Appendix A

Change-in-Ratio (CIR) Estimate

Change-in-Ratio (CIR) Estimate

The successful operation of the Muck Creek weir in 1978-79 gave us the opportunity to develop a run size estimate which is essentially independent of the marking and recapture process. The development of an independent estimate was particularly important because it provided the opportunity to evaluate the accuracy of our population estimates. Typically, mark-recapture studies are subject to problems which are very difficult to evaluate, especially the possibility of a delayed mortality of tagged fish. A second potential problem is straying of tagged fish from the target watershed. Although we estimated strays to other areas, the accuracy of the straying estimates may not be high. Either a delayed mortality or a straying problem will result in an overestimate of run size. An estimate which is independent of these potential problems and which agrees with the tagging estimates would increase our confidence in the validity of the population estimates.

Fortunately, the 1978-79 data were suitable for development of an independent estimate. The technique utilized is referred to as a "Change-in-Ratio" or "Dichotomy" method. Chapman (1955) gives a thorough description of the model. This technique can be used when the population is classifiable in two ways and harvesting from the population is selective with respect to one of these classifications. Then, with a knowledge of the initial composition, final composition and composition of the harvest, it is possible to develop a population estimate. In the Nisqually situation, the sex of the chum stock is the variable most amenable to this model. The purse seine catches should be random with respect to sex, the gillnet fishery is selective for males, and the Muck Creek weir should provide a random sample of the sex ratio after the occurrence of the fishery.

Following Ricker's (1975) notation, the required information is:

u_1, u_2 - size of samples taken in the purse seine tagging and at the Muck Creek weir.

x_1, x_2 - number of males in u_1, u_2.

y_1, y_2 - number of females in u_1, u_2.

$p_1 = x_1/u_1$; $p = x_2/u_2$.

x = number of males caught in the harvest

y = number of females caught.

The values for the 1978-79 Nisqually data are:

u_1 = 4907 (includes fish released untagged)

u_2 = 7218

x_1 = 2414

x_2 = 3201

p_1 = 2414/4907 = .49195

p_2 = 3201/7218 = .44347

C_x = 13,455

C_y = 11,175

C = 24,630

$$N = \frac{C_x - p_2 C}{p_1 - p_2} = 52{,}234$$

The close agreement between this estimate and the tagging estimate (50,280) gives us a great deal of confidence in the tagging estimates. Although the tests of recovery rate by condition at release indicated that it was unlikely that a delayed mortality was occurring, the change-in-ratio estimate is a much more direct approach and also indicates that straying was not a serious problem.

Chapman (1955) lists a variance estimate for the situation where the C_x and C_y must be estimated from a sample of size m.

For the 1978-79 chum data (with m = 8947):

Var (n) = 244,134

S.D. (n) = 494

Appendix B

Stratification Tests and Variance Subsamples

Table B1. 1974-75 Recovery Rate by Time of Tagging

Tagging Day	Number Tagged	Number Recovered
12/17/74	751	260
12/18/74	604	172
12/23/74	768	210
12/30/74	1,007	305
1/6/75	978	278
1/15/75	294	62
1/21/75	94	8

Chi-Square = 44.3 P(Chi-Square > 44.3) ≈ 0.0

Table B2. 1974-75 Tag Ratio by Time of Recovery (Commercial Fishery)

Recovery Period	Number Recovered	Number Tags
12/17-23/74	1,178	44
12/24-30/74	2,501	146
12/31/74-1/6/75	3,893	294
1/7-13/75	3,929	359
1/14-20/75	4,151	363
1/21-27/75	1,278	107
1/28-2/3/75	412	19
2/4-10/75	588	13
2/11-3/12/75	399	4

Chi-Square = 114 P(Chi-Square > 114) ≈ 0.0

Table B3. Subsamples Used in Estimating 1974-75 Variance Based on Method of Interpenetrating Subsamples

Sample	Number Tagged	Number Recovered	N
1	564	179.7	74,106
2	576	176.0	53,762
3	612	193.0	60,151
4	606	203.0	60,408
5	549	170.0	55,027
6	560	196.0	74,169
7	544	150.0	63,472
8	603	175.2	61,334
		N =	62,804

Standard Deviation = 7,695

Table B4. 1975-76 Recovery Rate by Time of Tagging

Tagging Period	Number Tagged	Tags Recovered
12/4	147	37
12/9,12	201	59
12/15,18	321	90
12/23	299	62
12/30	123	13
1/6-21	119	7

Chi-Square = 41.4 P(Chi-Square > 41.4) ≈ 0.0

Table B5. 1975-76 Tag Ratio by Recovery Location

Recovery Location	Number Sampled	Tags Recovered
Commercial Fishery	2,462	262
Yelm Creek	8	0
Muck Creek	236	22
Clear-Hill Creek	42	10
Mainstem Nisqually	85	5
Fish House Slough	172	12
Kalama Creek	36	2

Chi-Square = 14.58 P(Chi-Square > 14.6) ≈ .02

Table B6. 1975-76 Tag Ratio by Time of Recovery (Commercial Fishery)

Recovery Period	Number Sampled	Tagged Recoveries
Dec 7-20	387	44
Dec 21-27	846	89
Dec 28 - Jan 3	646	87
Jan 4-10	315	30
Jan 11-24	157	10
Jan 25 - Feb 7	111	2

Chi-Square = 18.2 P(Chi-Square > 18.2) ≈ 0.0

Table B7. 1975-76 Tag Ratio by Time of Recovery (Spawning Grounds)

Recovery Period	Number Sampled	Tagged Recoveries
Jan 4-24	73	9
Jan 25-31	153	16
Feb 1-7	70	9
Feb 8-21	274	17

Chi-Square = 5.28 P(Chi-Square > 5.28) ≈ .15

Table B8. 1975-76 Recovery Location by Time at Tagging

Tagging Period	Commercial Fishery	Muck Cr., Exeter Sp.	Fish House Sl.	Clear Cr., Mainstem, and Kalama Creek
Dec 1-20	176	5	3	3
Dec 21-27	53	4	2	4
Jan 6-20	10	4	4	3

Chi-Square = 42.61 P(Chi-Square > 42.61) ≈ 0.0

Table B9. 1976-77 Recovery Rate by Time of Tagging

Tagging Period	Number Tagged	Tags Recovered
12/5-11	480	209
12/12-18	494	197
12/19-25	1,035	386
12/26-1/1	468	142
1/2-8	505	148
1/9-15	513	129
1/16-22	42	13
1/23-29	22	4

Chi-Square = 59.6 P(Chi-Square > 59.6) ≈ 0.0

Table B10. 1976-77 Tag Ratio by Recovery Location

Recovery Location	Number Sampled	Tags Recovered
Yelm Creek	484	60
Muck Creek	591	33
Mainstem Nisqually	1,464	92
Clear Creek	471	38
Kalama Creek	34	7
Horn Creek	49	8
Fish House Slough	116	10

Chi-Square = 36.0 P(Chi-Square > 36.0) ≈ 0.0

Table B11. 1976-77 Tag Ratio by Time of Recovery (Spawning Grounds)

Recovery Period	Number Sampled	Tags Recovered
1/2-15	73	7
1/16-22	227	31
1/23-29	373	50
1/30-2/4	982	74
2/5-2/10	618	52
2/11-16	543	24
2/17-22	135	9
2/23-3/15	295	8

Chi-Square = 47.2 P(Chi-Square > 47.2) ≈ 0.0

Table B12. 1976-77 Time of Tagging by Recovery Location (Spawning Grounds)

	Recovery Location					
Tagging Period	Mainstem	Clear Creek	Fish House	Muck Creek	Yelm Creek	Kalama & Horn Creek
12/5-11	4	0	0	4	11	1
12/12-18	13	2	2	6	9	3
12/19-25	19	3	2	12	13	5
12/26-1/1	15	4	1	1	7	1
1/2-8	19	4	2	5	8	3
1/9-29	13	18	3	6	11	0

Chi-Square = 50.9 P(Chi-Square > 50.9) ≈ 0.0

Table B13. 1976-77 Time of Tagging by Time of Recovery (Spawning Grounds)

	Recovery Time					
Tagging Period	Jan 2-22	Jan 23-29	Jan 30 - Feb 4	Feb 5-10	Feb 11-16	Feb 17-28
12/5-11	6	4	2	2	1	1
12/12-18	7	9	11	5	1	0
12/19-25	4	11	21	7	2	3
12/26-1/1	1	9	4	5	6	1
1/2-8	2	8	18	6	3	1
1/9-29	0	4	11	10	10	9

Chi-Square = 67.5 P(Chi-Square > 67.5) ≈ 0.0

Table B14. Subsample Values Used in Estimating the Variance of the 1976-77 Estimate Based on Method of Interpenetrating Subsamples

Sample	Number Tagged	Number Recovered	N
1	414.3	70	46,782
2	448.7	61	44,778
3	496.4	75	54,242
4	420.8	71	42,856
		N =	47,165

Standard Deviation = 4,983

Table B15. 1977-78 Recovery Rate by Time of Tagging

Tagging Period	Number Tagged	Tags Recovered
12/5-6	704	60
12/12-13	1,051	100
12/19-20	1,170	115
12/27-28	1,126	117
1/3-4	792	105
1/9-10	1,044	186
1/16-17	240	50
1/24-25	138	27
1/31-2/2	28	3

Chi-Square = 81.7 P(Chi-Square > 81.7) ≈ 0.0

Table B16. 1977-78 Tag Ratio by Recovery Location (Spawning Grounds)

Recovery Location	Number Sampled	Tags Recovered
Yelm Creek	315	41
Muck Creek	4,552	557
Exeter Springs	1,430	159
Upper Res. Slough	62	10
Fish House Slough	161	13
Clear Creek	133	14
Lower Res. Slough	121	16
Mainstem Nisqually	353	40

Chi-Square = 5.5 P(Chi-Square > 5.5) ≈ .59

Table B17. 1977-78 Tag Ratio by Time of Recovery (Spawning Grounds)

Recovery Period	Number Sampled	Tags Recovered
1/4-14	363	39
1/15-21	1,314	159
1/22-28	1,344	157
1/29-2/4	779	106
2/5-11	1,652	203
2/12-18	856	101
2/19-25	432	43
2/26-3/22	387	42

Chi-Square = 4.9 P(Chi-Square > 4.9) ≈ .67

Table B18. Subsample Values Used in Estimating the Variance of the 1977-78 Population Estimate Based on Method of Interpenetrating Subsamples

Sample	Number Tagged	Number Recovered	N
1	560	171	45,760
2	582	146	50,830
3	572	152	49,240
4	583	140	52,074
5	599	143	52,274
6	556	138	51,135

N = 50,219

Standard Deviation = 2,226

Table B19. 1978-79 Recovery Rate by Time of Tagging

Tagging Period	Number Tagged	Tags Recovered
12/4-5	340	11
12/11-12	950	31
12/18-19	533	14
12/27-28	964	56
1/3-4	914	38
1/9-10	249	6
1/15-16	400	8
1/22-23	84	2

Chi-Square = 19.6 P(Chi-Square > 19.6) ≈ .01

Table B20. 1978-79 Tag Ratio by Recovery Location

Recovery Location	Number Sampled	Tags Recovered
Clear Creek	287	40
Yelm Creek	545	66
Mainstem, Tanwax, Lower Res. Slough	531	52
Fish House Slough	151	10
Muck Creek	246	29
Upper Res. Slough	14	4

Chi-Square = 11.2 P(Chi-Square > 11.2) ≈ .05

Table B21. 1978-79 Tag Ratio by Time of Recovery (Spawning Grounds)

Recovery Period	Number Sampled	Tags Recovered
12/30/78-1/13-79	38	5
1/14-20	280	38
1/21-27	510	55
1/28-2/3	468	55
2/4-10	162	18
2/11-17	229	20
2/18-24	101	9
2/25-3/7	40	2

Chi-Square = 5.5 P(Chi-Square > 5.5) ≈ .6

Table B22. 1978-79 Time of Tagging by Recovery Location (Spawning Grounds)

	Recovery Location		
Tagging Period	All Other	Clear Creek	Yelm Creek
12/4-12	35.90	6.49	5.89
12/18-1/4	52.69	25.95	55.39
1/9-23	6.47	7.56	4.71

Chi-Square = 24.3 P(Chi-Square > 24.3) ≈ 0.0

Table B23. Subsample Values Used in Estimating the Variance of the 1978-79 Population Estimate Based on the Method of Interpenetrating Subsamples

Sample	Number Tagged	Number Recovered	N
1	489	47	52,866
2	491	47	51,502
3	522	59	48,355
4	445	46	46,089
		N =	49,703

Standard Deviation = 3,061.5

Appendix C

Muck Creek Weir Counts

Table C1. Muck Creek Weir Counts

	1978-79		1979-80		1980-81	
	Cumulative Chum	Cumulative Steelhead	Cumulative Chum	Cumulative Steelhead	Cumulative Chum	Cumulative Steelhead
12/10	2	2	-	-	-	-
12/11	6	4	-	-	-	-
12/12	7	4	-	-	-	-
12/13	9	4	-	-	-	-
12/14	13	4	-	-	-	-
12/15	19	4	-	-	-	-
12/16	37	4	-	-	-	-
12/17	53	4	0	1	7	0
12/18	66	5	0	8	33	0
12/19	74	5	8	8	88	0
12/20	104	5	13	11	143	2
12/21	143	6	18	12	234	3
12/22	211	6	26	14	578	12
12/23	306	8	43	14	775	22
12/24	467	10	60	14	1,036	25
12/25	616	10	84	14	1,388	31
12/26	658	11	100	14	1,506	37
12/27	702	11	127	14	1,746	40
12/28	744	11	152	15	2,005	42
12/29	764	11	172	16	2,445	42
12/30	797	11	216	16	2,784	45
12/31	823	11	264	19	3,093	47
1/1	875	12	331	20	3,288	51
1/2	970	13	392	21	3,531	54
1/3	1,087	15	437	22	3,814	67
1/4	1,258	15	512	25	4,009	71
1/5	1,353	15	579	29	4,189	72
1/6	1,467	15	626	29	4,347	73
1/7	1,600	15	677	31	4,491	75
1/8	1,892	15	732	31	4,654	77
1/9	2,138	15	801	31	4,869	81
1/10	2,608	15	889	32	5,012	83
1/11	3,105	20	979	33	5,129	86
1/12	3,306	20	1,305	53	5,211	87
1/13	3,509	21	1,408	59	5,288	87
1/14	3,740	24	1,726	66	5,309	87
1/15	3,959	24	1,882	69	5,338	87
1/16	4,261	27	2,039	77	5,392	87
1/17	4,469	31	2,187	84	5,471	87
1/18	4,566	32	2,302	85	5,571	88
1/19	4,709	32	2,390	85	5,666	91
1/20	4,940	38	2,490	86	5,758	92
1/21	5,232	50	2,629	93	5,834	94
1/22	5,567	49	2,771	102	5,930	96
1/23	5,766	67	2,872	102	6,072	97
1/24	5,936	73	2,999	106	6,188	101
1/25	6,020	77	3,119	110	6,198	101

Table C1. (Continued)

	1978-79		1979-80		1980-81	
	Cumulative Chum	Cumulative Steelhead	Cumulative Chum	Cumulative Steelhead	Cumulative Chum	Cumulative Steelhead
1/26	6,062	77	3,227	116	6,265	102
1/27	6,126	77	3,271	116	6,364	102
1/28	6,215	77	3,309	118	6,402	102
1/29	6,263	79	3,347	118	6,488	109
1/30	6,296	79	3,392	118	6,555	114
1/31	6,335	79	3,490	119	6,586	121
2/1	6,372	80	3,705	119	6,604	124
2/2	6,407	80	3,939	130	6,645	125
2/3	6,500	80	4,045	131	6,686	131
2/4	6,609	87	4,152	135	6,693	131
2/5	6,677	91	4,236	140	6,707	132
2/6	6,809	159	4,302	141	6,744	132
2/7	6,894	218	4,370	147	6,762	132
2/8	6,977	291	4,452	149	6,763	133
2/9	7,016	305	4,492	155	6,788	134
2/10	7,041	323	4,534	156	6,830	134
2/11	7,069	335	4,580	161	6,860	135
2/12	7,078	363	4,619	161	6,906	157
2/13	7,091	389	4,654	161	6,920	175
2/14	7,114	386	4,691	161	6,928	190
2/15	7,123	389	4,732	163	6,943	195
2/16	7,128	391	4,749	163	6,962	208
2/17	7,136	391	4,813	165	6,974	227
2/18	7,151	396	4,846	169	6,985	237
2/19	7,158	401	4,891	172	6,989	248
2/20	7,163	403	4,913	175	6,990	253
2/21	7,175	404	4,931	176	6,998	264
2/22	7,176	404	4,948	176	6,998	274
2/23	7,181	405	4,958	177	6,999	278
2/24	7,186	405	4,961	177		281
2/25	7,192	407	4,970	179		283
2/26	7,199	407	4,985	180		285
2/27	7,205	413	4,993	188		
2/28	7,209	415	4,994	191		
March Total	(9)	(5)	(22)	(12)		
Total for Season	7,218	420	5,016	203	6,999	285

Appendix D

Tagging and Recovery Data Used for In-Season Projections

Table D1. Nisqually Tagging Data Used for In-Season Projections

	1974	1975	1976	1977	1978
12/4		147			72
				366	268
12/6			240	338	
12/7			240		
12/9		26			
12/11					701
12/12		173		579	
				472	
12/15		99	291		
12/16			203		
12/17	751				
12/18	604	222			299
				559	234
12/20			550	611	
12/21			485		
12/23	768	299			
12/27				633	458
12/28			318	493	506
12/29			150		
12/30	1,007	123			
1/3			377	652	710
1/4			128	140	204
1/6	979	105			
1/9				596	173
1/10				448	76
1/12		8	210		
1/13		5	303		
1/15	294				331
1/16				140	69
1/17				100	
1/18			17		
1/19			25		
1/20		3			
1/21	94				
1/22					21
1/23					63
1/24				89	
1/25			2	49	
1/26			20		
1/31			23		
2/2			5		

Table D2. Nisqually Recovery Data Used for In-Season Projections
(Cumulative thru 1/31)

	1974		1975		1976		1977		1978	
	Cum. Smpl.	Cum. Tagd.	Cum. Smpl.	Cum. Tagd.	Cum. Smpl.	Cum. Tagd.	Cum. Smpl.	Cum. Tagd.	Cum. Smpl.	Cum. Tagd.
12/6					2	0			1	0
12/7					22	1	89	0	11	1
12/8			3	0	49	2	181	2	15	1
12/9			11	0	113	6	231	4		
12/10			17	0	139	7				
12/11			37	1						
12/12			59	4						
12/13									40	2
12/14			117	8	333	13	292	8	82	5
12/15			156	14	441	16	383	11	248	11
12/16			230	23	679	22	499	21	412	19
12/17	99	0	314	34	814	34	716	30		
12/18	297	3	348	38					430	20
12/19	497	8	367	39					554	27
12/20	673	17	387	44	965	41	732	31	713	38
12/21					1,259	54	1,027	61	860	53
12/22	685	19	532	63	1,414	62	1,202	82	1,126	80
12/23	1,178	44	666	74	1,831	88	1,465	118		
12/24	1,470	65	855	90	2,566	143				
12/25	1,698	84	111	120						
12/26	2,362	125	1,233	133			2,106	181	1,259	92
12/27	2,681	142			3,397	189	2,531	219	1,550	110
12/28					2,718	210	2,988	264	1,733	119
12/29	2,972	146	1,489	179	4,622	284	3,597	331	1,916	138
12/30	3,679	190	1,752	207	4,766	295	4,253	413		
12/31	4,066	217	1,879	220	4,824	298				
1/1	4,824	263								
1/2	5,435	317					4,480	446	2,228	156
1/3	6,266	405			5,485	340	5,007	504	2,606	173
1/4					5,750	368	5,815	586	3,314	218
1/5	6,434	415			5,999	393	6,545	673	3,728	245
1/6	7,572	484			6,454	418	7,203	755		
1/7	8,206	545			7,492	499				
1/8	9,111	631	2,194	250						
1/9	9,980	707					7,458	788	4,043	266
1/10	10,508	753			7,906	544	7,747	823	4,861	333
1/11	10,636	768			8,638	607	8,270	895	5,511	388
1/12	10,846	786			9,413	665	9,010	984	6,230	499
1/13	11,501	843			10,004	707	9,335	1,025		
1/14	12,021	892			10,628	753				
1/15	12,932	960	2,284	255					6,506	474
1/16	13,691	1,024							6,745	491
1/17	14,268	1,082					9,705	1,070	7,071	513

Table D2. (Continued)

	1974		1975		1976		1977		1978	
	Cum. Smpl.	Cum. Tagd.	Cum. Smpl.	Cum. Tagd.	Cum. Smpl.	Cum. Tagd.	Cum. Smpl.	Cum. Tagd.	Cum. Smpl.	Cum. Tagd.
1/18	14,692	1,131					10,262	1,146	7,753	565
1/19					11,049	781	10,601	1,182	8,201	592
1/20	15,652	1,206			11,914	853	11,003	1,239		
1/21	16,050	1,239			12,241	879				
1/22	16,301	1,258	2,351	260			11,115	1,248	8,532	613
1/23	16,636	1,294							9,060	659
1/24	16,930	1,313					11,406	1,280	9,236	676
1/25							11,628	1,301	9,391	688
1/26					12,649	913	11,775	1,317	9,696	707
1/27			2,388	261					9,761	714
1/29			3,288	261	12,930	938				
1/30	16,972		1,316						9,961	730
1/31									10,011	737

Appendix E

Entry Timing Figures

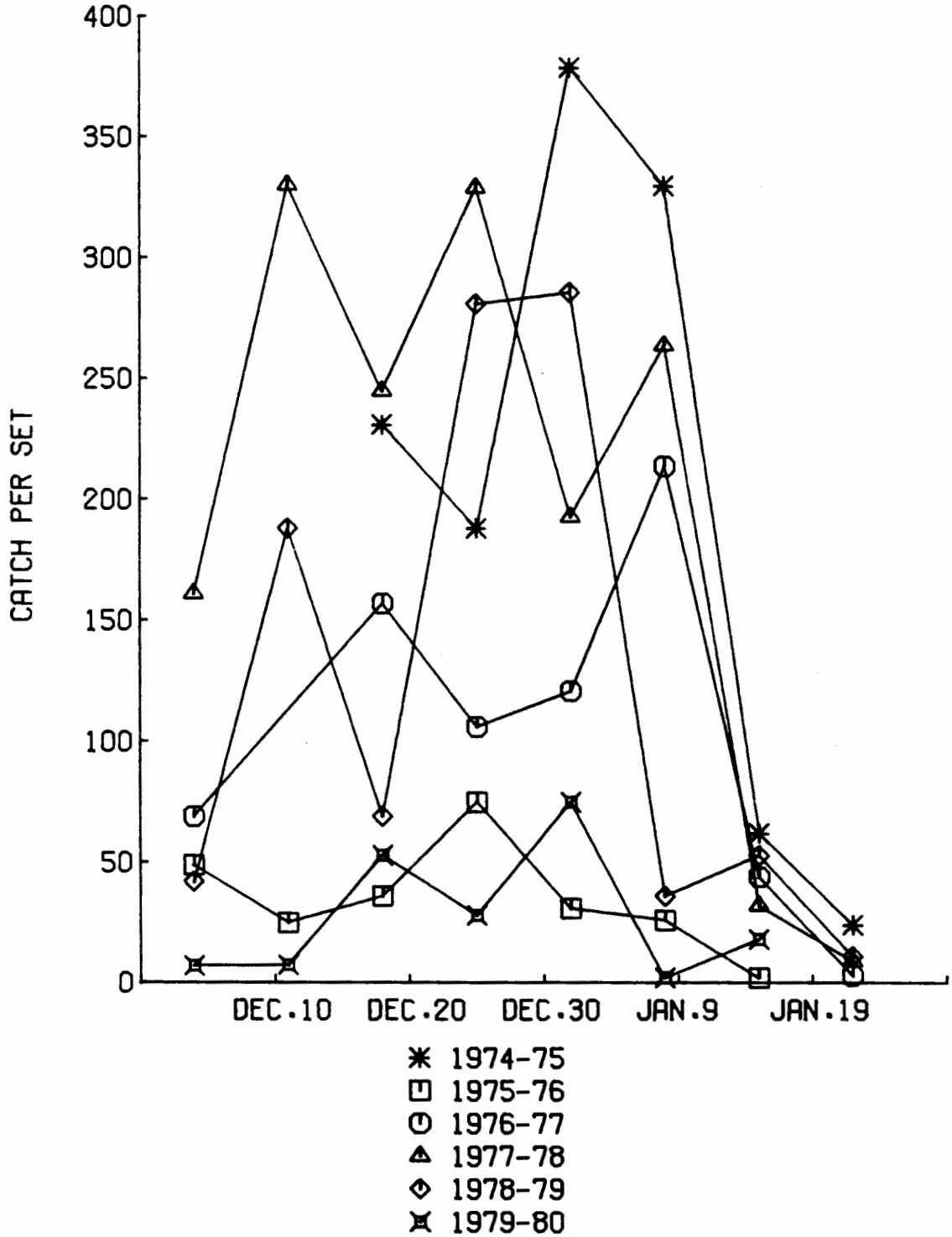

Figure 2. Timing of Purse Seine Catches of Nisqually Chum in the Estuary

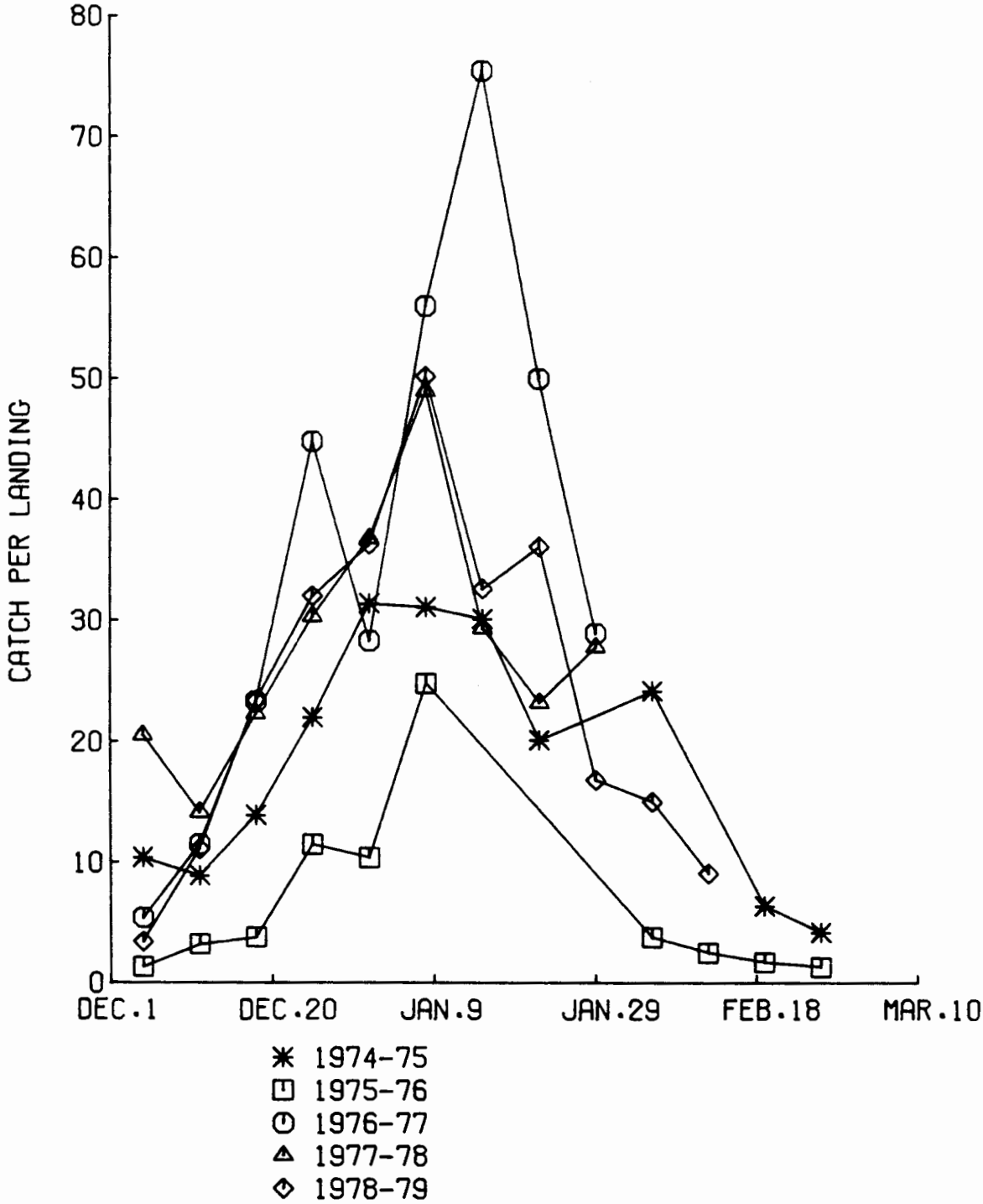

Figure 3. Timing of Nisqually Chum Catches in the River Fishery

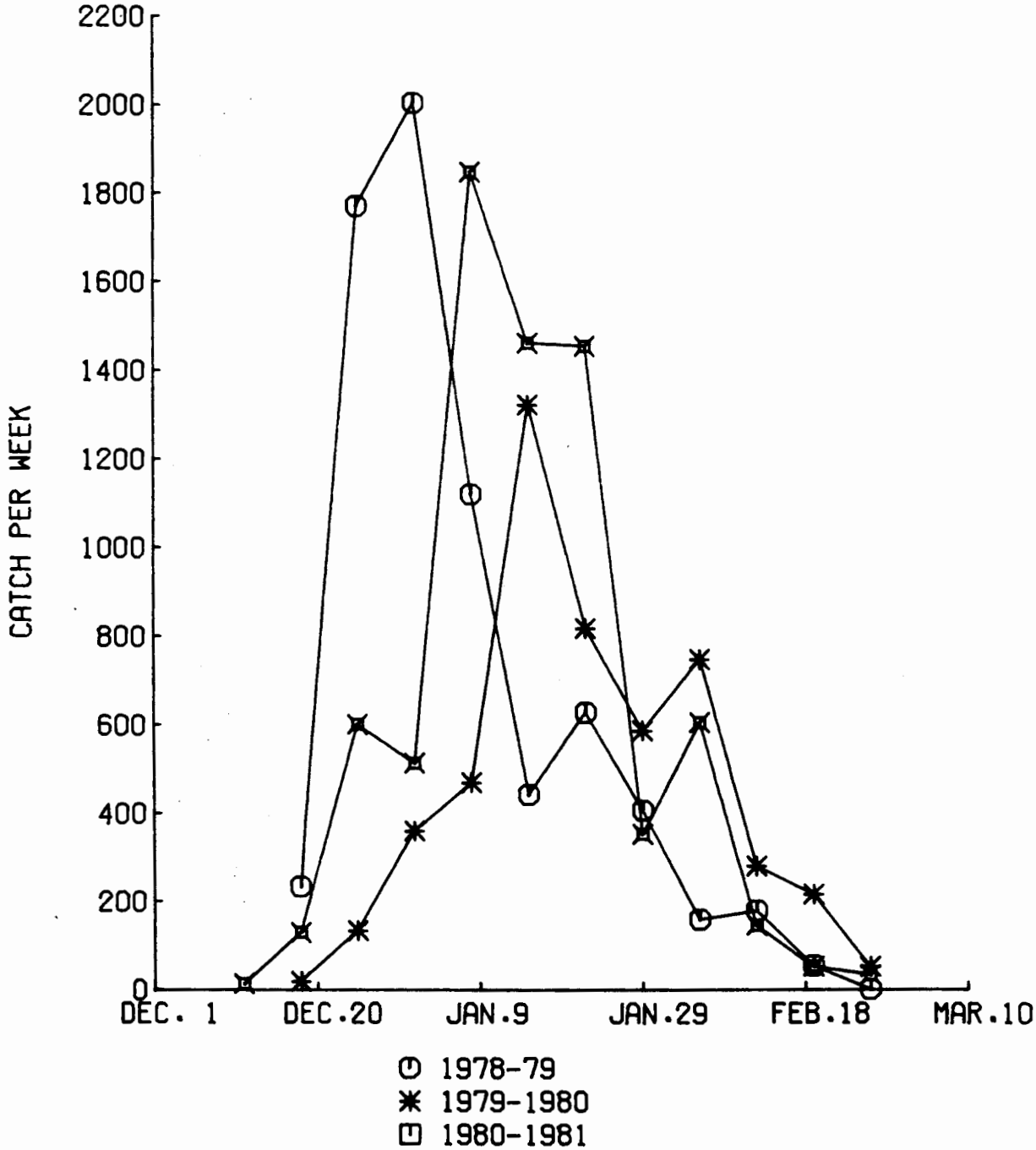

Figure 4. Timing of Nisqually Chum Entry into the Muck Creek Weir

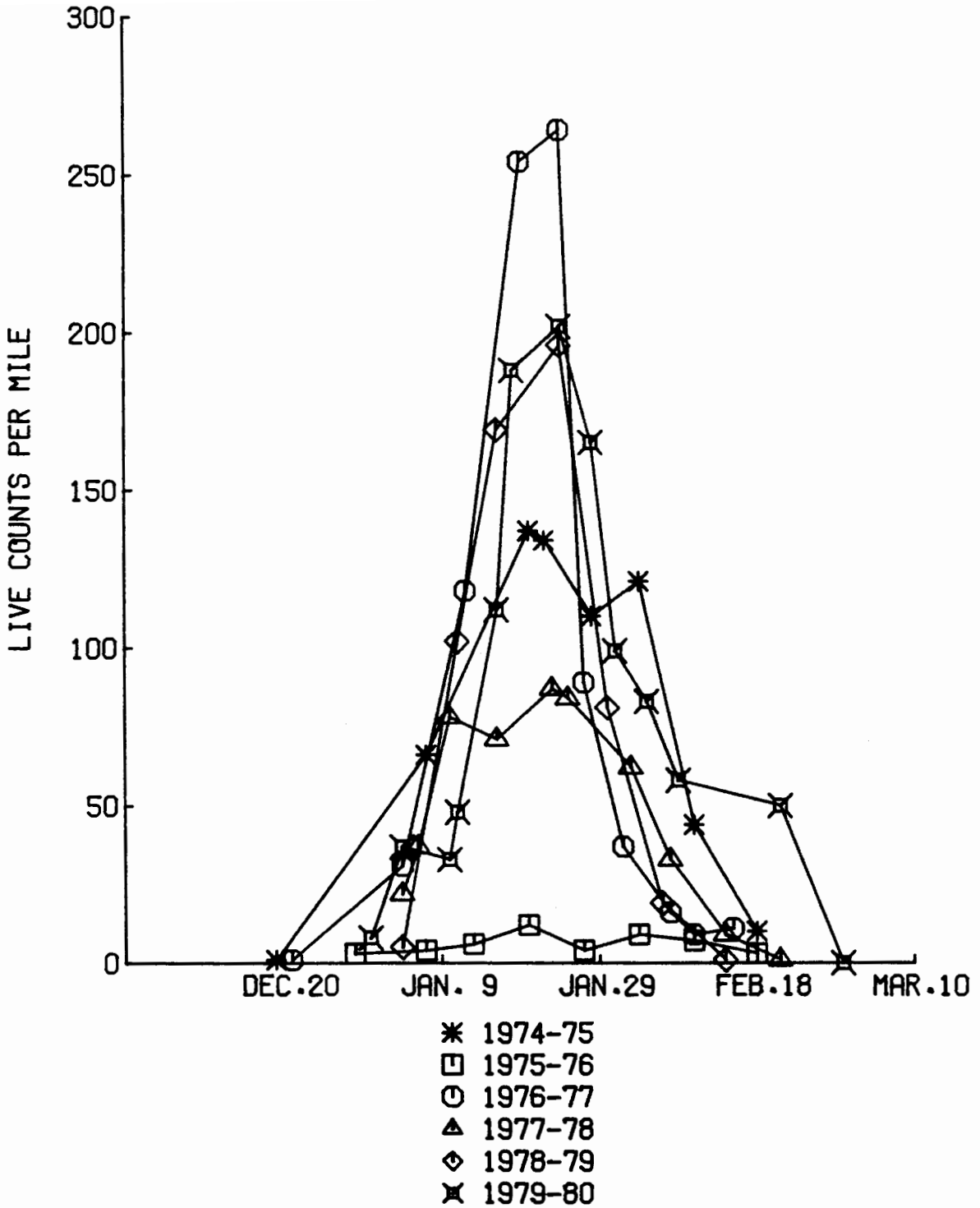

Figure 5. Timing of Live Counts of Nisqually Chum in Yelm Creek

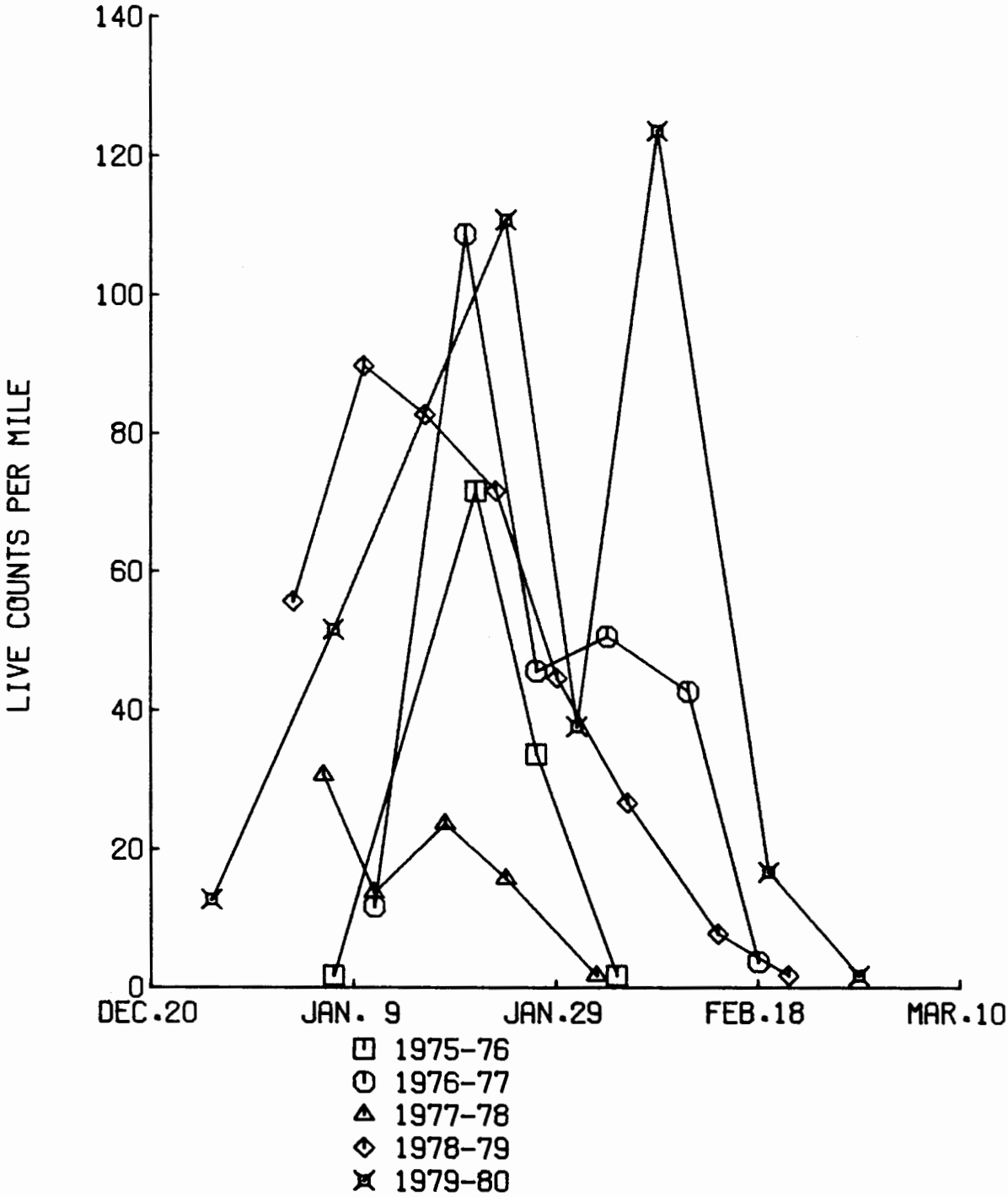

Figure 6. Timing of Live Counts of Nisqually Chum in Clear Creek

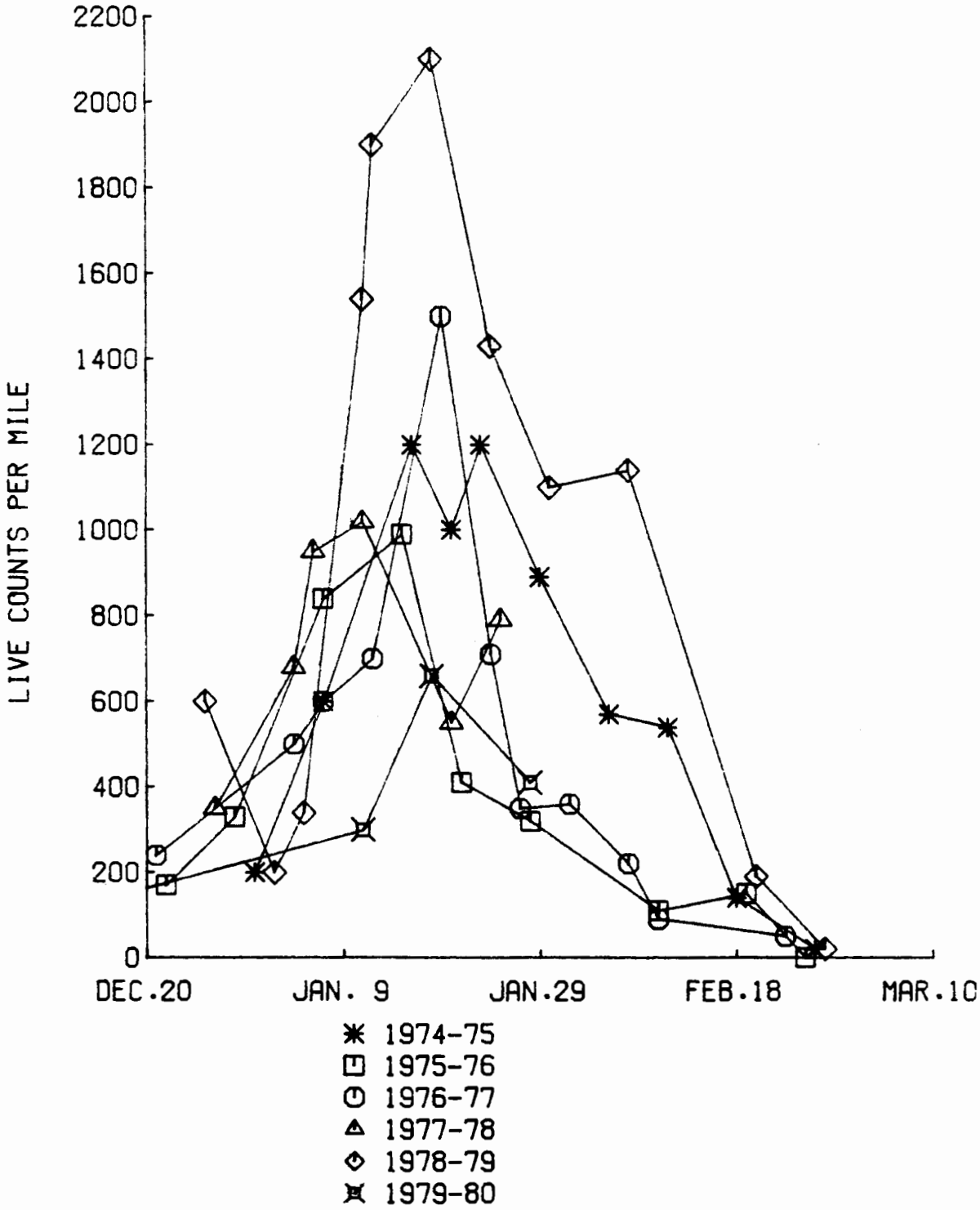

Figure 7. Timing of Live Counts of Nisqually Chum in McAllister Creek

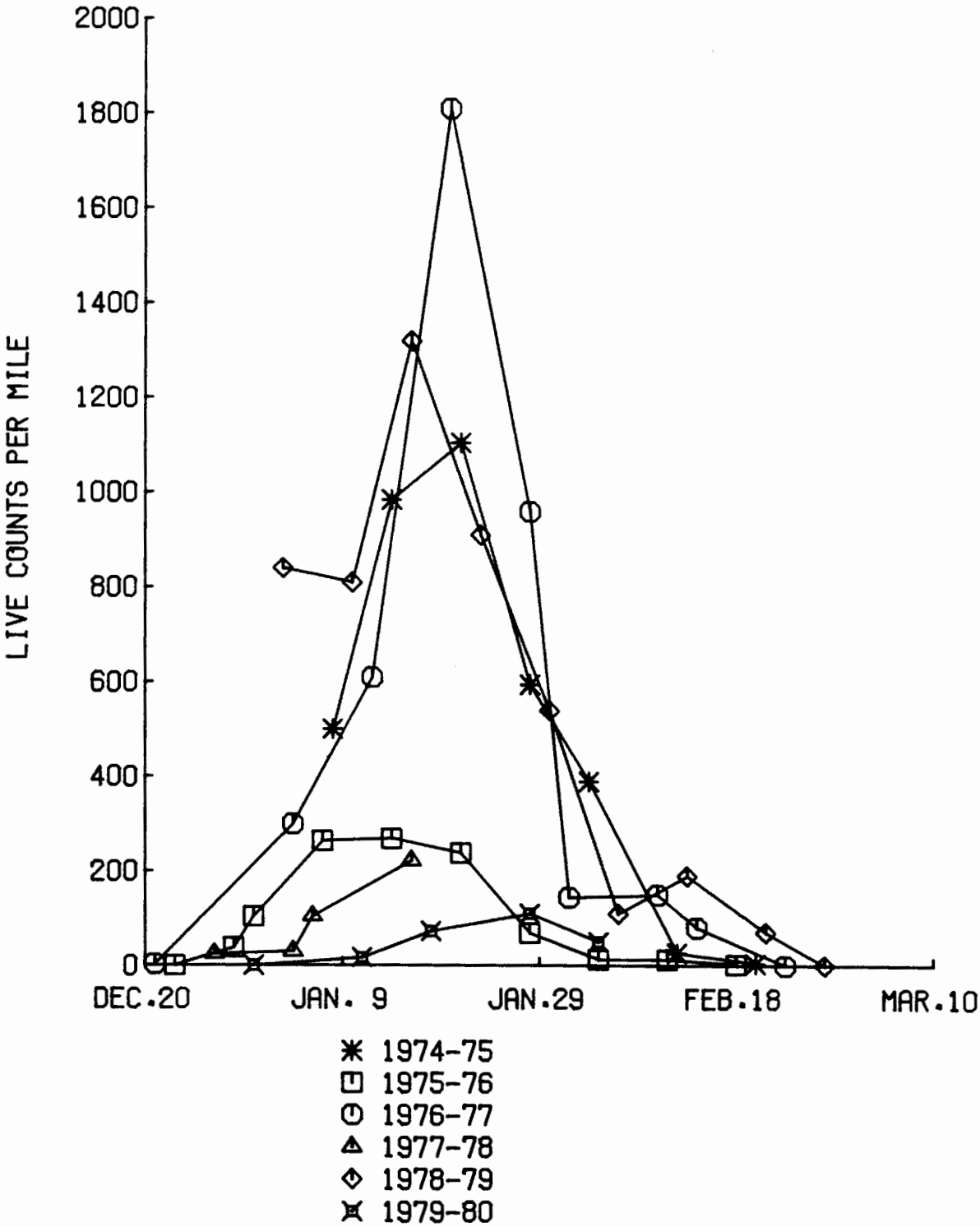

Figure 8. Timing of Live Counts of Nisqually Chum in Red Salmon Creek

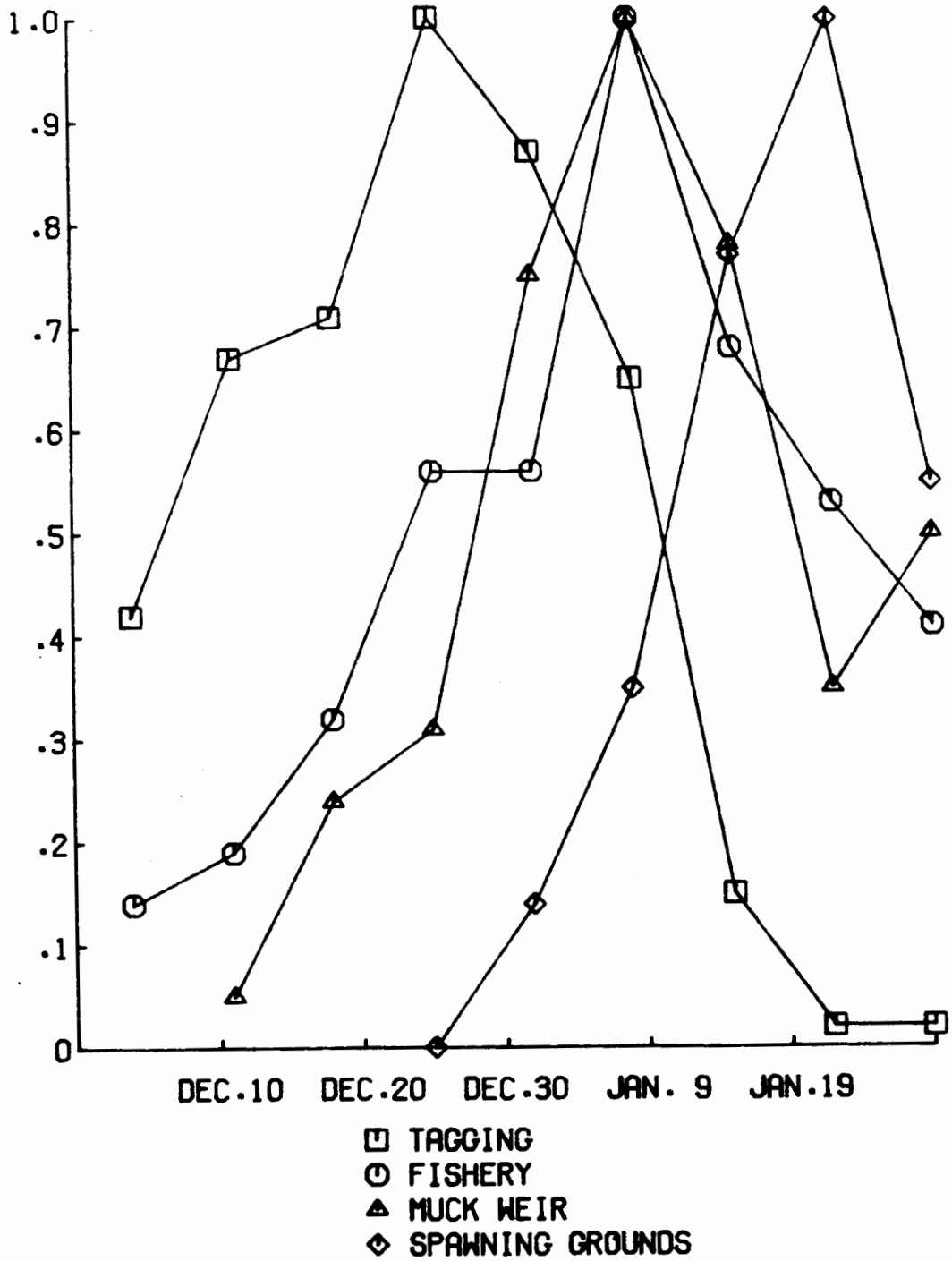

Figure 9. Comparison of Nisqually Chum Run Timing at Tagging in the Estuary, Capture in the Fishery, Recovery at the Muck Creek Weir and Observation on Spawning Ground Surveys