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Undetected Marks in Hatchery Escapement Sampling of Salmon 1988, 1989, 1990 and 1992

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UNDETECTED MARKS IN HATCHERY
ESCAPEMENT SAMPLING OF SALMON,
1988, 1989, 1990 and 1992

by

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CONTENTS

	Page
List of Figures	iv
List of Tables	iv
List of Appendices	v
Abstract	vi
Résumé	vi
Introduction	1
Sampling Methods	3
Data Analysis	7
Results	8
Adipose Mark Detection	8
Seasonal Variation in Mark Detection Efficiency	8
Adipose Mark Detection in Adults versus Jacks	12
Removal of Heads from Unmarked Fish	12
Detection of Fin-Clips in Chum Salmon	12
Correct Fin-Clip Interpretation in Chum Salmon	12
Detection of Regenerated Fin-Clips	17
Discussion	17
Seasonal Variation in Mark Detection Efficiency	21
Adipose Mark Detection in Adults versus Jacks	21
Removal of Heads from Unmarked Fish	21
Detection of Fin-Clips in Chum Salmon	22
Inaccurate Escapement Counts	22
Detection of Regenerated Fin-Clips	23
Effect of Hatchery Mark Sampling Techniques on Mark Detection Rates	24
Underestimation of Hatchery Errors	24
Recommendations for Improving Mark Detection Rates at Facilities	26
Summary	28
Acknowledgements	29
References	29
Appendices	31

LIST OF FIGURES

Figure	Page
1. Location of facilities surveyed during the mark resampling program in 1988, 1989, 1990 and 1992	2
2. Mark sampling strategy used by the hatchery and MRP crews to detect adipose marks in 1988, 1989, 1990 and 1992	4
3. Mark sampling strategy used by the hatchery and MRP crews to detect multiple clips in chum salmon in 1989, 1990 and 1992	5
4. Relationship between the total fish sampled, the overall Ad-marks recovered and the undetected Ad-marks in a given sample, 1988 and 1989 data ..	11

LIST OF TABLES

Table	Page
1. Pieces sampled, overall total Ad-marks and undetected Ad-mark component, and percent undetected Ad-marks for each facility and species resampled by MRP crew in 1988, 1989, 1990 and 1992	9
2. Heads removed in error from unmarked fish, 1988, 1989, 1990 and 1992	13
3. Comparison of fin-clip detection in chum salmon by hatchery and MRP crews, 1989	14
4. Comparison of fin-clip detection in chum salmon by hatchery and MRP crews, 1990	15
5. Number and percent of chum fin-clips correctly interpreted by hatchery crews, 1990	16
6. Incidence of regenerated fins in each of detected, undetected and total mark components; and percent detection for complete, regenerated and total fin-clips, 1988, 1989, 1990 and 1992	18
7. Summary of salmon sampled for undetected adipose fin-clips at eight Washington State hatcheries in 1982	20
8. Between-year comparison of mean undetected Ad-mark rates and of mark sampling techniques for each facility surveyed in 1988 - 1992	25

LIST OF APPENDICES

Appendix	Page
1. Mark sampling program, 1988, 1989, 1990 and 1992	31
2. Details on mark sampling and data analysis for 1988, 1989, 1990 and 1992	33
3. Mark sampling techniques at facilities surveyed for undetected marks, 1988, 1989, 1990 and 1992	35
4. Adipose-mark detection data for complete and regenerated Ad-clips in coho and chum salmon resampled by MRP crew, 1988	38
5. Adipose-mark detection data for chinook salmon resampled by DFO biologists, 1988	39
6. Adipose-mark detection data for chinook, coho and chum salmon resampled by MRP crew, 1989	40
7. Adipose-mark detection data for chinook, coho and chum salmon resampled by MRP crew, 1990 and 1992	41
8. Seasonal variation in Ad-mark detection efficiency at selected facilities, 1988 and 1990	42
9. Incidence of regenerated fins among the detected and undetected multiple clips in chum salmon resampled by MRP crew, 1989	44
10. Incidence of regenerated fins in each of the detected and undetected multiple clips resampled by MRP crew, 1990	45
11. Degree of ventral fin-clip regeneration in chum salmon from Chehalis and Chilliwack facilities, MRP data, 1990	46
12. Hypothetical examples showing the impact of undetected escapement marks on the estimates of survival rate, exploitation rate and production for hatchery-produced fish	47
13. Recounts of coho salmon by hatchery crew during sampling for marks at Quinsam facility, 1989	48
14. Chi-square analysis testing for differences in Ad-mark detection performance between the control year and the subsequent years	49
15. Methods for reducing the number of undetected marks, Chehalis Hatchery, 1989 ..	50

ABSTRACT

Cross, C.L., K.H. Wilson and A.Y. Fedorenko. 1994. Undetected marks in hatchery escapement sampling of salmon, 1988, 1989, 1990 and 1992. Can. Tech. Rep. Fish. Aquat. Sci. 1965: 50 p.

A mark resampling program was conducted between 1988 and 1992 at selected facilities in British Columbia to assess the problem of undetected marks and mark misinterpretation in returning salmon. Such undetected marks lead to underestimation of survival rate and production, and overestimation of exploitation rate of hatchery fish.

The present study showed that the mean annual undetected mark rate for adipose clips may exceed 10% at some facilities and may show considerable seasonal variation. Other identified problems included undetected and misinterpreted multiple fin-clips, undetected regenerated fin-clips, and heads removed in error from unmarked fish. Mark detection at most of the surveyed facilities improved significantly after 1988. This was attributed largely to the incorporation of a formal second examination of all fish.

RÉSUMÉ

Cross, C.L., K.H. Wilson and A.Y. Fedorenko. 1994. Undetected marks in hatchery escapement sampling of salmon, 1988, 1989, 1990 and 1992. Can. Tech. Rep. Fish. Aquat. Sci. 1965: 50 p.

Nous avons mené de 1988 à 1992 à certaines installations de la Colombie-Britannique un programme visant à évaluer le problème des marques non détectées ou mal interprétées faites sur les saumons de remonte. Les marques non détectées entraînent une sous-estimation du taux de survie et de la production et une sur-estimation du taux d'exploitation des poissons s'écloserie.

La présente étude a montré que le taux annuel moyen de non-détection des marques consistant en une coupe de la nageoire adipeuse peut excéder 10% à certaines installations et peut varier considérablement selon les saisons. Au nombre des autres problèmes repérés, on compte la non-détection ou la mauvaise interprétation des coupes de plus d'une nageoire, la non-détection des coupes par suite de la régénération des nageoires et le prélèvement erroné des têtes de poissons ne portant pas les marques indiquant la présence d'une micromarque dans le cartilage nasal. Il y a eu après 1988 une amélioration importante dans la détection des marques à la plupart des installations où nous avons réalisé notre échantillonnage, en grande partie parce qu'on a alors commencé à y réaliser systématiquement un deuxième examen de tous les poissons.

INTRODUCTION

Clipping fins is the most common method of marking juvenile salmon in British Columbia. Between 1985 and 1989, an average of 12.4 million fin-clipped salmon juveniles were released annually from B.C. enhancement facilities. The majority of these fish had the adipose fin clipped and a coded-wire tag (CWT) implanted. Marked fish are recovered annually in fisheries and escapements, and are used to estimate the survival, production and exploitation rates of hatchery fish.

When analyzing mark recovery data, one of the key assumptions is that all marked fish in the recovery sample are reported. It has long been recognized that relying on untrained observers (i.e. sport and commercial fishermen) for the recovery of marked fish may result in serious errors (Ricker 1975), especially if the mark is a subtle one, such as a clipped fin (Everhart and Youngs 1975). Several methods have been developed to correct for incomplete reporting of tags by untrained observers (Paulik 1961, Seber 1982). Generally, corrections are developed by sampling a portion of the catch using professional samplers. However, it is commonly assumed that professional samplers rarely fail to recognize a mark on a fish that they examine. Consequently, errors by professional samplers are seldom assessed unless the sampling environment is so complex that an error appears likely.

Mark recovery efficiency at salmon facilities in British Columbia had never been adequately examined despite the fact that in some instances, hatchery fish have had much lower mark rates at return (proportions marked based on Ad-CWT marks) than mark rates estimated at release. For example, at some facilities during the 1971 to 1981 brood years, the mean difference between the release and return mark rates reached approximately 20% for coho and 40% for chinook salmon (English et al. MS 1987). Circumstantial evidence suggested that the mark rates in escapements to Salmonid Enhancement Program facilities might be incorrect. For example, two field studies on two different systems provided anecdotal evidence of undetected hatchery marks. In each of these studies, upstream fish counts were made at the hatchery and several kilometers below the hatchery. Data from both studies indicated that the mark rate was greater at the downstream count site than at the hatchery. The discrepancy between the two count sites may be explained in several ways including higher mortality of marked fish than unmarked fish prior to entry into the hatchery, greater numbers of marked than unmarked fish spawning naturally below the hatchery, disproportionate entry of unmarked wild fish into the hatchery, and undetected marks in the hatchery escapement.

Based on the above concerns, several limited spot-checks were conducted at three B.C. hatcheries in 1987. Chinook salmon previously sampled for marks were rechecked and from 15% to 40% of the marks were found to be undetected.

To assess the problem of undetected marks more rigorously, a study was undertaken to examine the efficiency with which the hatchery crews were able to detect the presence of an adipose or other fin-clip on chinook, coho and chum salmon. From September to December of 1988, 1989, 1990 and 1992, a portion of the surplus hatchery chinook, coho and chum salmon were resampled for marks. The surveyed facilities were located in the lower Fraser Valley and on Vancouver Island. Six facilities were involved in the 1988 program, nine facilities in the 1989 program, six in 1990 and one in 1992 (Append. 1). The most frequently sampled facilities were Big Qualicum, Chehalis, Chilliwack, Inch Creek and Robertson Creek (Fig. 1), where formal resampling was conducted for up to four study years.

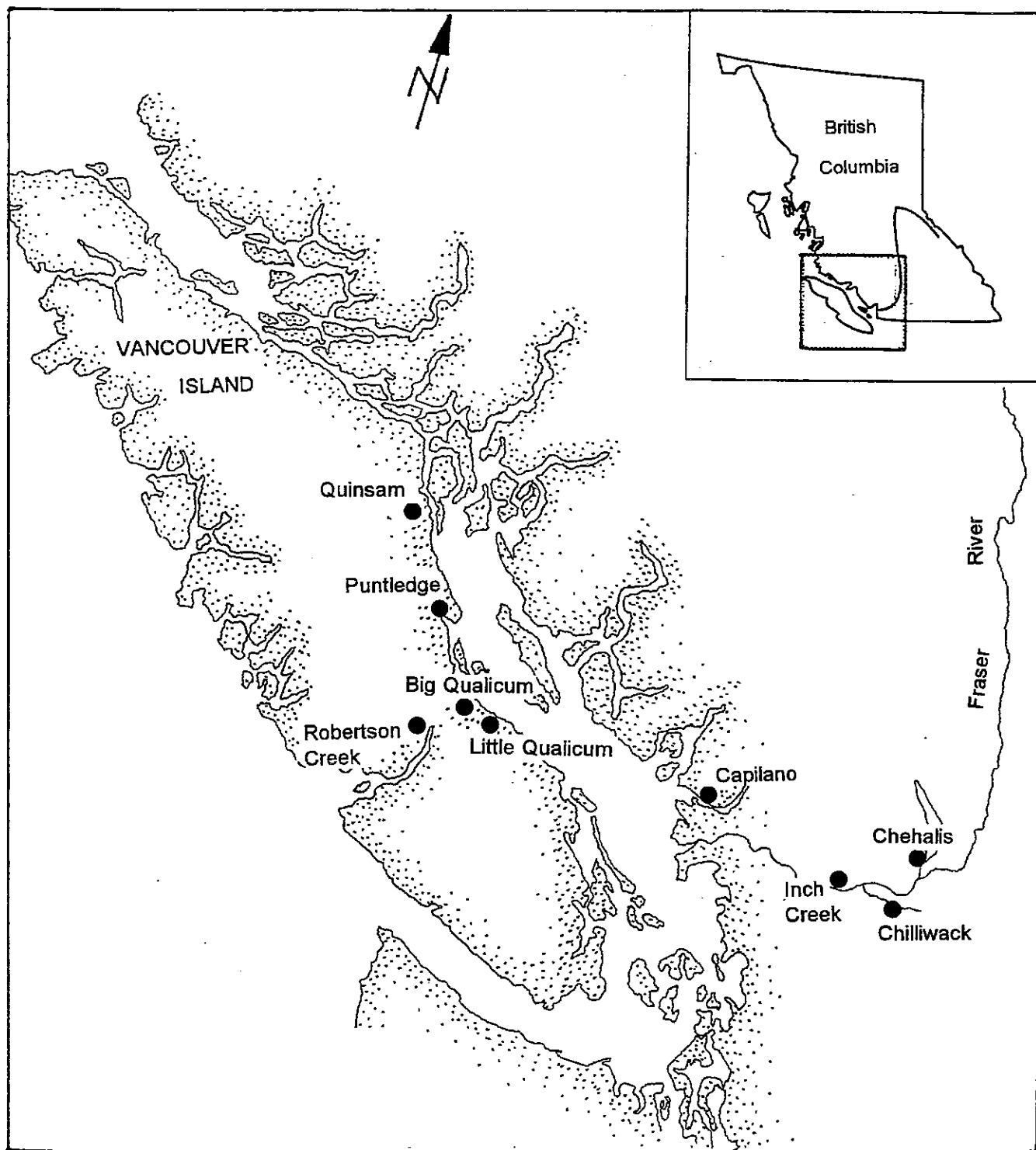


Fig. 1. Location of facilities surveyed during the mark resampling program in 1988, 1989, 1990 and 1992.

In this report, the following abbreviations and terms were used:

RV -- Right Ventral,
LV -- Left Ventral,
AdRV -- Adipose + Right Ventral,
AdLV -- Adipose + Left Ventral,
Multiple clips -- Collective term
 for the above four fin-clip types,

Ad -- Adipose,
CWT -- Coded-wire tag,
Head-ON fish -- Fish with head intact,
Head-OFF fish -- Fish with head removed,
MRP -- Mark Recovery Program,
SEP -- Salmonid Enhancement Program,
DFO -- Department of Fisheries and Oceans.

Note that the Ad-clips refer to adipose-only clips which are generally applied to chinook, coho and sometimes chum salmon; in these species the Ad-only clips must be associated with a CWT. In comparison, chum and pink salmon are frequently marked with an RV, LV, AdRV or AdLV fin-clip, and these marks are not associated with a CWT.

SAMPLING METHODS

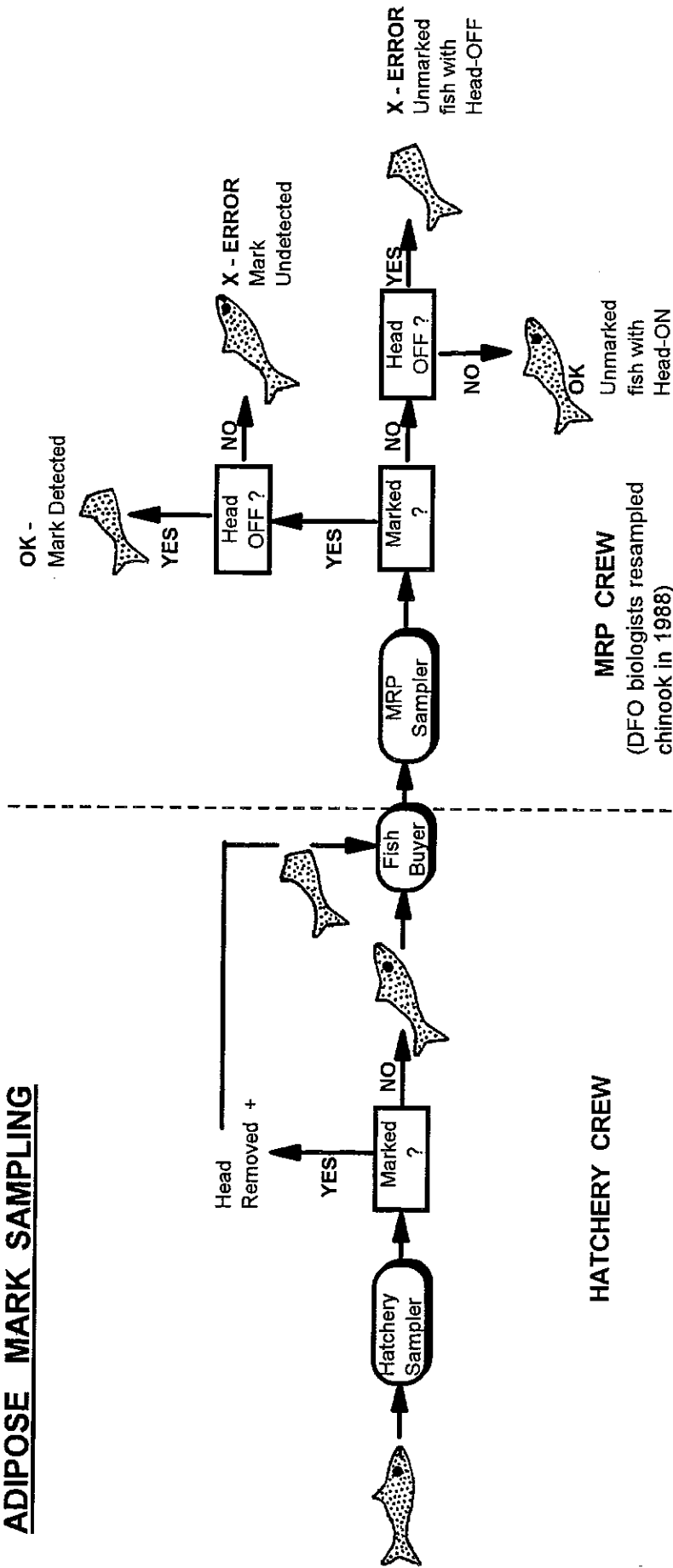
Mark recovery efficiency at a facility can be assessed by repeatedly examining the same group of fish for marks. Fish can be double-checked at the hatchery but this approach may result in a biased estimate of mark detection since the hatchery crew would be constantly reminded that their performance was being monitored. Alternatively, fish that are surplus to hatchery requirements and are sold for processing, can be intercepted and resampled off-site. Off-site resampling of surplus fish sales was the method chosen for this study because this approach did not disrupt the normal handling procedures at the hatchery, was less likely to result in changed sampling behaviour of hatchery crew, and allowed for a more orderly and thorough examination of the fish.

The resampling for marks was conducted under contract to J.O. Thomas and Associates by the MRP crew who sample commercial catches for marks, primarily at processing plants. One exception was in 1988 when DFO biologists resampled chinook salmon for marks on site.

At the outset of the season, the MRP personnel were provided with a list of anticipated returns for each sample site listed in the order of priority by hatchery, species and grade. Sampling effort was generally allocated to access the greatest number of samples while allowing sampling throughout the season. Due to a limited budget in 1990 and 1992, sampling effort was allocated to periods during which a maximum number of fish were anticipated to be sold, as indicated by sales records from previous years. When a sale was about to occur, the hatchery staff contacted the MRP personnel with information on the sale date, species, approximate number of fish, grade and processor. Some buyers also contacted the MRP project office with similar information.

The incidence of undetected marks was examined in all four years of the program. The focus was on the adipose-only clips in 1988, and on all fin-clips in 1989, 1990 and 1992. The problem of mark misinterpretation was addressed in 1990. The mark sampling strategy used by the hatchery and MRP crews is shown schematically for Ad-marks in Figure 2 and for multiple clips in Figure 3. The sampling details for each study year are outlined in Appendix 2.

ADIPOSE MARK SAMPLING

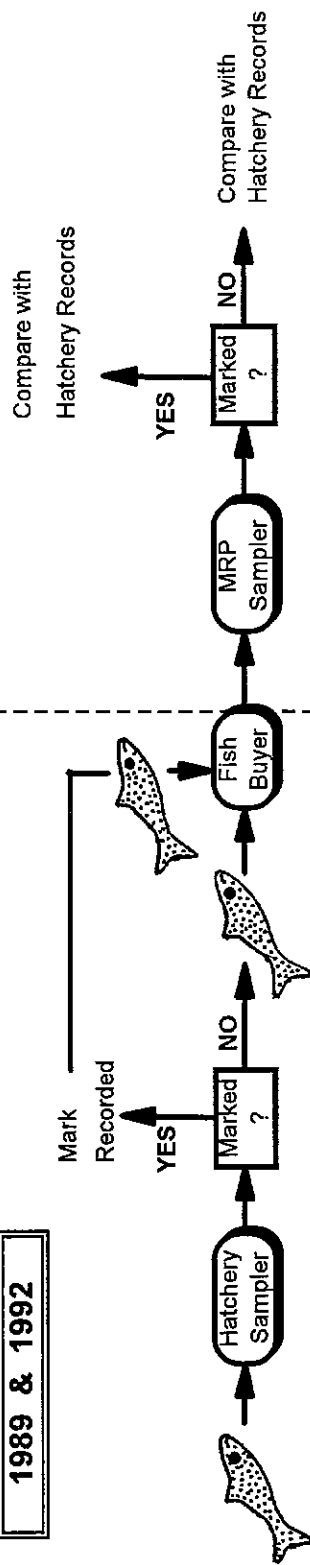


+ At Chehalis and Chilliwack facilities in 1988, hatchery crews removed heads from only a portion of Ad-clipped coho. Therefore, to determine the number of undetected marks, the hatchery and MRP records had to be reconciled and Method 2 used for data analysis (see text).

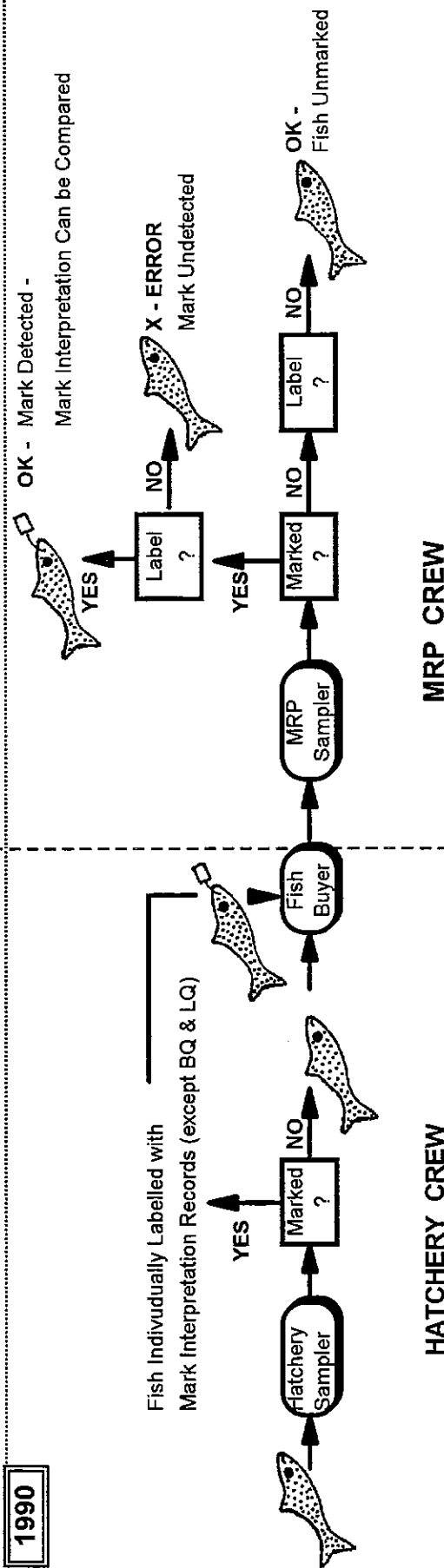
Fig. 2. Mark sampling strategy used by the hatchery and MRP crews to detect adipose marks in 1988, 1989, 1990 and 1992.

MULTIPLE FIN - CLIP SAMPLING

1989 & 1992



1990



HATCHERY CREW

MRP CREW

Fig. 3. Mark sampling strategy used by the hatchery and MRP crews to detect multiple clips in chum salmon in 1989, 1990 and 1992.

Depending on the facility, a combination of chinook, coho and chum salmon were resampled for marks each year. Both adults and jacks were resampled. The resampled fish consisted of hatchery returns which were surplus to broodstock requirements and of the carcasses of fish that had been used for hatchery broodstock. In general, the hatchery crew counted and examined for marks all salmon entering the facility, and removed heads from all Ad-clipped fish. A sample of these heads was subsequently dissected, and tags recovered and decoded. Removal of heads also served to indicate that a mark had been detected. In most cases, this mark sampling procedure was followed routinely whenever Ad-CWT marks were expected to return. This approach simplified the analysis of the re-check data because any salmon with a Head-ON and a missing adipose fin was recorded as an undetected mark. Exceptions to the above strategy occurred at Chehalis and Chilliwack hatcheries in 1988 when only a portion of the Ad-clipped coho had their heads removed (Append. 2).

Hatchery crews did not remove heads from chum salmon with multiple clips (except at Chehalis Hatchery in 1989, Append. 2). At those facilities where only multiple-clipped chum were expected to return (e.g. Big Qualicum, 1989), a recovered Ad-only clip was likely a stray fish or an artifact of a regenerated ventral fin. In such cases, a recovered Ad-only clipped chum was not considered a missed mark.

The MRP crew conducted most of the resampling at the processing plants. Exceptions were the Big Qualicum and Little Qualicum spawning channels where the MRP crew resampled the dead-pitched chum on site in both 1989 and 1990, and at Robertson Creek Hatchery where one sale was resampled on site in 1990. These exceptions were due to logistical problems at the processing plants.

During each sampling visit to a facility or a processing plant, the MRP crew examined all fins on each fish being resampled and identified it as Head-ON or Head-OFF. For each species, the MRP records included: 1) total number of fish examined, 2) number of marked fish per clip type, 3) number of Ad-only clipped fish with Head-OFF, 4) number of Ad-only clipped fish with Head-ON, and 5) number of fish with Head-OFF but Ad-fin not clipped. The resampled Ad-marked fish that were undetected at a facility had their heads removed (except in 1988, Append. 2) for subsequent CWT recovery and decoding. All undetected marks recovered during resampling were credited to the appropriate hatchery files.

The MRP crew assessed fin regeneration using two different methods, depending on the fin-clip type. For Ad-clips, the regeneration status was recorded as either 0% (no regeneration) or a "stub" (some degree of regeneration). For multiple clips (RV, LV, AdRV or AdLV) the two ventral "sister" fins on the same fish were compared and the clipped fin given a regeneration rating of 0% (no regeneration), 25%, 50% or 75% (severe regeneration).

Each year, changes were made to the study design of the MRP resampling program to address specific problems identified the previous year. For example, from 1989 onward, the MRP crew removed heads from all undetected Ad-marks for subsequent CWT recovery and decoding. In 1990, the hatchery crews attached head-labels showing mark type, to individual multiple-clipped chum. These labels were subsequently recovered by the MRP crew and the mark type verified to assess the problem of mark misinterpretation.

Improvements were made each year in the mark sampling techniques used at the surveyed facilities (Append. 3). In 1988, little or no double-checking for marks was conducted at the facilities. However, beginning in 1989, double-checking for marks became a routine procedure at most of the surveyed sites. Given these improvements in mark recovery procedures, a between-year comparison of mark detection rates at a given facility would in fact evaluate the improvements at that site in mark sampling techniques.

DATA ANALYSIS

Data analysis for each study year is described in Appendix 2. For the data analysis of Ad-only clipped fish, the MRP records were generally sufficient. The hatchery and MRP records were compared only to confirm that the same lot of fish sold was being compared. Exceptions were the Chehalis and Chilliwack coho sampled in 1988, when both the hatchery and MRP records were required for data analysis (see calculation Method 2 below).

The number of undetected Ad-marks in a sample was calculated in one of two ways:

Method 1

Where hatchery records showed that heads were removed from all Ad-clipped fish, a resampled Ad-clipped fish with Head-ON was treated as an undetected mark.

Method 2

Where hatchery records showed that heads were removed from only a portion of Ad-clipped fish (Chehalis and Chilliwack coho in 1988), a resampled Ad-clipped fish with Head-ON did not necessarily indicate a missed mark at the hatchery. It may have been recognized as a mark and counted, but the head not removed. For such samples, the number of undetected marks was calculated by subtracting the number of Ad-clipped fish with Head-ON recorded by the hatchery crew from the number of such fish recorded by the MRP crew:

$$\text{UNDETECTED MARKS} = \left| \begin{array}{l} \text{Ad-marks with} \\ \text{Head-ON} \\ \text{recorded by} \\ \text{MRP crew} \end{array} \right| - \left| \begin{array}{l} \text{Ad-marks with} \\ \text{Head-ON} \\ \text{recorded by} \\ \text{HATCHERY crew} \end{array} \right|$$

Because the MRP crew were highly trained and experienced in mark sampling, their records were assumed to be highly reliable and to contain the correct interpretation of the fin-clip type and the degree of fin regeneration. Throughout the program, every effort was made to discuss ambiguous data with hatchery managers or MRP crew in order to interpret samples correctly.

RESULTS

Appendix 1 details for each surveyed facility the total fish sales sampled and the total numbers of chinook, coho and chum salmon rechecked for marks during each of the 1988, 1989, 1990 and 1992 programs. These data are summarized below. Note that not all of the rechecked fish samples were included in the data analysis because of mix-ups at hatcheries and processing plants, incomplete resampling by MRP crew, and other problems.

Year	Facilities Included in Data Analysis	Sales Sampled	TOTAL FISH	
			Rechecked	Included in Data Analysis
1988	6	49	42,299	42,299
1989	9	127	130,206	107,200
1990	6	39	53,573	48,918
1992	1	6	5,209	4,953

ADIPOSE MARK DETECTION

Table 1 shows the mean undetected Ad-mark rate by species and year for each facility. Detailed data are given in Appendices 1 and 4 - 7.

In 1988, depending on the facility, the mean undetected Ad-mark rate was 0 - 13.8% for chinook, 1.6 - 15.7% for coho, and 7.7 - 21.9% for chum salmon.

In 1989, the majority of facilities showed an Ad-mark detection rate of over 95% (Table 1). However at Robertson Creek, the undetected Ad-mark rate was 6.4% and 6.7% for chinook adults and jacks, respectively; and 2.5% and 6.7% for coho adults and jacks, respectively. At Chehalis Hatchery, 3.3% of the Ad-marks in coho jacks and 4.5% of the Ad-marks in chum salmon, went undetected.

In 1990, the detection of Ad-marks improved at the Chehalis and Robertson Creek hatcheries where perfect and near-perfect records were observed. At Chilliwack Hatchery, over 2% of each of the chinook and coho Ad-marks went undetected, and at Inch Creek Hatchery, 4.5% of the chum Ad-marks went undetected.

In 1992, the one surveyed facility, Robertson Creek, had a high rate of undetected Ad-marks for both chinook (11.0%) and coho (14.3%).

SEASONAL VARIATION IN MARK DETECTION EFFICIENCY

In this report, the mean mark detection rate for a given facility, species and year was the average of the available samples and did not accurately represent the mean seasonal value. This was because the MRP resampling effort was in most cases not proportionate throughout the

Table 1. Pieces sampled, overall total Ad-marks and undetected Ad-mark component, and percent undetected Ad-marks for each facility and species resampled by MRP crew in 1988, 1989, 1990 and 1992. * (Adults shown in normal type; chinook and coho jacks in bold type; Mix - mix of adults and jacks.)

Facility	1988			1989			1990			1992		
	Fish Sampled	Tot. Ad-marks	% Undet.	Fish Sampled	Tot. Ad-marks	% Undet.	Fish Sampled	Tot. Ad-marks	% Undet.	Fish Sampled	Tot. Ad-marks	% Undet.
CHINOOK SALMON												
Big Qual.	718	19 \ 0	0	477	27 \ 0	0	-	-	-	-	-	-
Chehalis	-	-	-	918	45 \ 0	0	212 Mix	3 \ 0	0	-	-	-
Chilliwick	-	-	-	218 adults	32 \ 0	0	378 Mix	48 \ 1	2.1	-	-	-
Quinsam	561	-	-	106 jacks	12 \ 0	0	-	-	-	-	-	-
Robertson	1,031	40 \ 0	0	331	21 \ 0	0	-	-	-	-	-	-
		29 \ 4	13.8	9,202 adults	419 \ 27	6.4	5,772 Mix	210 \ 0	0	4,088 Mix	100 \ 11	11.0
				3,159 jacks	120 \ 8	6.7	-	-	-	-	-	-
COHO SALMON												
Big Qual.	-	-	-	600 adults	29 \ 0	0	-	-	-	-	-	-
Capilano	-	-	-	3,248 jacks	229 \ 0	0	-	-	-	-	-	-
Chehalis	4,363	237 \ 27	11.4	338 Mix	102 \ 0	0	173 Mix	9 \ 0	0	-	-	-
Chilliwick	20,476	773 \ 121	15.7	4,404 adults	205 \ 0	0	-	-	-	-	-	-
				742 jacks	30 \ 1	3.3	-	-	-	-	-	-
Inch Creek	1,684	247 \ 4	1.6	29,850 adults	1,388 \ 10	0.7	7,880 Mix	197 \ 5	2.5	-	-	-
Puntledge	-	-	-	3,881 jacks	91 \ 1	1.1	-	-	-	-	-	-
Quinsam	-	-	-	669 adults	116 \ 1	0.9	-	-	-	-	-	-
Robertson	-	-	-	50 jacks	11 \ 0	0	-	-	-	-	-	-
				253 Mix	15 \ 0	0	-	-	-	-	-	-
				5,990 adults	582 \ 6	1	-	-	-	-	-	-
				5,621 jacks	255 \ 2	0.8	-	-	-	-	-	-
				7,994 adults	434 \ 11	2.5	4,726 Mix	471 \ 0	0	865 Mix	14 \ 2	14.3
				3,079 jacks	312 \ 21	6.7	-	-	-	-	-	-
CHUM SALMON												
Chehalis	7,714	196 \ 43	21.9	10,390	132 \ 6	4.5	12,619	110 \ 1	0.9	-	-	-
Chilliwick	-	-	-	-	-	-	2,907	4 \ 0	0	-	-	-
Inch Creek	5,752	39 \ 3	7.7	4,970	104 \ 0	0	689	22 \ 1	4.5	-	-	-

* Data from Append. 1 and 4 - 7. Note that chinook resampling in 1988 conducted by DFO biologists.

** Tot. gives the overall total Ad-marks (Detected plus Undetected); Undet. gives the Undetected Ad-mark component.

season. For example, the number of days sampled for a given year, facility and species was often less than 10 (Append. 6, 7). Limited data on the seasonal range in undetected Ad-marks were provided by some of the more frequently sampled facilities in 1988 and 1989 (Append. 8). The data, summarized below, show that on a given sampling occasion (usually day), up to 72.7% of the total Ad-marks in a sample went undetected.

Year	Facility	Species	Total Fish Sampled	Overall Ad-marks	Undetected Ad-marks as % of Overall Ad-marks	
					Mean	Range
1988	Chehalis	Coho	4,363	237	11.4	(0 - 72.7)
	Chehalis	Chum	7,714	196	21.9	(0 - 35.9)
	Inch Creek	Coho	1,684	247	1.6	(0 - 6.7)
1989	Robertson Creek	Chinook	9,202	419	6.4	(0 - 21.1)

Note that in these examples, the total fish sampled represent the total fish handled, as the hatchery crews sampled for Ad-marks all fish entering the facility and the MRP crew rechecked these samples in their entirety.

Figure 4 shows the relationship between the three variables (Total fish sampled, Overall Ad-marks recovered, and Undetected Ad-marks) for each of the three examples where a significant number (>25) of Ad-marks went undetected in a given season (Append. 8). The correlation coefficients (r) for the Undetected Ad-marks and each of the other two variables (Total fish sampled and Overall Ad-marks recovered) are shown below for each example.

Examples (Fig. 4)	Variables Compared	d.f. *	r	Significance
Chehalis coho - 1988	Undetected vs Total Fish Sampled	10	-0.064	N.S. **
	Undetected vs Overall Ad-marks	10	0.020	N.S.
Chehalis chum - 1988	Undetected vs Total Fish Sampled	11	0.958	p<0.001
	Undetected vs Overall Ad-marks	11	0.754	p<0.01
Robertson Creek chinook - 1989	Undetected vs Total Fish Sampled	9	0.333	N.S.
	Undetected vs Overall Ad-marks	9	0.416	N.S.

* d.f. - Degrees of freedom.

** N.S. - Not Significant.

Only the Chehalis chum data showed a significant correlation between the numbers of undetected Ad-marks and each of the other two variables.

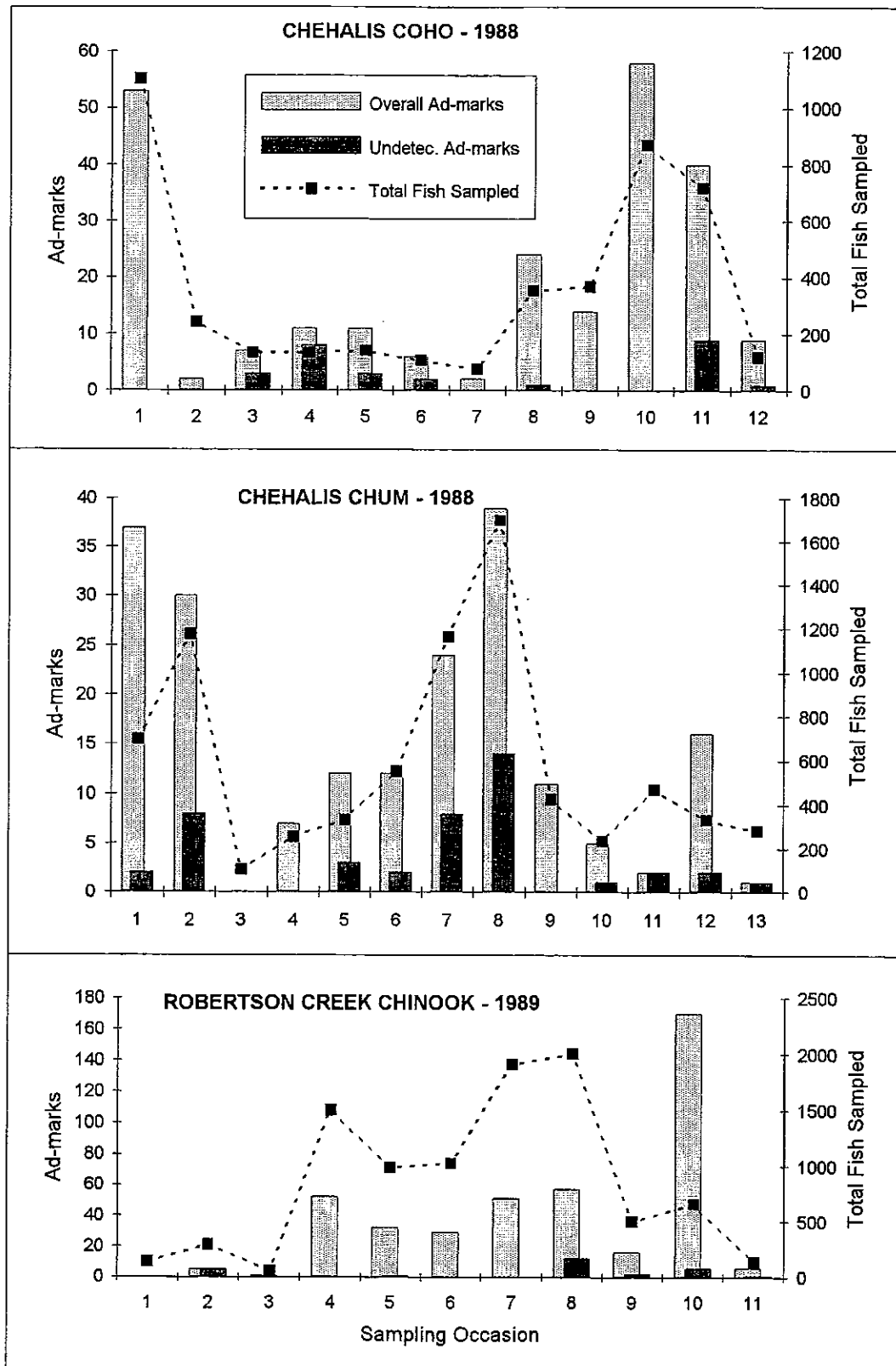


Fig. 4. Relationship between the total fish sampled, the overall Ad-marks recovered, and the undetected Ad-marks in a given sample, 1988 and 1989 data.

ADIPOSE MARK DETECTION IN ADULTS VERSUS JACKS

During the 1989 resampling program on chinook and coho salmon, the MRP crew recorded the data for adults and jacks separately (Table 1, Append. 6). For chinook salmon, little or no difference in Ad-mark detection rate was observed between the adults and jacks from Chilliwack and Robertson Creek hatcheries. For coho salmon, the error in detection rate was greater for jacks than adults, but only for the Chehalis and Robertson Creek hatcheries.

REMOVAL OF HEADS FROM UNMARKED FISH

During the study, the MRP crew observed fish with completely formed and normal adipose fins but with heads removed in error (Table 2). This error occurred for all three facilities resampled by the MRP crew in 1988 when a total of 14 unmarked fish with heads removed were reported. This represents 1.1% of the total heads removed from the sampled fish. In 1989, the incidence of heads removed in error was only 0.5% of the total heads removed, but still occurred at five of the resampled facilities. In 1990, this error occurred at only one facility and the incidence was 0.4%. In 1992, the one surveyed facility showed an error of 2.9%.

DETECTION OF FIN-CLIPS IN CHUM SALMON

The hatchery and MRP records on the numbers of chum salmon observed with multiple clips and Ad-only clips were compared for each of 1989 (Table 3) and 1990 (Table 4). The hatchery data in these tables may contain both correctly and incorrectly interpreted marks. Note that for chum salmon, when both Ad-only clips and multiple clips were reported at the same facility, the mark detection data for Ad-only clips and multiple clips were examined together because the misinterpretation of either mark type by the hatchery crew would alter the total for each clip category. For example, an AdRV mark misidentified as an Ad-only mark, would result in an inflated Ad-only total and a reduced multiple clip total.

In 1989, three facilities provided the data (Table 3). At Big Qualicum and Inch Creek, the hatchery crew observed only 90.7% and 40.0%, respectively, of the total multiple clips reported by the MRP crew. At Little Qualicum, the hatchery crew observed more multiple clips than the MRP crew. The discrepancy between the hatchery and MRP data was reduced considerably for the Inch Creek chum (from 40.0% to 97.5%) when the total marks (multiple plus Ad-only) were compared. Apparently, six of the multiple clips detected by the hatchery crew were assigned incorrectly to the Ad-only clip category.

In 1990, five facilities provided the data, and all of them had mark detection rates of 90% to 100% for both the multiple clips and the total clips (multiple plus Ad-only, Table 4).

CORRECT FIN-CLIP INTERPRETATION IN CHUM SALMON

One of the questions addressed in 1990 was what proportion of the multiple clips in chum salmon was correctly interpreted by the hatchery crew. The results were available only for the Chehalis and Chilliwack facilities (Table 5). For the Chehalis chum where four different combinations of multiple clips were observed, the hatchery crew correctly identified 88.3% (53 out of 60) of the marks. Only one of the 45 AdRV marks was misidentified as an RV clip but half of the 10 RV marks were misidentified as AdRV clips. For the Chilliwack chum where two different

Table 2. Heads removed in error from unmarked fish, 1988, 1989, 1990 and 1992.

Year	Facility	Species *	FISH WITH HEADS REMOVED		
			Total **	Unmarked	% Unmarked
1988	Chehalis	Coho (A)	213	3	1.4
		Chum	155	2	1.3
	Chilliwack	Coho (A)	659	7	1.1
	Inch Creek	Coho (A)	245	2	0.8
		Chum	36	0	0
	TOTAL		1,308	14	1.1
1989	Big Qualicum	Chinook (A), Coho (A+J)	285	0	0
	Capilano	Coho (M)	102	0	0
	Chehalis	Chinook (A), Coho (A+J)	279	0	0
		Chum	127	1	0.8
	Chilliwack	Chinook (A+J), Coho (J)	134	0	0
		Coho (A)	1,389	11	0.8
	Inch Creek	Coho (A)	116	1	0.9
		Coho (J), Chum	115	0	0
	Puntledge	Coho (M)	15	0	0
	Quinsam	Chinook (A), Coho (J)	274	0	0
		Coho (A)	577	1	0.2
	Robertson Creek	Chinook (A+J)	504	0	0
		Coho (A)	428	5	1.2
		Coho (J)	297	6	2.0
	TOTAL		4,642	25	0.5
1990	Chehalis	Chinook (A), Coho (M), Chum	121	0	0
	Chilliwack	Chinook (M), Coho (M), Chum	243	0	0
	Inch Creek	Chum	21	0	0
	Robertson Creek	Chinook (M)	210	0	0
		Coho (M)	475	4	0.8
	TOTAL		1,070	4	0.4
1992	Robertson Creek	Chinook (M)	91	2	2.2
		Coho (M)	13	1	7.7
	TOTAL		104	3	2.9

* A - Adults, J - Jacks, M - Mix of adults and jacks.

** Total fish (marked and unmarked) with heads removed.

Table 3. Comparison of fin-clip detection in chum salmon by hatchery (HY) and MRP crews, 1989.

Facility (No. MRP Samples)	Sampling Crew	Fish Sampled	RV	Multiple Clips			AdLV	TOTAL		Ad-only Clips		Overall Total Clips	% Detection Rate by hatchery crew *	
				LV	AdRV	AdLV		Hd-ON	Hd-OFF				Multiple Clips	Total Clips
Big Qualicum (8)	HY	8,485	14	46	8	0	0	68	1	0	0	69	90.7	89.6
	MRP	8,175	17	50	8	0	0	75	2	0	0	77		
	Diff. **	310	-3	-4	0	0	0	-7	-1	0	0	-8		
Inch Creek (7)	HY	4,753	6	0	0	0	0	6	0	110	116	116	40.0	97.5
	MRP	4,970	5	4	2	4	4	15	0	104	119	119		
	Diff.	-217	1	-4	-2	-4	-4	-9	0	6	***	-3		
Little Qualicum (5)	HY	2,868	9	2	8	5	5	24	0	0	24	24	109.1	109.1
	MRP	2,535	11	1	4	6	6	22	0	0	22	22		
	Diff.	333	-2	1	4	-1	-1	2	0	0	2	2		

* % Detection rate by hatchery crew = (Clips detected by hatchery crew / Clips detected by MRP crew) x 100.

** Diff. = Difference.

*** At Inch Creek Hatchery, the six additional chum salmon with heads removed were actually multiple clips.

Table 4. Comparison of fin-clip detection in chum salmon by hatchery (HY) and MRP crews, 1990.*

Facility (No. MRP Samples)	Sampling Crew	Fish Sampled	C H U M S A L M O N							% Detection Rate by		
			RV	LV	Multiple Clips		TOTAL	Ad-only Clips		Overall Total Clips	hatchery crew	
					AdRV	AdLV		Hd-ON	Hd-OFF		Multiple Clips	Total Clips
Big Qualicum (9)	HY	4,103	2	41			43	0	0	43	100.0	100.0
	MRP	4,093	1	42			43	0	0	43 [46] **	[93.5] **	[93.5] **
	Diff. +	10	1	-1			0					
Chehalis (7)	HY	N/A	6	6	53	0	65	0	109	174	92.9	96.7
	MRP	12,619	11	8	50	1	70	1	109	180		
	Diff.		-5	-2	3	-1	-5	-1	0	-6		
Chilliwack (9)	HY	2,861	116	20			136	0	4	140	99.3	99.3
	MRP	2,907	118	19			137	0	4	141		
	Diff.	-46	-2	1			-1		0	-1		
Inch Creek (1)	HY	663	3	3	6	6	9	0	22	31	100.0	100.0
	MRP	689	2	2	7	7	9	1	21	31		
	Diff.	-26	1	1	-1	-1	0	-1	1	0		
Little Qualicum (24)	HY	9,661	5	6	2	31	44	0	0	44	89.8 ++	89.8 ++
	MRP	9,469 ++	2	7	2	38	49	0	0	49		
	Diff.	192	3	-1	0	-7	-5			-5		

* Data include all fin-clipped chum, including those with only hatchery or MRP records.

** Adjusted mark detection rate. While both hatchery and MRP crews reported 43 multiple clips for Big Qualicum chum, within that total the hatchery records showed 3 marks (2 LV and 1 RV) not reported by MRP crew. Assuming MRP crew indeed missed those 3 marks, and including them in the total, gave an adjusted hatchery mark detection rate of (43/46) or 93.5%.

+ Diff. = Difference.

++ At Little Qualicum, an additional 129 chum (approx. 1.3 % of total sample) not resampled by MRP crew. This may result in slight underestimation of marks missed by hatchery crew.

Table 5. Number and percent of chum fin-clips correctly interpreted by hatchery (HY) crews, 1990. *

CHUM SALMON							
Facility	Sampling Crew	Fish Sample	Multiple Clips				Total
			RV	LV	AdRV	AdLV	
Chehalis	HY	N/A	5	4	44	0	53
	MRP	12,619	10	4	45	1	60
	Difference		-5**	0	-1***	-1	-7
	% Correct		50%	100%	97.8%	0%	88.3%
Chilliwack	HY	2,861	113	17			130
	MRP	2,907	116	19			135
	Difference		-3 ^	-2 ^^			-5
	% Correct		97.4%	89.5%			96.3%

* Hatchery and MRP interpretation records compared for individual chum marks.
 Hatchery entries included only those multiple clips correctly interpreted by hatchery crew.
 Correct interpretation of fin clips based on MRP records.

** Remaining 5 RV marks misidentified as AdRV.

*** Remaining 1 AdRV mark misidentified as RV.

^ Remaining 3 RV marks misidentified as LV.

^^ Remaining 2 LV marks misidentified as RV.

combinations of multiple clips were observed, the hatchery crew correctly identified 96.3% (130 out of 135) of the marks. Three of the 116 RV marks were misidentified as LV clips and two of the 19 LV marks were misidentified as RV clips.

Note that Table 5 includes only those chum salmon reported in both the hatchery and MRP records, and therefore, shows fewer fin clips than Table 4.

DETECTION OF REGENERATED FIN-CLIPS

In 1988, the incidence of regenerated fins among the overall Ad-marks was 1.5% (7 out of 482, Table 6). In comparison, a much higher incidence of regenerated fins was reported for the overall multiple clips (23.2% and 45.8% in 1989 and 1990, respectively, Table 6); the highest values being observed in 1990 for the Chehalis and Chilliwack facilities (61.4% and 43.8%, respectively, Append. 10). For the two latter facilities combined, severe fin regeneration of 75% was observed in 14 out of the total 205 clips (Append.11). Note that in this report, the regenerated multiple fin-clips are those with a 25% and higher regeneration level.

Table 6 compares mark detection rates for each of the complete and regenerated fin-clips. For the Ad-clips from the 1988 survey, 90.3% of the complete but only 42.9% of the regenerated Ad-clips were detected (the latter value was based on a small sample size, $n = 7$). For the multiple clips, both the complete and regenerated components showed a high detection rate of 99.3% and 93.3%, respectively (1990 data, Table 6).

DISCUSSION

An increase in the undetected escapement marks leads to a corresponding decrease in the detected escapement marks, which results in the underestimation of the marked escapement component (E in the equations below). As E decreases, survival rate and production appear to decrease, while exploitation rate appears to increase because for each tag code (where C = detected marks in catch, and E = detected marks in escapement):

$$\begin{aligned} \text{Survival Rate} &= (C + E) / \text{Total marks released,} \\ \text{Production} &= (C + E) \times \text{Mark rate at release,} \\ \text{Exploitation Rate} &= C / (C + E). \end{aligned}$$

Comparing the survival rates of two or more hatchery releases that represent different rearing or release strategies, is the primary way of developing improved hatchery practices. In addition, trends in survival rates serve as an important indicator of varying ocean conditions which in turn impact wild stocks. The production estimate expresses how many fish are produced by a given facility and, when summed over all facilities from the SEP program, provides a measure of the program's performance. The exploitation rate is a measure of the proportion of fish out of the total stock that is taken in fisheries. This rate is one of the tools used in: assessing the fishery impact on the enhanced stocks and on geographically similar wild stocks, managing fisheries on these stocks, and assessing the impact of regulatory changes.

The failure to detect escapement marks, as shown in the 1988 study (Table 1), is a cause for concern. The two examples shown below for the Chehalis and Chilliwack hatcheries, are based on the actual missed mark error observed in the 1988 study and illustrate the impact of

Table 6. Incidence (in parenthesis) of regenerated fins in each of detected, undetected and total mark components; and percent detection for complete, regenerated and total fin-clips, 1988, 1989, 1990 and 1992.+

Year	Species	Mark Category	Complete		Regenerated		Complete + Regenerated			Data Source
			No.	%	No.	%	No.	% by Category	(% Regen.)	
ADIPOSE CLIPS										
1988 *	Coho & Chum	Detected	429	90.3	3	42.9	432	89.6	(0.7)	Append. 4
		Undetected	46	9.7	4	57.1	50	10.4	(8.0)	
		Total	475	100	7	100	482	100	(1.5)	
1990 **	Chinook, Coho & Chum	Undetected	8	-	0	-	8	-	(0)	Append. 7
1992 **	Chinook & Coho	Undetected	12	-	1	-	13	-	(7.7)	Append. 7
MULTIPLE FIN - CLIPS										
1989	Chum	Detec.+Undetec.	86	-	26	-	112	-	(23.2)	Append. 9
1990	Chum	Detected	141	99.3	112	93.3	253	96.6	(44.3)	Append. 10
		Undetected	1	0.7	8	6.7	9	3.4	(88.9)	
		Total	142	100	120	100	262	100	(45.8)	

+ Regenerated multiple fin-clips include those with 25% and higher regeneration level.

* Data for 1988 limited to coho from Inch Creek and chum from Chehalis and Inch Creek.

** For 1990 and 1992, MRP crew checked for fin regeneration in undetected Ad-clips only.

undetected marks on the estimates of hypothetical survival rates, exploitation rates and production from hatchery releases (see Append. 12 for calculations):

	<u>CHEHALIS CHUM</u>		<u>CHILLIWACK COHO</u>	
	No Error *	Error **	No Error *	Error **
% Undetected Escapement Marks	0%	21.9%	0%	15.7%
% Overall Survival Rate	1.0%	0.9%	10.0%	9.5%
% Exploitation Rate	50.0%	56.0%	70.0%	74.0%
Production (pieces)	5,000	4,453	50,000	47,645

* No Error - All escapement marks are detected at the hatchery.

** Error - A portion of escapement marks is undetected at the hatchery.

That is, if 21.9% of the Chehalis chum escapement marks went undetected at the hatchery, then a release with an overall (catch plus escapement) survival rate of 1% and an exploitation rate of 50%, would show an underestimated survival rate of 0.9% and an overestimated exploitation rate of 56%. Similarly, if 15.7% of the Chilliwack coho escapement marks went undetected at the hatchery, then a release with an overall survival rate of 10% and an exploitation rate of 70%, would show an underestimated survival rate of 9.5% and an overestimated exploitation rate of 74%. Furthermore, in both of the above examples, hatchery production would be underestimated if escapement marks went undetected.

The above errors in exploitation rate (assuming no offsetting errors in the fishery catch sampling programs) may affect fishery management decisions and confound the assessment of different management actions, particularly where the escapement is a large component of the total return. Because the data from marked key stream stocks are used in management of fisheries and allocation of catches, the implication of these errors goes beyond the enhanced stocks.

While no general agreement exists on an acceptable error rate in hatchery mark recovery data, the error levels observed in the 1988 study are not acceptable. In an attempt to determine how widespread the problem is, the personnel managing government hatcheries in both Washington State and Alaska were contacted. Although no published studies on mark detection efficiency at salmon hatcheries were available, the results of an unpublished study conducted in 1982 by the Washington State Department of Fish and Wildlife were provided (L. Blankenship, unpubl. data). This study involved double-checking for Ad-marks fish from eight Washington State hatcheries (Table 7). Omitting the results of two small samples where the incidence of missed Ad-marks exceeded 50%, the average undetected Ad-mark rate among hatcheries was 15.6%. This value is similar to the 13.3% observed over all the facilities and species surveyed for undetected Ad-marks in our 1988 study (Append. 4).

Table 7. Summary of salmon sampled for undetected adipose fin-clips at eight Washington State hatcheries in 1982 (L. Blankenship, pers. comm.).

Facility	Fish Sampled	ADIPOSE MARKS		
		Detected	Undetected	% Undetected
1	19,896	368	406	52.5%
2	2,942	163	8	4.7%
3	1,956	73	23	24.0%
4	259	7	10	58.8%
5	11,410	512	108	17.4%
6	1,319	83	7	7.8%
7	25	0	1	100.0%
8	4,066	1,386	46	3.2%
Total	41,873	2,592	609	15.6% *

* Mean percent calculated as the average of hatchery percentages, excluding hatcheries No. 4 and 7 due to small sample size.

SEASONAL VARIATION IN MARK DETECTION EFFICIENCY

The pattern of seasonal variation in mark detection efficiency (Fig. 4) suggests that the non-detection of Ad-marks was not a constant low-grade problem which persisted throughout the season, but rather a few instances of particularly poor mark sampling, often unrelated to the total fish sampled that day. This suggests that, while the volume of fish handled per sampling occasion may affect significantly mark detection rates in some cases (e.g. Chehalis chum in 1988), other factors also may play a role.

Seasonal variation in mark detection efficiency is probably related to several factors including the differences in day-to-day pressures, such as impatient fish buyers; numbers of fish handled; tired crews; and the hiring of new and less experienced samplers during the sampling season. When major lapses in mark detection coincide with a peak run strength, the impact on the sampling results for the entire season could be significant. Due to the considerable seasonal variation in mark detection rates, it is not appropriate to double-check for marks a few times during the mark recovery period and then apply the mean detection rate to the entire season. Likewise, it is not appropriate to apply a seasonal rate to another return year because the results from different hatchery crews could be quite different. Instead, the ideal approach would be to measure the mark detection rates in a systematic way throughout the sampling period each year, and correct blocks of data for undetected marks. However, such extensive annual resampling for marks is unlikely due to logistical constraints and limited resources.

Another approach is to develop an adjustment factor to correct for undetected marks. For example, currently all expanded recoveries (in catch and escapement) of chum and pink salmon from all B.C. facilities are adjusted upwards by a factor of 30% (Big Qualicum facility is treated separately). This corrects for the lower mark rate at return than at release, which may be due to factors such as poorer survival of marked over unmarked fish, errors from undetected marks, and incorrect estimation of mark rates at release. (D. Bailey, pers. comm.).

ADIPOSE MARK DETECTION RATE IN ADULTS VERSUS JACKS

The limited 1989 data suggested that at some facilities, coho jacks may have a greater error of undetected marks than coho adults (Table 1). Coho jacks are smaller than adults, and probably less attention is paid to jacks during fish sorting.

REMOVAL OF HEADS FROM UNMARKED FISH

Heads were mistakenly removed from unmarked fish in all four years of the study. This error resulted in an increase of 1.1% in the total heads removed for CWT decoding in the 1988 study, and an increase of 0.5%, 0.4% and 2.9% in the 1989, 1990 and 1992 studies, respectively (Table 2). Such heads will show up as "no pins" in the data and will confound any efforts to reconcile "no pin" rates at release and "no pin" rates at return. The above error was reduced after 1988, probably due to improved hatchery techniques used in mark sampling (but not in 1992 when one hatchery provided the data).

DETECTION OF FIN-CLIPS IN CHUM SALMON

The differences observed between the hatchery and MRP mark recoveries of chum fin-clips in 1989 indicated that marks were being misinterpreted as well as missed. For example, the Inch Creek Hatchery records showed that the hatchery crew had detected and removed heads from 110 apparently Ad-clipped chum (Table 3). However, the MRP crew found that 6 of these fish actually had multiple clips. Had the hatchery crew assigned these 6 fin-clips to the correct mark category, the total Ad-only mark recoveries would have agreed exactly between the MRP and hatchery samplers. Also the multiple-clip totals, as reported by the hatchery and MRP crews, would have shown better agreement.

At Little Qualicum where chum were examined during a dead pitch in 1989, the hatchery crew reported more total marks than the MRP crew (24 versus 22 marks, Table 3). It is possible that the MRP sampler missed some marks because the sampling conditions encountered during a dead pitch were unusual for MRP samplers (the MRP crew typically sample at processing plants), and less than optimum for all samplers. The above observation at Little Qualicum did not diminish our overall confidence in the MRP resampling data because the MRP crew are reputed for their experience and reliability in mark detection, and consistently detected more marks throughout this study than the hatchery crews. The only two exceptions where the MRP crew may have missed marks, occurred during resampling of the dead-pitched chum at Little Qualicum in 1989 (Table 3), and at Big Qualicum in 1990 where three marks may have gone undetected (Table 4). The difficulty of detecting marks during a dead pitch was confirmed by some additional data collected in 1989 at the Big Qualicum facility; the detection rate for multiple clips was 100% for freshly killed chum used in egg-takes (both the hatchery and MRP crews recovered 32 marks), but only 84% for chum carcasses from a dead pitch (the hatchery crew recovered only 36 of the 43 marks recorded by the MRP crew). The above suggests that even experienced samplers may miss marks, especially when the sampling environment is unusual.

INACCURATE ESCAPEMENT COUNTS

The observed discrepancy between the hatchery and MRP counts for the "Fish Sampled" (Tables 3, 4) was likely due to reduced counting accuracy by hatchery crews especially during periods of peak salmon returns. This discrepancy ranged from 10 to 333 pieces and represented 0.2% to 13.1% of the respective MRP counts. The higher error rates are of concern as they would affect expansions of marked fish to the total escapement. (Note that the above counting errors were attributed to the hatchery crews because the MRP records were assumed to be the more accurate in both mark counts and total fish counts because of the better sampling conditions and experience of the MRP crew).

The problem of inaccuracies in escapement counts during mark sampling was also documented for the Quinsam facility in 1989 when each of the coho adults and jacks were recounted on 10 sampling days (Append. 13). For coho adults, the discrepancy between the first and second counts of unmarked fish ranged from 0 to 70 pieces and represented 0% to 10.9% of the initial count. For coho jacks, the discrepancy between the two counts ranged from 0 to 233 pieces and represented 0% to 28.5% of the initial count. A correlation analysis showed that for coho adults (but not jacks), the size of the discrepancy was significantly ($p < 0.05$) correlated with the total fish sampled (d.f. = 8, $r = 0.716$). The hiring of new and less experienced samplers in November of 1989 likely contributed to the counting errors (Append. 13).

DETECTION OF REGENERATED FIN-CLIPS

Fin regeneration was partly responsible for the failure of hatchery crews to recognize the fish as a marked fish. Regenerated Ad-clips are of special concern as the heads frequently yield a CWT. For example, the 1985 to 1987 tag recovery data for the B.C. commercial fisheries showed that 40% to 50% of the coho with regenerated Ad-clips, and approximately 70% of the chinook with regenerated Ad-clips yielded a CWT (Sager and Associates MS 1986, Thomas and Associates MS 1988a and 1988b).

For the Ad-marks in this study, the overall incidence of regenerated fins was only 1.5% (1988 data) but their detection rate was apparently poor (42.9%), based on a small sample size of 7 (Table 6). As a result, the regenerated Ad-clips were a notable component (8% or 4 out of 50) in the total undetected Ad-marks (Table 6). This reinforces the concern over the ability to recognize regenerated Ad-clips.

The situation was different for the multiple clips where despite the high incidence of regenerated fins in 1989 and 1990 (23.2% and 45.8%, respectively, Table 6), their detection rate was high (93.3% in 1990). Nevertheless, fin regeneration was apparently the dominant cause for undetected multiple clips in 1990 when 88.9% (8 out of 9) of the total undetected multiple clips were regenerated (Table 6).

As shown below, the failure to detect regenerated fin-clips will result in underestimation or overestimation of a given mark, depending on interpretation at the hatchery.

ACTUAL MARK *	HATCHERY INTERPRETATION	CONSEQUENCES
Regenerated <u>AdRV</u> or <u>AdLV</u>	Ad - only	Underestimation of multiple clips, overestimation of Ad-marks, and inflation of the "no pin" rate.
Regenerated <u>AdRV</u> or <u>AdLV</u>	LV or RV	Underestimation of multiple clips and overestimation of LV or RV clips.
Regenerated <u>Ad-only</u>	Unmarked	Underestimation of Ad-marks and overestimation of unmarked fish.
Unmarked	Regenerated Ad-only	Underestimation of unmarked fish, overestimation of Ad-marks, and inflation of the "no pin" rate.

* The regenerated fin is underlined.

The above first case scenario was actually observed at the Inch Creek Hatchery in 1989 when six chum heads were removed in error. Upon rechecking, the MRP crew found that three of those fish had both an adipose and a ventral clip, but that the ventral fin had regenerated. In this case, the hatchery crew had overestimated the Ad-clip counts and underestimated the multiple clip counts. Based on the above, improving the detection of regenerated fins should lead to some reduction in the undetected mark rate.

EFFECT OF HATCHERY MARK SAMPLING TECHNIQUES ON MARK DETECTION RATES

Table 8 compares for each facility the mean rate of undetected Ad-marks for the "control" year (1988) when no double-checking for marks was conducted, with each subsequent year when all fish were double-checked for marks (note that for Robertson Creek facility, double-checking for marks began in 1990). For the Chehalis and Chilliwack facilities, a marked improvement in the Ad-mark detection rate was observed between 1988 and each of the two subsequent years. Similarly, for the Inch Creek facility, the mark detection rate improved between 1988 and 1989 (but not 1990). For the Robertson Creek facility, the improvement in the Ad-mark detection rate observed between the control years (1988/1989) and 1990, was followed by a poor performance in 1992.

A chi-square analysis of the data showed that the improvement in Ad-mark detection rates between the control year and each of the subsequent years was highly significant ($p < 0.0005$) in all instances (Append. 14). Exception was the Robertson Creek facility where the Ad-mark detection rate was significantly poorer ($p < 0.01$) in 1992 compared to the control years of 1988/89.

The significant improvement in Ad-mark detection rate observed after 1988 for all the facilities combined (from 12.8% undetected Ad-marks in 1988 to less than 1% in each of 1989 and 1990, Table 8, Append. 14), as well as the reduction in the numbers of heads removed in error from unmarked fish during that period (Table 2), coincided with the commencement in 1989 (1990 for Robertson Creek) of formal double-checking for marks at the surveyed facilities. Therefore, the incorporation of a formal second examination of all fish appeared to be the more successful approach to reducing mark sampling errors, compared to simply advising the hatchery crews to "be more careful". Consequently, it is important that the double-checking procedures be maintained.

UNDERESTIMATION OF HATCHERY ERRORS

The error of undetected marks and incorrectly interpreted marks was likely underestimated in this study for several reasons.

- 1) At some facilities surveyed in 1988, the hatchery crews knew that rechecking for marks was taking place and may have taken extra care during mark sampling. This awareness by the hatchery crews likely continued throughout the study in view of the year-to-year changes in mark sampling procedures at the facilities to improve mark detection.
- 2) Heads were not always removed from all Ad-marked fish detected at a hatchery (e.g. Chehalis and Chilliwack coho in 1988), and the number of fish sampled at a processing plant did not always agree with the hatchery records regarding the number of fish sold and shipped. Fish may have been removed from the shipment prior to sampling at the plant, the MRP samplers may not have accessed all the fish prior to processing, or there may have been counting errors on the part of the hatchery or MRP crews. For these reasons, it is suggested that the reported hatchery error in mark detection may have been underestimated for both the Chehalis and Chilliwack coho resampled in 1988.

Table 8. Between-year comparison of mean undetected Ad-mark rates and of mark sampling techniques for each facility surveyed in 1988 - 1992. *

Facility	Return Year	Combined Species **	Pieces Sampled	No. Detec.	No. Undetec.	% Undetec.	Mark Sampling Technique per Year +
Big Qualicum	1988	CN	718	19	0	0	- No double-checking for marks.
	1989	CN, CO	4,325	285	0	0	- All fish double-checked for marks.
Chehalis	1988	CO, CM	12,077	363	70	16.2	- No double-checking for marks.
	1989	CN, CO, CM	16,454	405	7	1.7	- All fish double-checked for marks.
	1990	CN, CO, CM	13,004	121	1	0.8	- All fish double-checked for marks.
Chilliwack	1988	CO	20,476	652	121	15.7	- No double-checking for marks.
	1989	CN, CO	34,055	1,512	11	0.7	- A portion of fish double-checked for marks.
	1990	CN, CO, CM	11,165	243	6	2.4	- All fish double-checked for marks.
Inch Creek	1988	CO, CM	7,436	279	7	2.4	- No double-checking for marks.
	1989	CO, CM	5,689	230	1	0.4	- All fish double-checked for marks.
	1990	CM	689	21	1	4.5	- All fish double-checked for marks.
Quinsam	1988	CN	561	40	0	0	- Some informal double-checking.
	1989	CN, CO	11,942	850	8	0.9	- All fish double-checked for marks.
Robertson Creek	1988	CN	1,031	25	4	13.8	- No double-checking for marks.
	1989	CN, CO	23,434	1,218	67	5.2	- No double-checking for marks.
	1990	CN, CO	10,498	681	0	0	- All fish double-checked for marks.
	1992	CN, CO	4,953	101	13	11.4	- All fish double-checked for marks.
All Facilities	1988	CN, CO, CM	42,299	1,378	202	12.8	- No double-checking for marks.
	1989	CN, CO, CM	72,465 +	3,282	27	0.8	- All fish double-checked for marks.
	1990	CN, CO, CM	35,356	1,066	8	0.7	- All fish double-checked for marks.

* Data from Table 1.

** Species: CN - chinook, CO - coho, CM - chum. Adults and jacks combined.

+ Mark sampling techniques from Appendix 3.

++ Excluded Robertson Creek from 1989 total since fish at that facility were not double-checked for marks until 1990.

3) The hatchery samplers were given the benefit of the doubt in some of the instances where the data were inconclusive. For example, in 1990 the MRP crew resampled two Chehalis chum, each with a missing head but with an AdRV and an LV clip. It was assumed that the hatchery crew identified these clips correctly as multiple fin-clips but removed the heads in error. In another case, a resampled chum from the Chehalis facility consisted of only a head with an attached label indicating an AdRV clip. Although the body was missing, the MRP crew assumed that the hatchery samplers interpreted the clip correctly.

4) The MRP crew, despite being fully trained and experienced, may have missed or incorrectly interpreted some of the marks during resampling, leading to further underestimation of the hatchery error. This may have occurred in 1989 and 1990 during the resampling of dead-pitched chum at the Big Qualicum and Little Qualicum facilities.

Note that compared to the present results, fewer undetected marks would be expected in the early operational years of the SEP facilities when the salmon returns were fewer and the mark sampling techniques simpler.

RECOMMENDATIONS FOR IMPROVING MARK DETECTION RATES AT FACILITIES

The present study has identified several problems with mark detection at the SEP facilities. The factors contributing to the failure to detect marks include the rate at which the fish are handled, the complexity of the task, the recognizability of regenerated fin-clips as marks, as well as the training and experience of the hatchery crew. At some facilities, the samplers are required to keep mental tallies of the numbers of marked and unmarked fish by species and sex, as well as to select broodstock and grade surplus fish. With three species, two sexes, and in some cases more than one mark type, this mark sampling procedure clearly invites error.

Improving the mark sampling techniques so that all marks are recovered at facilities, is the most direct and simple way of improving estimates of the survival rate, production and exploitation rate of hatchery releases. One possible approach is to standardize mark sampling procedures for blocks of facilities with similar mark sampling requirements, and develop specific recommendations for each block of facilities. Whatever the approach, the following key guidelines should be incorporated into every mark sampling program:

- 1) **Simplify the sampling tasks wherever possible** (Append. 15).
 - Separate mark sampling from other activities as much as possible.
 - Improve data recording methods; do not expect the sampling staff to keep mental tallies but rather tally the marks as they are encountered.
- 2) **Provide adequate training and supervision to all sampling personnel.**
 - Identify mark sampling as an important activity.
 - Place a conscientious, experienced person in charge of sampling.
 - Provide consistent training for all sampling personnel, including good familiarity with regenerated fin-clips.

To improve the detection of regenerated fin-clips, the hatchery crews should make an effort to sample every fish that appears to have a mark. Where a concern arises about inflating the "no pin" rate because of uncertainty whether a given fish is marked or not, a note should be made on the individual fish label stating that the mark is suspect.

- Do not assign short-term or casual employees to mark sampling duty.
- 3) **Remove the heads from all Ad-only clipped fish and do not subsample for marks.**
(Note, this does not mean that a CWT from every head has to be decoded).
 - Examine every fish and mutilate every marked fish observed, including Ad-only clips and multiple clips. Mutilate either by head removal or some other standard means.
 - Verify that the fish are Ad-only clipped before removing heads.
 - 4) **Double-check every batch of fish for undetected marks and double-check mark tallies at the end of each activity period.**
 - Assume that any marked fish that has not been mutilated in some way is an undetected mark.
 - Triple-check occasionally.
 - 5) **Monitor the sampling efficiency of personnel.**
 - Correct errors.
 - Determine whether worker carelessness is involved.
 To identify whether the dominant cause of missed marks is due to worker carelessness or to lack of adequate training, a simple experiment may be conducted, based on the work of Brown (1982). For a given task, the sampler's performance can be inspected "blind" (without the sampler's knowledge) and then subsequently inspected in plain sight (with the sampler's knowledge). Errors that occur in the "blind" scenario are most likely due to carelessness or poor attitude. Errors that occur when the sampler knows he or she is being observed are most likely due to inadequate training.
 - Provide performance incentives.
 - 6) **Develop an overall adjustment factor to correct for errors in recovery data due to undetected marks, mark mortality and other causes.**
(This is already being done for chum and pink salmon, see p. 21).
 - 7) **Improve the counting accuracy of escapements at facilities.**
Such errors would affect expansions of marked fish to the total escapement.

SUMMARY

1. In 1988, 1989, 1990 and 1992, a mark resampling program was conducted at selected facilities in British Columbia to assess the problem of undetected escapement marks and of mark misinterpretation. Sampled species included chinook, coho and chum salmon.
2. Undetected escapement marks will lead to underestimation of survival rate and production rate, and overestimation of exploitation rate of hatchery fish.
3. In 1988 depending on the facility, the mean undetected mark rate for adipose clips was 0 - 13.8% for chinook, 1.6 - 15.7% for coho and 7.7 - 21.9% for chum salmon.
4. Mark detection rates may show considerable seasonal variation. Consequently, in correcting for undetected marks it is not appropriate to apply specific mark detection results to the entire season or to another year.
5. Coho jacks appeared to show a greater rate of undetected adipose marks compared to coho adults. This may be related to the smaller size of coho jacks compared to adults, and less attention likely paid to jacks during fish sorting.
6. The removal of heads in error from unmarked fish occurred in all four years of the study, resulting in an increase of 0.4 - 2.9% in the total heads removed for CWT decoding in a given study year. This error generally declined over the study period.
7. Considerable differences were observed in 1989 between the hatchery and MRP recoveries of total chum multiple clips. Marks were being missed as well as misinterpreted.
8. The proportion of multiple clips correctly interpreted by the hatchery crew in 1990 was 88.3% for the Chehalis chum and 96.3% for the Chilliwack chum.
9. The incidence of regenerated adipose fins in 1988 (coho plus chum) was 1.5%. The detection rate for these regenerated fins was only 42.9%. As a result, the regenerated Ad-clips were a notable component (8.0%) of the total undetected Ad-marks.
10. The situation was different for multiple clips where, despite the high incidence of regenerated fins in 1989 and 1990 (23.2% and 45.8%, respectively), their detection rate was high (93.3% in 1990).
11. In general, the detection of adipose and multiple clips improved significantly between 1988 and the subsequent years. This improvement was attributed largely to the incorporation by hatchery crews of a formal second examination of all fish.
12. Recommendations are presented for improving mark detection at the facilities.

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Appendix 1. Mark resampling program, 1988, 1989, 1990 and 1992. +

Hatchery Species	1988			1989			1990			1992		
	All species		Fish Sampled Adults	All species		Fish Sampled Adults Jacks Total	All species		Fish Sampled Adults & Jacks	All species		Fish Sampled Adults & Jacks
	Period Sampled	(Sales) ++		Period Sampled	(Sales) ++		Period Sampled	(Sales) ++		Period Sampled	(Sales) ++	
Big Chinook Qualicum Chum	Oct 19 - Oct 28.	{2}	718 - -	Oct 26 - Dec 15.	{16}	477 600 10,809 *	Dec 3 - Dec 6.	{10}	- 21 4,423 **	Not Sampled	Not Sampled	
Capitano Chinook Coho Chum	Not Sampled			Oct 5.	{1}	338 Mix -	Not Sampled			Not Sampled		
Chehalis Chinook Coho Chum	Oct 15 - Dec 4.	{18}	- 4,363 7,714	Oct 11 - Dec 12.	{40}	918 4,404 27,033	Oct 18 - Nov 22.	{7}	212 173 12,619	Not Sampled	Not Sampled	
Chilliwack Chinook Coho Chum	Oct 14 - Nov 30.	{12}	- 20,476 -	Sep 29 - Dec 12.	{35}	218 29,850 3,561 *	Sep 28 - Nov 9.	{11}	378 7,880 2,907	Not Sampled	Not Sampled	
Inch Chinook Coho Chum	Nov 1 - Dec 15.	{12}	- 1,684 5,752	Nov 2 - Dec 13.	{5}	- 669 5,098	Nov 27.	{1}	- 4 689	Not Sampled	Not Sampled	
Little Chinook Qualicum Chum	Not Sampled			Nov 24 - Dec 1.	{8}	1 7 2,535	Nov 20 - Nov 22.	{5}+++	1 18 13,750 **	Not Sampled	Not Sampled	
Puntledge Chinook Coho Chum	Not Sampled			Nov 8	{1}	4 253 Mix -	Not Sampled			Not Sampled		

(cont'd)

Appendix 1 (cont'd).

Hatchery	Species	1988			1989			1990			1992		
		All species		Fish	All species		Fish	All species		Fish	All species		Fish
		Period Sampled	{Sales} ++	Sampled Adults	Period Sampled	{Sales} ++	Sampled Adults	Period Sampled	{Sales} ++	Sampled Adults	Period Sampled	{Sales} ++	Sampled Adults & Jacks
Quinsam	Chinook	Oct 18 - Oct 27.	{2}	561	Oct 18 - Nov 22.	{6}	331 5,990	8 5,621	339 11,611	-	Nov 5	{1}	171 ***
	Coho			-									85 ***
	Chum			-									-
Robertson	Chinook	Oct 12 - Oct 26.	{3}	1,031	Sep 25 - Nov 1.	{15}	9,202 7,994	3,159 3,079	12,361 11,073	-	Oct 20 - Nov 6.	{5}	4,088 865
	Coho			-									-
	Chum			-									-
TOTAL	All	Oct 12 - Dec 15.	{49}	42,299	Sep 25 - Dec 15.	{127}	130,206				Oct 20 - Nov 6.	{6}	5,209
	Species												

+ Chinook resampling in 1988 conducted by DFO biologists.

All other resampling conducted by MRP crew (Thomas and Associates Ltd. MS 1990 a, b and MS 1993).

Note that not all of these fish included in data analysis due to mix-ups at hatcheries and processing plants, incomplete resampling by MRP crew, and other problems.

Mix = Mix of adults and jacks.

++ Number of salmon sales rechecked by MRP crew.

* For 1989 data analysis:

- 1) Excluded two Big Qualicum chum samples because a misunderstanding between hatchery and MRP crews resulted in an artificially high undetected mark rate in one case, and in another case, no match could be made between hatchery and MRP records;
- 2) Excluded a portion of Chehalis chum samples and all of Chilliwack chum samples because of incomplete resampling by MRP crew, mix-ups of Chehalis and Chilliwack fish at processor, or because no match with hatchery records could be found;
- 3) Excluded one Inch Creek chum sample due to incomplete resampling by MRP crew.

** For 1990 data analysis, excluded several Big Qualicum and Little Qualicum chum samples due to incomplete resampling by MRP crew.

*** For 1992 data analysis, excluded all of Quinsam samples due to incomplete resampling by MRP crew.

+++ Number of channel sections sampled by MRP crew at Little Qualicum in 1990.

Appendix 2. Details on mark sampling and data analysis for 1988, 1989, 1990 and 1992. *
(BQ = Big Qualicum, LQ = Little Qualicum)

YEAR	MARK SAMPLING	DATA ANALYSIS
1988	<ul style="list-style-type: none"> - Six facilities participated. <p><u>Coho and Chum - General</u> - (Resampled by MRP crew)</p> <ul style="list-style-type: none"> - Sampled Chehalis, Chilliwack (coho only) and Inch Creek fish. - Hatchery crews removed heads from all Ad-clipped fish (except Chehalis and Chilliwack coho, see below). - MRP crew resampled at processing plants for Ad-clips or multiple clips, as appropriate. - MRP crew checked for fin regeneration in each of detected and undetected Ad-clips (but in total combined Ad-clips for Chehalis and Chilliwack coho, due to different methodology). - Fish with undetected Ad-clips checked for CWTs with magnetic tag detector but heads not removed. <p><u>Coho - Chehalis and Chilliwack</u></p> <ul style="list-style-type: none"> - Hatchery crews removed heads from only a portion of Ad-clipped coho. <p><u>Chinook</u> - (Resampled by DFO biologists)</p> <ul style="list-style-type: none"> - Sampled BQ, Quinsam and Robertson Creek fish. - Hatchery crews removed heads from all Ad-clipped chinook. - DFO biologists resampled on site for Ad-clips and retained any undetected marks for hatchery records. - Hatchery crews deliberately not advised of resampling. 	<p><u>Chinook, Coho, Chum - General</u></p> <ul style="list-style-type: none"> - Used Method 1 for analysis (see Data Analysis in text), except for Chehalis and Chilliwack coho (see below). - Analyzed only Ad-clip data for adults only since few jacks or multiple clips available. <p><u>Chehalis and Chilliwack coho</u></p> <ul style="list-style-type: none"> - Used Method 2 for analysis. - Undetected Ad-clips calculated by reconciling hatchery and MRP records on total numbers sampled, Ad-clips with Head-ON, and Ad-clips with Head-OFF.
1989	<ul style="list-style-type: none"> - Nine facilities participated. - Hatchery crews removed heads from all Ad-clipped fish. - At Chehalis, hatchery crew also removed heads from a portion of multiple clipped chum. - MRP crew resampled at processing plants (except BQ and LQ where dead-pitched chum resampled on site). - MRP crew checked for fin regeneration in combined (detected plus undetected) multiple clips. (Ad-clips not assessed.) 	<p><u>Ad-clips</u></p> <ul style="list-style-type: none"> - Used Method 1 for analysis. - Adults and jacks analyzed separately where possible, for each of chinook and coho. - For Chehalis, a portion of chum samples discarded from Ad-clip analysis. ** <p><u>Chum Multiple Clips</u></p> <ul style="list-style-type: none"> - For BQ, LQ and Inch Creek, hatchery and MRP records reconciled by sales date. - For Chehalis and Chilliwack, all chum samples discarded from multiple-clip analysis, as reconciliation by sales date not possible.** - Other individual samples discarded for BQ and Inch Creek (see Append. 1 - footnotes).

cont'd

Appendix 2 (cont'd).

YEAR	MARK SAMPLING	DATA ANALYSIS
1990	<ul style="list-style-type: none"> - Six facilities participated. - Addressed two problems: Undetected marks and Misinterpreted marks. <p><u>Ad-clips</u></p> <ul style="list-style-type: none"> - Hatchery crews removed heads from all Ad-clipped fish. - MRP crew checked for fin regeneration in undetected Ad-clips only. <p><u>Chum Multiple Clips</u></p> <ul style="list-style-type: none"> - Hatchery crews attached a numbered head label to each chum salmon with a multiple clip (RV, LV, AdRV, AdLV), and recorded head label number with respective clip type and percent regeneration. - Hatchery crews did not attach head labels to chum dead-pitched from BQ and LQ spawning channels as the two crews worked concurrently at those sites. - MRP crew collected chum data on head-label number, mark type, fin regeneration, fish length and weight; and obtained scale samples. - MRP crew checked for fin regeneration in each of detected and undetected multiple clips (but for LQ, in detected plus undetected clips, see below). - At LQ, MRP crew sampled before hatchery crew so that MRP records represented total marks (detected plus undetected). <p><u>Overall</u></p> <ul style="list-style-type: none"> - MRP crew resampled at processing plants (except BQ and LQ where dead-pitched chum resampled on site, and Robertson Creek where one sale resampled on site). 	<p><u>Ad-clips</u></p> <ul style="list-style-type: none"> - Used Method 1 for analysis. - Analyzed chinook and coho data for a mix of adults and jacks. <p><u>Chum Multiple Clips</u></p> <ul style="list-style-type: none"> - For mark detection analysis: reconciled hatchery and MRP sales data records, and compared for the two sampling crews total chum marks recovered regardless of type (i.e. Ad-clips + Multiple clips). Chum salmon with only hatchery or MRP records also included in analysis. - For mark interpretation analysis: matched head labels for individual chum salmon in hatchery and MRP records (except BQ and LQ where no head labels applied). - Discarded several chum samples (BQ and LQ) as MRP resampling incomplete.
1992	<ul style="list-style-type: none"> - One facility, Robertson Creek, participated. (Quinsam Hatchery also participated but was excluded from study due to logistical problems and incomplete resampling by MRP crew.) - Hatchery crew removed heads from all Ad-clipped fish. - MRP crew resampled at processing plants. - MRP crew checked for fin regeneration in undetected Ad-clips only. 	<p><u>Ad-clips</u></p> <ul style="list-style-type: none"> - Used Method 1 for analysis. - Analyzed chinook and coho data for a mix of adults and jacks.

* See Appendix 1 for facilities and species sampled each year.

Nitinat Hatchery also participated in the program but was excluded from the report due to complications with data.

** Discarded a portion of Chehalis and all of Chilliwack chum samples from 1989 due to incomplete resampling by MRP crew, mix-ups of Chehalis with Chilliwack fish at processor, or because no match with hatchery records could be found. Remaining Chehalis chum samples analyzed for Ad-marks but not multiple clips. This is because Ad-marks were expected for Chehalis but not for Chilliwack facilities, and any mix-ups at processor between hatchery samples would not affect Ad-mark records for Chehalis. On the other hand, multiple clips were expected for both Chehalis and Chilliwack hatcheries, and any mix-ups at processor between hatchery samples would confound the multiple clip analysis for both facilities.

Appendix 3. Mark sampling techniques at facilities surveyed for undetected marks, 1988, 1989, 1990 and 1992.

Hatchery	Return Year	Species Considered	Mark Sampling Technique
Big Qualicum	1988	Chinook	<ul style="list-style-type: none"> • No double-checking for marks was conducted. • All chinook entering the hatchery were examined for marks. • Marked fish were removed during egg-takes. • Heads were removed from all Ad-clipped fish.
	1989	Chinook, Coho	<ul style="list-style-type: none"> • All fish were double-checked for marks. • Otherwise, as in 1988.
	1990	Chum	<ul style="list-style-type: none"> • No double-checking for marks was conducted. • All chum dead-pitched from the channel were examined for marks. • Marked chum were not mutilated. • Head labels were not applied to multiple fin-clipped chum.
Capilano	1989	Coho	<ul style="list-style-type: none"> • No double-checking for marks was conducted. • All coho were examined for marks. • Heads were removed from all Ad-clipped coho.
Chehalis	1988	Coho, Chum	<ul style="list-style-type: none"> • No double-checking for marks was conducted. • All fish entering the hatchery were examined for marks. • For chum, heads were removed from all Ad-clipped fish. • For coho, heads were removed from only a portion of Ad-clipped fish.
	1989	Chinook, Coho, Chum	<ul style="list-style-type: none"> • All fish were double-checked for marks. (A second sorting table was installed). • Sampling tasks were simplified (see Append. 12). • Heads were removed from all Ad-clipped fish. • Ad-marks were verified before head removal. • In some cases, heads were also removed from multiple fin-clipped chum.
	1990	Chinook, Coho, Chum	<ul style="list-style-type: none"> • All fish were double-checked for marks. • Heads were removed from all Ad-clipped fish. • Ad-marks were verified before head removal. • For multiple fin-clipped chum, individual head labels were applied for later comparison with the MRP records.

(cont'd)

Appendix 3 (cont'd).

Hatchery	Return Year	Species Considered	Mark Sampling Technique
Chilliwack	1988	Coho	<ul style="list-style-type: none"> • No double-checking for marks was conducted. • All coho entering the hatchery were examined for marks. • Only a portion of Ad-clipped coho had their heads removed.
	1989	Chinook, Coho, Chum	<ul style="list-style-type: none"> • Only a portion of fish were double-checked for marks. • All fish entering the hatchery were examined for marks, and the unmarked fish were tossed into totes. • Samples from totes were rechecked for marks. • Heads were removed from all Ad-clipped fish.
	1990	Chinook, Coho, Chum	<ul style="list-style-type: none"> • All fish were double-checked for marks. (A second sorting table was installed). • Heads were removed from all Ad-clipped fish. • For multiple fin-clipped chum, individual head labels were applied for later comparison with the MRP records.
Inch Creek	1988	Coho, Chum	<ul style="list-style-type: none"> • No double-checking for marks was conducted. • All fish were examined for marks. • Heads were removed from all Ad-clipped fish.
	1989	Coho, Chum	<ul style="list-style-type: none"> • All fish were double-checked for marks. • Otherwise, as in 1988.
	1990	Chum	<ul style="list-style-type: none"> • All fish were double-checked for marks. • Heads were removed from all Ad-clipped chum. • For multiple fin-clipped chum, individual head labels were applied for later comparison with the MRP records.
Little Qualicum	1989	Chum	<ul style="list-style-type: none"> • All fish were double-checked for marks upon dead pitch from the channel. (River dead-pitches were few). • Marked fish were not mutilated.
	1990	Chum	<ul style="list-style-type: none"> • All chum recovered from the channel were double-checked for marks. • Head labels were not applied to multiple fin-clipped chum.

(cont'd)

Appendix 3 (cont'd).

Hatchery	Return Year	Species Considered	Mark Sampling Technique
Puntledge	1989	Coho	<ul style="list-style-type: none"> • All coho were double-checked for marks. • A portion of the fish were triple-checked for marks. • Heads were removed from all Ad-clipped fish.
Quinsam	1988	Chinook	<ul style="list-style-type: none"> • All fish were examined for marks. • Some informal double-checking for marks was conducted. • Heads were removed from all Ad-clipped fish.
	1989	Chinook, Coho	<ul style="list-style-type: none"> • All fish were double-checked for marks. • Heads were removed from all Ad-clipped fish.
Robertson Creek	1988	Chinook	<ul style="list-style-type: none"> • All fish were examined for marks. • No double-checking for marks was conducted. • Heads were removed from all Ad-clipped fish.
	1989	Chinook, Coho	<ul style="list-style-type: none"> • No double-checking for marks was conducted. • Heads were removed from all Ad-clipped fish.
	1990	Chinook, Coho	<ul style="list-style-type: none"> • All fish were double-checked for marks. • Heads were removed from all Ad-clipped fish.
	1992	Chinook, Coho	<ul style="list-style-type: none"> • All fish were double-checked for marks. • Heads were removed from all Ad-clipped fish. <p>(Note that a second sorting table was installed in 1991 but MRP sampling did not occur that year.)</p>

Appendix 4. Adipose-mark detection data for complete and regenerated Ad-clips in coho and chum salmon resampled by MRP crew, 1988.

Facility	Species (all adults)	Days Sampled	Fish Sampled	Adipose Clip Status *	Detected Ad-marks (Hd-OFF)		Undetected Ad-marks (Hd-ON)		Overall Total Ad-marks	
					No.	% by Clip Status	No.	% by Clip Status	No.	Undetec. **
Chehalis	Coho +	18	4,363	Compl.	-		-		231	-
				Regen.	-		-		6	-
				Total	210		27		237	11.4
	Chum	11	7,714	Compl.	152	99.3	42	97.7	194	21.6
				Regen.	1	0.7	1	2.3	2	50.0
				Total	153		43		196	21.9
Chilliwack	Coho +	12	20,476	Compl.	-		-		750	-
				Regen.	-		-		23	-
				Total	652		121		773	15.7
Inch Creek	Coho	11	1,684	Compl.	242	99.6	3	75.0	245	1.2
				Regen.	1	0.4	1	25.0	2	50.0
				Total	243		4		247	1.6
	Chum	12	5,752	Compl.	35	97.2	1	33.3	36	2.8
				Regen.	1	2.8	2	66.7	3	66.7
				Total	36		3		39	7.7
All Facilities	Coho	41	26,523	Compl.	-		-		1,226	-
				Regen.	-		-		31	-
				Total	1,105		152		1,257	12.1
	Chum	23	13,466	Compl.	187	98.9	43	93.5	230	18.7
				Regen.	2	1.1	3	6.5	5	60.0
				Total	189		46		235	19.6
All Facilities	All Species	64	39,989	Compl.	-		-		1,456	-
				Regen.	-		-		36	-
				Total	1,294		198		1,492	13.3

* Compl.- Complete, Regen.- Regenerated.

** % Undetected Ad-marks = (Ad-marks with Hd-ON / Total Ad-marks) x 100.

+ For Chehalis and Chilliwack coho sampled in 1988, regeneration data available only for overall total Ad-clips.

Appendix 5. Adipose-mark detection data for chinook salmon resampled by DFO biologists, 1988.

Facility	Date Sampled	Fish Sampled	Detected (Hd-OFF)	Undetected (Hd-ON)	% Undetected *
ADIPOSE MARKS					
Big Qualicum	Oct 19	378	11	0	0
	Oct 28	340	8	0	0
	Total	718	19	0	0
Quinsam	Oct 18	197	14	0	0
	Oct 27	364	26	0	0
	Total	561	40	0	0
Robertson Creek	Oct 12	52	2	0	0
	Oct 19	631	16	4	20.0
	Oct 26	348	7	0	0
	Total	1,031	25	4	13.8
OVERALL TOTAL		2,310	84	4	4.5

* % Undetected Ad-marks = (Ad-marks with Hd-ON / Total Ad-marks) x 100.

Appendix 6. Adipose-mark detection data for chinook, coho and chum salmon resampled by MRP crew, 1989.*

Facility	Species **	Days Sampled	Fish Sampled	ADIPOSE MARKS		
				Detected (Hd-OFF)	Undetected (Hd-ON)	% Undetected +
Big Qualicum	Chinook - A	2	477	27	0	0
	Coho - A	9	600	29	0	0
	Coho - J	8	3,248	229	0	0
Capilano	Coho - M	1	338	102	0	0
Chehalis	Chinook - A	12	918	45	0	0
	Coho - A	29	4,404	205	0	0
	Coho - J	22	742	29	1	3.3
	Chum	N/A	10,390	126	6	4.5
Chilliwack	Chinook - A	11	218	32	0	0
	Chinook - J	5	106	12	0	0
	Coho - A	34	29,850	1,378	10	0.7
	Coho - J	19	3,881	90	1	1.1
Inch Creek	Coho - A	4	669	115	1	0.9
	Coho - J	1	50	11	0	0
	Chum	8	4,970	104	0	0
Puntledge	Coho - M	1	253	15	0	0
Quinsam	Chinook - A	5	331	21	0	0
	Coho - A	5	5,990	576	6	1.0
	Coho - J	4	5,621	253	2	0.8
Robertson Creek	Chinook - A	11	9,202	392	27	6.4
	Chinook - J	8	3,159	112	8	6.7
	Coho - A	12	7,994	423	11	2.5
	Coho - J	8	3,079	291	21	6.7
TOTAL			96,490	4,617	94	2.0

* Poor quality samples (e.g. mix-ups) excluded from analysis. Also samples with fewer than 50 pieces excluded. Multiple clips (e.g. AdRV) not included.
Chum Ad-mark data included only for Chehalis and Inch Creek facilities since at other facilities (Big Qualicum and Little Qualicum) few if any chum Ad-marks expected, while at Chilliwack Hatchery no chum Ad-marks expected and mix-ups in samples occurred.

** A - adults, J - jacks, M - mix of adults and jacks.

+ % Undetected Ad marks = (Ad marks with Hd-ON / Total Ad-marks) x 100.

Appendix 7. Adipose-mark detection data for chinook, coho and chum salmon resampled by MRP crew, 1990 and 1992. (Mix = Mix of adults and jacks) *

Facility	Species	Days Sampled	Fish Sampled	ADIPOSE MARKS		
				Detected (Hd-OFF)	Undetected (Hd-ON)	% Undetected **
1990						
Chehalis	Chinook - Mix	3	212	3	0	0
	Coho - Mix	5	173	9	0	0
	Chum	7	12,619	109	1	0.9
Chilliwack	Chinook - Mix	6	378	47	1	2.1
	Coho - Mix	10	7,880	192	5	2.5
	Chum	9	2,907	4	0	0
Inch Creek	Chum	1	689	21	1	4.5
Robertson Creek	Chinook - Mix	3	5,772	210	0	0
	Coho - Mix	4	4,726	471	0	0
TOTAL		48	35,356	1,066	8 (0)+	0.7
1992						
Robertson Creek	Chinook - Mix	5	4,088	89	11	11.0
	Coho - Mix	4	865	12	2	14.3
Total		9	4,953	101	13 (1)+	11.4

* Samples with fewer than 50 pieces per species excluded from analysis.

Chum data included only for those facilities with Ad-mark returns.

In 1992, several shipments may have been sampled on same day.

** % Undetected Ad marks = (Ad-marks with Hd-ON / Total Ad-marks) x 100.

+ Number in parenthesis shows regenerated component in the total undetected marks.

Appendix 8. Seasonal variation in Ad-mark detection efficiency at selected facilities, 1988 and 1990.

Data Set	Date Sampled	Total Fish Sampled	Overall Ad-marks *	Undetected Ad-marks	
				No.	% of Overall Ad-marks **

CHEHALIS COHO - 1988					
1)	Oct 15-16	1,103	53	0	0
2)	Nov 3	242	2	0	-
3)	Nov 4	134	7	3	-
4)	Nov 7	134	11	8	72.7
5)	Nov 8, 9, 10	140	11	3	27.3
6)	Nov 14	106	6	2	-
7)	Nov 17	75	2	0	-
8)	Nov 21	353	24	1	4.2
9)	Nov 22	367	14	0	0
10)	Nov 23, 24, 25	871	58	0	0
11)	Nov 28, 29	719	40	9	22.5
12)	Nov 30	119	9	1	-
TOTAL		4,363	237	27	11.4 *** (Range 0-72.7%)

CHEHALIS CHUM - 1988					
1)	Nov 6	696	37	2	5.4
2)	Nov 7	1,177	30	8	26.7
3)	Nov 8a	101	0	0	-
4)	Nov 8b	255	7	0	-
5)	Nov 14	333	12	3	25.0
6)	Nov 18	549	12	2	16.7
7)	Nov 21	1,163	24	8	33.3
8)	Nov 22	1,698	39	14	35.9
9)	Nov 24	425	11	0	0
10)	Nov 28	235	5	1	-
11)	Nov 29a	468	2	2	-
12)	Nov 29b	332	16	2	12.5
13)	Dec 4	282	1	1	-
TOTAL		7,714	196	43	21.9 *** (Range 0-35.9%)

INCH CREEK COHO - 1988					
1)	Nov 1	1	0	0	-
2)	Nov 23	207	32	0	0
3)	Nov 24	64	12	0	0
4)	Nov 28	122	24	1	4.2
5)	Nov 29	85	15	1	6.7
6)	Nov 30	16	2	0	-
7)	Dec 1	4	2	0	-
8)	Dec 6	171	18	0	0
9)	Dec 7	113	0	0	-
10)	Dec 12	195	27	0	0
11)	Dec 13	706	115	2	1.7
TOTAL		1,684	247	4	1.6 *** (Range 0-6.7%)

(cont'd)

Appendix 8 (cont'd).

Data Set	Date Sampled	Total Fish Sampled	Overall Ad-marks *	Undetected Ad-marks	
				No.	% of Overall Ad-marks**
INCH CREEK CHUM - 1988					
1)	Nov 1	539	6	1	-
2)	Nov 23	253	0	0	-
3)	Nov 24	465	8	0	-
4)	Nov 28	534	8	1	-
5)	Nov 29	275	2	0	-
6)	Nov 30	467	1	1	-
7)	Dec 1	428	0	0	-
8)	Dec 6	1,201	9	0	-
9)	Dec 7	788	2	0	-
10)	Dec 8	444	2	0	-
11)	Dec 12	276	1	0	-
12)	Dec 15	82	0	0	-
TOTAL		5,752	39	3	7.7 ***

ROBERTSON CREEK CHINOOK - 1989					
1)	Sep 25	135	0	0	-
2)	Oct 3	293	5	5	-
3)	Oct 6	55	1	0	-
4)	Oct 12	1,502	52	0	0
5)	Oct 14	988	32	1	3.1
6)	Oct 17	1,027	29	0	0
7)	Oct 19	1,906	51	0	0
8)	Oct 21	2,003	57	12	21.1
9)	Oct 23	499	16	2	12.5
10)	Oct 30	659	170	6	3.5
11)	Nov 1	135	6	1	-
TOTAL		9,202	419	27	6.4 ***
(Range 0-21.1%)					

* Overall Ad-marks (detected plus undetected).

** Calculated only for samples with 10 or more overall Ad-marks.

*** Mean calculated over all samples.

Appendix 9. Incidence of regenerated fins among the detected plus undetected multiple clips in chum salmon resampled by MRP crew, 1989. *

Facility	Total Fish Sampled	Fin-Clip Status **	CHUM MULTIPLE CLIPS				Total Clips	
			RV	LV	AdRV	AdLV	No.	% by Clip Status
Big Qualicum	8,175	Compl.	13	36	7	0	56	74.7
		Regen.	4	14	1	0	19	25.3
		Total	17	50	8	0	75	
Inch Creek	4,970	Compl.	3	2	2	4	11	73.3
		Regen.	2	2	0	0	4	26.7
		Total	5	4	2	4	15	
Little Qualicum	2,535	Compl.	9	1	3	6	19	86.4
		Regen.	2	0	1	0	3	13.6
		Total	11	1	4	6	22	
TOTAL	15,680	Compl.	25	39	12	10	86	76.8
		Regen.	8	16	2	0	26	23.2
		Total	33	55	14	10	112	

* MRP crew provided fin regeneration data for the combined (detected plus undetected) multiple clips. Regenerated multiple fin-clips included those with 25% and higher regeneration level.

** Compl. - Complete, Regen. - Regenerated.

Appendix 10. Incidence of regenerated fins in each of the detected and undetected multiple clips in chum salmon resampled by MRP crew, 1990.*

Facility	Total Fish Sampled	Fin-Clip Status **	C H U M M U L T I P L E C L I P S						
			Detected		Undetected		Overall Total Clips		
			No.	% by Clip Status	No.	% by Clip Status	No.	% by Clip Status	% Undetec.
Big Qualicum	4,093	Compl.	31 ***	72.1	0	0.0	31	67.4	0
		Regen.	12	27.9	3	100.0	15	32.6	20.0
		Total	43		3		46		6.5
Chehalis	12,619	Compl.	27	41.5	0	0.0	27	38.6	0
		Regen.	38	58.5	5	100.0	43	61.4	11.6
		Total	65		5		70		7.1
Chilliwack	2,907	Compl.	76	55.9	1	100.0	77	56.2	1.3
		Regen.	60	44.1	0	0.0	60	43.8	0
		Total	136		1		137		0.7
Inch Creek	689	Compl.	7	77.8	0	-	7	77.8	0
		Regen.	2	22.2	0	-	2	22.2	0
		Total	9		0		9		0
Little Qualicum	9,469	Compl.	39 +	79.6	-	-	39	79.6	-
		Regen.	10	20.4	-	-	10	20.4	-
		Total	49		-	-	49		-
TOTAL (except Little Qual.) +	20,308	Compl.	141	55.7	1	11.1	142	54.2	0.7
		Regen.	112	44.3	8	88.9	120	45.8	6.7
		Total	253		9		262		3.4

* Regenerated multiple fin-clips included those with 25% and higher regeneration level. Excluded from data analysis several Big Qualicum and Little Qualicum chum samples due to incomplete resampling by MRP crew.

** Compl.- Complete, Regen.- Regenerated.

*** At Big Qualicum, 3 marks (2LV and 1RV) detected by hatchery crew but not by MRP crew. These 3 marks included here in the category of "Detected and Complete" marks.

+ For Little Qualicum, used MRP records for total (detected plus undetected) marks, since sampling by MRP crew occurred prior to sampling by hatchery crew.

Appendix 11. Degree of ventral fin-clip regeneration in chum salmon from Chehalis and Chilliwack facilities, MRP data, 1990.

% Fin Regen.	LV		RV		AdRV		AdLV		Total Clips	
	No.	%	No.	%	No.	%	No.	%	No.	%
CHEHALIS CHUM										
0%	2	18.2	1	12.5	23	47.9	0		26	38.2
25%	5	45.5	0		12	25.0	1	100.0	18	26.5
50%	3	27.3	4	50.0	9	18.8	0		16	23.5
75%	1	9.1	3	37.5	4	8.3	0		8	11.8
Total	11	100.0	8	100.0	48	100.0	1	100.0	68	100.0
CHILLIWACK CHUM										
0%	70	59.3	7	36.8					77	56.2
25%	26	22.0	1	5.3					27	19.7
50%	19	16.1	8	42.1					27	19.7
75%	3	2.5	3	15.8					6	4.4
Total	118	100.0	19	100.0					137	100.0

Appendix 12. Hypothetical examples showing the impact of undetected escapement marks on the estimates of survival rate, exploitation rate and of production for hatchery-produced fish. *

CHEHALIS CHUM (No. Marks Released = 100,000)		CHILLIWACK COHO (No. Marks Released = 100,000)	
NO ERROR	ERROR	NO ERROR	ERROR
All escapement marks were detected at hatchery	21.9% of escapement marks were not detected at hatchery (only 78.1% were detected)	All escapement marks were detected at hatchery	15.7% of escapement marks were not detected at hatchery (only 84.3% were detected)
C = 500 E = 500	C = 500 E = 390.5 **	C = 7,000 E = 3,000	C = 7,000 E = 2,529 ***
Survival Rate: $1,000 / 100,000 = 1\%$	Survival Rate: $890.5 / 100,000 = 0.9\%$	Survival Rate: $10,000 / 100,000 = 10\%$	Survival Rate: $9,529 / 100,000 = 9.5\%$
Exploitation Rate: $500 / 1,000 = 50\%$	Exploitation Rate: $500 / 890.5 = 56\%$	Exploitation Rate: $7,000 / 10,000 = 70\%$	Exploitation Rate: $7,000 / 9,529 = 74\%$
Production: $1,000 \times 5 = 5,000$	Production: $890.5 \times 5 = 4,453$	Production: $10,000 \times 5 = 50,000$	Production: $9,529 \times 5 = 47,645$

* Survival rate = $(C + E) / \text{Total Marks Released}$; Exploitation rate = $C / (C + E)$; Production = $(C + E) \times \text{Mark rate at release}$.
(C = detected marks in catch, E = detected marks in escapement, Mark rate at release = $(500,000 / 100,000) = 5$,
i.e. assumed that 500,000 juveniles of which 100,000 were marked, were released from each facility.)

** $500 \times 0.781 = 390.5$.

*** $3,000 \times 0.843 = 2,529$.

Appendix 13. Recounts of coho salmon by hatchery crew during sampling for marks at Quinsam facility, 1989. *

Sampling Date, 1989	FIRST COUNT		SECOND COUNT		Difference between counts in Total Unmarked		Total Fish Sampled	**
	Total	No.	Total	Additional	Diff.	% of First Count		
	Unmarked	Marks	Unmarked	Marks				
COHO ADULTS								
Oct 12	666	76	656	0	10	1.5%	737	
Oct 17	336	42	347	1	-11	-3.3%	385	
Oct 20	510	57	507	1	3	0.6%	567	
Oct 24	2,277	296	2,320	1	-43	-1.9%	2,596	
Oct 26	2,412	339	2,473	1	-61	-2.5%	2,783	
Oct 31	503	92	448	2	55	10.9%	570	
Nov 6/7 +	1,969	294	1,899	14	70	3.6%	2,242	
Nov 10 +	1,959	304	2,022	13	-63	-3.2%	2,308	
Nov 17 +	1,214	155	1,253	17	-39	-3.2%	1,406	
Nov 21 +	928	131	928	10	0	0.0%	1,069	
COHO JACKS								
Oct 12	6,580	204	6,587	5	-7	-0.1%	6,793	
Oct 17	3,123	115	3,121	3	2	0.1%	3,240	
Oct 24	3,046	128	3,157	0	-111	-3.6%	3,230	
Oct 26	4,254	170	4,148	2	106	2.5%	4,373	
Oct 31	1,656	76	1,706	0	-50	-3.0%	1,757	
Nov 6/7 +	866	33	908	1	-42	-4.8%	921	
Nov 10 +	818	26	585	0	233	28.5%	728	
Nov 17 +	307	9	311	5	-4	-1.3%	323	
Nov 21 +	122	6	122	1	0	0.0%	129	

* Data from Quinsam memo on 1989 hatchery fish sales, April 4, 1990.

** Total fish sampled per day = Mean number of unmarked fish per day (i.e. average of two daily counts) plus total marks per day (i.e. sum of two daily counts).

+ Hired some new and less experienced samplers in November of 1989.

Appendix 14. Chi-square analysis testing for differences in Ad-mark detection performance between the control year when the original mark sampling techniques were used, and the subsequent years when all fish were double-checked for marks. *

Facility	Years Compared Control vs Later	d.f.	Chi-square	Significance **
Chehalis	1988 vs 1989	1	53.35	p<0.0005
	1988 vs 1990	1	20.09	p<0.0005
Chilliwack	1988 vs 1989	1	210.96	p<0.0005
	1988 vs 1990	1	30.35	p<0.0005
Robertson Creek ***	1988/89 vs 1990	1	38.15	p<0.0005
	1988/89 vs 1992	1	6.82	p<0.01
All Facilities	1988 vs 1989	1	343.13	p<0.0005
	1988 vs 1990	1	127.20	p<0.0005

* Data from Table 8.

Each chi-square test involved a 2x2 contingency table comparing two years of data for Detected and Undetected Ad-marks.

Excluded from analysis the Inch Creek data (Table 8), since several of the expected values (E) were less than 5 (Bailey 1969).

** Compared to the control year, mark detection rates were significantly higher in the subsequent years for all cases, except for Robertson Creek 1992 data (see below).

*** For Robertson Creek facility, used the combined 1988 and 1989 data as the "control". For this facility, mark detection was poorer in 1992 compared to the control years.

Appendix 15. Methods for reducing the number of undetected marks, Chehalis Hatchery, 1989.*

Key Changes:

- A second sorting table was installed.
- Sampling tasks were simplified.
- Fish handling was reduced to a minimum.
- All marked, as well as unmarked fish, were double-checked for marks.

Details:

- Two sorting tables were used.
- Each sampler had a tally counter.
- At the first sorting table, all fish were checked for marks, and all marks were placed uncounted into a separate "marked" tote. The unmarked fish were then counted by species and sex, and their total number recorded on a tally sheet. The unmarked fish were then moved to a second sorting table.
- Once on the second sorting table, the unmarked counted fish were rechecked for marks, sorted and graded into the fish sale totes, but not recounted. Any missed marks were placed into the "marked" tote.
- All fish in the "marked" tote were rechecked for marks (i.e. marks were verified) but not counted at this time.
- Heads were removed from all marked fish and placed into buckets labelled according to species, sex, and mark.
- All Ad-CWT heads were counted into a separate container and a numbered head-label was attached to each head.
- All heads from multiple fin clipped salmon were counted into another container and discarded.
- The mark totals were then recorded on a tally sheet.

In summary, samplers at the first sorting table counted the unmarked fish and removed the marked fish. Samplers who were removing heads from the marked fish, verified and counted the marks. Samplers at the second table rechecked the unmarked fish for missed marks but did not recount them.

* From DFO Memo (File No. 8052-C2) : L. Kahl (Manager) to K. Wilson (Biologist).