



Exxon Valdez Oil Spill Trustee Council

Long-Term Research and Monitoring, Mariculture, Education and Outreach

Annual Project Reporting Form

Project Number: 25120111-E

Project Title: Herring Disease Program

Principal Investigator(s): Paul Hershberger and David Páez, U. S. Geological Survey, Marrowstone Marine Field Station

Reporting Period: February 1, 2025 – January 31, 2026

Submission Date: March 16, 2026

Project Website: <https://gulfwatchalaska.org/>

Please check all the boxes that apply to the current reporting period.

Project progress is on schedule.

Project progress is delayed.

Budget reallocation request.

Personnel changes.

1. Summary of Work Performed:

Prince William Sound pre-spawn adult herring

Pacific herring (*Clupea pallasii*) were collected from three sites in Prince William Sound (PWS), Alaska (Table 1) during the spring pre-spawn period from March 27 – 30, 2024, to test for viral hemorrhagic septicemia virus (VHSV), viral erythrocytic necrosis (VEN), and *Ichthyophonus* prevalence (Table 1). *Ichthyophonus* was detected in 39% (68/175) of heart cultures from all sites combined. An inverted pattern of decreasing *Ichthyophonus* infection prevalence with size started around 2019 and continued through 2024, but the typical trend of increasing infection prevalence with herring size appears to be reestablishing in 2025 (Fig. 1). VHSV was isolated from one fish collected from Humphries Hole. The isolation was at a very low titer and was detectable only after blind passage. Neutralizing antibodies to VHSV were detected in 6.3% (24/378) of PWS herring in 2025, reflecting a gradual increase in seropositives over the past four



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years (Fig. 2). Erythrocytic inclusions indicative of VEN were detected 1/180 adult herring from Prince William Sound (n =180) in 2025. Samples were not collected from Kayak Island.

Table 1. Infection prevalence results from Prince William Sound pre-spawn herring in 2024. VHSV = viral hemorrhagic septicemia virus and VEN = viral erythrocytic necrosis. Additional fish were collected to assess the prevalence of VHSV neutralizing antibodies.

Location	Date	VHSV Prevalence	<i>Ichthyophonus</i> Prevalence (Heart Cultures)	VEN Prevalence
Humphries Hole	March 27	3.3% (2/60) ^a	29% (17/59)	2% (1/60)
Canoe Point	March 29	0% (1/60)	46% (26/57)	0% (0/60)
Hell's Hole	March 30	0% (0/60)	42% (25/59)	0% (0/60)

^aThe two fish were positive for VHSV after blind passage onto *epithelioma papulosum cyprini* cells; the minimum level of detection was 50 infectious particles /g of pooled tissue sample. Polyethylene glycol was used to increase cell culture sensitivity. The isolate was confirmed as VHSV by polymerase chain reaction.



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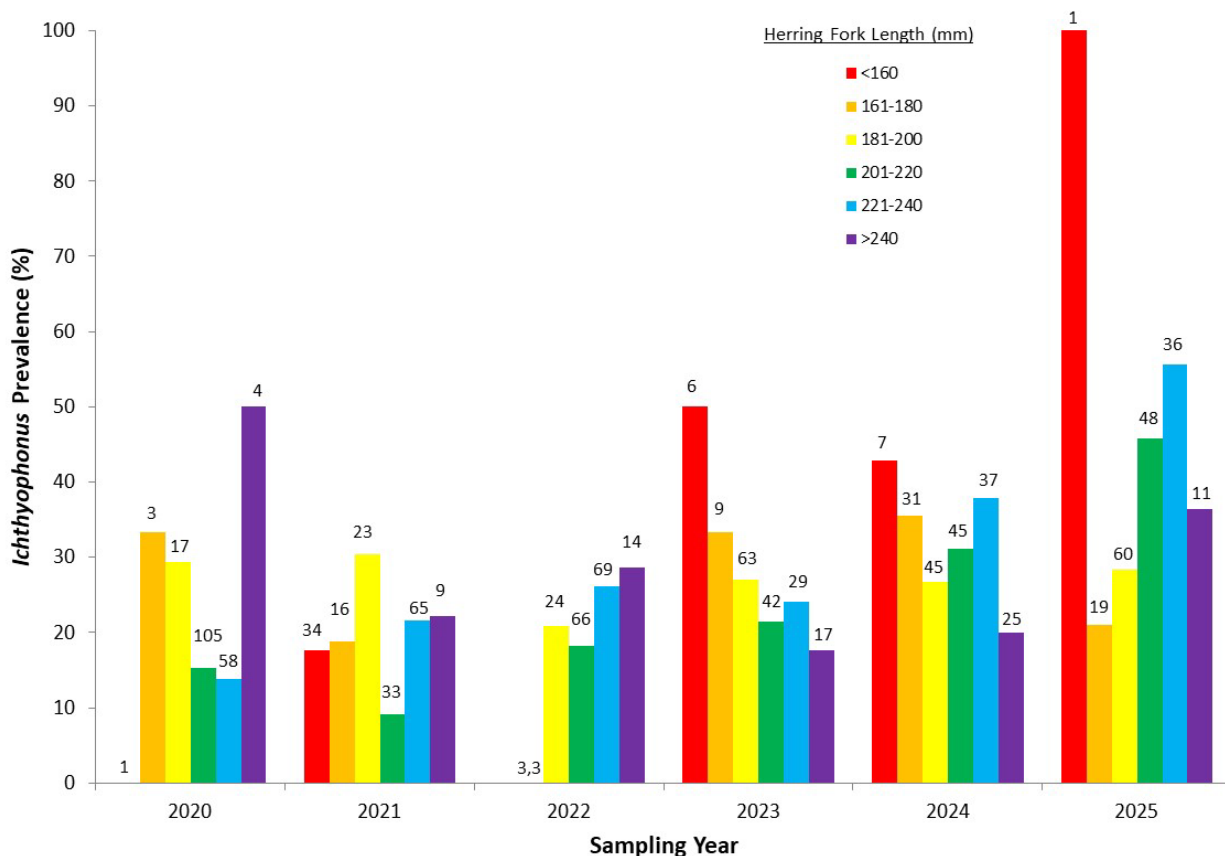


Figure 1. Temporal trend in *Ichthyophonus* infection prevalence in each size class of Prince William Sound herring. Numerals above each bar indicate sample size (n). Numerals immediately above the horizontal axis indicate the sample size for each size class with 0% infection prevalence.



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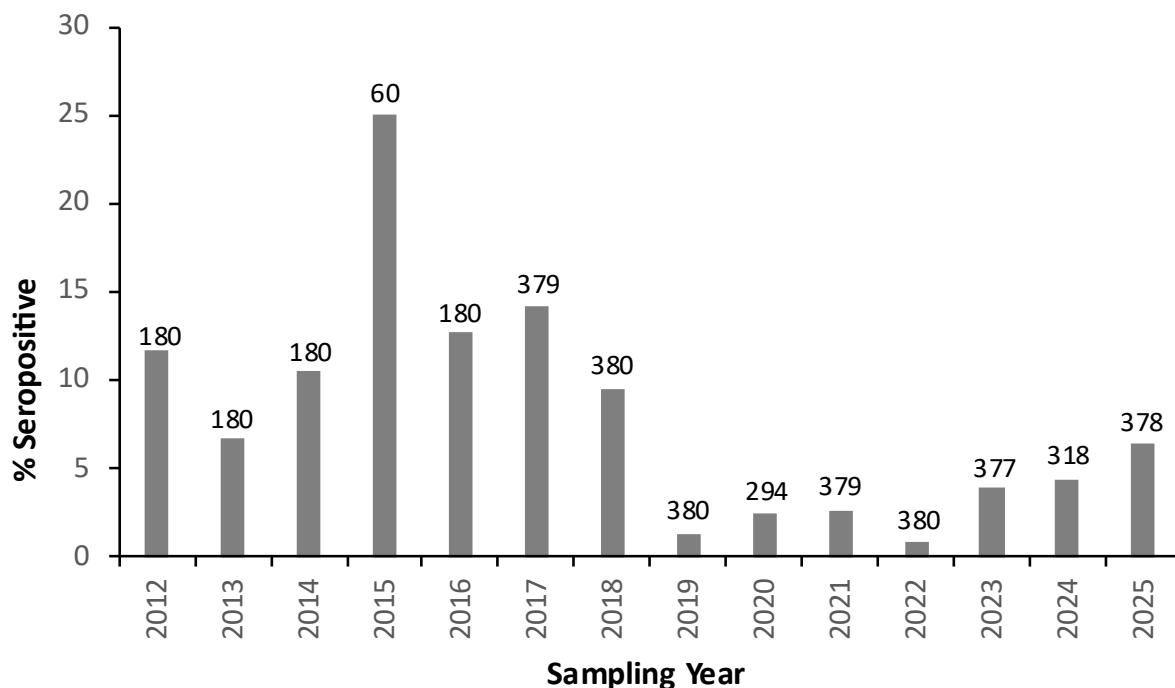


Figure 2. Annual prevalence of neutralizing antibodies against viral hemorrhagic septicemia virus in Prince William Sound herring. Numerals above the bars indicate the sample size (n).

Sitka Sound pre-spawn adult herring

Adult Pacific herring were collected from two events in Sitka Sound, Alaska during the spring pre-spawn period from March 25-26, 2025, to test for VHSV, VEN, and *Ichthyophonus* prevalence (Table 2). *Ichthyophonus* was detected in 46% (74/161) of herring hearts, and the prevalence of herring with clinical signs of ichthyophoniasis (24%; 39/161) is currently elevated. The typical trend of increasing infection prevalence with herring size class, accompanied by the highest infection prevalence in the largest size class, was re-established in 2025. VHSV was not detected in any samples, but cytoplasmic inclusion bodies indicative of VEN were detected in red blood cells from 1/161 fish. Neutralizing antibodies to VHSV were detected in only 2% (3/161) of herring plasma samples (Fig. 4). VHSV neutralizing antibody levels have remained relatively low in Sitka Sound for the past seven years (2019-2025), inferring a paucity of VHSV exposures during this period and a current population of adult herring that remains susceptible to the resulting disease.



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Table 2. Infection prevalence results from Sitka Sound pre-spawn herring in 2025. VHSV = viral hemorrhagic septicemia virus and VEN = viral erythrocytic necrosis.

Location	Date	VHSV Prevalence	Ichthyophonus Prevalence (Heart Cultures)	VEN Prevalence
Magonn Islands	March 25	0% (n=101)	43% (43/101)	0% (1/101)
Mud Bay	March 26	0% (n=60)	52% (31/60)	0% (0/60)

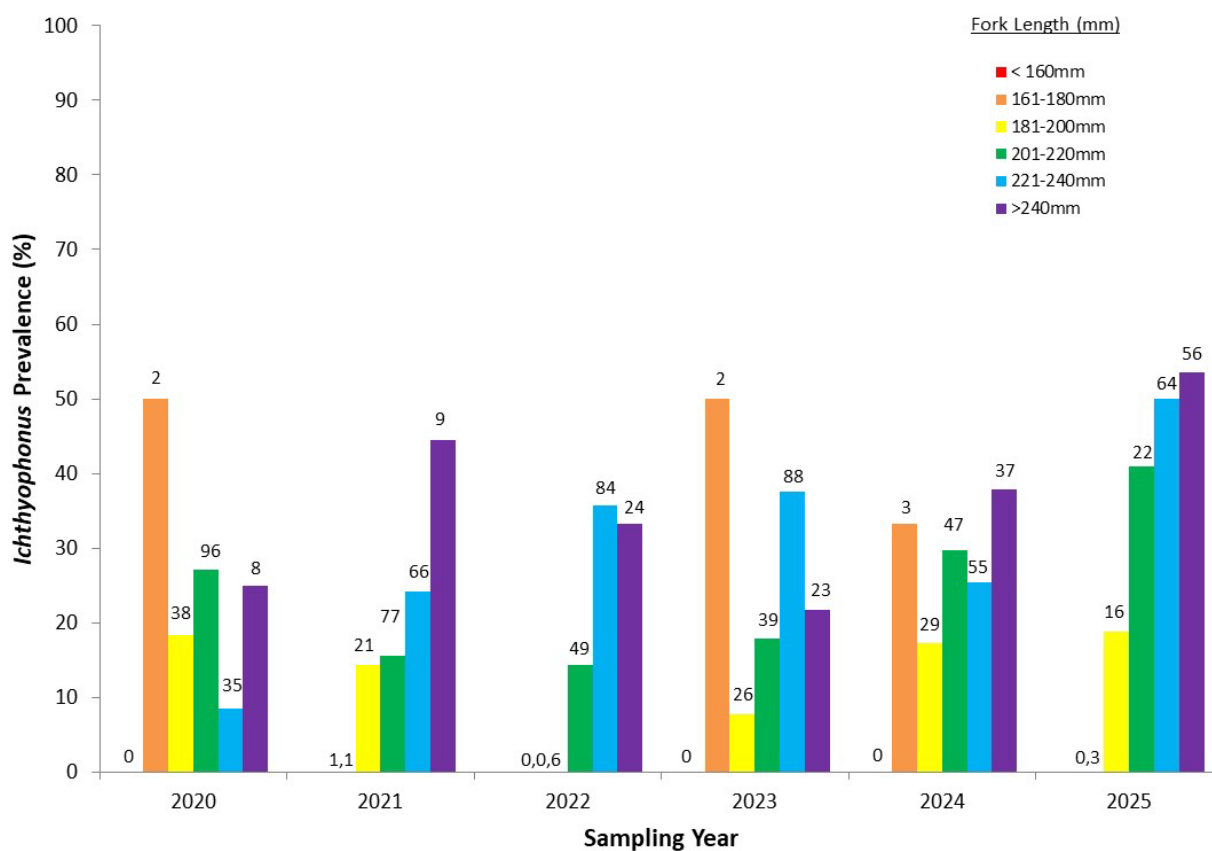


Figure 3. Temporal trend in Ichthyophonus infection prevalence in each size class of Sitka Sound herring. Numerals above each bar indicate (n). Numerals immediately above the horizontal axis indicate the sample size for each size class with 0% infection prevalence.



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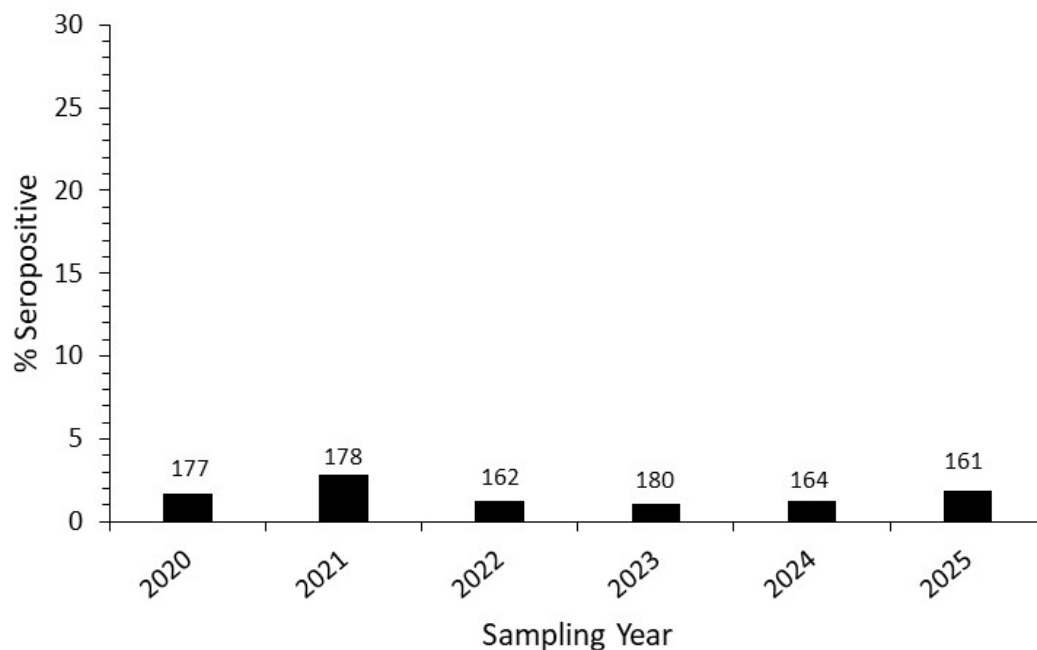


Figure 4. Annual prevalence of viral hemorrhagic septicemia virus neutralizing antibodies in Sitka Sound herring. Numerals above the bars indicate the sample size (n).

Herring / pink salmon interactions: VEN epizootic in PWS

Laboratory diagnostics were provided for the PWS pink salmon (*Oncorhynchus gorbuscha*) / herring interactions project (project 25220111-I, principal investigators [PIs] Rand and Gorman). Pacific herring and pink salmon were sampled from PWS during May – July 2025 and analyzed for the prevalence of VEN in blood films that were dried, methanol-fixed, and Diff-Quick-stained (Table 4). A VEN epizootic, characterized by high infection prevalences of fish demonstrating high VEN intensity levels, was detected among juvenile Pacific herring in numerous locations during the sampling period, including Shelter Bay (72%), Fox Farm Bay (84%), Squire Point (100%), Simpson Bay (84%), and Sheep Bay (100%). The epizootic was confined to juvenile herring cohorts, as VEN inclusions were not detected in any adult herring, pink salmon, or chum salmon juveniles.



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Table 3. Prevalence of viral erythrocytic necrosis (VEN) in pink salmon and Pacific herring from Prince William Sound cruises in 2025.

Location	Sampling Date	Fish species / Life Stage	VEN Prevalence (# Positive / n)*
Mummy Bay	May 29	Pink Salmon (Juvenile)	0/60
		Chum salmon (Juvenile)	0/2
Shelter Bay	May 30	Herring (Juvenile)	44/61
		Chum Salmon (Juvenile)	0/1
Fox Farm Bay	May 31	Herring (Juvenile)	21/25
Other	May 31	Herring (Juvenile)	11/31
		Pink Salmon (Juvenile)	0/57
		Chum Salmon (Juvenile)	0/8
Squire Point	June 1	Herring (Juvenile)	18/18
		Herring (Adult)	0/11
		Pink Salmon (Juvenile)	0/6
		Chum Salmon (Juvenile)	0/6
Fox Farm	June 10	Chum Salmon (Juvenile)	0/1
		Herring (Adult)	0/3
Prince of Wales	June 16	Herring (Juvenile)	48/57
		Pink Salmon (Juvenile)	0/7
Simpson Bay	June 17	Herring (Juvenile)	8/8
		Pink salmon (Juvenile)	0/33
		Unknown Salmon (Juvenile)	0/6
Chenegra Point	June 23	Pink Salmon (Juvenile)	0/53
		Chum Salmon (Juvenile)	0/5
Prince of Wales	June 23	Chum Salmon (Juvenile)	0/1
Fox Farm Bay	June 24	Herring (Adult)	0/1
		Pink Salmon (Juvenile)	0/1
Prince of Wales	June 24	Pink Salmon (Juvenile)	0/44
		Chum Salmon (Juvenile)	0/21
Sleepy Bay	June 24	Pink Salmon (Juvenile)	0/11
Point Brazil	June 25	Pink Salmon (Juvenile)	0/5
Point Brazil	July 7	Pink Salmon (Juvenile)	0/23
		Chum Salmon (Juvenile)	0/9
Prince of Wales	July 8	Pink Salmon (Juvenile)	0/29
		Chum Salmon (Juvenile)	0/5
Chenegra Point	July 8	Pink Salmon (Juvenile)	0/40
		Chum Salmon (Juvenile)	0/6

*An additional 200 blood films have been read, but their sampling provenance has not yet been confirmed with the principal investigators.



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Oviovory study

Several attempts were made to test whether *Ichthyoponus* could be transmitted to Pacific herring through the consumption of parasite-associated walleye pollock (*Gadus chalcogrammus*) eggs. However, field impediments with the pollock collections prevented testing this hypothesis in 2025. Further efforts to test this hypothesis will continue in 2026.

Long term antibody study

A prior study indicated that neutralizing antibodies can be detected in 60% of VHS survivors 2.8 years after the initial laboratory exposure. However, when testing for antibodies in wild herring, we found that neutralizing antibodies were detectable in only approximately 27% of VHS survivors that were fully refractory to the disease. Differences in the antibody kinetics between laboratory and wild fish may be reflective of continuous virus cycling between laboratory herring held in a tank, thereby artificially boosting antibody levels beyond what may be expected in the wild. Because we are trying to accurately assess the exposure history of groups of wild herring, we are seeking alternative techniques for more accurately deducing their exposure histories.

Since completing the aforementioned-laboratory-based studies, we have realized that VHSV remains in association with the gills of some VHSV survivors for extended periods. Therefore, this long-term follow-up experiment was designed to determine whether the detection of VHSV on herring gills can serve as a long-term proxy for deducing whether herring survived prior exposure and are now immune to the disease. In this study we exposed herring to VHSV in the laboratory, then traced their antibody levels at monthly intervals (similar to the previous study); additionally, these samples were paired with qPCR samples of gills to assess where gene copy number on the gills might serve as an alternative technique to deduce the VHSV exposure history in Pacific herring.

Briefly, neutralizing antibodies remain detectable in the plasma of VHSV survivors for at least 3.8 years after initial exposure (Fig. 5), supporting the results from the previous study. Neutralizing antibodies were not detected in any fish from the negative control group that were not exposed to VHSV (data not shown). The gill samples from these same fish are currently being processed; preliminary qPCR results should be available for the FY26 reporting period.



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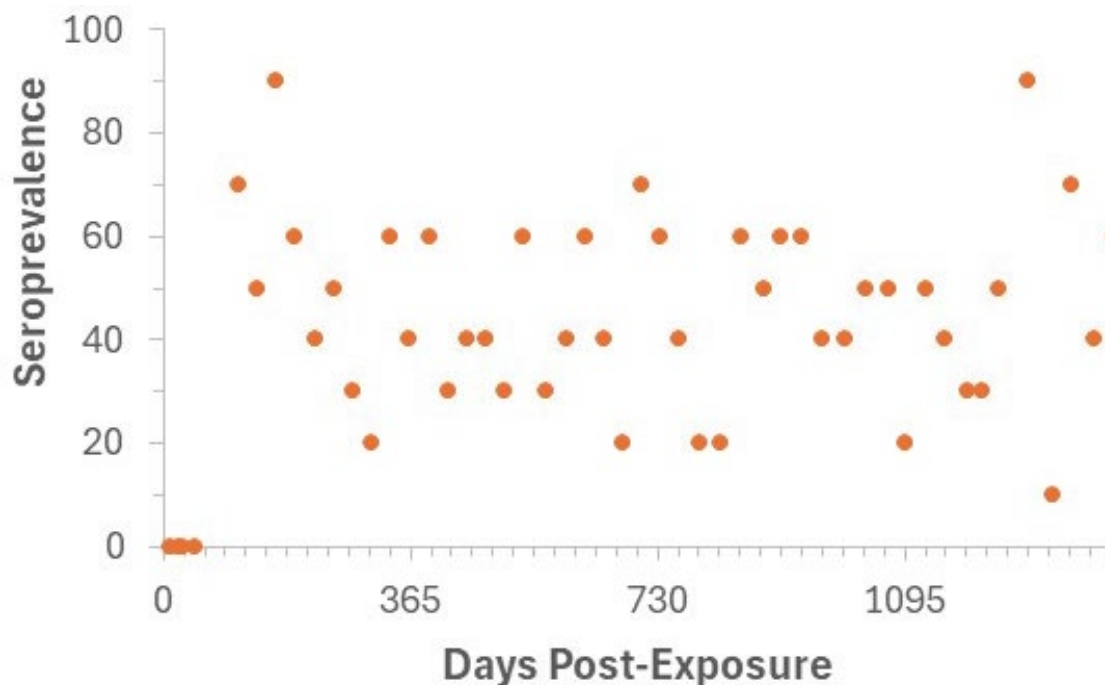


Figure 5. Detection of neutralizing antibodies in Pacific herring that survived a single viral hemorrhagic septicemia virus (VHSV) exposure on October 22, 2021 (Day 0). Each data point reflects the seroprevalence based on a terminal subsample ($n = 10$). Antibody samples were paired with gill samples that will be processed by qPCR using VHSV primer sets (data not yet available).

2. Products:

Peer-reviewed publications:

Carlino, A., M. M. Loehrer, D. J. Páez, P. K. Hershberger, N. Wolf, and J. Mihaljevic. *Accepted*. Stochastic within-host dynamics and climate-sensitive traits generate predictable patterns of variation in disease outcomes. *Philosophical Transactions B*.

Páez, D. J., C. Grady, J. Gregg, W. N. Batts, M. M. Loher, S. Williamson, and P. K. Hershberger. *Accepted*. The impacts of co-circulating pathogens in Pacific herring depend on interactions between viral life cycle traits and transmission parameters



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highlighting interdependencies between pathogen epizootics. *Philosophical Transactions B*.

Cypher, A. D., A. Gill, T. Linbo, J. Cameron, K. Peck, J. Bolton, J. Gregg, P. Hershberger, A. Whitehead, N. Scholtz, and J. Incardona. *In Review*. Pacific herring stocks differ in embryonic cardiotoxic and xenobiotic responses to crude oil exposure. *Elementa: Science of the Anthropocene*.

Lepeule, A., P. K. Hershberger, and M. L. Groner. *In Review*. Modelling temperature-dependent herd immunity and survival of Pacific herring exposed to viral hemorrhagic septicemia. *Ecosphere*.

Reports:

No new contributions for this reporting period.

Popular articles:

No new contributions for this reporting period.

Conferences and workshops:

Ferguson, J. A., P. K. Hershberger, J. Murphy, N. Wolf, K. Herron, and Z. W. Liller. 2025. Investigating the impacts of *Ichthyophonus* of Yukon River Chinook salmon. 64th Western Fish Disease Workshop, Bozeman, Montana, June.

Harsha, M. L., Y. Salas-Ortiz, A. Cypher, E. Osborn, E. Turcios Valle, J. L. Gregg, P. K. Hershberger, P. Zito, M. A. Tarr, P. L. Tomco, and D. C. Podgorski. 2025. Unresolved complex mixtures from crude oil: Hidden toxicity to Pacific herring embryos. *Pacificchem 2025*. Honolulu, Hawaii, December.

Hershberger, P. K., J. L. Gregg, C. A. Grady, S. S. Ferreiro-Luce, V. L. Herron, and D. J. Páez. 2025. Effects of viral erythrocytic necrosis on the swimming performance of Pacific herring. Poster presentation, Alaska Marine Science Symposium. Anchorage, Alaska, Anchorage.

Loeber, M., D. Paez, J. Mihaljevic, N. Wolf, and P. Hershberger. 2025. Sentinel cage studies indicate that VHS virus transmission persists for extended periods after natural epizootics



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in Pacific herring have completely waned. 64th Western Fish Disease Workshop, Bozeman, Montana, June.

Roth-Monzón, A. J., W. Daniel, C. D. Raines, M. E. Neilson, P. K. Hershberger, M. K. Purcell, and J. Lovy. 2025. Building AquaDePTH: A national repository for sharing aquatic animal health data. 155th Annual Meeting of the American Fisheries Society, San Antonio, Texas, August.

Sriwanayos, P., B. Torrevillas, A. Hassan, P. Hershberger, and T. Waltzek. 2025. Phylogenomic characterization of erythrocytic necrosis virus (ENV) from Pacific Herring (*Clupea pallasii*). Poster presentation, Diverse Minds, Diverse Microbes Symposium, American Society for Microbiology, Pullman, Washington, April.

Sriwanayos, P., B. Torrevillas, A. Hassan, P. Hershberger, and T. Waltzek. 2025. Phylogenomic characterization of erythrocytic necrosis virus (ENV) from Pacific Herring (*Clupea pallasii*). 64th Western Fish Disease Workshop. Bozeman, Montana, June.

Williamson, S., P. Hershberger, D. Paez, N. Wolf, M. Loher, and C. Grady. 2025. In vitro and in vivo insights into the effects of temperature on VHS virus. 64th Western Fish Disease Workshop, Bozeman, Montana, June.

Public presentations:

No new contributions for this reporting period.

Data and/or information products developed during the reporting period:

We are developing a nation-wide database for Aquatic Disease and Pathogens (AquaDepth). This U. S. Geological Survey (USGS)-hosted effort will serve as a repository for pathogen and disease surveillance data for freshwater and marine fish pathogens. The database infrastructure is currently being developed, and all the surveillance data from the past 15 years of the Herring Disease Program are at the top of the queue for inclusion. We anticipate that the database and the associated herring disease surveillance data will be public facing in late 2026.

Data sets and associated metadata:

Hershberger, P. 2024. Herring disease program. Gulf of Alaska Data Portal: <https://gulf-of-alaska.portal.aos.org/#metadata/61b4ec5a-f15c-4347-b0ba-8a25ad763675/project>



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Data for all peer reviewed publications is published on ScienceBase.

Additional Products not listed above:

We are developing a feature length documentary, entitled “Tiny Fish” that describes the Herring Disease Program and other associated projects. Anticipated release is in late 2027; until then, the trailer can be viewed at <https://www.impactmedialab.com/film>.

Owing to the highly labor-intensive process of screening blood films for the presence of VEN, we acquired additional funds to develop machine learning software that can analyze stained blood films for the detection of VEN inclusion bodies. The software is now largely developed, and we are fine tuning the machine reads to reduce read errors on the 2025 blood films. The completed software is expected to be available by October 1, 2026.

3. Coordination and Collaboration:

Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U. S. Government. All USGS field sampling and laboratory studies described in this report were approved by the USGS, Western Fisheries Research Center Institutional Animal Care and Use Committee (IACUC) Protocols #2008-51 and #2008-52.

This project was leveraged to obtain funding from the National Science Foundation (NSF) for a complementary herring disease study intended to evaluate the effects of climate change on herring diseases. The NSF project partners with Alaska Pacific University and Northern Arizona University.

This project was further leveraged to acquire funding from the USGS Ecosystems – Biothreats Program to develop machine learning software capable of enumerating VEN inclusions in stained blood films from Pacific herring.

The Alaska SeaLife Center or Prince William Sound Science Center

This project coordinates closely with the Prince William Sound Science Center (PWSSC), as the lead coordinator for the Herring Research and Monitoring (HRM) component. PWSSC provides administrative support, serves as a logistical liaison coordinating PWS herring cruises, and assists with metadata transfer for the Herring Disease Program.



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EVOSTC Long-Term Research and Monitoring Projects

The Herring Disease Program is within the HRM component of the Gulf Watch Alaska-Long-Term Research and Monitoring (GWA-LTRM) program. We work with other HRM component projects as the component as a whole works to understand the lack of recovery of PWS herring, particularly the following projects:

- We work closely Alaska Department of Fish and Game (ADF&G; project 25170111-F: Herring surveys and age, sex, and size collection and processing; PI Morella to collect herring tissue and plasma samples, using a shared platform for the spring herring cruises. Additionally, ADF&G provided age data for the fish health samples.
- Pathogen survey data are shared with Dr. Trevor Branch for incorporation into the age structured analysis model (project 25120111-C: Modeling and stock assessment of PWS herring). Additionally, revised antibody data for PWS were shared with Dr. Branch, for incorporation into a VHSV hindcasting model.
- This project will provide pathogen surveillance information for Drs. Rand and Gorman (project 25220111-I: Ecological interactions between Pacific herring and Pacific salmon in PWS). VEN surveillance results for pink salmon / herring interactions are included in their report.

EVOSTC Mariculture Projects

The Herring Disease Program has not coordinated with EVOSTC mariculture projects. However, if these projects would benefit from herring disease data, publications, and reports, we would be happy to work with them.

EVOSTC Education and Outreach Projects

Project team members organized Cordova Trivia Night on herring and herring diseases on February 10, 2025.

Feb 11, 2025: Project team members contributed to the Tuesday night lecture series in Cordova

Individual EVOSTC Projects

The Herring Disease Program works with the Data Management program to ensure our data are properly reviewed, have current metadata, and are posted to the Gulf of Alaska data portal within



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required timeframes. We will work with other individually funded EVOSTC projects if collaborative efforts make sense based on data collected.

Trustee or Management Agencies

USGS is a Trustee Agency, and our herring disease work complements other fisheries disease research conducted at the Marrowstone Lab. In addition, we partner with ADF&G on a variety of disease issues, specifically the following:

- We collect herring infection and disease data onboard the shared ADF&G seining platform in coordination with Cordova-based biologists.
- We collect herring infection and disease data from pre-spawn aggregations in Sitka Sound with Sitka-based biologists.
- We continue to partner with ADF&G Juneau Fish Pathology Laboratory who has provided consistency for processing all fish virology samples from PWS and Sitka Sound since the onset of herring health assessments in the early 1990s.

Native and Local Communities

PIs and staff participated in the Collective Alaska Natives Perspectives Training with the CORaL Network in Cordova, Alaska, February 11-13, 2025.

4. Response to EVOSTC Review, Recommendations and Comments:

No review, recommendations, or comments were provided in 2025. This project responded to comments in the FY24 annual report.

5. Budget:

The USGS portion of the project continues to be behind in spending because of the delay in the release of funding that began in FY22, uncertainties in federal laboratories in 2025, and federal hiring restrictions.



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**EXXON VALDEZ OIL SPILL TRUSTEE COUNCIL
PROGRAM BUDGET PROPOSAL AND REPORTING FORM**

Budget Category:	Proposed FY 22	Proposed FY 23	Proposed FY 24	Proposed FY 25	Proposed FY 26	5-YR TOTAL PROPOSED	ACTUAL CUMULATIVE
Personnel	\$221,276	\$310,206	\$227,886	\$235,462	\$301,248	\$1,296,078	\$716,196
Travel	\$21,826	\$21,826	\$21,826	\$21,826	\$21,826	\$109,130	\$33,559
Contractual	\$0	\$0	\$0	\$0	\$0	\$0	\$0
Commodities	\$39,300	\$39,000	\$39,000	\$39,000	\$39,000	\$195,300	\$137,463
Equipment	\$15,000	\$0	\$0	\$0	\$0	\$15,000	\$10,583
Indirect Costs (varies by proposer)	\$18,424	\$18,424	\$0	\$0	\$0	\$36,849	\$36,623
SUBTOTAL	\$315,826	\$389,456	\$288,712	\$296,288	\$362,074	\$1,652,357	\$934,424
General Administration (9% of subtotal)	\$28,424	\$35,051	\$25,984	\$26,666	\$32,587	\$148,712	N/A
PROGRAM TOTAL	\$344,251	\$424,508	\$314,696	\$322,953	\$394,661	\$1,801,069	
Other Resources (In-Kind Funds)	\$124,245	\$127,724	\$131,396	\$135,129	\$138,910	\$657,404	

COMMENTS:
 This is the combined budget for PIs Hershberger and Paez at USGS and collaborator Groner at Bigelow Lab. The contract for collaborator Groner runs through PWSSC's NOAA grant. Please see attached budgets for details.

The USGS portion of the project is behind in spending because of the delay in release of funds that began in FY22, uncertainties in federal laboratories during 2025, and federal hiring restrictions. The personnel costs reflect a combination of salary and benefits for federal personnel and a pivot towards contracted personnel (Pacific States Marine Fish Commission) that was necessary because of federal hiring freezes. Delays in receiving funds and hiring staff at Bigelow resulted in delayed spending in FY22 and FY23. Because of that, PI Groner's work, which was scheduled to phase out at the end of FY23, continued through FY25 to complete proposed work with a no-cost extension.

FY22-26	Project Number: 25120111-E Project Title: Herring Disease PI(s): Hershberger & Paez (USGS) Collaborator: Groner (Bigelow)	SUMMARY TABLE
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