Pacific Herring Recruitment Time Series from Prince William Sound, Alaska, Compared to Herring Elsewhere on the West Coast of North America: Is Low Recruitment a Problematic Constraint in Prince William Sound?

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INTRODUCTION

In the spring of 1993, reports of unusual herring behavior and conditions surfaced among fishermen awaiting an expected large harvest in the Prince William Sound (PWS) herring sac roe fishery. Test fishing then began showing fish with lesions, and unusual schooling patterns; both fishermen and biologists flying aerial surveys noted a dramatically less than expected showing of herring schools.

Subsequent studies revealed that viral hemorrhagic septicemia virus (VHSV), associated ulcers, and the fungus-like organism *Ichthyophonus hoferi* cause the major diseases in Pacific herring, and that VHSV and associated ulcers probably contributed most to population decline in 1993 (Meyers et al. 1994; Marty et al. 1998). PWS Pacific herring fisheries were severely curtailed in 1993, and were never opened in 1994 or 1995. Herring abundance remains at low levels in PWS. Debate continues among scientists about how much of the unusual condition of PWS herring can be attributed to the 1989 Exxon Valdez oil spill (Marty et al. 1998, Pearson et al. 1999).

Concurrent with the increased prevalence of the two pathogens during the 1990s, recruitment to the herring population appeared to be unusually low. This paper examines the historical and contemporary information about herring recruitment in PWS, contrasting it to recruitment patterns elsewhere on the west coast of North America to determine whether the low post oil-spill recruitment patterns are unique to PWS, or whether they are within the expected range of natural variability.

METHODS

The longest possible time series of recruitment and spawning biomass were synthesized from multiple available sources. Williams and Quinn (2000) had previously distilled the available historic herring stock assessment information into long time series of recruitment, with year class strength in some cases dating back to 1917. However, the most recent year class analyzed by Williams and Quinn (2000) was 1993. Contemporary stock assessment documents and consultation with Pacific coast herring stock assessment scientists were used to extend Williams and Quinn's (2000) information through the 2001 year class. Alaska reference populations contrasted with PWS include Togiak (Bristol Bay), Sitka, Craig, and Southeast Alaska combined. To the south, recruitment and spawning biomass information was compiled for Prince Rupert, Queen Charlotte Islands, Central B.C. Coast, Strait of Georgia, and the West Coast of Vancouver Island in British Columbia, and for Cherry Point in northern Puget Sound. San Francisco Bay herring information was also reviewed, but is not included in these recruitment comparisons.

The historic time series of recruitments is examined for patterns and trends, and cast into spawner-recruit form, using the time series of spawning biomass for each area. Because of the strong time-series correlations in these spawner-recruit datasets, it would be inappropriate and misleading to reduce the spawner-recruit pairs to a "Ricker" or other simplistic mathematical model to describe the relationship of spawners to recruits. More complex models incorporating environmental data and properly treating the time-series nature of these data are possible, but are beyond the scope of this analysis. Recruitment patterns plainly evident in the graphical analysis of the suite of areas examined are not so subject to misleading interpretation and are sufficient for the conclusions that need to be drawn regarding recent Prince William Sound herring recruitments.

Prince William Sound

The time series of spawning biomass (1980 to 2004) and resulting age 3 recruits for PWS was drawn from Hulson et al. (2006). The herring population model in their age-structured approach derives the best fit of abundance time series to all the available stock assessment information: a time series of age compositions, spawn deposition surveys, aerial milt surveys, and hydroacoustic surveys. The incorporation of hydroacoustic information is a recent addition to the PWS stock assessment approach, but ended up having little effect on the abundance time series, even over a broad range of weights for the acoustic information. In this analysis, the time series of hydroacoustic information with a weight (lambda) of 0.5 was used. Data for the 1925-55 and 1970-76 year classes were taken from Williams and Quinn (2000), while the Quinn et al. (2006) were used as the source for the 1977- 2001 year class information. There is no stock assessment information for the 1956 through 1969 year classes.

Togiak

An age-structured model (Funk et al. 1992) has been used for annual stock assessments in the Togiak district of Bristol Bay for over a decade. The model synthesizes test and commercial catch age compositions, catch, and aerial survey biomass estimates. Spawning biomass and recruitment time series were drawn from 2004/2005 stock assessments (West 2005, Lowell Fair, Alaska Department of Fish and Game, Anchorage, personal communication). The time series in these assessments spans 1977 to 2005, or the 1973 through 2001 year classes (recruitment at age 4). The 1969-1972 year class information is from Williams and Quinn (2000).

Southeast Alaska

Age-structured assessment models are used for the major spawning locations in Southeast Alaska. In this analysis, assessments for the two largest spawning aggregations, Sitka and Craig, span the years 1971 through 2005, corresponding to the 1968 through 2002 year classes. 1971 through 1997 data was taken from Carlile et al. (1999), 1998-2003 from Dressel et al. (2005), 2004 from Pritchett (2005), and 2005 from Davidson et al. 2005). These contemporary time series were combined with older historic time series from Williams and Quinn (2000), dating back to 1917.

British Columbia

A long time series of data is integrated into stock assessment models for the principal spawning locations in British Columbia, dating back to the 1948 year classes (Schweigert 2004). These data completely replaced the historical time series given in Williams and Quinn (2000). When specified, the age of recruitment is taken to be two years in British Columbia.

Cherry Point (Washington)

Abundance is estimated annually for herring spawning near Cherry Point, though a formal stock assessment model is not used. Point estimates of abundance are derived from spawn deposition surveys and acoustic surveys. Cherry Point herring are unique to the region with an extremely late spawning time. They are also genetically distinct from other Washington herring, as well as from British Columbia herring (Stick 2005). The Cherry Point time series extends back to 1973, with recruitment at age 2, so that the data series encompasses the 1971 through 2002 year classes.

San Francisco Bay (California)

San Francisco Bay herring were tentatively included in this research pending a review of stock assessment information. Age-structured assessment models were used in a preliminary peer review of the San Francisco Bay herring management (Dewees and Leet, 2003), but age compositions and age-structured models are not yet routinely used in the California fishery. Also, the age composition of the catch has changed towards younger individuals over time that likely resulted from changes in fishery selectivity. At present there are essentially no individuals aged 6 years or older in the catch, while in earlier years these ages made up over 50% of the catch (Dewees and Leet, 2003). Also, the fishery may have been targeting younger fish in recent years, distorting the view of year class strengths. The San Francisco Bay herring population has been reduced to a level of roughly 20% of the unfished level and is presently at or near the lowest abundance observed since the early 1970s. High fishery exploitation rates may have affected the stock productivity. Because these factors are not comparable to other west coast herring populations, San Francisco Bay herring were not considered further in this analysis.

RESULTS

Most of the year class strengths after 1960 were updated from those given in Williams and Quinn (2000), using the more recent stock assessment information (Table 1). The range between the weakest and strongest year classes spans two to three orders of magnitude at all areas (e.g. from 9.4 to 1,337.8 million recruits in PWS). For the more northerly areas, strong recruitment events tended to occur in a single year or a pair of back-to-back strong year classes, separated by a run of years with low recruitment (Figures 1 and 2). For the southerly areas (Strait of Georgia and Cherry Point), stronger recruitments tended to occur over a 10-15 year series of adjacent years, with no intervening runs of low recruitment. The Strait of Georgia and Cherry Point herring in particular, almost completely lack the very strong recruitment "spikes" that characterize herring from the more northerly regions.

Togiak

For Togiak, the northern-most herring population examined, herring have had strong year classes about every 10 years, within the range of these data (Figure 1). In the Bering Sea, herring are larger (likely an adaptation to long-distance migration), and have longer reproductive lifespans (approximately 12 years) than in the Gulf of Alaska. Togiak's two strongest year classes (1977 and 1978) were generated from the two lowest observed spawning biomasses (Figure 3). The 1993 to 2001 year spawner-recruit pairs are in the middle of the distributions (shaded pink area of Figure 3).

Prince William Sound

In PWS, strong year classes generally occurred at shorter intervals (4-6 years), until recently. Reproductive lifespans are shorter than Bering Sea herring as well (approximately 7 years). The last strong year class was 1988. Subsequently, recruitments fell to lower levels, with the 1995 through 1998 year classes being some of the smallest on record. However, there have been 3 "modest" recruitment events observed since the 1993 crash: the 1993, 1994, and 1999 year classes.

In terms of spawner-recruit, the recent year classes (1993-2001) are in the far lower-left of the spawner-recruit space (Figure 3). No large year classes have ever resulted from spawning biomass in the lower range of spawning biomass in PWS, although modest year classes of around 200 million recruits have been observed. The four largest year classes assessed (1980, 1981, 1984, and 1988) were spawned from biomasses double to four times the recent biomass.

Southeast Alaska

Southeast Alaska displays the same 4 to 6 year cyclical recruitment events as in PWS, up through the 1988 year class. There was remarkable synchrony of a 4-year recruitment cycle in PWS and the Southeast Alaska outer coast herring (Sitka and Craig). The Southeast Alaska areas do not show extremely low abundance of the 1995 through 1998 year classes, as in PWS.

At Sitka, the 1993-2001 spawner-recruit pairs indicate moderate recruitment throughout (Figure 3), with very poor recruitment from the largest year class (2001). The 1993-2001 spawner-recruit pairs are spread over a very broad range of spawning biomass, including the largest spawning biomass ever observed. The largest year classes (1984 and 1988) occur in the middle of the spawning biomass range.

Like Togiak, Craig has produced its two largest year classes from the two smallest spawning biomasses (1984 and 1985), and has the 1993-2001 spawner recruit pairs in the lower middle of the spawner-recruit space.

British Columbia

Herring spawning along the northern and central coasts of British Columbia show the same episodic near four-year cycle as in PWS and Southeast Alaska. However, unlike PWS, the spiked recruitment trends continued up to the present time (2001 year class). Occasional single year classes were weak between 1995 and 1998, but this rare occurrence was not unusual, and there was no indication of a four-year span of low recruitment, as in PWS.

Herring in southern British Columbia (Strait of Georgia and Vancouver Island West coast have very different recruitment patterns (Figure 2), perhaps resulting from different oceanographic conditions and life history strategies. Herring recruitment strengths appear cyclic on a much longer scale, and there are runs of strong back-to-back year classes, not individual strong year "spikes", as in the more northerly areas.

At Prince Rupert, the largest recruitment events are produced from the largest year classes, with 1993-2001 year classes around the medians of the spawner-recruit space. The Queen Charlotte Islands has a very strong year class (1952) produced from low biomass. The 1993-2001 observations at the lower left of the spawner-recruit space. The Central B.C. coast has a single very strong year class (1952) near the median spawning biomass. Like Sitka, the 1993-2001 recruitments are spread over the larger biomass observations. The Strait of Georgia spawner-recruit observations (Figure 4) look remarkably similar to Prince Rupert (Figure 3), except that the 1993 to 2001 observations are near the larger end of the spawning biomass. For the west coast of Vancouver Island, 1993-2001 spawner-recruit pairs are spread over lower third of the spawning biomass range. Moderate year classes (>400 million recruits) occurred during this time period.

Cherry Point (Washington)

Cherry Point also does not exhibit single-year spikes of strong year classes, similar to the adjacent southern British Columbia herring. However, recent genetic studies have suggested that the Cherry Point herring stock is genetically distinct from other Washington and British

Columbia stocks (Beacham et al. 2002, Small et al. 2004). Cherry Point recruitment has fallen to extremely low levels since 1993, similar to PWS. The 1993-2001 spawner recruit observations are in the lower left of the spawner recruit space at Cherry Point (Figure 4).

DISCUSSION

Concern over fluctuating herring populations in PWS is not new (e.g. Rounsefell and Dahlgren 1931). However, the magnitude and duration of the current low herring population event in PWS is unprecedented in historical times. In PWS, year class strength held up with at least occasional strong year classes through the early 1990s. It was adult mortality that caused population declines starting in 1993. However, a low recruitment phenomenon also occurred in the late 1990s (Figure 3), contributing to the very low current population level. For Prince William Sound, the Queen Charlotte Islands, and Cherry Point, the 1993-2001 spawner-recruit information (pink shaded area) is all at the lower-left of the spawner-recruit space. In all other areas, spawner-recruit information is near the median of the respective ranges or higher. If there is a linkage in productivity affecting recruitment among these widely disparate herring populations, it is not a simple matter of geography.

For PWS, the population "crash" and sustained low abundance levels are not really due to a lack of recruitment (as the RFP for this project had suggested), although there is a dangerously low run of recruitment in the late 1990s. Fortunately for PWS, this run of low recruitment ended with the modestly strong recruitment event of the 1999 year class, before the duration of low recruitment had exceeded the reproductive lifespan of the remaining herring. However, accelerated adult mortality is keeping the population at very depressed levels.

CONCLUSIONS

1. Six of ten examined herring populations have recovered from low biomass, generating strong recruitment events when biomass is relatively low.
2. Prince William sound has never generated a strong recruitment event from low biomass.
3. Prince William Sound has experienced 3 modest recruitment events since the 1993 crash (the 1993, 1994, and 1999 year classes) which under other circumstances would have caused greater recovery than has been observed.
4. Elevated adult mortality (heavily influenced by VHSV and *Icthyophonus*), not low recruitment, is suppressing the Prince William Sound herring population.

LITERATURE CITED

Carlile, D.W., R.C. Larson and K.P. Hebert 1999. Stock assessments of Southeast Alaska herring in 1997 and forecasts for 1998 abundance. Regional Information Report 1J99-10. Alaska Department of Fish and Game, Juneau.

Davidson, W., W. Bergmann, P. Doherty, K. Monagle and D. Gordon. 2005. Southeast Alaska Sac Roe Herring Fishery, 2005. Alaska Department of Fish and Game, Fishery Management Report No. 05-05, Anchorage. (http://www.adfg.alaska.gov/FedAidpdfs/Fmr05-05.pdf")

Dewees, C. and B. Leet. 2003. Peer Review of the California Department of Fish and Game's Commercial Pacific Herring Fishery Management and Use of the Coleraine Fishery Model. Unpublished manuscript, available at: (http://www.dfg.ca.gov/mrd/herring/peerreview_2003.pdf)

Dressel, S., K. Hebert, M. Pritchett, and D. Carlile 2005. Southeast Alaska Herring. In: Boldt, J. (ed). Ecosystem Considerations for 2006 (Appendix C to the Stock Assessment and Fishery Evaluations for Bering Sea/Aleutians and Gulf of Alaska Groundfish). November, 2005. North Pacific Fishery Management Council, Anchorage, Alaska.

Funk, F., L.K. Brannian, and K.A. Rowell. 1992. Age-structured assessment of the Togiak herring stock, 1978-1992, and preliminary forecast of abundance for 1993. Juneau: Alaska Department of Fish and Game, Division of Commercial Fisheries. Regional Information Report 5J92-11 (http://www.adfg.alaska.gov/FedAidPDFs/RIR.5J.1992.11.pdf)

Hulson P.F., S. E. Miller, T.J. Quinn, G.D. Marty, S.D. Moffitt, and F. Funk. 2006. Incorporating hydroacoustic data into the Prince William Sound herring assessment model. *ICES Journal of Marine Science*, Volume 65(1):25–43. (https://academic.oup.com/icesjms/article/65/1/25/611634)

Marty, G. D.; Freiberg, E. F.; Meyers, T. R.; Wilcock, J.; Farver, T. B., and D.E. Hinton. 1998. Viral hemorrhagic septicemia virus, *Ichthyophonus hoferi*, and other causes of morbidity in Pacific herring (*Clupea pallasi*) in Prince William Sound, Alaska, USA. Diseases of Aquatic Organisms 32:15-40. (https://www.int-res.com/abstracts/dao/v32/n1/p15-40/)

Meyers, T.R., S. Short, K. Lipson, W.N. Batts, J.R. Winton, J. Wilcock and E. Brown.1994. Association of viral hemorrhagic septicemia virus with epizootic hemorrhages of the skin in Pacific herring *Clupea harengus pallasi* from Prince William Sound and Kodiak Island, Alaska, USA. Diseases of Aquatic Organisms 19:27-37. (https://www.int-res.com/articles/dao/19/d019p027.pdf)

Pearson, W.H. R.A. Elston, R.W. Bienert, A.S. Drum, and L.D. Antrim . 1999. Why did the Prince William Sound, Alaska, Pacific herring (*Clupea pallasi*) fisheries collapse in 1993 and 1994? Review of hypotheses. Canadian Journal of Fisheries and Aquatic Sciences . 56 (4):711-737.(https://www.nrcresearchpress.com/doi/pdf/10.1139/f98-207 -abstract only)

Pritchett, M. 2006. Southeast Alaska-Yakutat herring fisheries: Report to The Alaska Board of Fisheries. Alaska Department of Fish and Game, Fishery Management Report No. 05-67, Anchorage. (http://www.adfg.alaska.gov/FedAidPDFs/FMR05-67.pdf)

Rounsefell, G.A and E.H. Dahlgren. 1931. Fluctuations in the supply of herring (Clupea Pallasii) in Prince William Sound, Alaska. U.S. Dept. of Commerce, Bureau of Fisheries Doc. No. 9: 263-291. (https://spo.nmfs.noaa.gov/sites/default/files/pdf-content/fish-bull/fb47.9.pdf)

Schweigert, J. 2004. Stock Assessment For British Columbia Herring In 2004 and Forecasts Of The Potential Catch In 2005. Research Document 2004/081. Canada Department of Fisheries and Oceans, Pacific Biological Station, Nanaimo, B.C. (https://waves-vagues.dfo-mpo.gc.ca/Library/316462.pdf)

Stick, K.C. 2005. 2005 Washington State Herring Stock Status Report. SS 05-01. Washington Department Of Fish And Wildlife, Olympia, Washington.

West, F. 2005. Togiak Herring Population Trends. In: Boldt, J. (ed). Ecosystem Considerations for 2006 (Appendix C to the Stock Assessment and Fishery Evaluations for Bering Sea/Aleutians and Gulf of Alaska Groundfish). November, 2005. North Pacific Fishery Management Council, Anchorage, Alaska.

Williams, E.H., and Quinn, T.J., II. 2000b. Pacific herring, Clupea pallasi, recruitment in the Bering Sea and Northeast Pacific Ocean: I. Relationships among different populations. Fisheries Oceanography 9: 285-299. (https://onlinelibrary.wiley.com/doi/pdf/10.1046/j.1365-2419.2000.00145.x – abstract only)

Table 1. Recruiting year class strength (millions) for herring stocks along the west coast of North America, for the 1917-2001 year classes. Purple italics denote values that have been updated from Williams and Quinn (2000) from recent stock assessments.

Year Class	Togiak	Prince William Sound	Sitka	South east	Craig	Prince Rupert	Queen Charlotte	Central Coast	Vancouver Island	Strait of Georgia	Cherry Point
1915											
1916											
1917				7.6							
1918				45.2							
1919				18.5							
1920				39.8							
1921				55.2							
1922				171.3							
1923				238.2							
1924				164.0							
1925		122.4		2,080.1							
1926		301.3		907.9							
1927		209.5		295.5							
1928		247.1		856.0							
1929		189.0		265.6							
1930		1,337.8		2,124.8							
1931		115.7		171.5							
1932		103.5		160.5							
1933		82.8		218.6							
1934		908.2		581.1							
1935		782.2		166.8							
1936		145.2		45.2							
1937		194.1		24.3							
1938		219.5		76.8							
1939		31.1		283.3							
1940		131.2		191.8							
1941		220.0		535.7							
1942		125.5		224.9							
1943		461.6		869.2							
1944		103.5		152.6							
1945		112.5		149.4							
1946		64.2		305.2							
1947		155.3		150.6							
1948		20.2		79.9		*469.5*	*148.0*	*323.3*	*290.8*	*1,130.6*	
1949		17.7		102.5		*269.7*	*76.0*	*129.3*	*302.5*	*1,148.7*	
1950		202.1		211.2		*386.3*	*159.2*	*233.3*	*444.1*	*1,210.7*	
1951		22.1		92.5		*580.6*	*953.7*	*1,113.2*	*772.3*	*1,920.6*	
1952		427.6		1,717.9		*166.0*	*167.3*	*90.6*	*326.0*	*1,097.1*	
1953		9.4		112.9		*374.9*	*131.2*	*99.8*	*579.9*	*519.7*	
1954		21.9		72.7		*118.9*	*64.7*	*194.6*	*449.8*	*577.4*	
1955		38.2		73.1		*229.7*	*62.2*	*278.8*	*551.7*	*547.9*	

1956				602.5		452.7	190.3	285.2	681.6	1,025.5	
1957				1,009.7		121.5	39.4	88.4	418.8	719.7	
1958				94.0		746.8	170.8	164.7	241.8	369.0	
1959				70.0		371.3	190.5	459.9	595.0	1,088.5	
1960				87.3		187.9	365.1	299.0	306.8	966.8	
1961				23.0		520.0	104.5	242.0	388.6	909.4	
1962				16.4		71.4	337.9	106.3	137.2	586.4	
1963				117.9		56.8	6.7	193.1	123.2	168.9	
1964			442.1	442.1		63.6	21.0	152.6	113.3	189.6	
1965			54.2	54.2		35.2	29.7	27.8	56.0	40.7	
1966			27.5	27.5		35.7	37.6	21.9	80.2	74.1	
1967			13.8	197.3	183.5	149.7	73.2	89.5	323.6	235.7	
1968			20.4	132.0	37.1	111.4	154.9	97.9	614.2	262.3	
1969	4.2		16.5	161.0	13.1	54.2	192.1	123.9	466.9	208.9	
1970	12.9	353.9	118.4	309.5	42.6	210.2	421.1	201.7	564.5	252.2	
1971	0.9	130.3	13.5	201.5	17.6	134.4	341.2	121.8	606.4	426.9	0.2
1972	80.6	116.7	17.1	66.1	10.9	119.0	323.0	175.7	1,011.1	604.8	0.5
1973	213.9	110.3	2.9	20.9	6.2	66.6	81.6	70.7	428.6	388.2	0.2
1974	239.1	81.8	84.9	144.5	4.5	111.3	144.7	57.1	282.5	795.0	5.5
1975	20.7	146.4	122.5	160.7	2.5	57.5	142.6	58.6	500.8	573.9	13.9
1976	50.8	889.6	575.2	640.2	10.6	55.6	72.8	41.1	165.6	298.4	1.2
1977	846.6	230.8	134.1	1,186.3	566.7	389.4	1,162.8	353.7	332.3	465.1	3.8
1978	743.9	127.8	17.5	222.2	88.9	76.9	80.3	69.9	242.3	379.5	40.2
1979	293.6	134.9	75.3	396.4	211.1	95.5	39.2	70.8	123.8	329.9	6.0
1980	83.8	425.8	545.9	765.6	77.8	137.8	34.5	33.5	92.4	247.8	16.4
1981	189.0	347.8	203.3	671.7	211.1	372.1	223.9	28.0	154.9	198.6	24.7
1982	38.3	97.0	41.8	207.3	44.4	67.4	92.3	102.6	315.6	259.7	24.0
1983	159.0	101.2	158.1	340.8	88.9	71.3	23.9	43.6	335.2	406.5	23.9
1984	137.9	1,064.6	1,000.4	1,741.8	588.9	247.3	50.8	87.6	131.6	257.5	30.8
1985	41.8	97.0	114.5	449.9	255.6	195.4	395.7	485.2	762.2	698.6	12.6
1986	77.6	74.2	7.2	160.1	77.8	102.9	114.8	34.9	141.6	203.6	14.8
1987	392.0	84.5	34.0	120.5	33.3	65.3	45.7	31.0	179.2	600.4	34.1
1988	275.8	980.9	1,041.1	1,441.9	144.4	240.7	19.0	101.9	107.5	282.6	27.2
1989	130.4	91.2	61.2	262.6	66.7	267.0	138.6	468.3	337.8	804.6	10.6
1990	142.6	92.7	27.4	156.4	55.6	58.6	11.5	55.9	174.1	570.9	23.8
1991	152.0	48.6	45.1	103.1	22.2	26.5	7.9	100.1	128.9	601.1	55.3
1992	115.3	140.2	247.3	431.9	77.8	68.2	18.7	28.9	60.7	275.2	73.7
1993	202.5	150.9	188.6	701.8	222.2	269.1	67.7	85.6	82.7	610.8	20.3
1994	41.0	193.3	389.6	478.5	88.9	111.2	80.9	340.1	446.9	868.9	8.7
1995	53.0	75.3	350.7	472.9	122.2	163.6	217.3	288.3	120.7	921.9	3.9
1996	253.8	17.1	98.6	176.4	77.8	43.7	12.8	63.0	65.1	454.6	13.1
1997	383.1	23.0	246.6	391.0	144.4	122.8	39.6	113.2	58.5	722.2	4.2
1998	107.0	18.3	241.1	330.0	88.9	169.4	37.6	47.5	132.9	976.8	5.2
1999	15.0	223.7	137.0	203.7	66.7	104.3	39.4	149.1	248.3	1,502.4	5.6
2000	12.3	67.7	197.3	419.5	222.2	449.5	115.1	363.8	321.6	1,455.8	11.2
2001	10.3	38.3	7.8	7.8		47.4	7.8	56.7	141.8	725.2	14.4
Mean:	167.3	220.6	187.4	358.3	116.9	190.6	153.3	169.4	316.0	614.0	17.1
Min:	0.9	9.4	2.9	7.6	2.5	26.5	6.7	21.9	56.0	40.7	0.2

Max:	846.6	1,337.8	1,041.1	2,124.8	588.9	746.8	1,162.8	1,113.2	1,011.1	1,920.6	73.7

Figure 1. Time series of recruitment for herring spawning from Togiak (Bristol Bay) through Prince Rupert, British Columbia.

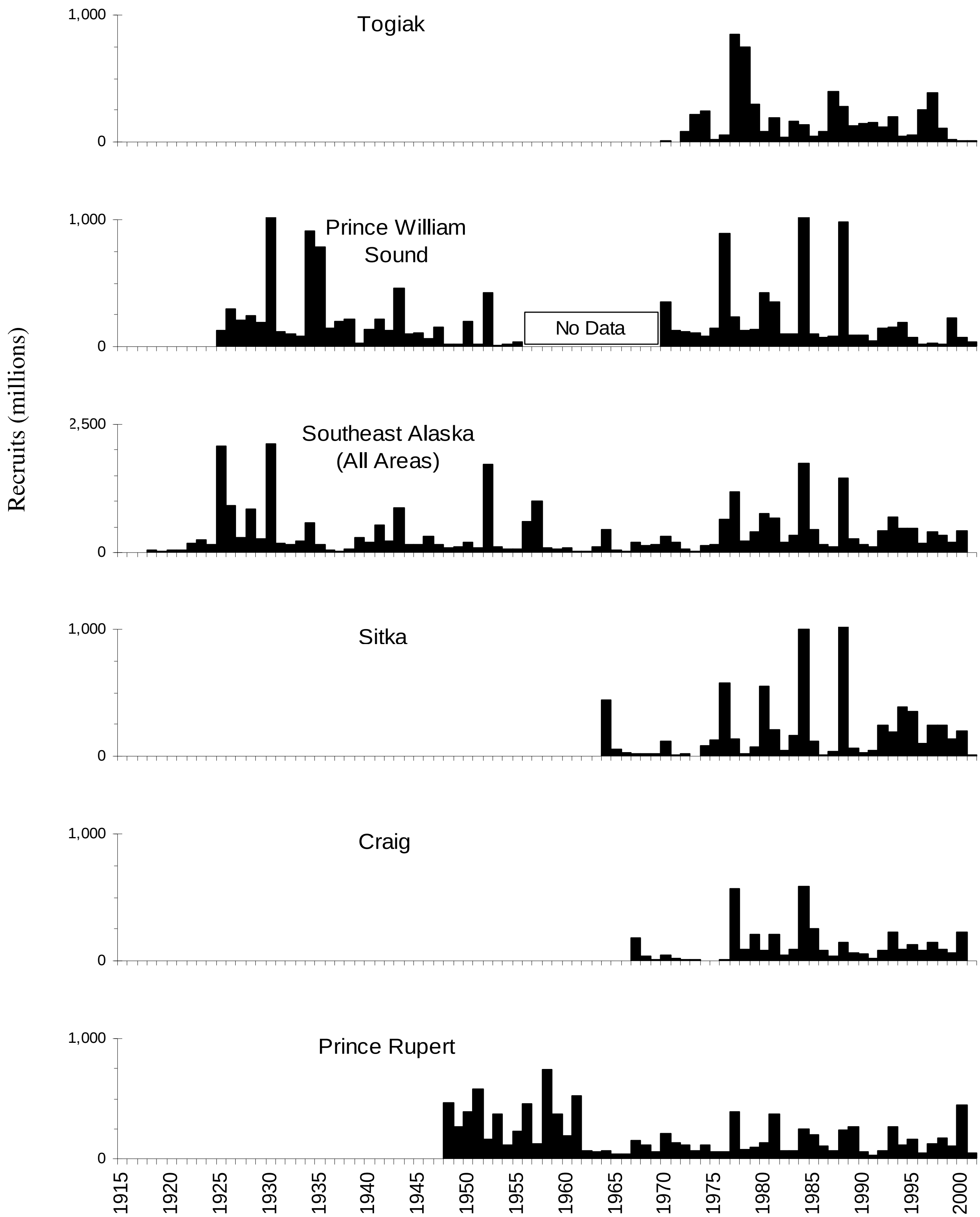

Figure 2. Time series of recruitment for herring spawning from the Queen Charlotte Islands, British Columbia, through Cherry Point, Washington.

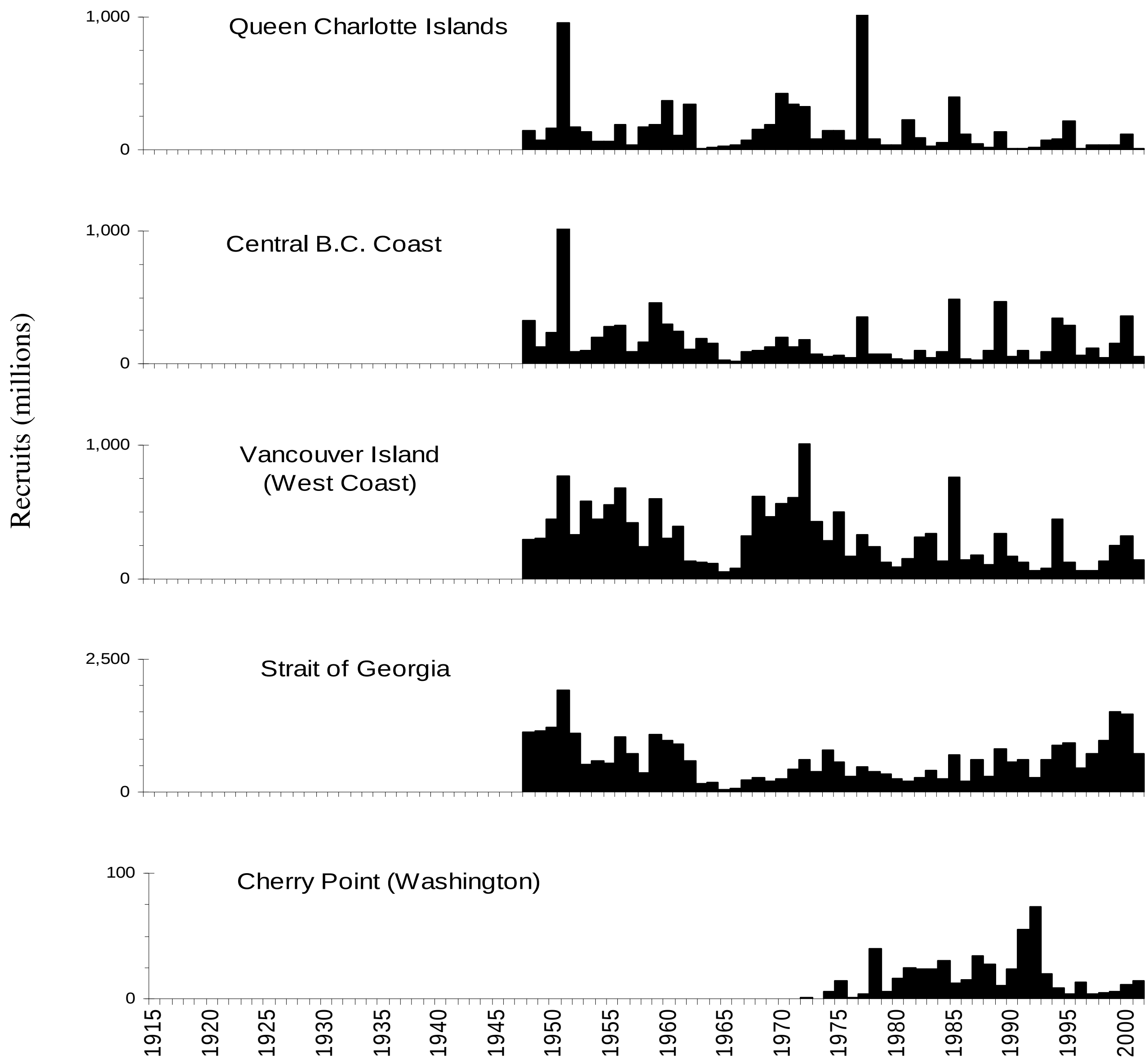

Figure 3. Herring spawner-recruit information for Alaska and northern British Columbia. Red open squares and pink shaded area indicate the 1993-2001 year classes.

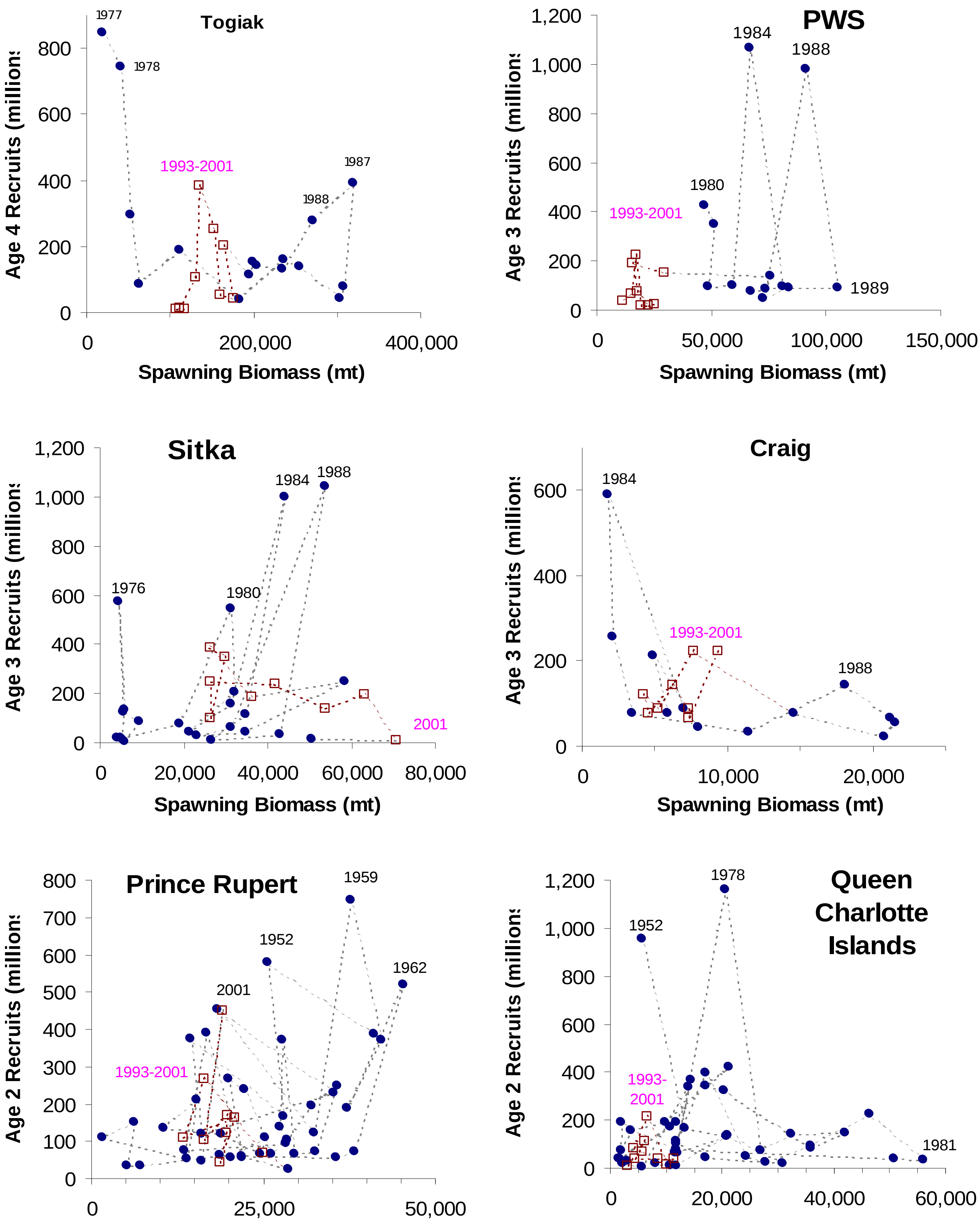

Figure 4. Herring spawner-recruit information for central British Columbia to northern Puget Sound (Cherry Point). Red open squares and pink shaded area indicate the 1993-2001 year classes.