.

One way to know if overall capacity increased is if you see more fish in the restored habitat with no corresponding decrease in fish from the unrestored areas. A decrease in the unrestored areas could mean that the fish had just shifted from one spot to another with no net increase of fish in the river.

Based on their snorkel surveys, Polivka and Claeson confirmed that was not the case. The restored habitat locations had not simply attracted fish from unrestored habitat in the same reach. They also found that fish population densities were similar between the engineered logjams and naturally occurring wood structures.

"I was impressed with how well the human-made structures compared to the natural structures," Claeson says.

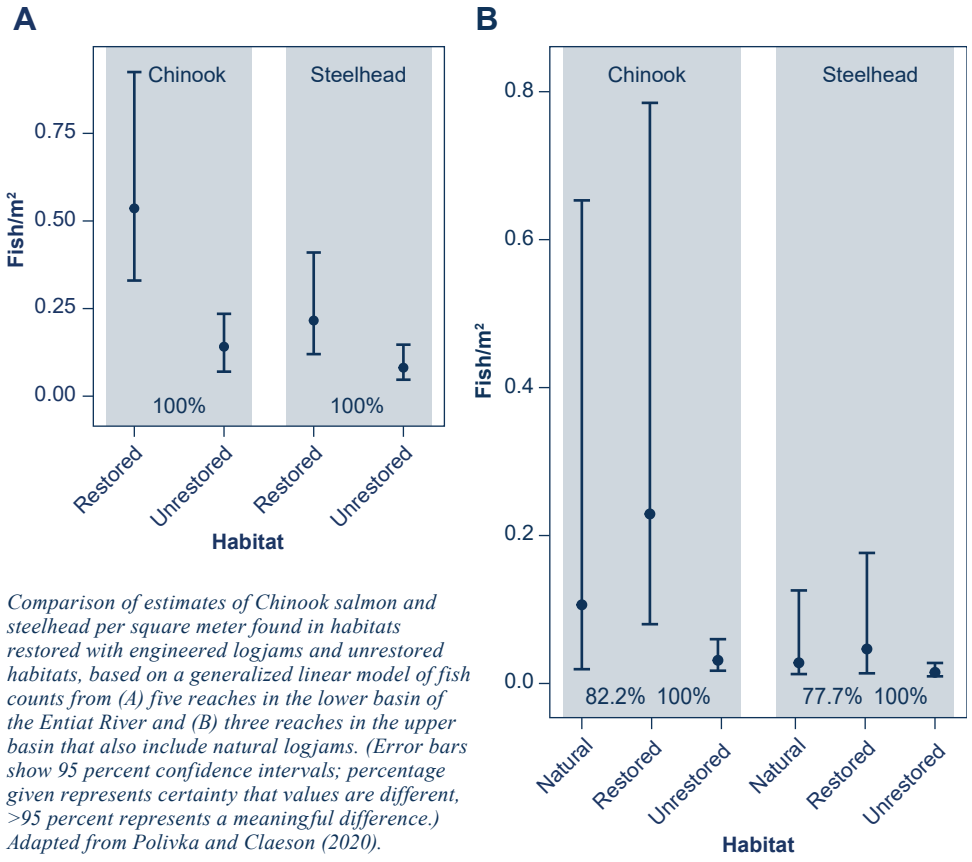
So, yes, habitat capacity did increase, at least in the broader neighborhood of the engineered logjams. The analytical tools Polivka and Claeson developed for the research showed that restoration increased the capacity of several restored stream reaches in the same river for both Chinook and steelhead.

More work will be required to see just how much capacity was expanded into bigger portions of the river system.

"It may require multiple surveys in different areas and over many years," Claeson says.

As to the question, "If you built it, and they came, did they actually do better there?" the answer was generally yes.

After observing fish behavior, movement, and growth in restored and unrestored pools, and analyzing 5 years of data showing both density and fish size, Polivka concluded that juvenile Chinook salmon that spent much of their time living in the pools created by the engineered logjams were bigger than fish that moved from one habitat to another.



Comparison of estimates of Chinook salmon and steelhead per square meter found in habitats restored with engineered logjams and unrestored habitats, based on a generalized linear model of fish counts from (A) five reaches in the lower basin of the Entiat River and (B) three reaches in the upper basin that also include natural logjams. (Error bars show 95 percent confidence intervals; percentage given represents certainty that values are different, >95 percent represents a meaningful difference.) Adapted from Polivka and Claeson (2020).

Researchers Polivka and Claeson found a higher density of both juvenile Chinook salmon and steelhead (pictured) in the deep, slow pools created by the engineered logjams compared with untreated habitat in the same river. Photo by John McMillan/National Ocean and Atmospheric Administration.

"The results for steelhead were far less consistent, possibly because steelhead are less abundant overall and have a more 'generalist' pattern of habitat use," Polivka says.

So not only did density of salmon increase, but the individual fish appeared to be more robust. That's a good testament to the effectiveness of the logjams and good news for salmon.

"Individual salmonids that grow larger prior to overwintering and migrating downstream to the ocean often have higher survival rates than smaller individuals," Polivka says.

LAND MANAGEMENT IMPLICATIONS

- Restoration in the Entiat River was largely successful in improving rearing habitat for subyearling Chinook salmon, which bodes well for similar restoration projects in other rivers.
- This research gives managers conceptual and empirical tools for more rigorous monitoring after habitat restoration projects.
- The scale of monitoring efforts can influence results. The results from large-scale surveys that include a lot of untreated habitat may not accurately capture the positive effects of engineered logjams on fish abundance.

Going Forward

Studying the Entiat revealed that restoration projects are largely successful in improving rearing habitat for young Chinook salmon. The fact that it worked on the Entiat bodes well for similar restoration projects in other rivers.

"The research Carlos has done has been instrumental in not only identifying appropriate habitat restoration actions, but also helping us better understand the biological benefits of those actions," says Tracy Hillman, chairman of the Upper Columbia Regional Technical Team, which is responsible for prioritizing habitat restoration and protection actions within the upper Columbia.

The regional technical team, which Polivka is also on, is an arm of the Upper Columbia Salmon Recovery Board, which facilitates salmon and steelhead habitat restoration projects on the Entiat, as well as in the Wenatchee, Methow, and Okanogan subbasins. The team uses scoring criteria to plan for the most effective, longest lasting restoration projects.

"The work Carlos has done really affirms the value of these human-made log structures," Hillman says. "We've known for a long time that fish like wood. We knew it attracted fish, but we didn't know if it increased capacity. Carlos was one of the first to evaluate that, and what he found was really cool."

Not only do the engineered logjams increase density of fish, but they produce higher growth and, potentially, higher survival rates. Another insight from the research is that Chinook salmon tend to like the deep pools created by large log structures; steelhead, on the other hand, like shallower pools created by smaller structures. "Because the recovery board is tasked with enhancing both species, this finding will likely guide the way specific projects are designed in the future," Hillman says.

But Polivka says it's difficult to observe increased fish abundance in entire rivers. Whereas an engineered logjam in one part of a reach may be effective in attracting fish, the fish are likely to spread out into other parts of the reach that are untreated—so much so that the population dilution may give the impression of low numbers. That's why Polivka says postrestoration monitoring must be scaled appropriately.

Polivka also found that counting fish doesn't tell the whole story of a logjam's effectiveness. Some years, fish numbers may not increase, but the fish that are there are larger and more robust than in other years. This is where studies of fish behavior can complement observations of mere abundance. They can reveal a positive benefit to restoration even if there is no observed increase in fish numbers.

"Although such studies can be time intensive at the cost of larger scale surveys of fish density, they are somewhat less labor intensive and provide a level of rigor that makes conclusions more robust," he says.

The research Polivka and his colleagues performed provides managers with the empirical tools to make monitoring more rigorous, allowing them to get the full picture of how well a restoration project performs.

The Independent Scientific Advisory Board in 2017 and 2018 reviewed recovery and research efforts for Chinook salmon in the upper Columbia Basin—including the Entiat River—to determine their success. Their final written report cites Polivka's work prominently. Other management agencies have consulted with Polivka regarding the design of ongoing and future restoration projects.

Polivka hopes his work has influence well beyond the Pacific Northwest. "I hope that stream restoration worldwide can benefit from this," he says.

"A river seems a magic thing.
A magic, moving, living part
of the very earth itself."

—Laura Gilpin, photographer

For Further Reading

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Writer's Profile

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Scientist Profiles

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SHANNON CLAESON is an aquatic ecologist with the USDA Forest Service, Pacific Northwest Research Station. Her research interests include the interaction of riparian and aquatic systems, the role of aquatic invertebrates in streams and lakes, and other factors that affect the complex web of life in natural bodies of water. She earned an M.S. in fisheries science from Oregon State University.

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