Pacific herring (*Clupea pallasii*) in Lynn Canal, southeast Alaska:

Endangered, Threatened, or Struggling?

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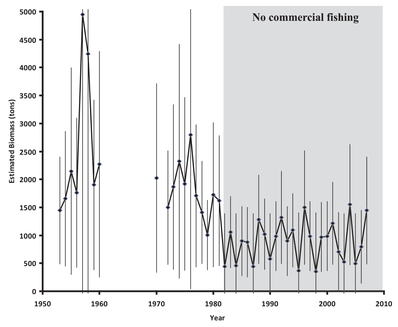
Abstract

Examination of the Pacific herring (*Clupea pallasii*) population in Lynn Canal (near Juneau, Alaska) suggests that although it declined in the 1970s and has not recovered, the population is not discrete and significant as defined by the Endangered Species Act (ESA), hence it cannot be protected by this law. The biological review team (BRT) assembled to examine and discuss the data concluded the smallest defensible distinct population segment (DPS) that includes Lynn Canal is southeast Alaska (SEAK). Although the team recognized the possibility that there may be subdivisions within SEAK, available biological data are either too incomplete or too similar to definitively separate herring populations within this region. Furthermore, recent genetic results continue to suggest Pacific herring in the Gulf of Alaska region form a metapopulation, implying significant gene flow between impaired populations such as Lynn Canal and Prince William Sound and healthy populations such as at Sitka, Alaska.

Problem: Lynn Canal herring stock has declined and remained low for more than two decades. Uncertain population estimates complicate understanding of herring population change in Lynn Canal (vertical bars identify the 95% confidence interval).



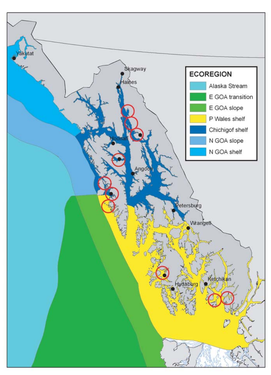
Petition: In April 2007, the Sierra Club petitioned to list Lynn Canal herring under the Endangered Species Act (ESA).

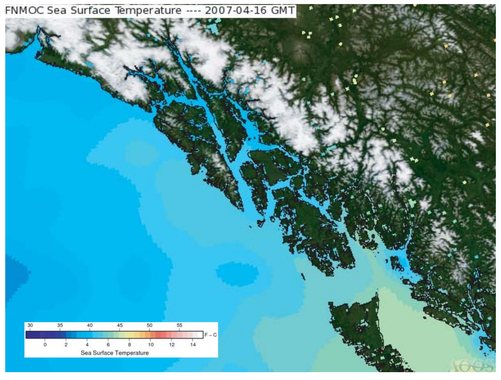
ESA question 1: Are Lynn Canal herring discrete?

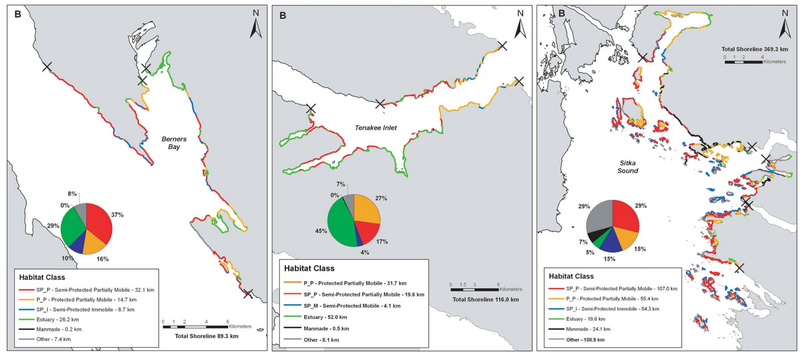
The ESA states "*a population segment of a vertebrate species may be considered discrete if it satisfies either one of the following conditions: 1) it is markedly separated from other populations of the same taxon as a consequence of physical, physiological, ecological, or behavioral factors. Quantitative measures of genetic or morphological discontinuity may provide evidence of this separation. 2. It is delimited by governmental boundaries...*" To understand Lynn Canal herring in their physical and biological context, a variety of data were examined at large to small geospatial scales.

Physical and Ecological Factors

The extent of kelps (canopy and understory) and eelgrass is less in Lynn Canal compared to other southeast Alaska areas. There is an inshore-offshore salinity gradient and a north-south temperature gradient[37,38,40] in SEAK. Inside waters are more estuarine, more protected from wave action, and have larger seasonal temperature and salinity fluctuations than outside waters. Eelgrass meadows, kelp communities, sand-gravel beaches, and bedrock outcrops comprise a continuum of habitat types available to herring throughout SEAK. Illustrated below are examples from ten specific spawning areas where habitat was examined; each was categorized by a "ShoreZone" mapping project[33]. Also illustrated are proposed ecoregions[41] and sea surface temperature[40].

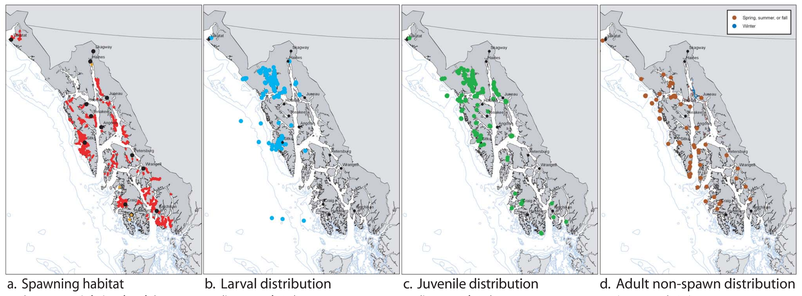




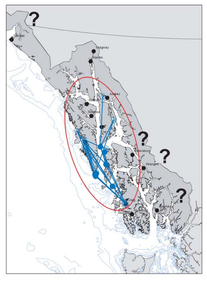


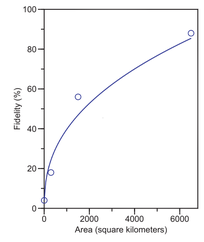
Behavioral factors: Pacific herring habitat utilization in southeast Alaska

Pacific herring distribution is essentially ubiquitous in SEAK. Illustrated are spawning locations and management areas[1,10,12-16](a); red depicts spawning areas mapped by ADFG, orange identifies other known spawning sites. Larval[17-25](b), juvenile[17,22,23,26-30](c), and adult non-spawn[4,6,8,9,17,28,29,31,32](d) distributions are incomplete and do not represent total habitat utilization. Likewise, only commercial sized spawning locations are generally mapped.



a. Spawning habitat (commercial sized only) b. Larval distribution (incomplete) c. Juvenile distribution (incomplete) d. Adult non-spawn distribution (incomplete)

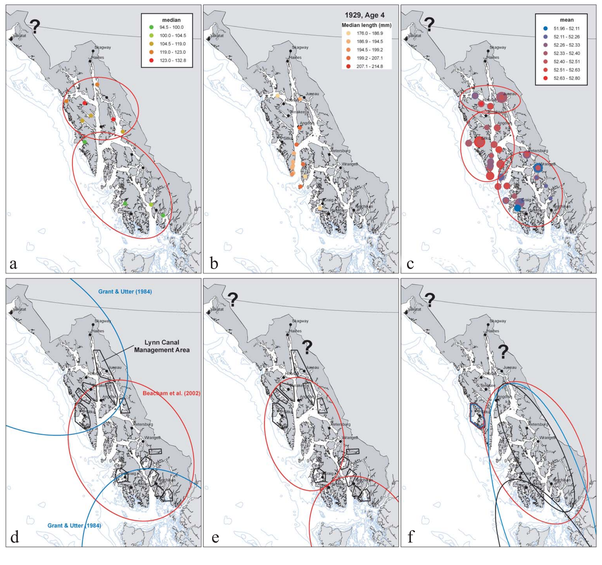


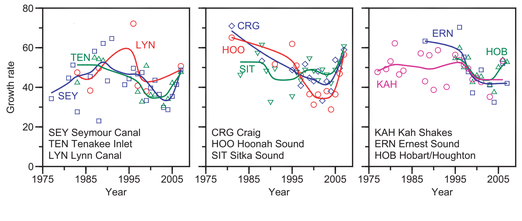


Pacific herring migrate from many spawning areas in southeast Alaska to a common summer feeding area[4,6-9](far left). Open symbols depict release sites; closed symbols indicate capture sites. No spawning fidelity data exist in SEAK. However, spawning fidelity has been extensively studied in British Columbia. On large scales, fidelity of Pacific herring approaches 100% and declines to near 0 as geographic scales decline to beach size (left). This suggests fish that mingle in summer areas do not all return to the same spawning beaches in SEAK. Based on this relationship and spatial scales in SEAK, considerable mixing among stocks is expected (60 to 80%).

Physiological factors

Some physiological data suggest adult Pacific herring in SEAK can be subdivided into more than one grouping, other data do not. Data include median spawn timing[1-3](Julian day; a), length at age[4](b), number of vertebrae[4](c), genetic measures[10,11](d), weight at age[5](e), and recruitment[5](g). Question marks indicate geographic areas without adequate data. Specific geographic information for genetic data (d), weight at age (e), and recruitment (f) were not available; these figures only generalize the conclusions of original authors.





Pacific herring cohort growth rate varies among southeast Alaska herring stocks; none are exceptionally different. Data for nearly 79,000 fish were supplied by ADFG (Alaska Department of Fish and Game).

Conclusion 1: Lynn Canal herring are not discrete as defined by the ESA

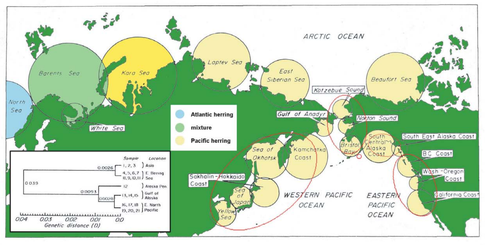
The BRT concluded that herring in Lynn Canal were not markedly discrete from other populations of the same taxon in SEAK. Spawning beaches are not continuous in SEAK and are repeatedly utilized, thus ADFG manages herring as discrete stocks. However, available biological data, including genetics, spawn timing, biomass, recruitment, growth, meristics, and migration do not identify definitive divisions among SEAK stocks. Limited tagging studies within SEAK demonstrate fish migrate and mix over most of the region. Migration data from British Columbia, were used to roughly predict repeat spawning fidelity of herring stocks in SEAK; these approximations suggest considerable mixing among stocks (about 60 to 80%), implying that SEAK herring are part of an interrelated metapopulation. Work remains to understand the relationships among SEAK herring stocks, such as more detailed spawn-oriented and seasonal tagging studies.

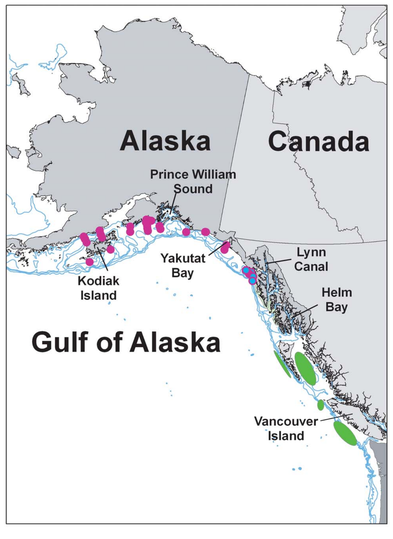
ESA question 2: Are Lynn Canal herring significant with respect to the taxon?

If a population segment is considered discrete, its biological and ecological signficance must be considered. Significance evidence is that the discrete population segment 1) persists in a unique or unusual ecological setting, 2) its loss would result in a significant gap in the taxon range, 3) that it represents the only surviving natural occurrence of a taxon that may be abundant elsewhere, or 4) that it differs markedly from other populations of the species in its genetic characteristics.

Global distribution of taxon

Pacific herring are distributed around the northern Pacific Ocean and extend into the Arctic Ocean[34]. Genetic distance is inset[10] (based on protein allozymes); red ellipses identify these groupings.





Offshore herring in the Gulf of Alaska

Offshore migratory behavior may increase the odds of 'stock' or 'metapopulation' mixing. This figure illustrates examples of Pacific herring on the continental shelf along the Gulf of Alaska; the data are not synoptic. Herring that spawn in inside waters of British Columbia feed offshore in the summertime[35,36](green elipses). The relation between offshore herring and inshore spawning has not been studied in Alaska, though the behavior observed in British Columbia is anticipated in Alaska[36]. What is known about herring migration in Alaska is from tagging studies where fish were tagged on spawning grounds and recovered in a summer fishery[4,6-9](irregular light green polygons within central SEAK).

Conclusion 2: Lynn Canal herring are not significant as defined by the ESA

No members of the BRT perceived Lynn Canal herring to be significant with respect to the taxon (although all recognized the importance of herring to the local ecosystem), thus even if the team had concluded that Lynn Canal herring were discrete, the ESA significance criterion precludes its definition as a distinct population segment.

Conclusion 3: The smallest defensible DPS that includes Lynn Canal is southeast Alaska

The southern limit of the DPS, Dixon Entrance, is identified by genetic differences between herring in southeast Alaska and those in British Columbia and by differences in parasitism between herring stocks north and south of the Queen Charlotte Islands. Genetics did not provide a definitive northern separator, rather the northern border is near Icy Point and defined by a physical barrier: mobile, open ocean beaches are inadequate as spawning and rearing habitat. SEAK Pacific herring are significant with respect to the taxon; the population persists in a unique habitat intermediate between areas further south and further north. Loss of SEAK herring would result in a significant gap in the taxon range.

Conclusion 4: The ESA may not be generally suitable for the protection of pelagic marine fish

The BRT based its decision on the best available science, yet recognizes that the science behind these decisions is imperfect. They also recognize that precautionary management of animals and ecosystems is a wise approach that goes beyond the language of the ESA. Precautionary management is the current stance of the Alaska Department of Fish and Game, the agency responsible for Pacific herring in Lynn Canal; the fishery has not been open since 1982.

1. Davidson, W., D. Gordon, K. Monagle, and D. Harris. 2005. Northern southeast Alaska herring spawn-on-kelp pound fishery, 2005, in *Fishery Management Report No. 05-11*. Alaska Department of Fish and Game. p. 29.
2. Pritchett, M. 2006. Historic spawn herring database: Alaska Department of Fish and Game, Juneau, AK.
3. Coonradt, E. 2008. Spawn timing in Sitka, AK. Alaska Dept of Fish and Game.
4. Rounsefell, G.A. and E.H. Dahlgren. 1935. Races of herring, *Clupea pallasii*, in southeastern Alaska. Bulletin of the Bureau of Fisheries. 17.
5. Williams, E.H. and T.J. Quinn. 2000. Pacific herring, *Clupea pallasi*, recruitment in the Bering Sea and northeast Pacific Ocean, I: relationships among different populations. Fisheries Oceanography. 9: p. 285-299.
6. Rounsefell, G.A. and E.H. Dahlgren. 1933. Tagging experiments on the Pacific herring, *Clupea pallasii*. Journal du Conseil International our l'Exploration de la Mer. VIII: p. 371-384.
7. Dahlgren, E.H. 1936. Further developments in the tagging of the Pacific herring, *Clupea pallasii*. Journal du Conseil International our l'Exploration de la Mer. 11: p. 229-247.
8. Skud, B.E. 1963. Herring tagging experiments in southeastern Alaska. Fishery Bulletin. 63: p. 19-32.
9. Carlson, H.R. 1977. Results of a tagging study of Pacific herring in southeastern Alaska in 1960-62 using radioactive body cavity tags. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northwest Fisheries Center: Seattle, WA. p. 9.
10. Grant, W.S. and F.M. Utter. 1984. Biochemical population genetics of Pacific herring (*Clupea pallasi*). Canadian Journal of Fisheries and Aquatic Sciences. 41: p. 856-864.
11. Beacham, T.D., J.F. Schweigert, C. MacConnachie, K.D. Le, K. Labaree, and K.M. Miller. 2002. Population structure of herring (*Clupea pallasi*) in British Columbia determined by microsatellites, with comparisons to southeast Alaska and California. Fisheries and Oceans Canada, Canadian Science Advisory Secretariat.
12. Carlson, H.R. 1980. Seasonal distribution and environment of Pacific herring near Auke Bay, Lynn Canal, southeastern Alaska. Transactions of the American Fisheries Society. 109: p. 71-78.
13. Leon, H. 1993. Stock discreteness of Pacific herring (*Clupea harengus pallasi*) in southeast Alaska. University of Washington: Seattle, WA. p. 128.
14. Herbert, K. and D. Carlile. 2002. Southeast Alaska/Yakutat annual herring research report, 2000/2001 season. Alaska Department of Fish and Game. Regional Information Report No. IJ02-36: p. 1-146.
15. Pritchett, M. 2005. 2006 Report to the Alaska Board of Fisheries: southeast Alaska -- Yakutat herring fisheries, in *Fishery Management Report No. 05-67*. Alaska Department of Fish and Game. p. 25.
16. Pritchett, M. 2007. Personal communication.
17. Arimitsu, M.L., J.F. Piatt, M.D. Romano, and D.C. Douglas. 2007. Distribution of forage fishes in relation to the oceanography of Glacier Bay. in *Proceedings of the fourth Glacier Bay science symposium, October 26-28, 2004*: U.S. Geological Survey Scientific Investigations Report 2007-5047.
18. Haldorson, L. and J. Collie. 1991. Distribution of Pacific herring larvae in Sitka Sound, Alaska. in *Proceedings of the International Herring Symposium October 1990*: Alaska Sea Grant College Program, University of Alaska Fairbanks.
19. Haldorson, L.J., J.D. Watts, and D.A. Sterritt. 1986. Larval fish production in Auke Bay, Alaska - 1986, in *APPRISE: association of primary production and recruitment in a subarctic ecosystem*, O.A. Mathisen, J.J. Goering, and P.K. Bienfang, Editors., School of Fisheries and Science (University of Alaska-Juneau), Institute of Marine Science (University of Alaska-Fairbanks), the Oceanic Institute (Waimanalo, Hawaii), and NOAA/National Marine Fisheries Service (Auke Bay Laboratory): Juneau, AK. p. 321-360.
20. Haldorson, L.J., J.D. Watts, and D.A. Sterritt. 1987. Larval fish production in Auke Bay, Alaska - 1987, in *APPRISE: association of primary production and recruitment in a subarctic ecosystem*, O.A. Mathisen, J.J. Goering, and P.K. Bienfang, Editors., School of Fisheries and Science (University of Alaska-Juneau), Institute of Marine Science (University of Alaska-Fairbanks), the Oceanic Institute (Waimanalo, Hawaii), and NOAA/National Marine Fisheries Service (Auke Bay Laboratory): Juneau, AK. p. 301-360.
21. Haldorson, L.J., J.D. Watts, and D.A. Sterritt. 1988. Larval fish studies, in *APPRISE: association of primary production and recruitment in a subarctic ecosystem*, O.A. Mathisen, J.J. Goering, and P.K. Bienfang, Editors., School of Fisheries and Science (University of Alaska-Juneau), Institute of Marine Science (University of Alaska-Fairbanks), the Oceanic Institute (Waimanalo, Hawaii), and NOAA/National Marine Fisheries Service (Auke Bay Laboratory): Juneau, AK. p. 147-183.
22. Johnson, S.M., ML; Csepp, DJ; Harris, PM; Thedinga, JF. 2003. Survey of fish assemblages in eelgrass and kelp habitats of southeastern Alaska U.S. Department of Commerce, NOAA Technical Memorandum NMFS AFSC-139. p. 1-50.
23. Johnson, S.W. 2007. Nearshore fish atlas of Alaska. http://www.fakr.noaa.gov/habitat/fishatlas/.
24. Mattson, C.R. and B.L. Wing. 1978. Ichthyoplankton composition and plankton volumes from inland coastal waters of southeastern Alaska, April-November 1972. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service. p. 1-16.
25. Wing, B.L., C.W. Derrah, and V.M. O'Connell. 1997. Ichthyoplankton in the eastern Gulf of Alaska, May 1990. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Alaska Fisheries Science Center. p. 1-54.
26. Cieciel, K. 2008. personal communication.
27. Muret-Woody, H. 2008. personal communication.
28. Orsi, J.A. 2008. Personal communication.
29. Orsi, J.A., J.A. Harding, S.S. Pool, R.D. Brodeur, L.J. Haldorson, J.M. Murphy, J.H. Moss, E.V.J. Farley, R.M. Sweeting, J.F.T. Morris, M. Trudel, R.J. Beamish, R.L. Emmet, and E.A. Fergusson. 2007. Epipelagic fish assemblages associated with juvenile Pacific salmon in neritic waters of the California current and the Alaska current. American Fisheries Society Symposium. 57: p. 105-155.
30. Piatt, J.F. 2008. U.S.G.S. Alaska Science Center.
31. Farley, E. 2008. Personal communication.
32. Vollenweider, J.J. 2008. Personal communication.
33. Harney, J.N., M. Morris, and J.R. Harper. 2007. ShoreZone coastal habitat mapping protocol for the Gulf of Alaska. Sidney, BC.: Coastal & Ocean Resources, Inc. 1-137.
34. Hay, D.E. 1985. Reproductive biology of Pacific herring (*Clupea harengus pallasi*). Canadian Journal of Fisheries and Aquatic Sciences. 42: p. 111-126.
35. http://www.pac.dfo-mpo.gc.ca/sci/herring/hertags/pages/default4_e.htm. Herring migratory behavior. 2008 [cited.
36. Hay, D. 2008. Personal communication.
37. Murphy, J.M. and J.A. Orsi. 1999. Physical oceanographic observations collected aboard the NOAA ship John C. Cobb in the northern region of southeastern Alaska, 1997 and 1998. U.S. Dept of Commerce. NMFS-AFSC Proc. Rep. 99-02. p. 239.
38. Quast, J.C. 1968. New records of thirteen Cottoid and Blennoid fishes for southeast Alaska. Pacific Science. 22: p. 482-487.
39. Carls, M.G., S.W. Johnson, M.R. Lindeberg, A.D. Neff, and P.M. Harris. 2008. Status review of Pacific herring (*Clupea pallasii*) in Lynn Canal, Alaska. Final Report --
40. AOOS. (Alaska Ocean Observing System). 2008 [cited.
41. Piatt, J.F. and A.M. Springer. 2007. Marine ecoregions of Alaska, in *Long-term ecological change in the northern Gulf of Alaska*, R.B. Spies, Editor., Elsevier: Amsterdam. p. 522-526.
42. Wildes, S.L., J.J. Vollenweider, and J. Guyon. 2009. Pacific herring in Southeast Alaska: one big happy metapopulation? Abstract -- Alaska Marine Science Symposium.